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November 26-27, 2015

A roadmap for the improvement of earthquake resistance and eco-efficiency of existing buildings and cities

Alessio Caverzan, Marco Lamperti Tornaghi and Paolo Negro
Editors

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SAFESUST Workshop

A roadmap for the improvement of earthquake resistance and eco-efficiency of existing buildings and cities

Joint Research Centre, Ispra
November 26-27, 2015

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A roadmap for the improvement of earthquake resistance and eco-efficiency of existing buildings and cities

The global population now exceeds seven billion. This means that during the past 250 years or so, it has increased tenfold that of the Industrial Revolution in the mid-18th century, which is believed to have been 700 million. Eighty percent of the global population lives in developing regions, which means that the consumption of resources and energy will increase enormously in the future. Resources and energy are some of the most fundamental elements for the daily life of humankind. In recent years, it has been recognised that increasing fossil energy consumption could even change the global climate. It is anticipated that global warming will cause extremely serious problems in the future, in fact, climate change driven by global warming has already increased the intensity and frequency of weather action such as typhoons/hurricanes and torrential rainfalls, causing enormous damage; in addition, the frequency or intensity of heavy precipitation events has likely increased in North America and Europe[1]. On the other hand, developed countries, such as EU, have accumulated a huge amount of infrastructure and building over a long time. It means that these structures have to be properly maintained by taking cost, natural resources consumption, and more severe loading and environment into consideration. In other words, it is very important how to incorporate *sustainability* concepts into construction industry.

SAFESUST is an acronym to mean *SAFE*ty and *SUST*ainability. It identifies a research work-package on *Impact of sustainability and energy efficiency requirements on building design and retrofit*, being conducted by the *European Commission - Joint Research Centre*, *Directorate Space Security & Migration*, as a part of the project: *Safe and Cleaner Technologies for Construction and Buildings*. The acronym appeared in the title of the workshop: *A roadmap for the improvement of earthquake resistance and eco-efficiency of existing buildings and cities*, and the word soon during the discussions which took place, became a neologism. Expressions such as "*SAFESUST* concept", "*SAFESUST* problem" and "*SAFESUST* approach" were commonly used. For this reason, in this freshly created word, possibly remain the essence of the roadmap which has been started to be drawn at the workshop: SAFEty and SUSTainability.

There is sufficient evidence of the fact that there could be not anymore safety without sustainability. This evidence underpins actions to mitigate what could be the most difficult problem mankind have faced since ever: saving our only planet, and this was not to be discussed at the workshop. *What became soon evident during the discussion is that there can be no sustainability without safety, in tackling the improvement of the existing building heritage.*

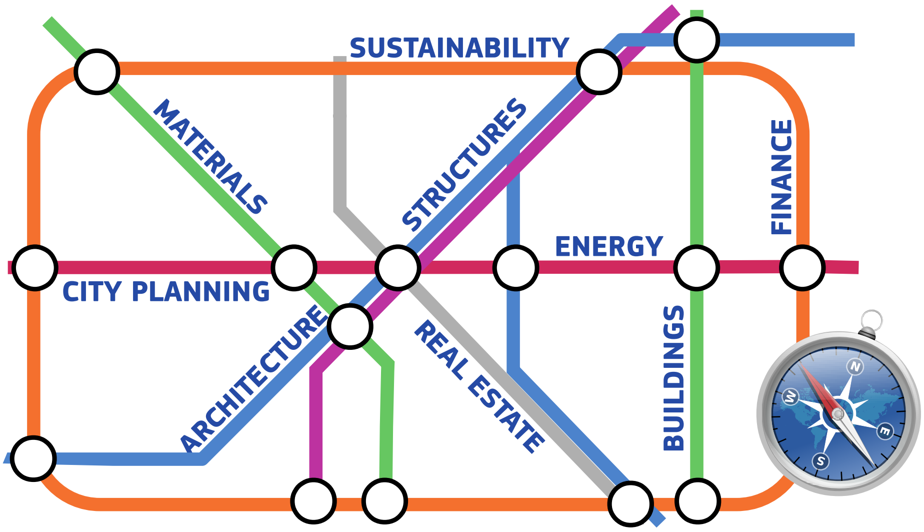
SAFESUST**: SAFETY + SUSTAINABILITY =* ***INTEGRATED RENOVATION

[1]IPCC, *Climate change working group I: The Physical Science Basis*

Why a Roadmap?

Today, more so than ever before, global issues such as the climate change are overlapped to local crises like the shrinkage of the construction sector, which followed the economic and financial crisis in EU[2]. On one hand this scenario is a nightmare for stakeholders involved in the building process, but - on the other hand - it represents a good chance to create the technical conditions for a deep and lasting urban transformation. This is a stimulating challenge that the construction chain will face in the coming decades.

The destinations of this route are smart, resilient and sustainable cities and the starting point is the present building stock. The path is made by the innovation of products and processes and the basic tools to have a coherent and safe travel are a compass and a map to guide the action. Without a roadmap, all efforts would lack direction and thus could easily be inefficient. The age profile analysis of the EU's building heritage[3] reveals that only the minority of these 27 billion m^2 is recent, namely built after 1991: the main part of the stock was built between 1961 and 1990 and a significant percentage before 1960. This means that those buildings are likely to have poor thermal and environmental performances and, in addition, they were built without modern structural design codes and often without seismic prescriptions.



Any actions aimed at improving energy and environmental efficiency without addressing safety at the same time is bound to failure. No seismic provisions were considered in the construction of very old buildings, and those enforced at the time of the construction of more recent ones are typically considered to be insufficient. The problem of seismic safety is being considered also in those regions which were not considered as affected by the earthquakes in the past and, sometimes, it is technically more severe there. The improved knowledge of the seismicity of Europe has significantly increased the areas for which at least some seismic provisions should be enforced.

[2] Eurostat, *Construction production (volume) index overview*

[3] BPIE, *Europe's buildings under the microscope. A country-by-country review of the energy performance of buildings*

Other dynamic actions, e.g., traffic disturbances, industrial or mining activities, pose similar problems. In more general terms, requirements for service loads are nowadays more stringent than those considered in the design and construction of old buildings, as well as for the deformability requirements. Ageing of materials, poor maintenance and corrosion also affect the resulting structural safety of existing buildings.

The need to pursue the integrated renovation with the SAFESUST approach: to tackle the problem of the improvement of the structural safety at the same time of the energy and environmental performance in a *Life Cycle* (LC) perspective, should then be kept in mind.

Courtesy *Telestense TV, Ferrara Italy* - from "TV giornale", May 21st 2012

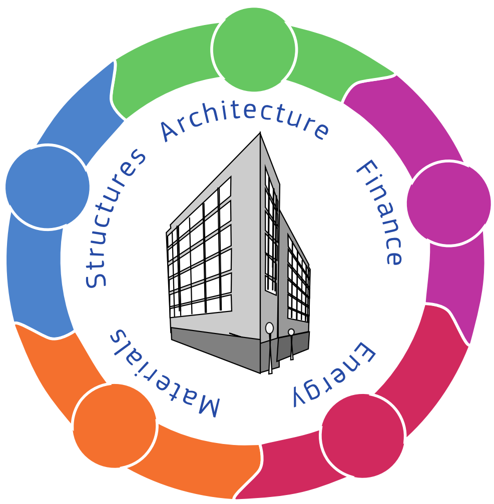
This was expressed in a strong iconic format at the workshop, with the pictures of an industrial building which had been improved as for its energy performance, by placing an array of solar panels on the roof, and collapsed as a result of a recent, relatively weak, earthquake in Italy (Emilia 2012). Moreover, the damage resulting from seismic risk is not actually included in the evaluation of environmental impact of existing buildings. Non performing buildings might be severely damaged – or even collapse – as a result of an earthquake, calling for the disposal of large volumes of construction waste. Ways of including the seismic risk in *Life Cycle Assessment* (LCA) and *Life Cycle Cost* (LCC) procedures should be defined.

Who's game?

In defining a roadmap, those who will have to follow it have to be identified. To this extent, the experience of the SAFESUST workshop has been instrumental. Many individuals from the scientific committee have expressed doubts and concern about the format of the workshop. The idea of mixing traditional sessions based on oral presentations, open discussions and take-home assignments to be left with the rapporteurs was seen as rather uncommon, however, it worked well. What was seen as rather bizarre, and possibly unprecedented as for this topic, was to ask for the participation of experts from differing disciplines. The workshop was intended to bring in the same room experts on *structures*, *architecture and city planning*, *materials*, *energy* and *finance*, so that they could learn from each other, discuss and seek synergies and possible agreed priorities. From one side it might have been difficult to identify the leading experts from all disciplines, and convince them that it might have been worth playing that game. From the other, somebody was preoccupied because the disciplines were seen as too far apart to speak the same language, or too close to reach a common view.

The workshop was unanimously seen as a success by the participants, and the main lesson learnt from this success is profound: *a solution to the problem of the improvement of safety and eco-efficiency of existing buildings can be found only in a multidisciplinary perspective*. Defining the rules of the game calls for the participation of all technical experts.

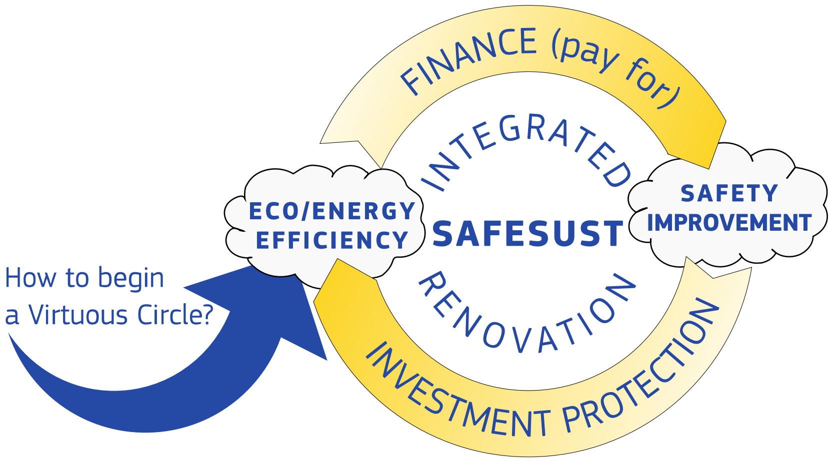
Any solution conceived having in mind only one aspect of the problem is bound to failure. The need for new, interdisciplinary, expertise was expressed. Different roles will continue to be necessary; at the same time, a new approach calls for a common language as well as shared rules. This is best expressed by the need for *new taxonomy*, *semantic* and *metric*, as mentioned in the conclusions. Moreover, it became evident from the presentations, as well as during the discussions, that not all the players were indeed in the room: other actors have to be involved, such as local authorities and communities, owners and investors; to that extent, another issue has to be included to the roadmap. The SAFESUST approach will from now on also refer to the involvement of all experts and stakeholders, sharing the new common language.



The circle game

Circular economy: *Cradle to grave* (or *Cradle to cradle*?). Prevent, reduce, reuse, recycle... Where is the starting point?

Everybody would agree that there is no starting point in circle. There has been a strong agreement at the workshop: it is not effective to just check the safety requirements of a satisfactory design in terms of eco-efficiency, as well as it is not effective to check the level of eco-efficiency of a compliant safety design. *Safety and eco-efficiency should be addressed together, at the same time, and this should be done in the design phase*.



At the moment, design norms just relate to safety performance, and eco-efficiency can just be checked afterwards. Design norms should be extended to include eco-efficiency. Speaking about safety, the neighbors' safety is equally important than ours. In case of accident, especially in historic town centres, the fire propagation, or the seismic interactions among buildings, can affect also inherently safe buildings. In addition, to preserve one property is not enough if the surrounding is injured. For all these reasons, an innovative approach must be developed at urban scale to improve the city resilience.

The rules

He/she who moves first loses. There seem to be a first move advantage in chess, for sure not in addressing the improvement of safety and eco-efficiency of buildings. If one tries to improve the energy efficiency of a building, without making adequate structural safety, loses. No point in having your old car repainted, if the engine has not been fixed!

Who holds the starting pistol? Typically, owner/investor and architect initiate the game. However, in a circle game, moving first does not make sense if the others remain still, therefore each actor should be encouraged to move. The architect is often the first technical interface with the owners/investors, his/her role is crucial at the beginning, to collect and represent the requirements from the other experts and stakeholders since the first project stage. The architect must define, together with his/her counterparts the main aspects of the building in terms of cost and general layout.

A rational and collaborative pre-design analysis should prevent jeopardising the integrity of the project at later stages. For this purpose, rules should be known in advance, so that whoever moves does that without preventing the others from setting their objectives and applying their methods. SAFESUST objectives should be put forward from the beginning, so that they can be defined in economic terms and be considered by all the experts who intervene in the design. A specific training might be required, and possibly a new coordinated expertise should take the lead: a SAFESUST expert.

Good and bad players

Eco-efficiency is a challenge, but it can also be an opportunity. When the opportunity is addressed in economic terms, players try to demonstrate that their products are superior to the others'.

There are no doubts that industrial competition harvests innovation; however, a general consensus was soon reached about the fact that there is no good, or bad, material. The use of structural materials is responsible for a huge fraction of the global CO_2 production; however, there is no alternative to the current wide use of steel and concrete. No material is *per se* better performing in environmental terms, the best solution can be identified only when the environmental performances, together with the safety performances, are defined for the building, in a life cycle perspective: the SAFESUST approach.

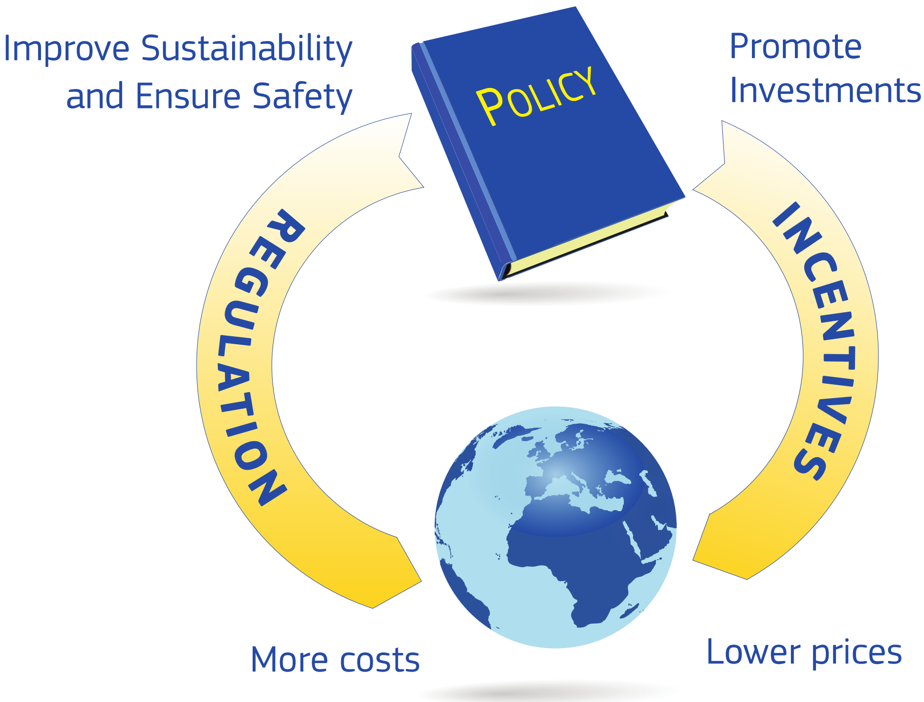
Technical advances could help to give the start. For instance, it is much easier to recycle materials which have been designed for recycling, whereas reusing normal scrap might be difficult or even impossible. To that extent, new technologies to ensure the possibility to completely recycle the construction materials have been developed. As it has been shown at the workshop, it is for instance possible to produce concrete from which aggregates can be fully recovered at the end of its life. Adopting such technologies would for sure help in starting the game.

Pay to play

It's a long way. In each technical session, many needs were identified as for research and innovation, awareness increase, education, training, barrier breaking, integration… *The main obstacle to enter the virtuous cycle is economic*.

From one side, it should become evident that the cost increase for buying a better performing, more efficient and safer building corresponds to an investment with a high return. The investor should be made fully aware of this, as well as of the importance of preserving the resources and ameliorating the quality of his life and the life of his community. Moreover, the figures shown at the workshop seem to indicate that the cost for design is a small percentage of the total cost of the building (and it might become negligible if compared to the cost of operating the building). It was also shown that in recent years that, as an effect of energy efficiency regulations, the building's price index has increased, but it has much less than constructions cost: *the owner should realise that investing in safety and eco-efficiency is a good business. Education and public awareness play an important role, to this extent.*

On the other hand, the fact that the increase in the costs associated to new eco-efficient construction is not reflected by the increase in retailing prices of new buildings might not be good news for the construction industry. The advantages for the community should govern over those of the owner or of the single investor, and this could be enforced by means of regulations and incentives.



In a roadmap, the most urgent need should be identified, and a consensus was soon reached about the importance of adequate investments in research and innovation. And also in this case, a specific, SAFESUST, approach was said to be needed: the current lines of funding for research and innovation are focused on eco-efficiency, but seem to forget the problem of the improvement of safety of existing buildings.

In the last resort, citizens pay for the game. They do it indirectly – as taxpayers – fostering studies/research/policies, and they do directly, incurring higher prices to buy or rent buildings with better performance. *If people are not aware of these technical advances, and even more if safety and sustainability are not recognised as crucial for their lives, how is it possible to call for resources on this?* In other words: *who will pay for a show no one has ever heard of*?

Table of Contents

Structure Session

Session Rapporteur: **Paolo Riva**

The need of integrated renovation of the existing building stock in Macedonia

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ABSTRACT

Republic of Macedonia is a seismic prone country with a long tradition and positive experience in the field of seismic design of new and strengthening of the existing buildings up to pre-defined levels of seismic protection. The current construction practice generally target only one of the basic work requirements defined in CPD/CPR i.e. mechanical resistance and stability.

Starting from 2013, when the first national regulation for energy performance of the building was issued, there are some positive initiatives/examples at national and local scale. These initiatives encompassed building capacities in construction sector and launching the energy efficiency program for public buildings at municipality level (pilot-project). However, till today there is no integrated methodology which will target simultaneously earthquake resistance and eco-efficiency of the existing building stock in the country.

Keywords

Earthquake resistance, strengthening, eco-efficiency, seismic hazard, integrated renovation

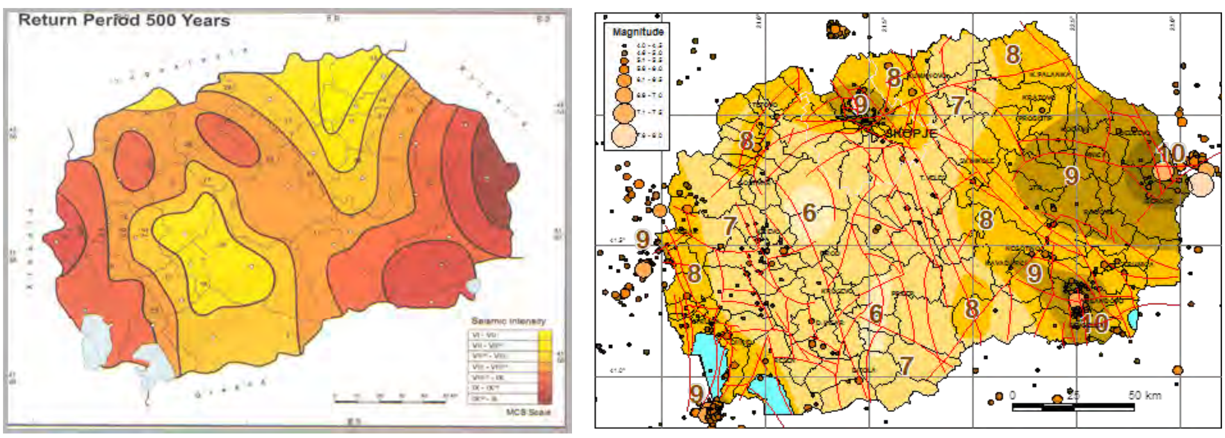
INTRODUCTION

Seismic hazard and building inventory in Macedonia

The territory of Macedonia, situated in the Mediterranean seismic belt, is quoted as an area of high seismicity. In the seismic history of Macedonia, the Vardar zone appears as a region where earthquakes occur quite frequently, and the Skopje region is considered to be the most mobile part of the Vardar zone.

As a result of investigations done by different researchers and institutions, the set of seismic hazards maps of Macedonia have been compiled, covering different recurrence time periods – 50, 100, 200, 500, 1000 and 10000 years. In figure 1 (left), the seismic zoning map with return period of 500 years, is presented and the map of maximum observed seismic intensities (right).

Figure 1. Seismic zoning maps (RP=500 years) and maximum observed seismic intensity map (source: RISK-UE project).



The total residential exposure according to the data from 2002 Census (the last official one) is 49,67 mil m^2 of dwellings with 82, 26% in urban and 17,74% in rural regions of the country. The roughest general building categorization could be done according to the main structural system and year of construction meaning three basic building types, (Table 1).

Table 1. General building categorization

Building categorization	Description
Non-Earthquake Resistant Masonry Buildings	Unreinforced, plain masonry buildings with several sub-categories, that have been implemented dominantly in urban and rural areas up to 1964, that is enforcement of the first seismic code.
Moderate Earthquake Resistant Confined Masonry Buildings	Plain masonry structure strengthened by vertical and horizontal reinforced concrete belts in both orthogonal directions, or by jacketing of the bearing walls; very frequently implemented after Skopje earthquake (1963) for seismic upgrading of existing buildings as well as in constructions of new houses, dwelling and low-rice public buildings.
Earthquake Resistance Reinforced Concrete Buildings	Low, mid and high-rise reinforced concrete, used dominantly after 1965 for construction of mid and high-rise public and residential buildings, residential complexes in urban areas, with extensive usage after 1970.

According to some raw estimation, the percentage of non-earthquake resistant buildings built up to 1970 of the existing building stock is 34.7%. The most of the building structures constructed after 1991 belong to the category of earthquake resistant structures.

Existing national regulation and practice of design of earthquake resistant structures

The territory of the Republic of Macedonia is situated in a seismically active region with an increasing seismic risk. As in many other countries exposed to seismic hazard, technical regulations for design of seismically resistant structures have been elaborated and adopted in Macedonia, as well. As part of former Yugoslavia, Macedonia represents one of the first European countries that passed its first Rulebook on Technical Norms for Construction of Buildings in Seismic Areas (PIOVS) as early as 1964. The passing of this Rulebook was initiated by the catastrophic Skopje earthquake of 1963 that, in fact, drew the attention of the national and world professional public toward design of seismically safe structures. Chronologically speaking, the second issue of PIOVS was published in 1981 (Official Gazette of SFRY no. 32) and it was revised on three occasions with the Rulebooks on Modifications and Amendments (1983, 1988 and 1990). According to the existing National code and in correlation with the established world practice, the principal design philosophy is based on protection of human lives against strong earthquakes and partially on controlled damage during occurrence of the so called frequent earthquakes.

IMPROVEMENT OF EARTHQUAKE RESISTANCE OF EXISTING BUILDINGS – CASE STUDIES

Most building codes in the world explicitly or implicitly accept the occurrence of structural damage in buildings during strong earthquakes as long as the life hazard is prevented. Indeed, many earthquakes (Haiti, Chile, Japan, New Zealand) caused such damage in the past. Seismic design codes were improved after each earthquake disaster, but existing structures were left unprotected by a new technology. As a consequence, seismic assessment and retrofitting of existing structures has become top priority issue worldwide. Within this, the undertaking of corresponding engineering measures for reduction of the seismic risk in densely populated urban regions represents the main component of the policy of earthquake risk management.

Since the disastrous 1963 Skopje earthquake, Macedonia has gathered an ample experience in seismic assessment, but also definition of measures for retrofitting of buildings. It is important to note that Macedonia, as part of Former Yugoslav Federation, was the first European country which enforced the regulation for seismic retrofit of buildings in 1985 (PSOROV, 1985).

As a result of the ample analytical and experimental studies, carried out at the Institute of Earthquake Engineering and Engineering Seismology, IZIIS in Skopje, a method and a corresponding package of computer programs have been developed in-house for seismic assessment of existing RC building structures, (Necevska-Cvetanovska, 2000). Special attention was put on seismic strengthening of historic buildings and monuments due to their individual historic, architectonic, documentary, economic, social and even political or spiritual value. The methodology which is based on the philosophy of "minimal intervention – maximal protection" has originally been developed at IZIIS, Skopje and it has been experimentally and analytically verified (Shendova et al. 1994, 2012).

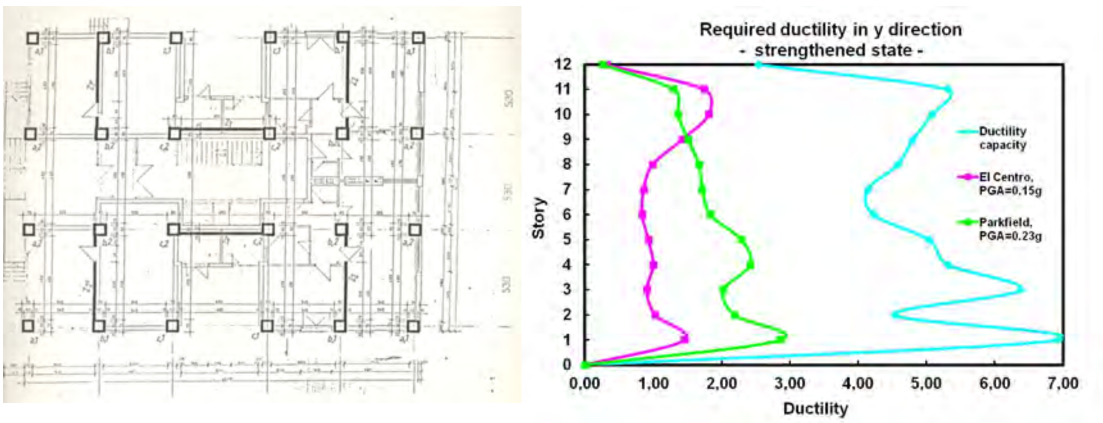
The developed methodologies have been widely applied in Macedonia and in the region and only few selected case studies are briefly presented in the following paragraphs.

Case study # 1: RC building "Tower 5", Skopje

The building structure consists of a basement, a ground floor and ten stories. The load bearing system is designed and constructed as a RC frame system with ribbed floor structure. The structural system was designed in 1968 without dynamic analysis. The obtained results showed that the earthquake demands expressed in terms of relative displacements were far beyond the displacement capacity, leading to structural failure. The results from the analysis of ULS for gravity loads show that, in most of the columns running up to the seventh story, the normalized axial force factors and safety factors for concrete are bigger than those allowed by the regulations.

The strengthening solution anticipated insertion of columns with RC jackets (d=10cm) and concrete compressive strength of 40MPa and incorporation of new RC walls with d=15cm up to the tenth story (2 walls in longitudinal and 4 in transversal direction) (Figure 2).

Figure 2. Layout of the solution for retrofitting (left) and demand versus capacity in terms of ductilities (right).



Case study # 2: Parliament building of the Republic of Macedonia

The structure of the Assembly of the Republic of Macedonia exists more than 70 years. After the Skopje earthquake 1963 it has been repaired but strengthening of the structural system wasn't performed. In its life time the building structure experienced a lot of changes, adaptations and annexes. The structural system is massive masonry (seven units in total) which consists of massive bearing walls with lime mortars in two orthogonal directions. The floor and roof structure is RC fine ribbed ceiling.

Different variant solutions from the aspect of stability, economy and possibility for construction were analyzed. Finally, selection of most appropriate solution using classical methods and elements (insertion of RC shear walls and RC jacketing on existing masonry walls) were applied (Figure 3). An example of the efficiency of the selected methodology for one of the structural units of the building was presented in Table 2, (Bozinovski et al., 2011).

Figure 3. Layout of the solution for strengthening with insertion of RC shear walls and RC jacketing (Unit_5).

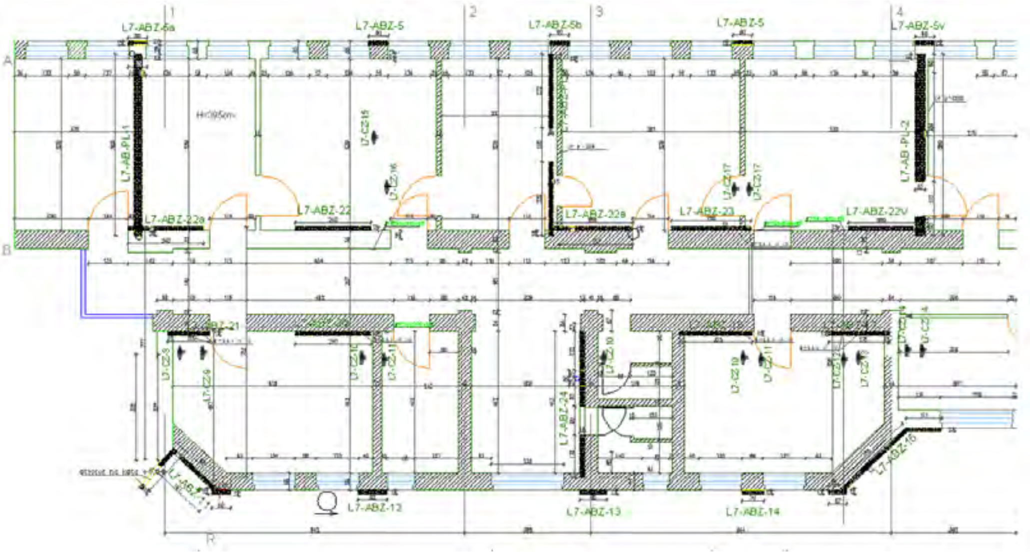


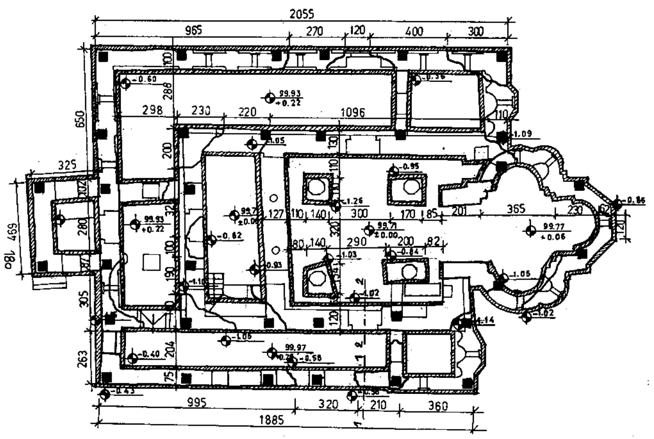
Table 2. Bearing and ductility demand/capacity (Unit_5).

	Required bearing capacity (% of weight)		Bearing capacity (% of weight)		Ductility demand (max)		Ductility Capacity (max)	
UNIT_5	x-x	y-y	x-x	y-y	x-x	y-y	x-x	y-y
Existing state	30		11.54	12.5	3.33	2.81	1.63	1.72
Strengthened state	24		23.1	23.7	1.8	2.2	2.74	2.75

Case study # 3: St Panteleymon Church in Plaoshnik, Ohrid

The above referred methodology was applied for rehabilitation and seismic strengthening of St. Clement's Church, Plaoshnik, Ohrid. To renovate the structure based on the original foundation dating back to the IX century, complex multidisciplinary investigations were performed in the field of archaeology, conservation, engineering and construction. The concept of repair and seismic strengthening of the church consisted of incorporation of horizontal and vertical steel ties in the bearing walls of the structure, (Figure 4). The techniques of consolidation of the authentic foundation of the structure and the existing walls with original fresco-paintings have been performed also (Necevska-Cvetanovska and Apostolska, 2008).

Figure 4. Layout of the strengthening and construction phase.



Case study # 4: Mustafa Pasha Mosque, Skopje

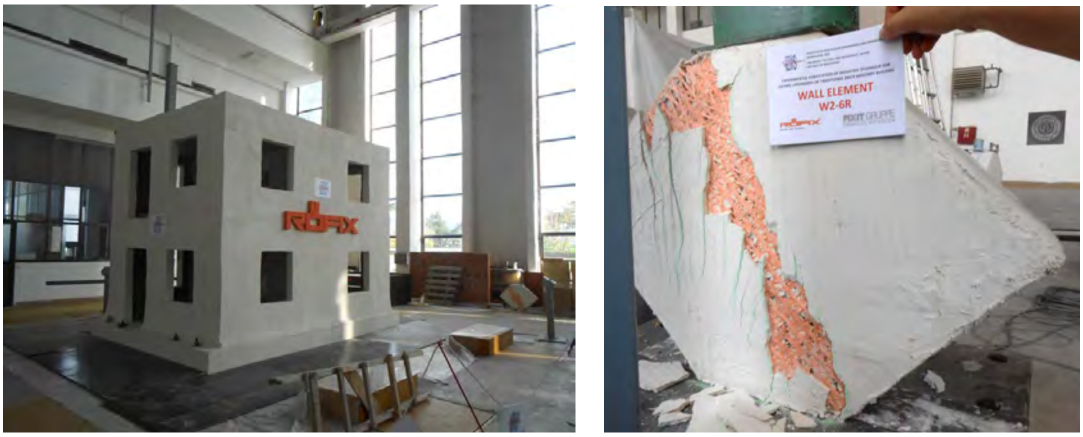
The main principles of seismic strengthening of the Mustapha Pasha Mosque in Skopje were: (i) application of new technologies and materials, (ii) reversibility and (iii) invisibility of the applied technique. Based on the submitted architectonic data, the investigations of the soil conditions, the investigations of the characteristics of the built-in materials, visual inspection of the structure as well as previous experimental investigations of a mosque model, a solution for repair and strengthening of the existing structure is elaborated (Figure 5), followed by a detailed analysis and computation of the bearing system under gravity and seismic loads, (Shendova et al., 2012).

Figure 5. Original state and strengthened state with CFRP bars and wrap.

Case study # 5: Innovative methodology for earthquake resistance and energy efficiency – ROFIX case study

Providing both the earthquake resistance and energy efficiency of existing buildings was the triggering issue for developing an innovative technology called *System ROFIX SismaCalce* by the company ROFIX, member of the of Fixit Gruppe from Austria. It combines the system *ROFIX Sisma* for seismic upgrading and the multilevel *ROFIX system* for thermal insulation; applied together they enable earthquake resistant and completely thermal insulated structure. The testing programme which main goal was experimental investigation of the efficiency of this newly developed integrated methodology was carried out in IZIIS (Figure 6), (Shendova et al., 2013).

Figure 6. Retrofitted model on shaking table (left) and failure mechanisms of strengthened wall element (right).

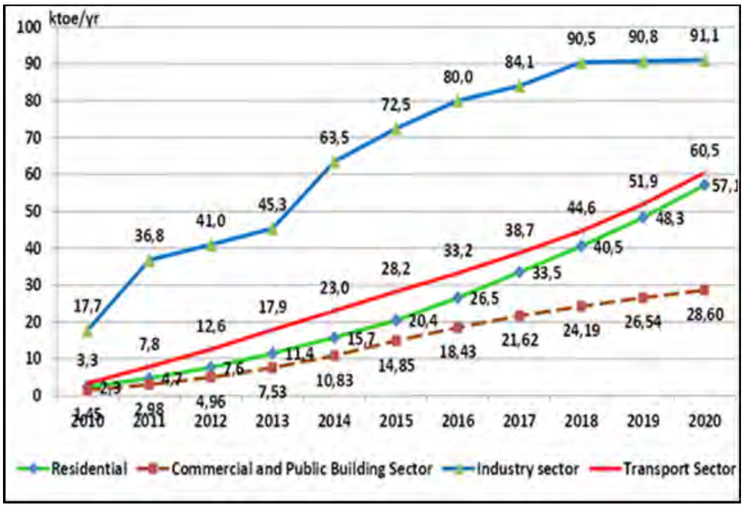


ECO-EFFICIENCY OF BUILDINGS: REGULATIONS, TRAINING SKILLS & SUPPLY CHAINS

The National Status Quo Analysis (February, 2013) showed that around 70% of existing buildings in Macedonia are more than 25 years old with the high average specific energy consumption. The lack of National Regulations on energy performance of buildings in Macedonia has been an obstacle for the improvement of energy & eco - efficiency of buildings for many years, together with education for certification of energy controllers. National Regulations were delivered in July 2013 (Official Gazette of the Republic of Macedonia, No. 94) pursuant to the directive 2010/31/EU and revised in 2015. Their application should lead to an improvement in the energy performance of buildings in the long term.

Following emerging needs for smart energy society, the "First energy efficiency action plan (EEAP) of the Republic of Macedonia by 2018", was developed pursuant to the directive 2006/32/EC. National indicative energy saving targets is presented in Figure 7. These targets should be achieved through set of comprehensive energy efficiency improvement (EEI) program and measures. The most efficient ones in the residential sector are adoption and enforcement of building energy codes and EE retrofits in existing buildings.

Figure 7. Goals in potential of energy savings according to the Strategy of EE, up to 2020 (Apostolska and Samardziovska, 2014)



Potential of energy savings of 57.1% in residential buildings and 28.6% in commercial and public buildings in 2020 have been identified refer to planned EEI program. The building sector is estimated to contribute with 1.660ktCO_2 saved by 2020.

One of the projects at national level which represent good practice and can boost development in this field is **BUILD UP SKILLS MK** - Building capacities in the construction sector - supported by Intelligent Energy Europe (http://www.buildupskills.mk). Its main objective is to provide competent and qualified Macedonian workforce in building sector, necessary for achievement of national energy efficiency targets. The target is training of 4800 on-site buildings workers on energy efficiency and renewable energy sources skills on two qualification levels by 2016.

Another positive example is Municipality of Karposh in Skopje who is a pioneer in the country in application of the energy efficiency policies at the local level together with different relevant stakeholders. As a first initiative the "Program for energy efficiency 2008-2012" was issued and within this frame program the following activities were carried out: (1) reconstruction of public facilities – 10 primary schools and 3 kindergartens applying energy efficiency measures (EEM); (2) reconstruction of 4 residential buildings with collaboration with "Habitat Macedonia", applying EEM, ($Q \leq 100$ kWh/m2/per year) and (3) construction of 63 new buildings according "Regulation on energy efficiency measures", ($Q \leq 70$ kWh/m2/per year). The Municipality of Karposh is one of the first users of the software tool for energy monitoring Ex-CITE with monthly data updating. The important outcome from this programme is 40% to 70% less consumption of energy in comparison with the same buildings construct/retrofit without applications of EEM.

Another example of positive practice, although in the very begging phase in Macedonia, is building ecologically with hollow wood-chip concrete blocks (Figure 8). These blocks are characterized with excellent noise insulation, heat storage and vapour diffusion, as well as fire resistance and earthquake safety due to their compact core.

Figure 8. Hollow wood-chip concrete blocks with integrated insulation & placing reinforcement in the wall and installing the elements (Samardziovska and Apostolska, 2015).

CONCLUSION

From the presented above it can be concluded that in the Republic of Macedonia there is a long tradition and positive experience in the field of seismic design of new and strengthening of the existing buildings up to defined by code levels of seismic protection. However, this practice generally target only one of the basic work requirements defined in CPD/CPR i.e. mechanical resistance and stability.

Starting from 2013, when the first national regulation for energy performance of the building was issued, there are some positive initiatives/examples at national and local scale. One of the unique case study who offers innovative technology for providing both, earthquake resistance and energy efficiency of the existing buildings, is System ROFIX. However, it should be pointed out that this is not national brand and IZIIS served only as an experimental logistic for verification of this integrated method.

Therefore, the national roadmap for integrated renovation which should include not only structural safety but also energy efficient and environmentally friendly buildings should be elaborated further.

Contributes to the roadmap

The possible drivers for setting-up the roadmap for the improvement of earthquake resistance and eco-efficiency of existing buildings and cities are:

1. Appropriate institutional support (in the whole phase of renovation: preparation of technical documentation, obtaining the construction permits, construction etc.)
2. Transfer of knowledge and best practices from the economies/regions who already set the roadmap
3. Networking of projects (finished/on-going) involving topics as eco-efficiency, smart renovation, low-carbon construction, sustainability etc. in order to profit from their gathered knowledge

Open issues

There are a several open issues which deserve our attention during the round table discussions:

- Facilitation of research in the field of integrated renovation of existing buildings (experimental verification of the proposed innovative methodologies/techniques/materials)
- Multidisciplinary education of the engineers who should deal with this integrative approach – updating of high schools curricula and training
- Increasing public awareness concerning energy issues and necessity to live in eco-efficient buildings
- Financial, institutional and regulatory barriers

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Coupling energy refurbishment with structural strengthening in retrofit interventions

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ABSTRACT

The reinforced concrete constructions built after World War II represent almost half of the European building stock. Such buildings are characterized by low energy efficiency, living discomfort and structural vulnerabilities especially in seismic prone areas, having been designed before the enforcement of modern building codes.

A global integrated intervention for the sustainable restoration of the considered building stock is proposed in this paper. The conceived approach overcomes the shortcomings of the traditional renewal practice, targeting uncoupled solution of single deficiencies. The solution also stems as an enhancement of past pioneering techniques, such as the double skin, focusing on architectural restyling and energy efficiency upgrade. In the proposed approach energy efficiency and structural upgrading measures are coupled, and the exoskeleton is complemented with ad-hoc systems and devices to increase structural safety and seismic resilience. The intervention is carried out from the outside, with reduced impairment of the inhabitants and possible building downtime. Unlike traditional energy efficiency interventions, the structural upgrade entails a series of co-benefits: it allows lengthening the building service life, thus representing a viable and more sustainable alternative to the building demolition and reconstruction practice; it increases seismic resilience at district level, reduces life cycle costs and minimizes environmental impact over the building life cycle.

Despite the research work be multidisciplinary, in this paper emphasis is made on the sole structural issues. The exoskeleton conceptual design is discussed and either over-resistant or dissipative solutions are proposed. Main principles of performance based design are presented, which allow minimizing the damage on the existing building. Finally, the case study of a typical residential building is presented, in which the possible use of the engineered double skin is proposed as an alternative to the basic double skin.

Keywords

Sustainable requalification; Seismic retrofit, Modern RC buildings, Double skin façades, Engineered double skin coupled interventions.

INTRODUCTION

The reinforced concrete (RC) constructions built between 1950 and 1970 in Europe represent about 50% of the existing building stock and were mainly built to quickly meet the pressing housing demand of those times, often in the absence of any architectural, urban and environmental general planning. These buildings are typically multi-storey, with poor and anonymous architectural features, characterized by low energy efficiency and living discomfort.

The international growing attention to sustainability, the awareness of the substantial environmental impact of the existing building stock (building sector is liable of 40% of the total final energy consumption in Europe, and 36% of CO_2 emissions throughout the whole building life cycle), together with special European directives fostering the transition toward a low carbon society, have led to granting large national and European funds for the energy efficiency improvement of the existing building stock, encouraging the upgrade of the envelopes, the use of renewable energy sources and eco-friendly materials.

Most of these buildings have already exhausted the typically considered service life (50 years) and, being designed for static loads lower than those currently adopted and without accounting for modern requirements for seismic loads and detailing, they often exhibit significant structural deficiencies with respect to both vertical and horizontal actions. Therefore, the sole energy efficiency requalification or architectural redevelopment leave such buildings dangerously unsafe. In addition, durability concepts were neither wholly acknowledged, nor addressed at the time of construction and many buildings currently show significant signs of material and structural decay. Recent earthquakes have emphasized the little forethought of interventions aimed at the sole energy refurbishment. The 2012 Italian earthquake hitting the Emilia region caused the total and partial collapse of many buildings, especially industrial facilities (Belleri et al. 2014), some of which previously undertook energy efficiency upgrades taking advantages of national subsidies (Figura1).

Traditionally the seismic retrofit of existing buildings has been acknowledged as an issue only in areas with high seismicity, such as in the Mediterranean countries (Italy, southern France and Spain, Portugal, Greece, Turkey). Interestingly, the new developed seismic zonation increases the hazard level and extends the seismic hazard map over the whole continent, making the strengthening of the building stock a priority in order to improve the seismic resilience of European communities.

Furthermore, recent studies have emphasized the substantial environmental impact associated to the seismic risk, related to the possible need of major repair and reconstruction following damage or collapse induced by an earthquake (Belleri and Marini, 2015). The remarks is even more critical when projected at district levels, as the vulnerability of entire districts may jeopardise the effectiveness of extensive energy saving measures. This in turn highlights the need to update sustainability assessment procedures (such as Life Cycle Assessment and Life Cycle Costs) to account for structural deficiencies of the buildings, and the need to update the leading concepts of sustainability to include the fundamental requirement of structurally safe building and resilient society.

In Europe, renovation of existing buildings has typically been approached by solving **episodic, contingent problems** exhibited by the building, either referring to specific energy deficiencies or architectural or structural problems (Figure 1.b, referred to as “non-integrated” or un-coupled intervention approach in the following). The interventions have often been carried out on single buildings, mainly following emergency situations, without either general or integrated planning, and based on a case by case approach, disregarding the urban scale and context.


a)


b)

Figure 1. Traditional non-integrated refurbishment approach: (a) Solely energy retrofit: scene after the Emilia-Romagna earthquake showing the collapse of an industrial warehouse renovated with photovoltaic panels (2012); (b) Solely structural retrofit: typical seismic retrofit of an existent building through fiber reinforced polymer..

After a brief overview of the primary building deficiencies, the paper illustrates the most common uncoupled interventions on buildings, with special emphasis on the structural retrofit interventions. The first European attempts to overcome non-integrated interventions through the use of double-skin solutions encasing existing buildings, fostering energy upgrade and architectural restyling, are concisely commented. Ultimately, the structural engineered double-skin concept is proposed, which consists in an attempt to include structural rehabilitation in the integrated renovation process. The engineered double-skin can be regarded as an effective “integrated” solution to promote the sustainable renewal of the vast RC building stock built after World War II (WWII). The feasibility of the solution and the most critical aspects are discussed through the analysis of its potential application to a case-study, representative of a typical residential building.

MAIN BUILDING DEFICIENCIES AND “UNCOUPLED” RETROFIT INTERVENTIONS

The considered building stock was built before 1970, when neither strict nor mandatory requirements for energy efficiency were enforced, and only a small part of these buildings underwent significant energy retrofit interventions since their construction (the European refurbishment rate is about 1%). The **poor energy performance** depends on low thermal insulation of the envelope layers and on the obsolescence of the supply systems and the finishing, resulting in condensation, high loss of heat through external surfaces and overheating in summer, and thus in poor living comfort.

Recent reports on energy consumption in Europe, based on data collected with massive energy audit assessment campaigns, highlighted the extremely high operational energy consumption of the existing residential building stock. In 2009 the whole European households were acknowledged as responsible for 68% of the total final energy use in buildings (Marini et al. 2014). Data on the average heating consumption show that the post-WWII buildings are particularly energy-demanding, with an average annual energy consumptions higher than 200 kWh/m^2. **Substantial energy demand reduction** can be obtained by improving the performance of the building envelope, by introducing innovative solutions for heating, lighting, ventilation and air conditioning systems, and by adopting eco-efficient energy sources.

From a **structural** point of view, post-WWII RC buildings, lacking any seismic detailing and being designed prior to the introduction of modern seismic building codes, exhibit remarkable static problems and seismic vulnerabilities, thus requiring structural safety assessment and possible strengthening interventions to maintain their functionality (NTC 2008).

Post-WWII structures are typically characterized by one-way RC frames with masonry infills, and a “pilotis” floor is frequently present at the building basement, which may lead to the onset of soft-story failure mechanisms in the case of strong seismic events. Low-ductility structural details are typical of these structures. Floors are made by one-way lightweight RC ribbed slabs, often lacking additional RC topping. All these features highly contribute to increase the seismic vulnerability of these constructions.

Seismic vulnerability is also affected by the frame–to–masonry infill interaction (Klinger and Bertero 1978). Such interaction may be positive for buildings having regular infills distribution and located in low seismicity areas. In this case the infills may provide the seismic strength required to counteract the modest seismic actions, and the building structural behavior can be more effectively modeled as a ribbed-masonry rather than a RC frame. On the other hand, frame-infill interaction is often negative in highly seismic prone areas, and the collapse of the infill often causes the early collapse of the frame (Preti et al. 2012).

The strengthening approaches for **structural retrofit** can be distinguished into local and global: the "local approach" consists in the retrofit of the frame joints and members (Figure 2a); the "global approach" consists in providing a brand new seismic resisting system (Figure 3b). Intermediate solutions can be also proposed.

Typical **local strengthening techniques** are the jacketing of the frame elements and joints with high performance concrete jackets (Martinola et al. 2007), or with fiber reinforced polymer (FRP) wrappings (Antonopoulos and Triantafillou 2003, FIB 2001). Operational difficulties may jeopardize the effectiveness of the local strengthening of frame nodes. Furthermore, local interventions are generally quite expensive as they require substantial demolition of the finishing, impairment of the inhabitants, the temporary downtime of the building, and are ineffective in the case of one-way frames or shallow beams.

Global interventions, introducing a new global seismic-resistant system, are often preferred. The new resisting system may consist for instance in additional external seismic resistant walls (Figure 2b), or in the strengthening of existing structure by complementing the frame with bracing systems, or by jacketing selected infilled bays. The use of new steel bracing systems or RC walls is generally the most effective and reliable retrofitting technique from the structural point of view (Riva et al. 2010), but it may raise several issues related to the architectural and formal compatibility.

Given their high stiffness possible **existing RC walls**, designed for vertical loads only and typically located around the staircases, should be considered in the seismic resistant system design. The seismic action transferred to these elements is significant and may result in their severe damage prior to the activation of any other devised anti-seismic system. In these cases, either their structural upgrade (Marini and Meda 2007) or downgrade may be pursuit. The same can be said with respect to masonry **infill walls** (Preti et al. 2012).

Regardless of the conceived vertical seismic resisting system, the diaphragm action of the floors must be ensured for an adequate performance of the retrofitted building, in order to collect and transfer the seismic loads to the vertical members of the resisting structure. Traditional floors are rarely designed as in-plane diaphragms, hence strengthening of the existing floors is often required in the seismic risk mitigation intervention. **Floor strengthening** can be attained by introducing new diaphragms made of thin concrete slabs (either Normal Strength or High Performance) cast overlaying the existing floor extrados (Marini et al., 2010). This intervention requires the demolition of the entire floor topping and therefore entails high rehabilitation costs and the necessary relocation of the inhabitants. For the minimum impairment of the residents, alternative "dry solutions", such as intrados diaphragms made of steel truss work connected to the floor intrados, concealed at the sight with false ceilings, have been proposed (Feroldi et al., 2013). Noteworthy, the need of introducing floor diaphragms can hinder the entire renovation process, and it is acknowledged as one of the main barrier to existing building structural renovation. For this reason, special attention should be paid in the evaluation of the actual in-plane resistance and stiffness of existing floors.

Figure 2. a) Local strenghtening of existing frame joints. Global interventions with: b) construction of new seismic resistant systems; c) strengthening of existing RC buildings by transforming existing frames into walls..

TOWARDS COUPLED INTERVENTIONS: FROM DEMOLITION AND RECONSTRUCTION TO REMODELAGE AND CAMOUFFLAGE SOLUTIONS

The renovation of buildings, intended a series of non-integrated interventions, has **failed** under different points of view. From an economical point of view, uncoupled interventions can be more expensive than an integrated solution. Furthermore, it may be questionable to invest money on the sole energy upgrade of existing buildings having a vulnerable structure. Post-earthquake assessment showed that social and economic costs connected with the emergency management and the reconstruction could be extremely high: for emergency management, the Italian government spent about 3.6 billion € per year since the Belice earthquake (1968). If the same amount of money had been spent for the seismic refurbishment of existing buildings, very different scenarios would be expected in the case of future earthquakes.

Given the extremely poor performance of the post-WWII RC building stock, **demolition and re-construction** have been considered in the past. Such a practice is nowadays neither conceivable nor sustainable, both in terms of raw material consumption, and of production of hazardous waste (JRC 2012, Eurostat 2013). Such an approach would further worsen a situation which is already critical, with data showing that the construction sector use about 50% of the raw materials supplied in the EU and that construction and demolition waste is about one third of the total amount of European waste (the waste produced during the construction being about 15-20 m^3 for 100 m^2; whereas the demolition waste is 900 kg/m^2).

The need for urban requalification dates back in the 1980s, when pioneering projects for the sustainable requalification of social housing started in different European Countries (Masboungi, 2005). These first prototypal interventions tried to couple energy refurbishment, urban and architectural restyling either through double-skin solutions ("**camouflage intervention**") or by re-designing the total volume of the buildings through selected demolition and expansion works ("**remodelage intervention**"). Such interventions were carried out as part of larger renovation projects of entire districts, introducing the concept of interoperability of the single intervention at district level (Prin 2009).

New envelopes can be **configured** either in adhesion or as an enlargement of the existing building on one or more sides, with modular thickness depending on urban planning restrictions. The latter solution allows for additional living spaces, new balconies, solar greenhouses, incorporating the technological energy saving measure.

Over the years, many examples of urban regeneration were carried out in Europe; with distinguished examples promoted in France, Germany, Netherlands, Denmark, UK and in Italy. To the authors' knowledge, however, **none of these accounted for structural issues** (either static or seismic, or both).

INTEGRATED RETROFIT SOLUTION COUPLING STRUCTURAL AND ENERGY INTERVENTIONS

A possible **integrated retrofit solution** targeting the sustainable redevelopment of the vast post-WWII European RC building stock is proposed in the following. The solution stems as an enhancement of the camouflage interventions: the double skin is further engineered to improve the structural safety of the construction. The structural double skin can be therefore regarded as a **global intervention,** entirely carried out from the **outside**, introducing an exoskeleton configured either in adhesion or as an enlargement of the existing building, and allowing for the improvement of energy efficiency, structural safety, architectural and urban environmental quality and the inhabitant living well-being. These objectives can be pursuit within the framework of minimum rehabilitation cost requirements, through an accurate selection of construction materials and structural technologies, and of minimum environmental impact principles, also accounting for the influence of the seismic risk (Figure 3). It has been shown (Belleri and Marini 2015) that in the case of old poorly performing buildings located in regions with moderate to high seismicity, the sole energy refurbishment without seismic retrofit could lead to an expected annual embodied carbon due to seismic risk, which could be as high as the annual operational carbon after thermal refurbishment.

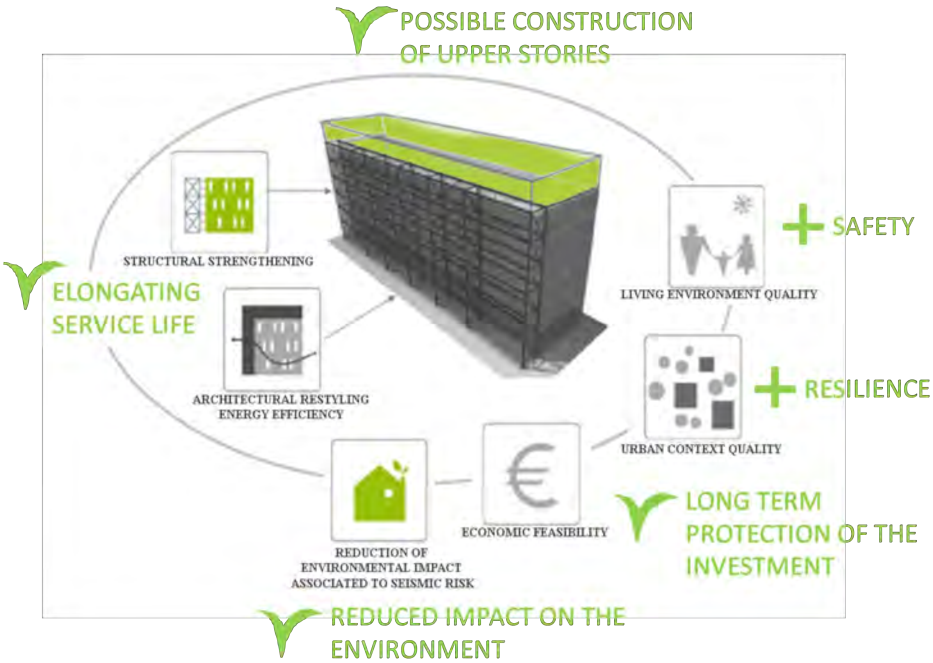

Figure 3. Figure 1. Conceptual design of the engineered structural exoskeleton. The pictures highlights beneficial effects, both direct and indirect, of integrating structural safety measures within a "traditional" double skin solution.

The engineered exoskeleton innovatively integrates ad-hoc systems and devices to attain the building structural safety in two alternative ways: (i) by adopting **shear walls or braced frames** complemented in the encasing exoskeleton, or (ii) by conceiving and exploiting the whole new involucre **shell behaviour**.

In the **shear wall solution** the structural safety is entirely entrusted to the external shear walls or braced frames, whereas the energy efficiency upgrading is guaranteed by the finishing curtain walls or by the ventilated façade technology that integrate the new structural system. Structural elements are part of the exoskeleton on which the energy devices are installed, thus the two systems work in parallel. Both traditional (steel braced frames or RC walls) and innovative (rocking walls, pin-supported walls, weathering steel walls) solutions can be adopted (Qu et al. 2012). With the shear wall and braced frame solution, the additional structural strength and stiffness are provided by and concentrated into few elements (Figure 4a1), resulting in high loads to be transferred through the foundation system. When necessary, the added structural system can be conceived as dissipative bracing systems (Figure 4a2) (Metelli 2013). Alternatively, dissipation may be triggered through dissipative links, connecting the existing structure to the new structural elements (Xu et al., 1999; Trombetti and Silvestri, 2007); such solution enables both the reduction of the shear wall and braced frame dimensions (or their number) and lumping all the damage into few selected and replaceable elements, thus significantly lowering repair costs and shortening building downtime after an earthquake.

In the **shell solution**, the envelope can be innovatively designed to enable both energy efficiency upgrade and structural safety through the dual-use of the same elements and devices (i.e. the façade components serve both energy and structural purposes). The approach exploits the shape and the extension of the new façade to reduce the cross section area of each single structural component and to enforce a box-structural behaviour (Figure 4b, Giuriani et al. 2015), resulting in a reduced overload to the foundations. Given the reduced stress level, the twofold use of the thermo-insulating panels as seismic resistant elements can be envisioned and the new layer becomes both a thermal insulating shell and an in-plane seismic resisting structure. When located in adhesion to the existing building, the shell may be considered as a special structural-thermal coating. Dissipative devices and innovative technologies may be implemented to enhance the new shell performances, such as dissipative panels, or dissipative interfaces along adjoining panels, among other.

Both shear wall and shell solution can be conceived as **responsive structures**, changing their properties as a function of the earthquake intensity. For low intensity earthquakes, such structures can be conceived as to avoid any possible damage; whereas for high intensity earthquakes, a change of the static scheme can be envisioned as to reduce the stiffness of the anti-seismic structure and to increase its fundamental period, thus reducing the seismic action on the building and increasing in the displacement demand.

The conceptual design of the retrofit solution (either shell or shear walls; either dissipative or stiff) and its proportioning mainly depend on the **initial stiffness of the existing building** and **the presence of structural irregularities** (both planar and in elevation). The retrofit option may significantly vary depending on the actual possibility of carrying out preliminary interventions aimed at regularizing the structural response and at reducing the initial stiffness of the structure (Preti et al. 2012). Anytime massive preliminary corrective measures are unviable, the response of the retrofitted building could be controlled by limiting the intervention to the sole ground floor and by introducing base isolation or by enforcing a base isolation-like behaviour (Agha et al. 2014). Finally, in the case of stiffer existing building, when no preliminary interventions are foreseen, quite massive new structures might be necessary for the conceived new anti-seismic systems to compete with the significant stiffness of the existing structure; and given the reduced displacement demand, dissipative solutions could be ineffective and stiff solutions may be preferred.

Both the shear wall and shell solutions require the **floor diaphragm action**. The need of strengthening existing floors may constitute a main barrier to the renovation, and may require internal works, thus missing the target to operate outside of the building. Extensive field surveys carried out on RC buildings after strong earthquakes have assessed that in-plane failure of the floor is rarely observed, whereas common failure modes follow the formation of a kinematic mechanism in the frame for overcoming flexural and/or shear strength in some critical sections. Following these observations, a complementary theoretical and experimental study was started to evaluate the actual in-plane resistance of existing floors and the effects of the additional lateral force resisting system on the floor loads. The purpose of this ongoing research is to evaluate when the floor in-plane resistance is enough as to guarantee the diaphragm action of the floor in the “as it is” conditions (Feroldi 2014).

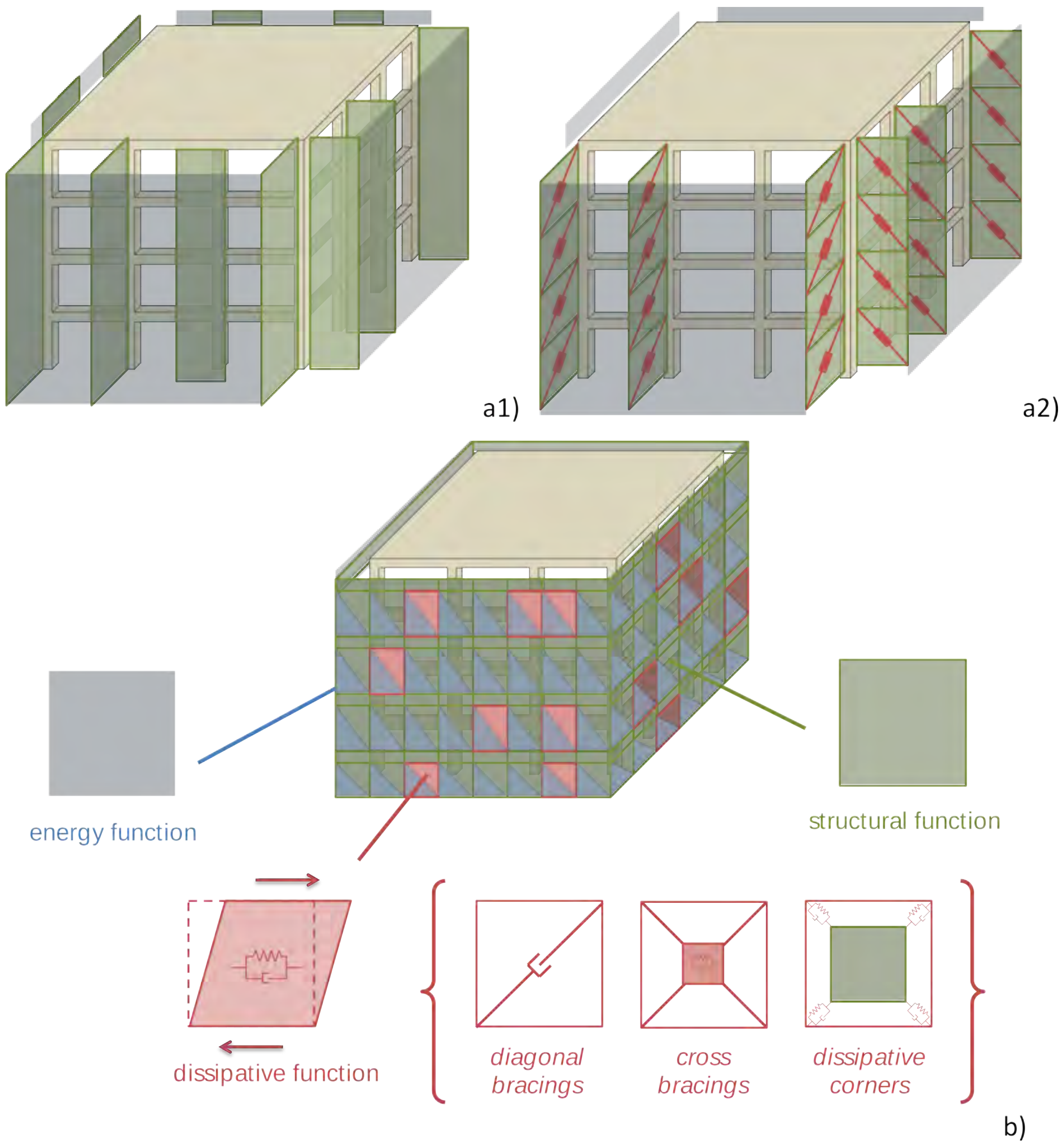

Figure 4. Retrofit solutions: a1) stiff or a2) dissipative shear walls embedded in the external exoskeleton; b) shell structure triggering the box structural behaviour with twofold use of the same encasing components.

Besides reducing structural vulnerability, guaranteeing resilience and safety of the inhabitants, coupling structural retrofit in the renovation process allows for **further co-benefits**: (a) elongation of the building service life, which would be left unchanged by any intervention disregarding structural issues, such as those aimed at upgrading the sole architectural and energetic performances (Figure 5); (b) minimization of post-earthquake downtime of the building and repair costs; (c) improvement of seismic resilience at district level; (d) it can be designed as fully demountable or easily supplemented with other components, guaranteeing maximum flexibility and adaptability over time: dry solutions, standardised connections, as well as eco-compatible materials and recyclable devices should be preferably adopted; (e) the external solution does not require temporary relocation of the inhabitants, nor building downtime; (f) invasive internal intervention or possible changes in the internal architectural plan are optional; (g) with respect to the existing building demolition and reconstruction practice, it allows reducing both raw material consumption and the construction and demolition waste; (h) besides the substantial reduction of the operational energy achieved with energy refurbishment, the structural intervention allows reducing the environmental impact associated to seismic risk over the building life cycle; (i) it allows for the construction of new stories, whose sale revenues might partially cover the renovation costs; (l) major investment warranties, provided that investors benefit both the immediate money saving entailed by the adopted energy efficiency measures and the long term protection of the investment guaranteed by the attained structural safety; a long term protection which would be otherwise jeopardised by possible severe damages caused by earthquakes.

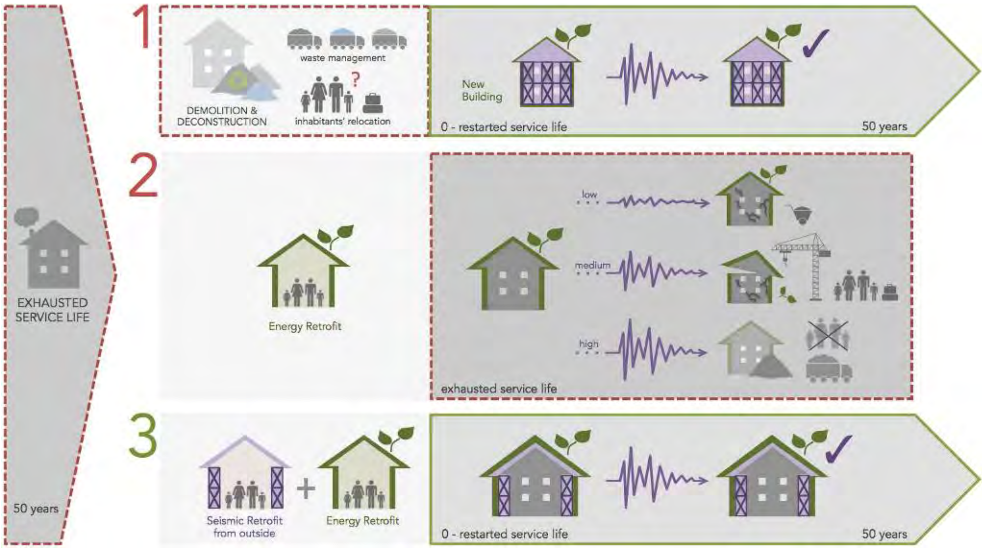

Figure 5. Demolition and Reconstruction vs Refurbishment - comparison between different retrofit strategy in terms of environmental impact and structural service life of the buildings (adapted from Belleri and Marini 2015)..

STRUCTURAL SYSTEM PROPORTIONING CRITERIA

Once the structural deficiencies of a building have been assessed, the seismic retrofit can be designed by applying the principles of Performance-Based Design (PBD), defining some significant performance design targets for a given building and for a given Seismic Hazard Level (Bagheri and Miri, 2010) (ASCE 41, 2013). It is worth noting that, in seismic retrofit intervention, displacement based design (DBD) targeting the maximum displacement, could be insufficient in controlling the seismic response of the existing building. Other parameters, such as the seismic action on existing foundations and floor diaphragms, the acceleration on some acceleration-sensitive non-structural components, the inter-storey drift and the residual drift should be also taken into account. In this scenario, some more advanced performance-based design methods were developed by considering a multiple response indicators. In particular, Ciampi et al. (1995) introduced some design curves that optimize effective damping and base shear forces. With a similar approach, new design spectra are developed to design some of the previous retrofit interventions considering the total displacement (target ductility) and the dissipated energy as control parameters.

As an example, in the following reference is made to the sole stiff shear wall solution to briefly explain derivation of the design spectra. For a given existing building (SDOF parameters: stiffness K_{fr} and yielding point $d_{y,fr}$, Figure 6a) a feasibility study was aimed at defining the optimal characteristics of the bracing system (SDOF parameters: stiffness K_b and yielding point $d_{y,b}$), ensuring minimum damage to the existing building (Feroldi 2014). The SDOF parameters were derived according to nonlinear static procedures; then parametric nonlinear dynamic analyses were carried out for varying properties of the building and the bracing wall, considering five different spectrum-compatible accelerograms.

Fundamental parameters for the calibration of the bracing system were identified in the stiffness ratio (K_b/K_{fr}), and yield displacement ratio ($\delta = d_{y,b}/d_{y,fr}$); the yielding strength of the bracing wall was directly derived as $F_{y,b} = K_b\ d_{y,b}$. Different parameters were controlled, namely: ductility demand after the retrofit (μ_{ret}, defined as the ratio of the maximum displacement experienced by the retrofitted building under seismic excitation, $d_{max,ret}$, and the yield displacement of the non-retrofitted building, $d_{y,fr}$), maximum drift, interstorey drift, residual drift, maximum base shear.

Parametric analyses showed that, for buildings with medium to high resistance, stiffness ratios K_b/K_{fr} = 2-3 and yield displacement ratio δ = 0.2-0.5 guarantee minimum damage of the existing building, maximum energy dissipation in the bracing system and minimum energy dissipation in the existing building (ED_{fr}).

The main results of the parametric analyses were rearranged in design spectra, suitable for determining the design parameters of the bracing systems ensuring the envisioned structural performance. An example of such spectra is shown in Figure 6: given the building capacity $F_{y,fr}$ and a selected value of δ, the target ductility (μ_{target}) is a function of the stiffness ratio K_b/K_{fr} and the building period T_{fr}. Therefore, once the building fundamental period (T_{fr}) is known, the point in the spectrum corresponding to T_{fr} and μ_{target} provides the required stiffness ratio K_b/K_{fr}. Derivation of the bracing capacity is straightforward.

Similar analyses were performed and similar results were obtained in the case of stiff shear walls connected to the existing building by dissipative links (Feroldi 2014).

The development of design spectra for different retrofit strategies may represent a useful next step of the research, allowing for feasibility assessment and retrofit proportioning.

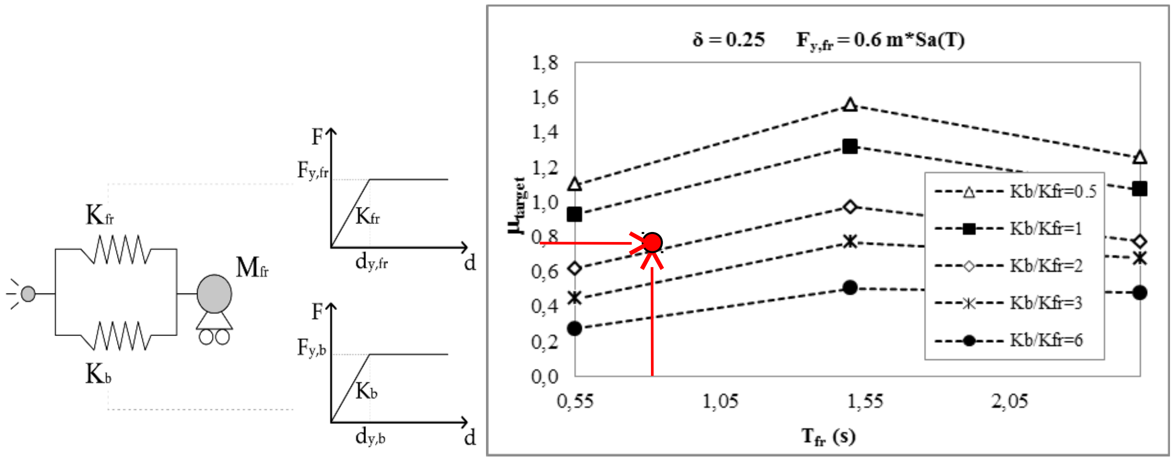

Figure 6. a) Single Degree of Freedom (SDOF) model of the system composed by the existing structure (stiffness Kfr, yield displacement dy,fr, mass Mfr) and the bracing wall (Kb, dy,b); Example of design spectrum controlling the maximum ductility demand on the existing building after the retrofit.

CASE STUDY: RETROFIT OF AN EXISTING BUILDING THROUGH STRUCTURAL – TECHNOLOGICAL DOUBLE SKIN

The proposed integrated retrofit concept is here applied to a case study building, representative of the considered post-WWII construction typology (Figure 7). The building, built in 1972, lays in the suburb of Brescia (Italy) and it is part of a larger residential complex of about ten buildings with similar features.

Numerical simulations of both structural and energy performance were carried out to identify the main building needs and the refurbishment targets. The engineered structural double skin was proposed for the building integrated refurbishment.

The building has a rectangular plan (48 m x10 m), three floors and a basement; a midspan thermal expansion structural joint divides the building into two independent structures (Figure 8a). Possible seismic induced pounding between the adjacent portions is not considered herein.


Figure 7. a) Residential district in Brescia, a city in Northern Italy, where the case study building is set; b) view of the case study building.

The lateral force and gravity load resisting system is provided by 3 RC frames spanning in the longitudinal direction. The frames are connected to each other in the transverse direction through RC one-way ribbed floors embedding lightweight bricks. Transverse side frames are present at the building east and west ends. The external cladding is provided by infills made of two brick leaves (12+8 cm) with an inner cavity. On the southern side the basement presents short columns (see the basement strip windows in Figure 7b) while the northern side is characterized by regular columns without infills (the garage entrances). The ribbed floors (20.5cm thickness) have a 25mm concrete topping without steel reinforcement.

The finite element model of the building was assembled with reference to both the original construction documents and specifications, and by addressing standards and manuals adopted at the time of construction (reference standard n°1086 of 05/11/1971). Columns and beams were modelled with lumped plasticity beam elements, the infill panels were modeled with equivalent diagonal compression-only struts, characterized by the relationship proposed by Bertoldi et al. 1994 (Figure 8b). The floors were modelled as in-plane rigid diaphragms.

Nonlinear static finite element analyses were carried out to investigate the structural performances of the existing building highlighting a reduced displacement capacity of the structure, mainly associated to the onset of a soft story failure mechanism, following the shear failure of the short columns alongside the basement on the southern side (Figure 9a).

The site location of the building, the property boundaries and the distances from surrounding buildings in the neighborhood represent the main urban planning constraints in the conceptual design. In the considered case study, urban constraints allow the structural double skin to detach as an enlargement of the existing building along the sole southern side, whereas the new integrated system must adhere to the existing façades elsewhere. Accordingly, the new bracing system was enclosed in the involucre as shown in Figure 10. Traditional concentric steel bracings were considered. Rigid links were adopted to connect the bracing system to the existing building.

For the conceptual design and preliminary proportioning of the new lateral load resisting system, optimal design values of the stiffness (K_b) and of the activation force ($F_{y,b}$) were selected based by adopting the design spectra proposed in (Feroldi 2014). Design parameters are listed in Table 1. Figure 9b shows the capacity curve of the retrofitted building, showing the effectiveness of the structural retrofit intervention.

Energy audit and energy balance analyses were carried out by assessing the thermal performance of the existing envelope (infills and windows) in both stationary and dynamic regime, and by analysing the efficiency of the heating plant system. Very poor energy performance of the building was assessed, with an annual average energy consumption of about 100 kWh/m^2. The energy refurbishment design was aimed at minimizing the dispersions of the envelope and at maximizing the solar contribution and the free internal gain: a new adherent high-performance thermal insulation layer was introduced, whereas solar green houses and shadings were complemented in the exoskeleton expansion along the southern façade. The stationary and dynamic thermal analyses of the building prior to and after the retrofit showed that the refurbishment entailed a reduction of the heating energy consumption by 70% and a substantial increase of the solar irradiation with considerable free internal gain (Zanardelli et al. 2014). Interestingly, even if the solar greenhouses significantly increase the glassed surface, the total thermal dispersions decrease both through the windows and the infills after the energy refurbishment.

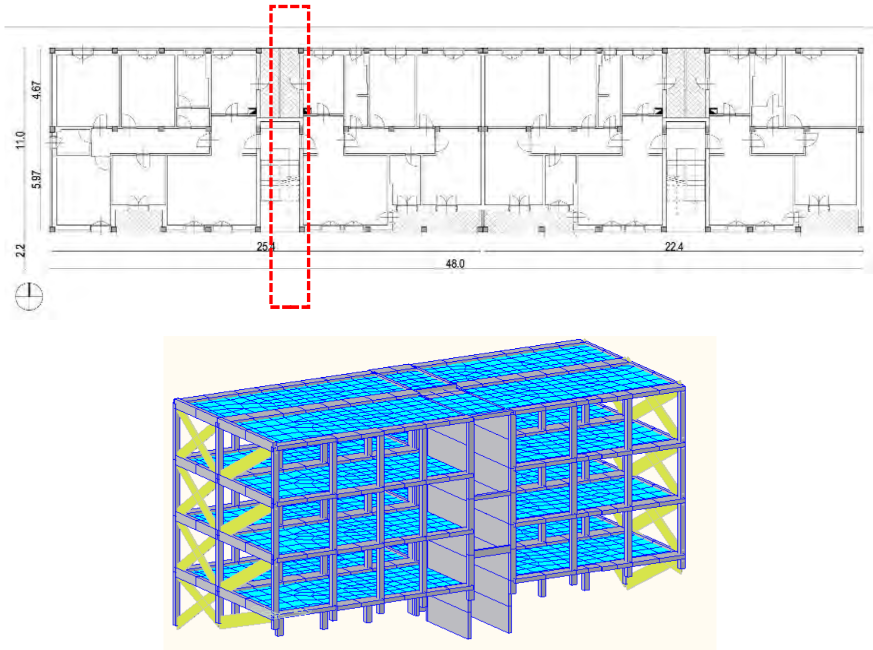

Figure 8. a) Plan view of a typical floor (units in meters): in evidence the thermal expansion joint; b) Finite element model used in the non linear analyses..

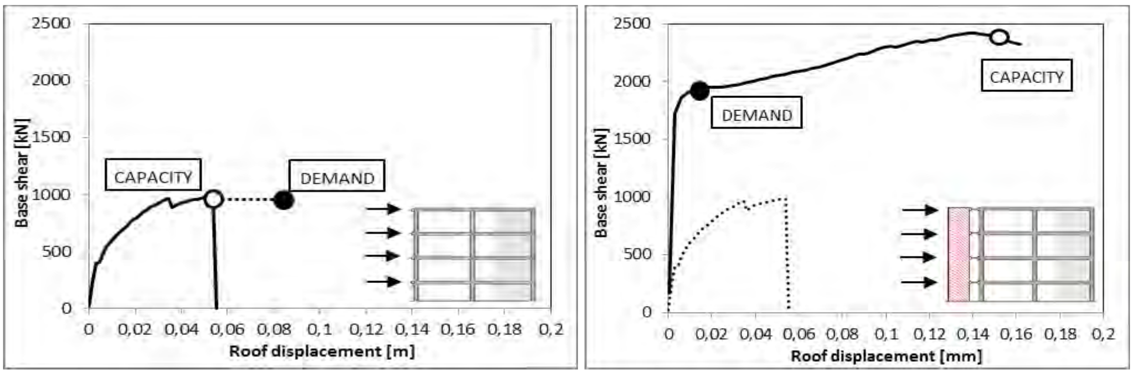

Figure 9. Shear-Displacement- curves of the building in the transversal direction: a) before the retrofitting the displacement capacity is smaller than the demand; whereas b) after the retrofitting: the displacement capacity is larger than the displacement demand..

Regarding the environmental sustainability of the selected building, Belleri and Marini (2015) showed that, for the given building, the expected annual embodied carbon associated to seismic risk is about 25% of the annual operational carbon if thermal refurbishment is carried out without seismic retrofit. Such value drops to 3% in the case of structural retrofit. In the case the same building would have been located in L'Aquila, those values would become 87% and 10% respectively, highlighting how the sole energy refurbishment is unable to effectively reduce the environmental impact of old buildings located in high seismicity regions.

Ultimately, some rendering of possible new layout of the existing building are shown in Figure 11 upon completion of the structural intervention, in which the new structural system (Figure 11b) is integrated within the energy and architectural refurbishment involucre (Figure 11c, d), defining new spaces (such as solar greenhouses and balconies) and increasing the wellbeing of the inhabitants.

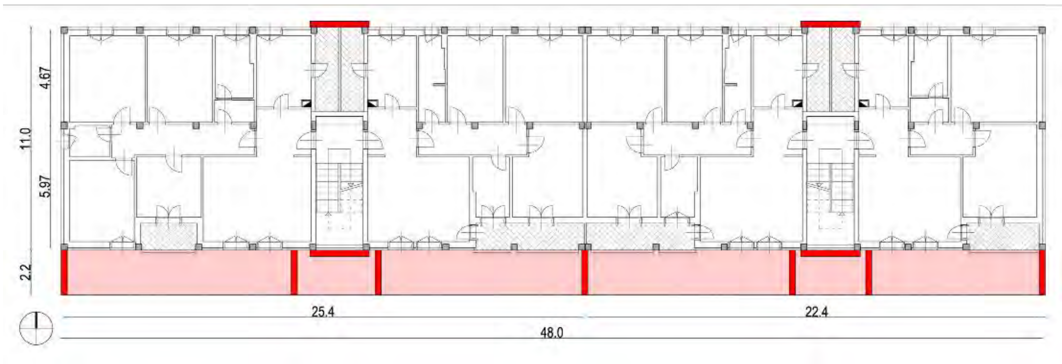

Figure 10. Plan layout of the bracing system (red elements).

Table 1. Values of stiffness (K), yielding displacement (dy) and strength (Fy) for the existing frame and the dissipative system.

Frame	Bracing system
K_{fr}= 60593 kN/m	K_b=2* K_{fr} = 121186 kN/m
$d_{y,fr}$= 0.015 m	$d_{y,b}$=0.25* $d_{y,fr}$ = 0.00375 m
$F_{y,fr}$= 909 kN	$F_{y,b}$= 454.5 kN

Figure 11. Example of two possible retrofits of the existing building (a) through structural double skin: b) solely structural retrofit c) (Abelli et al. 2014), d) integration of structural, energetic and architectural refurbishments, with the creation of new living spaces (Foti et al. 2014).

CONCLUSION

A global integrated intervention for the sustainable restoration of the post WWII building stock was proposed, which tries to overcome the major disadvantages of the traditional renewal practice, targeting uncoupled solution of single deficiencies. The solution can be also regarded as an enhancement camouflage interventions combining architectural restyling and energy saving measures. A holistic solution is proposed, which couples structural retrofit in the renovation process. The intervention is carried out from the outside, minimizing impairment of the inhabitants and building downtime.

The exoskeleton is engineered by introducing ad hoc systems increasing structural safety and seismic resilience. External shear walls and shell solutions, either stiff or dissipative, are proposed. In the former solution structural walls are embedded in the exoskeleton on which the energy devices are installed, hence the two different systems (energy-structure) work in parallel. In the shell solution, the envelope can be innovatively designed as to enable both energy efficiency upgrade and structural safety through the twofold use of the same elements and devices; this approach allows stretching the concept of holistic solution to the highest level, fostering integration of several functions into each component of the encasing structure.

Proportioning of the retrofit solution is affected by the presence of possible stiff elements, such as infills and staircase walls; unless preliminary interventions are carried out to downgrade the initial stiffness, stiffer existing buildings could require excessively stiff retrofit systems.

In-plane strength of the floor system must be assessed to verify the possibility to exploit the floor in the “as is” condition as a diaphragm collecting and transferring the seismic actions to the seismic resistant system. The need for a new diaphragm may represent a major barrier to structural renovation and jeopardize the main intent to operate outside of the building.

The retrofit can be conceived by applying the principles of Performance-Based Design, hence by defining some relevant performance design targets for the given building and for the specific Seismic Hazard Level.

As a result of the coupled structural intervention a series of co-benefits can be obtained: lengthening of the building service life; seismic resilience; long term protection of the investment; construction of upper storeys; reduced life cycle costs and minimization of the environmental impact over the building life cycle.

Contributes to the Roadmap

Enhancement of existing building environmental sustainability is only achieved if such buildings are structurally safe. For older buildings, not designed according to modern codes, energy saving measures and architectural re-styling should be combined with structural retrofit.

In order to improve feasibility of coupled energy-structural solutions and to limit the impairment of the inhabitants, retrofit strategy should be carried out from the outside and should focus on the building envelope.

Several structural solutions have been proposed in order to couple energy efficiency interventions with structural retrofit. These solutions are dependent on the building characteristics, in terms of structural vulnerability, and site seismicity.

Design abaci could be developed under the Performance-Based-Design perspective in order to control the retrofitted building in terms of maximum displacement, acceleration, base shear and so on during a seismic event.

The coupled structural intervention provides a series of co-benefits such as the lengthening of the building service life, seismic resilience, long term protection of the investment, construction of upper storeys, reduced life cycle costs and minimization of the environmental impact over the building life cycle.

Environmental impact associated to seismic risk can be high. The relevance of such a remark is emphasized when considering the district and city level, where the vulnerability of entire districts may jeopardize the effectiveness of extensive energy saving measures.

Open Issues

It is possible to achieve a box-structure behavior acting on the sole building envelope?

The role of floor diaphragm action during seismic excitation is critical and the need for new floor diaphragm may be a major barrier to the entire renovation process. Are the existing floors able to perform like in-plane diaphragms?

Disregarding building structural vulnerability may result in erroneous expectations on the actual effect of extensive energy saving measures. Should the current way to assign national subsides for energy refurbishment be changed?

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Improving Sustainability Performance of Existing Buildings: A Case Study

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ABSTRACT

The attention on renovation of European existing building heritage has arisen in last years mainly following EU policies focused on the achievement of ecological and energy improvements. Nevertheless, buildings dating back at the period ranging from 1960 to 1990 represent the biggest amount of the current built environment. This category of constructions often shows inadequate seismic response and a very advanced stage of deterioration, as well, thus requiring huge investments in repair measures, or even the need of demolition.

In light of these considerations, this study aims at introducing an integrated approach for the retrofit of existing buildings, accounting for both structural design and sustainability requirements. After a brief introduction on the main characteristics of EU building stock, the work focuses on Italian situation, giving particular attention to reinforced concrete residential buildings, which represents the majority of constructions erected in Campania district at that time (i.e. the '60s -'90s of the last century).The proposed sustainable integrated approach is described and also discussed through an application to a seismic deficient building in Naples.

Keywords

Reinforced concrete residential buildings, seismic retrofit, integrated approach, life-cycle.

INTRODUCTION

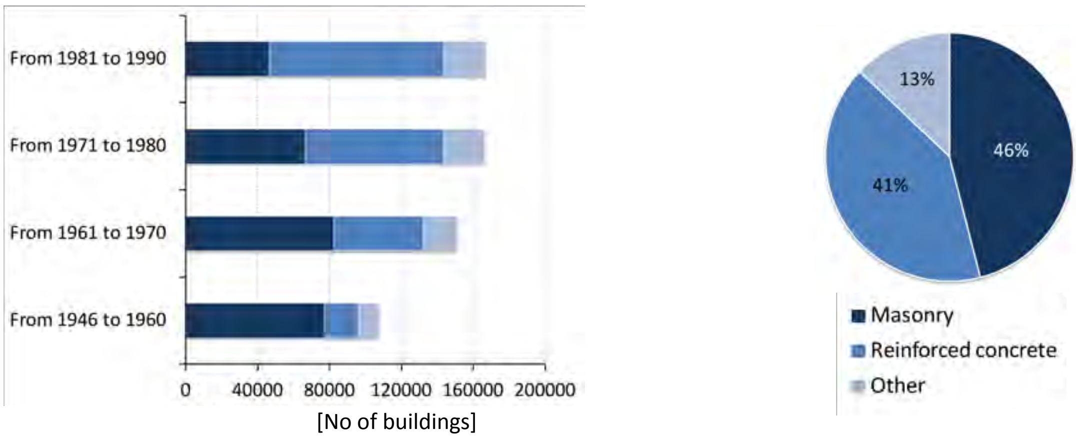
The built environment represents a large share of economic assets of individuals, organizations and nations which leads the construction sector to be one of the largest industrial market. Nevertheless in the last seven years the European construction market lost about 21% in volume due to the deep economic crisis, especially with regard to the branch of new buildings. Activities related to renovation of buildings still have an important cushioning effect for the entire construction sector. As a matter of fact, the existing building heritage could be a significant resource to enhance social, economic and environmental benefits of future cities towards sustainability. Indeed, in order to reach the European '20/20/20' goals in relation to energy

saving and CO_2 emissions reduction, a large-scale upgrade of the existing building stock would be required, as also foreseen in 2011 by the European Commission that estimated an amount of 60% of buildings to be retrofitted by 2050.
The European existing building stock, considering both the residential and non-residential sector, accounts for 25 billion m^2 of useful floor space in the EU27 (BPIE, 2011). The residential building stock is the biggest segment with a EU floor space of 75% of the total building heritage. A substantial share of the stock in Europe is older than 50 years with many buildings in use today are hundreds of years old. More than 40% of residential buildings have been constructed before the 1960s when seismic design codes, as well as energy building regulations were very limited. A large boom in construction in 1961-1990 is also evident for the housing stock which more than doubled in this period (BPIE, 2011). A common European single family house (SFH), built before 1970s, have a masonry bearing structure and it is mainly a non-insulated construction with regard to the secondary elements. A typical apartment block, built in 1950-1970s, instead, is characterized by a reinforced concrete framed structure. It often has non-insulated brick (cavity) walls and single glazed windows. Pre-1970 residential buildings are often designed not to resist lateral forces, thus seismic resistance could be inadequate and extensive damages or failures may result. Several structural deficiencies in terms of seismic response of the pre-1970s residential constructions have been observed on the basis of damages and failures documented after EU earthquakes of the last three decades. For instance the past 1999 Athens earthquake registered typical damage ranged from out of plane failure and corner damage for buildings with no strengthening to shear cracks with regard to masonry heritage, while the two 1999 devastating Turkey seismic events reported that more than twice of the damaged buildings were reinforced concrete structures. With regard to the recent events it is worth to consider earthquakes in Italy (L'Aquila - 2009; Emilia Romagna - 2012) which registered several collapse for the masonry historic heritage. Nevertheless also r.c. and pre-cast structures have been highly damaged or collapsed mainly because of inadequate transversal reinforcement in beam-to-column joints, revealing high levels of vulnerability for reinforced concrete frame buildings even if these buildings had been recently built when seismic design standard (Italian code, NTC 2008) was codified to conceive seismic resistant structures. Moreover, with regard to the secondary elements commonly used for the pre-1970 residences, the lack of proper insulation for the external walls, partitions, roof is clear in all EU countries due to the deficiency of standards in this field in those construction years with a consequent average energy intensity of residential buildings of 200 kWh per m^2 as reported by 2011 BPIE analysis. It is worth noticing that a drastic reduction of about 50 kWh per m^2 is needed in order to respect the current EU energy target. All that considered two main problems affect existing EU residential building heritage: earthquake vulnerability and a large consumption of energy.
In this perspective, it is clear that, nowadays, the renovation of building stock is a priority issue to deal with. Besides eco-efficiency concerns, many essential needs related to the structural efficiency and reliability arise and they shall be ensured both in ordinary and seismic conditions.
The present contribution aims to highlight the importance of considering sustainability requirements in designing seismic retrofit interventions in order to reach an effective strategy for a comprehensive building stock renovation. In that line, an integrated multi-performance based approach which creates a balance between requirements related to the common triple bottom line of sustainable development with structural engineering ones, is required. In the next sections, following this brief outline on the European existing building stock, attention is deserved on the Italian situation and particularly on Campania district. Special attention is devoted to reinforced concrete residential buildings, briefly discussing their main seismic vulnerability and energy non-efficiency factors, as well as the potential practical solutions to improve those critical issues. The concept and the principles of sustainable design of structures are then discussed and in particular, a multi-performance time dependant approach is presented. Finally, in order to provide a practical application of this approach, a case study which refers to a seismic-deficient reinforced concrete residential building located in Naples is presented.

THE ITALIAN CONTEXT: A FOCUS ON EXISTING REINFORCED CONCRETE RESIDENTIAL BUILDINGS IN CAMPANIA DISTRICT

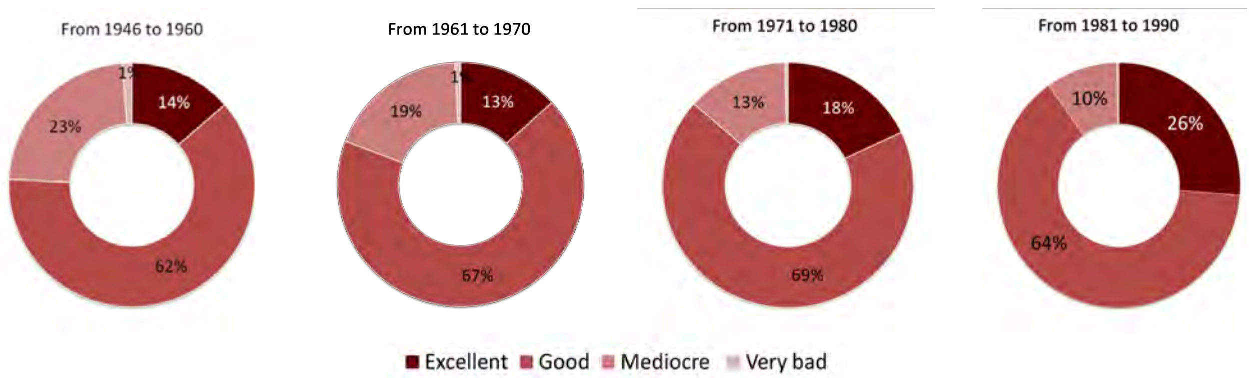
The Italian residential building stock accounts of about 84% of the global national building heritage, according to the last 2011 population and household analysis of the national statistic institute (ISTAT). Masonry constructions represent the major segment with 57% of buildings, followed by reinforced concrete residences with a percentage of 30% and only 13% of households turn out to be built with other construction materials. During the first building boom related to the period between the '50s and '70s the number of r.c. households remarkably increased, overtaking masonry buildings during the second building boom which dates back to the period 1971-1980. Despite the 1979 energy crisis with a consequent deep inflation, the number of r.c. buildings increased during the consecutive age bands (after 1980), resulting more than twice if compared to the masonry stock. Limiting the geographic context to the region Campania, located in South Italy, 85% of the existing building stock belongs to the residential sector (ISTAT database). In particular, a focus on the chronological periods related to the building boom shows that the total number of reinforced concrete buildings turns out to be nearly equivalent to the masonry buildings one, as reported in terms of percentage in Figure 1.

Figure 1. Number of residential buildings for type of material in the region Campania (South Italy) from 1946 to 1990.



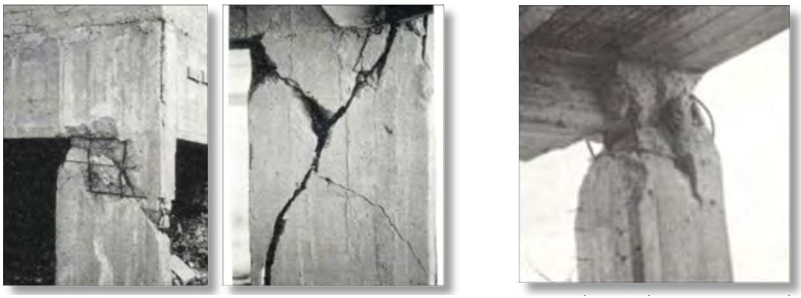
In that situation, attention should be deserved on the state of conservation of r.c. building (Figure 2). The majority of residential buildings - an average of 65% of the total number - exhibits good conservation conditions, while pre-1970 residences represents the existing building heritage with mediocre conditions of conservation, accounting for an average of 21%.

Figure 2. State of conservation of r.c. residential buildings in Campania from 1946 to 1990 according to ISTAT database



Although the state of conservation scenario turns out to be quite positive, interventions on pre-1970 r. c. households in Campania is needed in order to improve structural performance against seismic events. Indeed most of those buildings, were primarily designed for gravity loads and currently show an inadequate structural response. In addition, an eco-efficiency retrofit has to be considered aimed at ensuring a comprehensive renovation in the perspective of a sustainable and resilient solution. The main vulnerability factor for the pre-1970 r.c. existing buildings, as well known, consists on the absent or inadequate seismic resistant structure which is characterized by frames conceived only for vertical loads and oriented in a single direction (one-directionally resistant frame) with r.c. beams oriented orthogonally to the floor direction and absent transversal beams leading to a high transversal deformability. Other factors observed are the irregular shape in plan with a consequent high eccentricity between the center of masses and the center of stiffness; absence of floor diaphragm system; short columns; shear failure and concrete crushing failure in concrete columns which represents the most undesirable non ductile modes of failure; soft-storey effects, leading to a shear brittle failure of the column till the floor global collapse; inadequate or incorrect structural detailing such as insufficient anchorage of beam reinforcement, lack of adequate ties and excessive tie-spacing in beams and columns, inadequate confinement of joints (Figure 3).

Figure 3. Seismic vulnerability factors of r.c. buildings in Campania, mainly observed after the 1980 Irpinia earthquake



Shear failure of short structural elements

Joint failure for absence of confinement

Soft-storey effect of a building in Avellino

The main problem related to a low energy efficiency of a typical pre-1970 r.c. residential building is the absence of insulation. It is worth noting that envelope accounts an impact of 57% of the building thermal loads. Several practices could be considered in order to improve energy efficiency of residential building. In particular, limiting the thermal conductivity of major construction materials is the most common thermal performance requirement for buildings. These are based upon thermal transmittance (U-value) requirements for the main building envelope elements. Typical U-values of exterior walls for the r.c. existing building in the Italian context are around 2 - 1.5 W/m^{2}K for residential buildings built before 1970. A drastic reduction is needed, considering that many existing regulations demand U-value approximately equal to 0.2 W/m^{2}K for roofs and walls which means about 200 mm thick insulation layers.

A SUSTAINABLE INTEGRATED APPROACH FOR STRUCTURAL RETROFIT INTERVENTIONS

Nowadays, one of the most ambitious challenges of civil engineering research is focused on the achievement of an effective way to conceive structures with the aim to develop a competitive sustainable construction sector. The research of sustainable solutions applied to structural design should be stimulated also for the interventions on existing building heritage. In particular seismic retrofit solutions on reinforced concrete existing buildings should satisfy not only structural reliability but also economic and environmental requirements in order to reach an optimum solution for earthquake resistant and eco-efficient buildings.

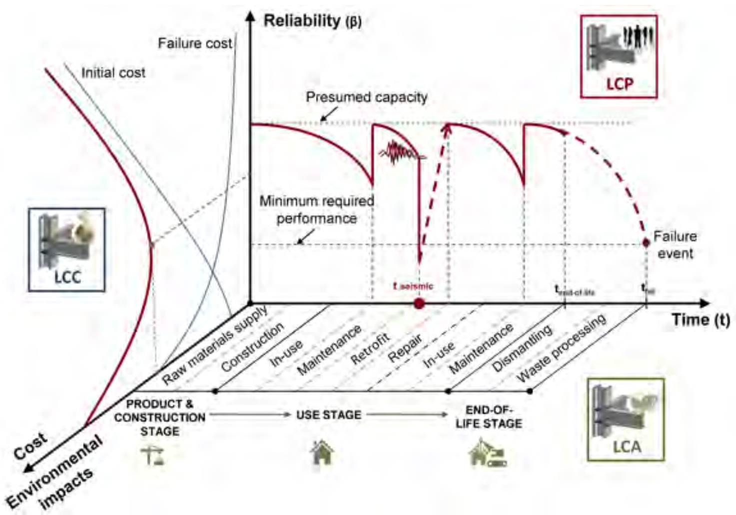
For this reason an integrated approach is needed and from a structural point of view Life Cycle Performance (LCP) assessment is required. Indeed it is a performance based approach for the verification of durability (ISO 13823:2008) with the aim to define the period of time where a structure or any components is able to achieve the required performance level, considering the effects of the deterioration on the structural capacity. LCP methods are based on the prediction of the deterioration that will act on the structure and the corresponding effect over time in order to prevent a premature failure of the structure. In that line, design for the life-cycle becomes the possible answer to conceive sustainable structures both for new and existing buildings. It means to make decisions related to structural, environmental and economic requirements in design phase of a retrofit intervention that will affect on the entire life-cycle.

Sustainable structural design is an integrated time-dependant multi-performance based design and/or assessment methodology, which takes into account the performances of a structure related to the environment, the economy and the society during the whole life-cycle. In particular this methodological design philosophy is aimed at maximizing mechanical, durability, economic and environmental performance of a structure during the whole life-cycle, reducing at the same time the negative impacts played on the three dimensions of sustainability (Landolfo, Cascini and Portioli, 2011). The method consists on the evaluation of structural, environmental and economic performance of a structure during its entire life-cycle (Figure 4), foreseeing performance design scenario focused on service life profiles that should be defined both in ordinary and in exceptional conditions.

The sustainable structural methodology is characterized by three key points:

1. It is a **multi-performance** based design approach, aimed at satisfying not only the traditional requirements of reliability, safety and serviceability, but also new sustainable needs such as reduced environmental impacts, optimized life-cycle costs, optimized building management.
2. It is a **life-cycle** oriented methodology: the time unit considered goes beyond the ordinary design working life. The life-cycle may include all the stages of the construction's life: from the extraction of raw materials to the end of life of the construction works, taking into account design, construction, maintenance, dismantling and/or demolition, disposal and recycling and/or re-use of materials and/or structural elements.
3. It envisages the use of **quantitative design procedures**, based on performance levels in accordance with the assessment methodologies developed in the framework of international research and received by ISO standards.

Figure 4. A schetch of the sustainable integrated approch



In the next section a simplified application of the proposed sustainable integrated approach to seismic retrofit case-study is briefly presented.

AN APPLICATION TO A REINFORCED CONCRETE EXISTING BUILDING

The examined building (Figure 5)is part of several housing units forming a large urban district, namely 'rione Luzzatti' which represents one of the first examples of social housing realized in the Neapolitan context after the II World War (Landolfo, Losasso, Pinto, 2012).

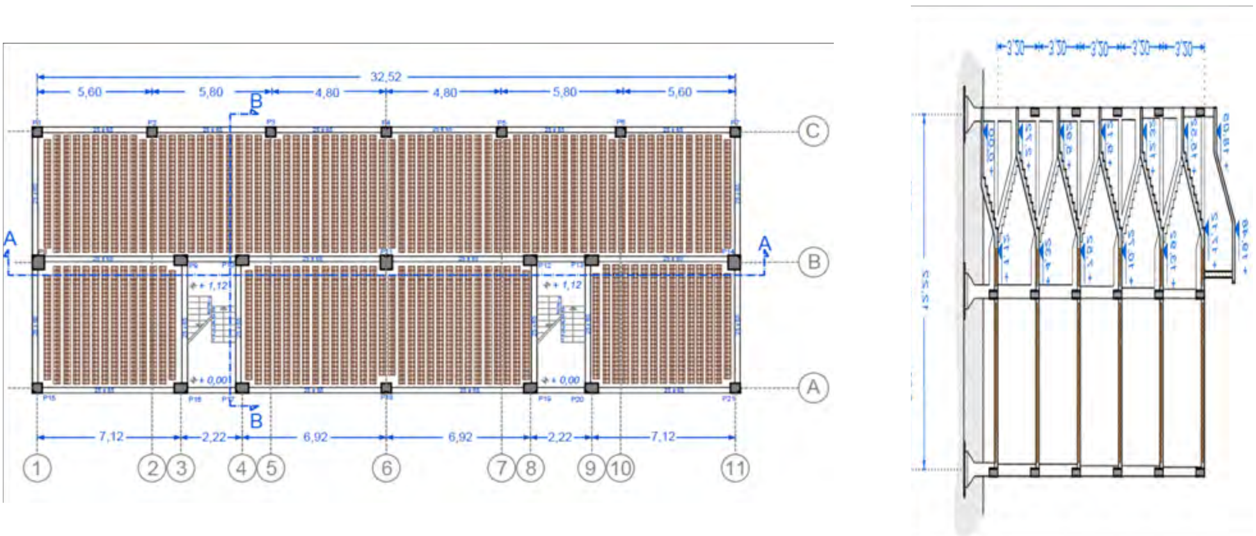
Figure 5. Building of Rione Luzzatti (Naples).

1946 Current situation

It is a five floors multi-family building with residential function for each level composed by four dwellings with an area of around 80 m^2, accessible thanks to two vertical connections. The building has a rectangular shape with dimensions in plan of 32.5 m and 12.2 m in direction x and y, respectively and an inter-storey height of 3.20 m. The bearing structure, designed only for gravity loads is composed by three frames with 6 spans and two perimeter frames along x-axis and y-axis, respectively (Figure 6). The vertical bearing super-structure is composed by 21 columns with variable sections: from (60 x 45 cm) at the first level to (30x30 cm) at the sixth level. The horizontal bearing system is characterized by a reinforced concrete cast in situ floor with a depth of 25 cm and beams with rectangular section of 25 x 65 cm for all building levels. Finally the sub-structure is characterized by isolated footings.

In the examined case study, the absence of original documents led to a limited knowledge level (LC1) with the consequent elaboration of a simulated design. The first step aimed at assessing the structural reliability of the building consists on destructive and non destructive testing which have carried out an advanced degradation of reinforcement bars due to corrosion and carbonation of concrete, as well as the value of yield strength for the reinforcement bars equal to around 370 MPa and the medium compressive strength for the concrete of 35.1 MPa. Then the existing structure assessment has been carried out according to the simulated design steps. In particular, as regard for seismic assessment, Naples was not classified as seismic area during the construction period. In order to carried out a seismic analysis (static linear), on the basis of the seismic hazard map for Italy, the Neapolitan district is classified as zone 2 with a PGA =0.25g and a soil ground type C. The period T_1 is equal to 0.664 s and the structure turns out to be regular in plan and height, thus respecting limits issued by standard. In addition the simulated design allows assessing bars deficiency in structural elements with a variance from 5% to 72%. The structural analysis mainly highlights that the examined building is a non earthquake resistant structure, thus a seismic retrofit is required.

Figure 6. Layout of the structure in plan (a) and section (b).

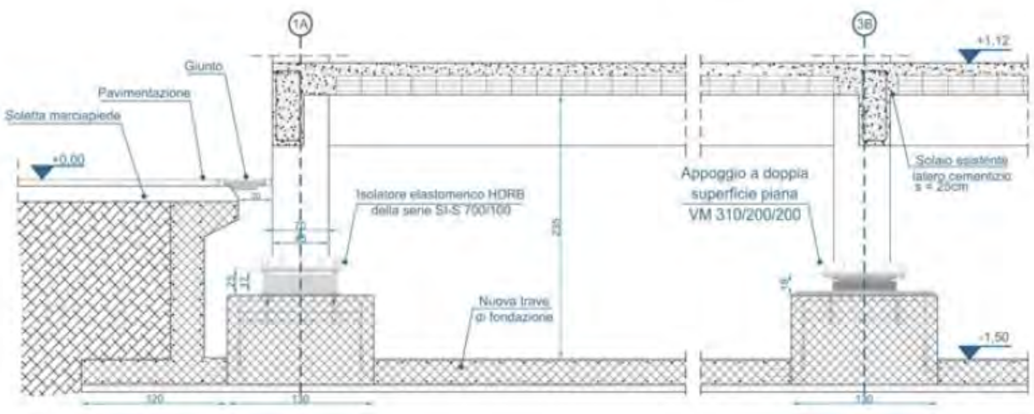


(a) (b)

Two different solutions have been considered: a traditional intervention consisting on reinforced concrete jacketing of the main structural elements (beams and columns) and the strengthening of slabs and an innovative one which considers the base isolation. In details, the first technique consists on both the introduction of new beams in y-axis direction in order to realize a new frame and the jacketing of beams and columns with new longitudinal and transversal reinforcement bars (Figure 7). Moreover the joints strengthening thanks to the introduction of longitudinal reinforcement and jacketing has been considered in order to avoid plastic hinges in the beam-to-column joints. Finally, with regard to slabs a new electro-welded net has been inserted. The second intervention (Figure 8), instead, foresees the introduction of foundation beams for the connection of isolated footings and the introduction of two types of base isolation devices: the low-friction sliding isolators and elastomeric High Damping Rubbing Bearings (HDRB) at the base of central and perimeter columns, respectively. The isolation devices position has been optimized in order to avoid torsion effect of the structure. Finally a seismic gap along the building perimeter has been considered with the aim to allow superstructure motions.

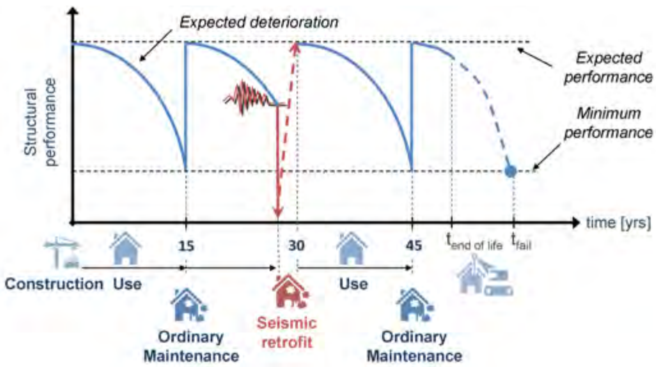
Figure 7. RC jacketing intervention.

Figure 8. Base isolation intervention.



In order to assess the most advantageous solution in terms of sustainability a multi-performance life cycle approach with several simplified assumptions has been considered, taking into account structural and economic performance. In particular a service life profile (Figure 9) which considers an unexpected earthquake in the middle of the lifetime of the structure after the seismic retrofit is considered. In relation to the *structural performance* the traditional solution show local collapse with consequent new repair interventions, while with regard to the innovative option seismic damages are limited to non-structural elements. As for the *economic performance* for both solutions initial retrofit costs are similar. Indeed it has been estimated an amount of 515.50 k€ for the RC jacketing solution and 580.29 k€ for the base isolation one, while on the basis of the potential earthquake damages, repair costs result higher for the traditional technique option. In conclusion the base isolation intervention turns out to be the most advantageous alternative for both structural and economic performance. Further detail will be reported in the extended paper.

Figure 9. Service life profile.



CONCLUSION

Deep renovation of existing buildings is an European high-priority issue to achieve in order to make cities safer and sustainable and to increase the competitiveness of construction sector. As for the Italian context pre-1970 reinforced concrete residential building show an inadequate structural response particularly in relation to seismic loads, thus retrofit interventions are urgently needed also in the light of the recent earthquakes which hit this country. In order to improve not only structural safety but also energy efficiency and urban quality an integrated approach is recommended, so a potential integrated life-cycle multi-performance based design and/or assessment methodology is briefly discussed.

In that light a non-seismic resistant structure in Naples has been analyzed and two seismic retrofit interventions have been considered: a reinforced concrete jacketing and a base isolation. The innovative retrofit turns out to be the most advantageous alternative both in terms of structural and economic performance.

Contributes to the roadmap

On the basis of the present contribution the following issues should be taken into account in the *Roadmap for the improvement of earthquake resistance and eco-efficiency of existing buildings and cities*:

1. The increasing importance of **renovation** of the EU existing building heritage, considering the enormous amount of buildings constructed during the period 1960-1990.
2. The need to ensure **structural reliability** of pre-1970 structures with a particular regard to seismic loads, considering the more effective and sustainable retrofit solution.
3. The need to satisfy in a holistic way several requirements related not only to structural design, but also to the triple bottom line of sustainable development (Environment - Economy - Society) during the whole **life-cycle** of a structure.

Open issues

1. BUILDING RENOVATION SHOULD BE PROMOTED AT **URBAN SCALE**.
2. **Life cycle thinking** concept should be considered in defining methodology for an integrated approach.

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Seismic retrofitting and new way of living in existing social housing settlements

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ABSTRACT

This paper proposes a method for architectural requalification and seismic retrofitting of social housing through substitution of external walls with prebuilt panels of fixed dimensions; all panels have a metal frame, but some of them include metal shear panels, in order to stiffen the structure, while the remaining are closed by wood layers and filled with thermal insulation. Panels can be easily changed to allow modifications in internal arrangements, so to offer a real flexibility for inhabitants.

Metal panels have another structural goal, in fact one or two new floors can be realized on the top of the building, to create cooperative dwellings for singles, who have difficulties to find an exact solution for their housing needs. New floors can also be used to relocate apartments placed at ground level; floor apartments can be leased as office to young freelancers at a low cost, to compensate the prize of works.

Keywords

Seismic retrofitting, metal shear panels, social housing, architectural requalification, flexibility.

INTRODUCTION

We can rely on Irpinia's earthquake of 1980 to a significant upgrade in Italian anti-seismic regulations, confirming the use of correcting the risk after it became emergency. Seismic retrofitting just can be a solution for this bad routine, aiming to realize a wide securing, not only for few public structures, but also for residential buildings; in fact we have to consider that in Italy a great part of the edifices realized with a reinforced concrete structure were designed during 60's and 70's, without any anti-seismic standard, only thought for vertical loads, sometimes reaching heights that were never matched later.

Vulnerability of these buildings is to be evaluated, also considering that they show the effects of time. Italian Law 1/2011 (Piano Casa Campania) suggested a possible solution, offering volumetric bonus for those construction works connected to an energetic up-grade, to which also seismic retrofitting could be joined. Such incentives, together with tax deductions, can be a spring for a wide work of renovation. Nowadays many methods for seismic reinforcement are available, both for works spread to all the elements of the structure, such as strengthening of pillars and beams with FRP (Fiber Reinforced Polymers) or with CAM system by steel elements, and for punctual actions on few elements, like insertion of friction pendulum bearings, damping rubber bearings or hysteretic bracing systems, that can much reduce time and problems of construction site.

To consider these methods as closed to themselves, only aiming to reduce as much as possible building times and bothers for inhabitants, can result a short-sighted approach, overlooking possibilities connected to them and neglecting qualities that these systems have to own. In fact we have to consider that any structural intervention has some costs connected to construction-site and physical effect on existing structure with unavoidable inconveniences for inhabitants, therefore it makes sense to convert these problems in an opportunity for a complete refurbishment of the building, including architectural aspect, that can involve both facades (and energetic performances) and internal arrangement (increasing habitability and flexibility).

Integrated interventions for refurbishment (architectural – energetic - structural – city planning) of social housing spread all around Europe, sparking interest in scientific community; particularly they were located in those countries that had severe damages during second world war, to which a quick reconstruction came along, often characterized by the use of prebuilt systems and reiterated schemes. Druot and Lacaton&Vassal realize a significant intervention on the tower Bois-le-Prete in Paris, in fact, without entering inside the edifice, it succeeds in deeply changing both its external aspect and the way of enjoying lodgings, as well as the relation between flats and outdoor spaces, while interior spaces change growing up, expanding themselves in new filter-spaces. Bois-le-Prete is an intervention made by steel and glass, and above all architects choose a prebuilt system, whose advantages are evident: short building times, quick and flexible construction-site, dry mounting and changeability in the aftermath. Flexibility is particularly worthy of attention, because in many interventions the upgraded structure has the same immutability of the previous one, no doubt that it has preferable qualities, it better fits nowadays dwelling needs, offers higher energetic needs, and so on, but people have no possibility to adapt spaces to their expectations. Particularly social housing has claimed its housing disadvantage for a long time, and also works of famous architects became a symbol of decline, so to impose their demolition; in this case refurbishment has to increase not only structural safety, but also functional flexibility so that future inhabitants can easily find a suitable solution to their dwelling needs.

There are two main goals to be pursued: using seismic retrofitting systems that can be easily reactivated after an earthquake, and offering to people a flexibility of apartments that goes beyond chaos of singular actions that often humiliates facades of social housing reducing them to mish-mash of thrown together verandas, canopies and any other creation like ‘bad sunday’s bricolage’.

STRUCTURAL INTERVENTION

In this paper we propose a method for seismic retrofitting through the use of metal shear panels in order to stiffen existing structure. Seismic vulnerability indicates probability that a structure, during an earthquake, can present damages. Vulnerability depends on two aspects: characteristics of the earthquake and low resistance to horizontal forces of involved structures, that is often caused by late adoption of anti-seismic rules for constructions, in Italy it can be attributed to the period following the earthquake of 1980 (D.M. 03/06/1981 n.515 e D.M. 12/02/1982), but, considering that 60s and 70s were characterized by a wide building development, nowadays we have a great number of edifices, whose structure was designed without any anti-seismic criterion, on the contrary, they are often dimensioned according to an inverse capacity design, with tall beams on thin pillars. Scientific research much worked to find systems able to strengthen vulnerable existing structures made by reinforced concrete, in order to increase their resistance to horizontal strain, but at the same time these devices are thought to perform the function of sacrificial victims, concentrating on themselves the most of the damage, so protecting existing structure; on this purpose we can remember shape memory alloy braces, base isolation (rubber bearings or friction pendulum) and metal shear panels, all avant-garde technologies deeply debated in in the scientific research field, that employ steel elements to guarantee a quick reactivation to be realized through dry mounting, in order to avoid a traditional construction site. In this way structural rehabilitation becomes an up-grade of higher level, increasing resistance of the building and also creating a new type of maintenance.
This paper proposes a method for structural rehabilitation through employ of shear metal panels, i.e. sheets of LYS steel or aluminium assembled inside a steel frame whose dimensions are fixed (any element is a module), this frame creates a closure panel that is bolted to a steel plate connected to existing concrete structure through epoxy resin. Perimetral beam is stiffened with steel plates so that metal panels can be connected; metal shear panels and border beams realize a tube-frame structure, like the ones used in skyscrapers, in fact in presence of a horizontal force, panels that are parallel to the force contrast shear action, while panels perpendicular to it absorb flexural action by means of compression-traction deformations. In this system, panels have a dissipative role, creating both an increase of initial stiffness and an energy dissipation through hysteretic cycles connected to the deformation of the slab. In order that slab may have a full dissipative behaviour, it has to deform in plastic field, without showing buckling phenomenon, in fact in this case energy dissipation is mainly due to shear stress, showing a full hysteretic

cycle. In case of buckling, pinching phenomenon arise with reduction of energy dissipation and a quick decline of mechanical features, to avoid this phenomenon employed material has to present $\tau_{cr} > \tau_y$, where τ_{cr} is critical stress connected to buckling behaviour and τ_y is the yielding shear stress, that's why LYS (Low Yield Strenght) steel or pure aluminium are used for these purposes. The steel frame, inside which metal slab is set, is designed to remain in elastic field, so that after a seismic event the slab is the only element to be changed.

Figure 1. left: metal shear panels connected to existing structure – right: the structure is closed by not-structural panels made of a metal frame covered by a wood panel to which thermal insulation is put on.

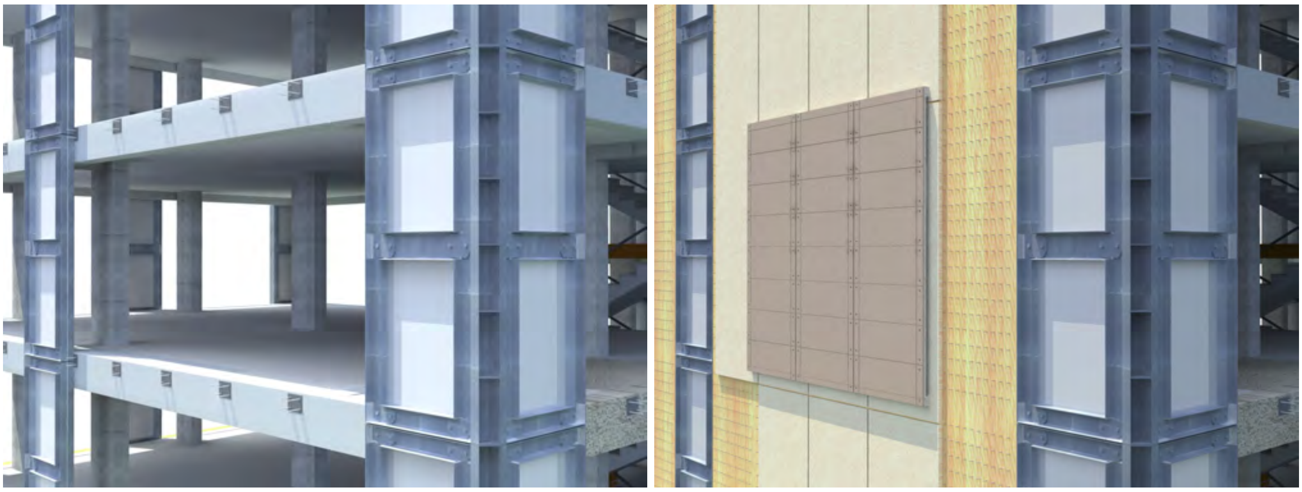

Figure 2. detail of not-structural panels

CASE STUDY – CASALBORE SQUARE – SALERNO (SA) – I

Buildings in Casalbore Square in Salerno, were built in 50s, at the time they were in a peripheral area of the City. Cause of grow up of Salerno in the second half of 20th century, this neighbourhood of social housing nowadays is set in a central area of the Town, nevertheless, some initial design choices last unaltered with effects unsuitable for actual housing standards, much penalizing life quality. Particularly, as buildings are on a slope, a part of dwellings on ground floor are partially underground, causing low privacy and unhealthy conditions to their inhabitants. Methodology, proposed in this paper, suggests in a rising of one or two floors that allows taking up apartments that are now on the ground floor, while lower spaces can be rented low cost to young freelancers, so paying part of the investment. Considering following images, compared with metric survey, buildings show to have a framework in reinforced concrete with thin pillars and tall beams characterized by lacking shear reinforcements.

Figure 3. below and in following images we see the neighborhood both from high through web site 'Bing Maps', and by means of photos of the authors. Buildings treated in the paper are highlighted in yellow. We can notice that the area is completely integrated in urban pattern, so that nowadays it has revenue of a position that grew up as time passed by, but at the meantime living conditions of lower floors are inadequate, because they are partially underground, unhealthy, unable to guarantee the least privacy and exposed to the smog of city traffic

Figure 4. the quarter seen from Casalbore Square

Figure 5. left: as the street advances, ground floor becomes underground – right: discomfort of ground floors

Figure 6. details of RC structure, it's evident that pillars are undersized compared with beams

They have perimetral walls in tuff blocks, that was usual in first RC structures, both for a low confidence in this structural system, and to realize a bracing element, and perhaps it had a relevant role during earthquake of 1980. Even if we have not detailed data on steel reinforcements, it may reasonably be supposed that original structure is inadequate to bear new load of the rising, especially considering that we are in a seismic zone, but we can imagine a scaffolding system having a bracing role, made by panels of shear metal sheets assembled in a metal frame (one for each pillar) connected between them by original beams reinforced by a metal truss connected to the old one by epoxy-resin these elements (panels and reinforced beams) realize a tube frame able to substitute contribution given by tuff walls, increase resistance to horizontal actions and bear weight increase due to raised part. As these edifices are two floors shorter than the neighboring, building code allows this significant rising. Rehabilitated structure can host a closure system made by prebuilt panels, realized with a metal frame closed by wood panels and filled with wood thermal insulation. Panels will have a fixed dimension, in order to facilitate their substitution, that not only means an easier maintenance, but also possibility of changing the type of panels, in fact they will be realized according to an abacus of types: with window, french window, vasistas, closed panel, etc., furthermore, they will include a balcony borne by the metal frame of the panel, that allows to create a filter-space indoor-outdoor that can be organized through separating vertical elements, so as to create spaces of privacy. Balcony can also get an air-conditioning element for indoor spaces, i.e. during summer a curtain on its edge creates a shadow to mitigate heat, while during winter it can be closed by a glazed panel, made by a light metal frame that hosts tilting glass sheets, so to realize a greenhouse effect, saving energy for heating.

Figure 7.

Methodology

Intervention is basically shown in essential drawings placed below: building is actually made of five floors above-ground, the one of these (the lower one) is partially underground (step 1). A perimetral beam on micro-piles is realized in foundation to bear strength derived from rehabilitating system (step 2-3). New perimetral beam works as a foundation for metal shear panels, that are connected to external pillars (step 4). Metal shear panels hold up new floor, they are connected by a lattice girder, so to unload increasing weight from existing r.c. pillars (step 5); lower dwellings are relocated on the top, while ground floor is dedicated to offices low-coast for young freelancer or shops for fair-trade commerce, temporary shops for young entrepreneurs, etc.. In this particular case rising can be two floor high (step 6), higher floor can be arranged to create cooperative-dwellings, i.e. apartments where each inhabitant has a room complete of bathroom and some accessories to allow him having a certain level of independence and privacy, but there are also common rooms, as kitchen, dinner room and living in which all the residents can be together. These kind of co-housing allows getting low rent and is very suitable for singles searching a small living solution, as divorced men, people working far from their families where they go back at the week-end, and so on.

Figure 8. steps of building rehabilitation

Figure 9. internal view on a flat, we can see how balcony becomes a filter element adjusting internal clime, in fact, during winter (left) it saves heat creating a greenhouse effect, while during summer a curtain rejects sun light

CONCLUSION

Seismic retrofitting shows to be an opportunity for architectural requalification of social housing, in order to offer a new quality of life given by a higher flexibility of dwellings. Introduction of anti-seismic devices can be joined to substitution of traditional perimetral walls with prefabricated panels that can be easily changed according needs of inhabitants; added balconies can be used as a filter-space between indoor-outdoor spaces.

Contributes to the Roadmap

Buildings of future must be easy to maintain, also the design of anti-seismic devices must have this goal, their reactivation after an earthquake will be easy and quick, a possible solution is to use metal shear panels assembled in a metal frame that remains in the elastic field, while the sheets have plastic deformations. Best practise is to imagine a deep change of the edifice that involves also its perimetral walls, that are replaced by prebuilt panels, so to get a new way of inhabiting made of flexible spaces, changeable, that can be disassembled and reassembled according to changed needs, a new dynamic concept of living. These goals can be reached only by means of prefabricated elements, both for structural devices and for architectural elements. Prefabrication and flexibility are the high road to an integrated requalification of social housing.

Open Issues

What can be the role of prefabrication in seismic retrofitting and more broadly in future buildings?

What about opportunity of uniting seismic retrofitting to architectural requalification?

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Assessment of Seismic Resilience of Buildings

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ABSTRACT

Earthquakes occurred worldwide caused to excessive economic losses and causalities at many countries. For reducing these losses, activities are concentrated into two main subjects: preparedness to seismic event and reducing vulnerability of structures and society. Communities should satisfy these both conditions in order to achieve high resilience against earthquakes.

Earthquake codes are mainly focused on structural safety for satisfying life safety. Losses are not considered directly during design phase. In this paper it is aimed to figure out the main aspects of the earthquake resilience concept. Some parts of resilience, such as loss estimation, recovery functions, fragility functions, are described. Based on these explanations, some suggestions for quantifying resilience are provided.

Keywords

Seismic resilience, loss function, fragility function, recovery function.

INTRODUCTION

After recent destructive earthquakes, earthquake resistant design of new buildings and seismic retrofitting of existing buildings become more important for reducing economical losses and casualties. In order to reduce losses, various performance levels consistent with usage purpose of the buildings have been identified. In the design of new buildings, it is intended to ensure the life safety performance level. In current regulations, the performance levels are determined by the behaviour of structural elements of the building. However, earthquake caused losses arising during building design is not taken into account.

In the present paper, main part of the seismic resilience is described and some suggestions for quantification of resilience are given.

SEISMIC RESILLIENCE OF BUILDINGS

The concept of seismic resilience is used for evaluation of both direct and indirect losses of the structural design based on predefined loss functions within a specified recovery period. Resilience term represents the capability to sustain level of functionality or performance of structure over predefined control time. According to importance of the structure, to desired functionality or performance level is decided by owner or society. After the natural or man-made disaster, such as earthquake, the time required for restore the functionality of a structure to a desired functionality or performance level is defined as recovery time. Recovery time consist of two parts: the construction recovery time and business recovery time. Recovery time is includes high uncertainties and depend on many factors, such as earthquake intensity, distance to epicenter, location of building to resources, etc. Earthquake resilience concept is schematically shown in Figure 1.

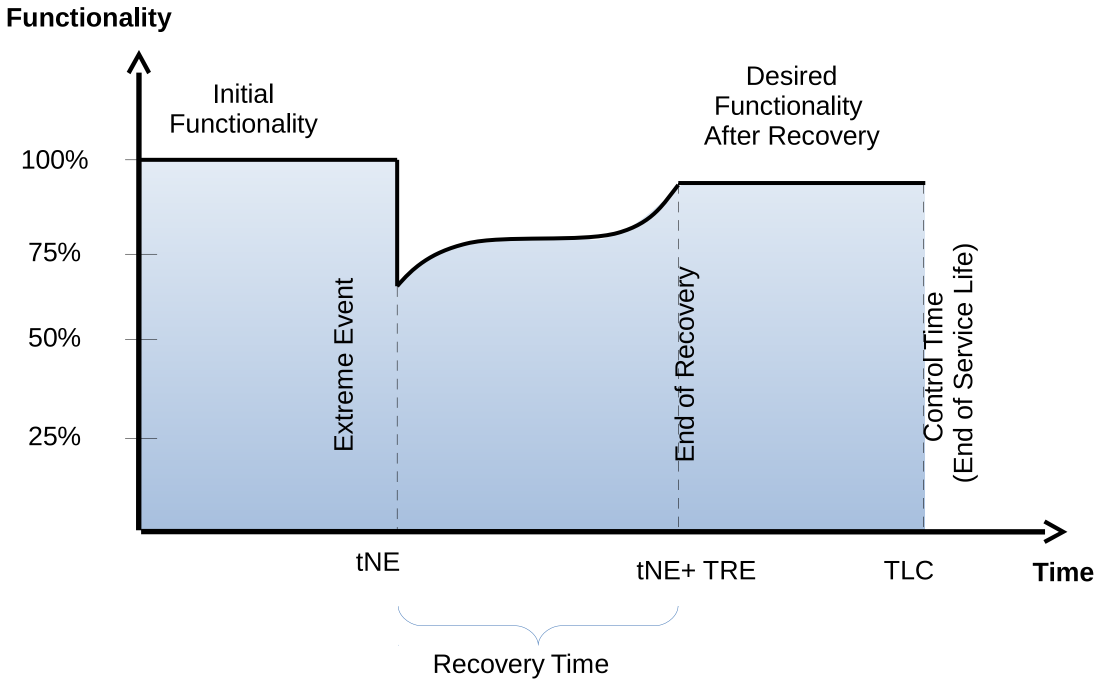

Figure 1. Schematic representation of earthquake resilience

Earthquake induced economic losses or causalities are estimated based on different damage scenarios. Earthquake losses are depend on many uncertain parameters but in general identified by loss function which is expressed as a function of earthquake intensity and recovery time. Losses are combination of structural and non-structural losses. Non-structural loses are divided into four parts: Direct economic losses, direct causalities losses, indirect economic losses, and indirect causalities losses.

Loss Estimation

Estimation of earthquake induced losses is very complicated due to complex nature of the event. Every specific scenario causes to change the level of losses. Losses are divided into two main parts: Direct losses and indirect losses. These parts may be divided into two groups: Economic losses and causalities. All these losses are predicted by loss a function which is expressed as earthquake intensity and recovery time. Loss estimation models are focused on prediction of initial losses relative to pre-earthquake conditions but are not involve post-earthquake losses during recovery period.

Recovery Functions

For evaluating the resilience of the structure, recovery time is considered by simple recovery function models. It is not easy to define detailed recovery function for quantification of resilience. Recovery functions, in general, are selected as linear, exponential or trigonometric function depends on recovery time and the instant of time when the earthquake occurs based on preparedness of the both community and structures.

Fragility Functions

Functionality losses after earthquake are estimated by fragility functions. Fragility curves represent the probability for the exceedance of target performance state of building during various ground motions. Evaluation of the fragility curves is a one of the key parameter for evaluation of the resilience.

CONCLUSION

Concept of resilience includes many disciplines from earthquake engineering to economics and social sciences. Due to complexity of the earthquakes, it is not easy to quantify the direct and indirect losses by a simple function. For this reason, main parameters for evaluating seismic resilience should be determined prudently and risk must be minimized depend on the importance of the designed building.

Contributes to the Roadmap

Earthquake performance of the buildings should be defined based on economic losses and causalities. For this purpose, loss functions should be identified. After seismic event, it needs to establish recovery time, recovery functions, and desired level of functionality depend on type of the structure.

Open Issues

Main parts of the resilience concept should be established clearly for quantification. Connections between community, building and cities should be discussed.

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Experimental study on the seismic behavior of multi-layer energy efficient sandwich wall panels

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ABSTRACT

A new type of energy efficient building structural system applying multi-layer sandwich wall panel is recently developed in China. The panel is composed of five layers, while both outside layers serve as the formwork during the construction and decoration for the afterword normal use. The center core is made of precast foam concrete slab which may significantly reduce energy loss. Rest part of the wall panel is cast in place with fine concrete reinforced by wire mesh and restrained by small fine bar reinforced columns with specified spacing. In this paper, the seismic behavior of this innovative wall panel is investigated by experimental technologies. Based on the different thickness of concrete layer and the section shape of the wall panels, a total of 3 groups (6 specimens included) are built and tested under quasi-static loads. The hysteretic curve, bearing capacity, stress and strain of steel and concrete, cracking process and failure pattern are obtained for wall panels. The tests show that the vertical reinforcements of the end columns yield in tension, while the bottom concrete of end columns crush, the diagonal cracks distribute along the wall panel, and the width of all cracks are relatively narrow except the ones which induce the final failure. According to the experimental results and theoretical analyses, one can find that multi-layer sandwich wall panel has quite good ductility and may be used in the area with earthquake risk.

Keywords

Energy Efficient Building Structure, Multi-Layer Wall Panel; Seismic Behavior; Quasi-Static Test.

Seismic isolation for existing masonry houses in Groningen/NL combined with thermal upgrading

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ABSTRACT

Induced earthquakes, caused by the winning of natural Gas in the North of the Netherlands (Groningen province), are causing significant damage to the existing, often relatively weak, masonry buildings. This seismic hazard and seismic rehabilitation problem in the Groningen area involves much more than just a technical seismic safety problem. Many different stakeholders are involved, not in the least the local population, attached to their local environment and their often privately owned houses. The proposed seismic rehabilitation method can preserve and improve these masonry housing units, by combining seismic isolation with thermal insulation. Core of the approach is applying seismic base isolation by removing the existing, often poor quality, timber floor structure, and, making new foundation footings with a new thermal insulated structural (reinforced concrete) ground floor. First calculations indicate that the rehabilitation method can significantly reduce the seismic impact and seismic hazard of these existing masonry houses.

Keywords

Induced earthquake, seismic base isolation, seismic retrofit, rehabilitation, thermal upgrading, masonry structures, Groningen, sustainability, seismic hazard.

INTRODUCTION

Due to the winning of natural Gas in the north of the Netherlands (in the province of Groningen) more and more induced earthquakes have been registered with increasing ground-motion accelerations. The shallow nature of these induced earthquakes, combined with the relatively weak structures of these mostly masonry brick buildings, are causing significant damage to the buildings. Also, the shallow nature of these earthquakes cause relatively big peak ground accelerations (PGA) that are comparable to other European earthquake regions in Italy, Greece or Turkey. The Dutch code (NPR 9998, 2015) now prescribes PGA reference values as high as 0,42 g (return period of 475 years). Due to the amount of existing buildings and different stakeholders, many parties are now involved. The seismic hazard and seismic rehabilitation problem in the Groningen area is quite clearly much more than just a technical seismic safety problem. Economic as well as cultural and societal aspects (strongly varying for different stakeholders) are involved in the decision process regarding options to do nothing, to demolish and replace, or to rehabilitate existing buildings to different standards. Building owners find it difficult to grasp the risks involved. They respond differently to visible damage and have sometimes little economic means. On top of that a lot of the existing houses in this region are of a relatively low quality masonry with poor structural integrity. It is now estimated that 35.000 houses need immediate strengthening measures (Arup, 2015) in (Steering Group NPR, 2015). It can be expected that these strengthening measures can have a large impact on the users and occupants of the buildings because often they will have to vacate the buildings for a longer period. Eindhoven University of Technology TU/e is, as we speak, involved in the testing of many different brickwork samples taken from various buildings in the Groningen area, in order to evaluate the current situation better. The proposed seismic rehabilitation of these low quality masonry housing units, combines seismic isolation with thermal insulation. The method is now further developed and investigated at TU/e.

SHORT DESCRIPTION OF THE PROPOSED REHABILITATION METHOD

The core of the proposal is to shift the load transfer from the existing poor quality strip footing foundations (often in masonry) to a limited number of new foundation footings. Between these new footings and the new structural ground floor of the house high damping/ sliding bearing blocks are applied. Figure 1, (a/b/c), shows the stepwise approach of the rehabilitation process in a schematic cross-section of the foundation and ground floor of an imaginary masonry house.

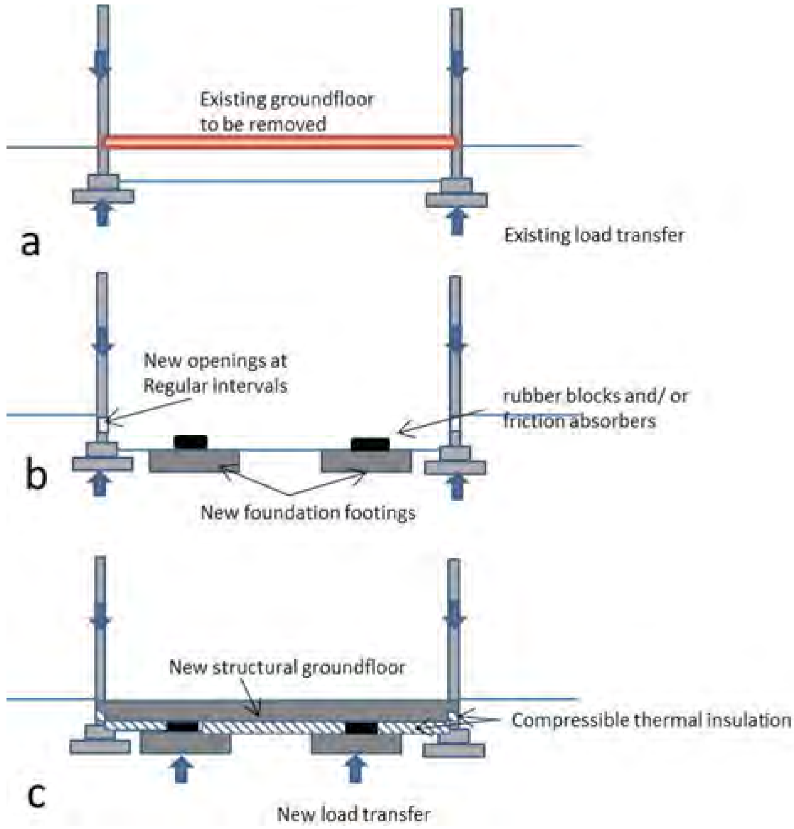
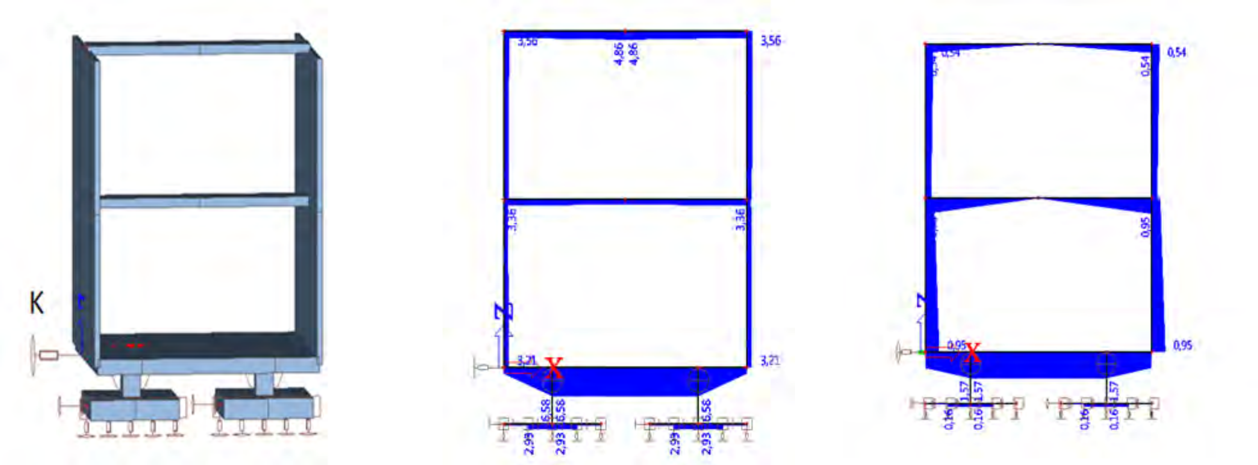


Figure 10. a/b/c/: Construction steps, showing the change in the load transfer from poor quality strip footings to a seismic isolated footings combined with thermal insulation of the ground floor.

The principle of this method, to create a new structural ground floor, is a rather common approach in existing foundation rehabilitation techniques, where a poor strip footing foundation is replaced by a pile foundation, or where a failing timber pile foundation (for example in the Amsterdam area) is replaced by a new pile foundation. Also the principle of seismic isolation through the use of isolating bearings is a known approach for new structures and quite common in bridge engineering. Elastomeric bearings, Lead-rubber bearings, often combined with additional damping systems for energy dissipation can be used. For optimal use of the systems and for economic reasons it is useful to concentrate the vertical loads on a limited number of new bearings. Due to the relative light construction method of these low rise buildings, this concentration of forces is feasible, by constructing a relatively thick reinforced concrete ground floor. The open space under the previous timber floor makes this possible. Point of attention is that these new bearings should provide sufficient rigidity under minor earthquakes and wind loading. A major advantage of this approach is that the new groundfloor can be cast on a new layer of groundfloor insulation. Thus the ground floors' thermal insulation properties can be drastically improved. Ground floor insulation is still one of the best investments for building owners in the Netherlands in terms of energy reduction and payback time. The thermal insulation improves the economic feasibility and can greatly enlarge the building owners willingness to invest in such a method.

FIRST MODELLING

The proposed method by TU/e has not yet been put into practise in the Groningen area. Dynamic calculations show however, that this method of base isolation can be quite promising. First simple elastic modelling (figure 2 a/b/c/) using earthquake response spectra indicate that this foundation rehabilitation approach on sliding/ absorbing bearings can significantly reduce the impact on the masonry upper structure.



(a) (b) (c)

Figure 11. Elastic model of new concrete floor with existing brickwork and timber frame on new (sliding) bearings with a horizontal spring stiffness K; Figure 2b: Resulting bending moments due to seismic loading with high horizontal spring stiffness (M = 3,56 kNm). Figure 2c: Similar, with a low horizontal spring stiffness (M = 0,95 kNm).

The damping and/or sliding bearings at the top of the new foundations are here modelled as horizontal springs in which the stiffness is varied. Low stiffness here can significantly reduce the accelerations and the seismic response, for example the bending moment, in the poor quality masonry superstructure of the house. The reductions in bending moments need further verification however.

ADAPTED SDOF MODELLING

First calculations in the time domain with SDOF (Single Degree Of Freedom) models involve the comparison of structures with and without horizontal sliding bearings. The calculations use a time stepping approach following Wilson's recurrence formulae (Wilson, 2002) with a scaled earthquake (to a max PGA of 5 m/s^2) as input accelerations. The calculations use a single constant coefficient of friction. Obviously different values depending on the horizontal sliding deformation of the foundation could be used to decrease the horizontal sliding deformation. Furthermore additional damping at the base level could further improve the behaviour. Figure 3 shows the comparison of a SDOF model using representative masses and spring stiffness for a small 2 story masonry house with on top of that a pitched roof. (Mass: 105.000 kg; Spring stiffness 2.000.000 N/m) The model without friction slider uses a damping of 5% of the critical damping. The model with friction slider uses a constant friction coefficient: 0,2 and an increased damping of 15 %. The slip of the base (new ground floor on top of the new footings) was calculated from the reduction in seismic input acceleration. The base slip deformation has been calculated as the resulting relative horizontal deformation and speed due to the difference in acceleration between base and ground.

Figure 12. Comparison of the Spring and damper forces with on the left: SDOF model without friction sliding (max Spring Frce 188,5 kN); On the Right SDOF model combined with friction sliding and enlarged damping (max Spring Force 113,7 kN). isolated footings combined with thermal insulation of the ground floor.

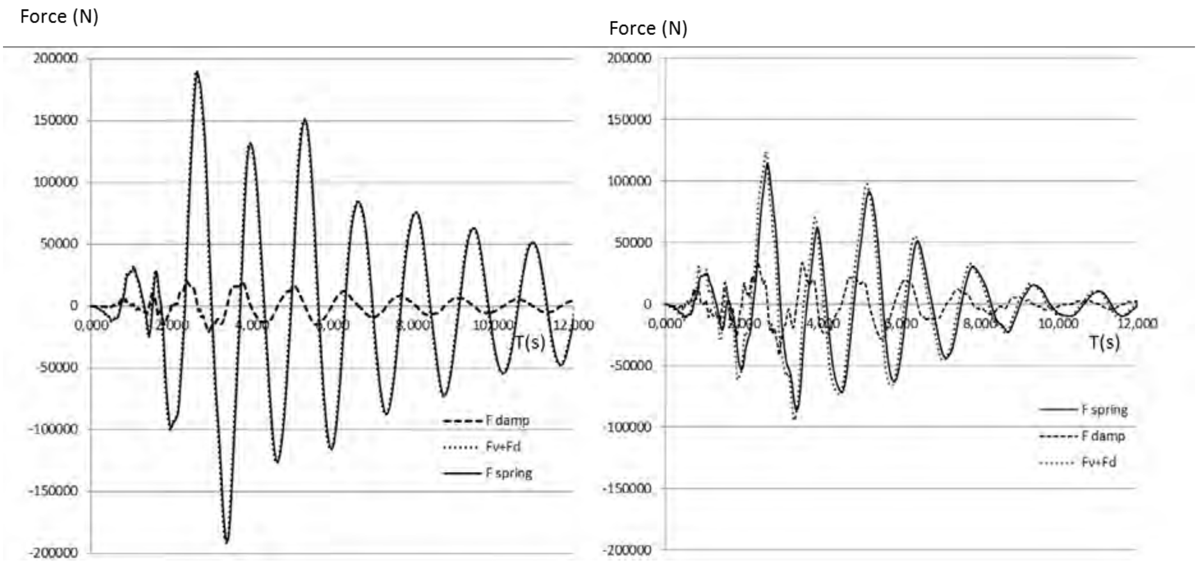
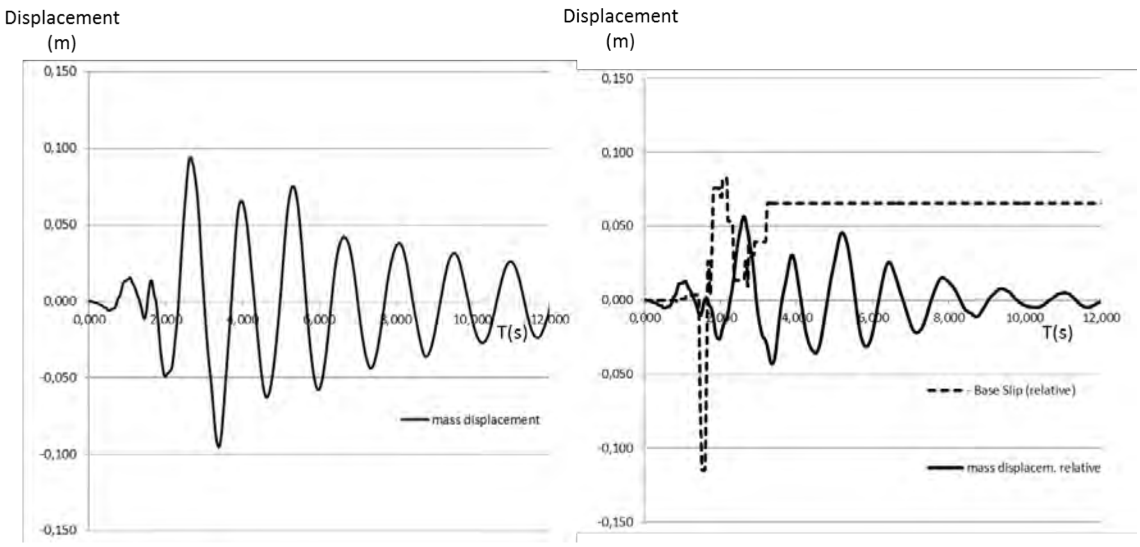


Figure 13. Comparison the Mass deformations with on the left: SDOF model without friction sliding; On the Right SDOF model combined with friction sliding and enlarged damping.



The comparisons show a significant decrease in the maximum Spring force, from 188,5 kN to 113,7 kN. Similar the relative Mass displacement decreases from 0,094 m to 0,057m (excluding the sliding, slip of the foundation). Although the masonry buildings are relatively low weight structures, calculations show that the model has sufficient stiffness to withstand the maximum horizontal wind forces.

By using extra damping at the base level instead of extra damping in the model applied in the Mass and by using for example Triple Friction Pendulum Bearings (TPB) the system can be further optimised and customised depending on the housing specifications as well as the input parameters and characteristics of the induced Groningen earthquakes. Figure 5 shows such a TPB with adjustable backbone curve where the friction characteristics depend on the specific dimensions of the TPB. (Fenz 2008) and (Open sees Berkeley.edu 2015)

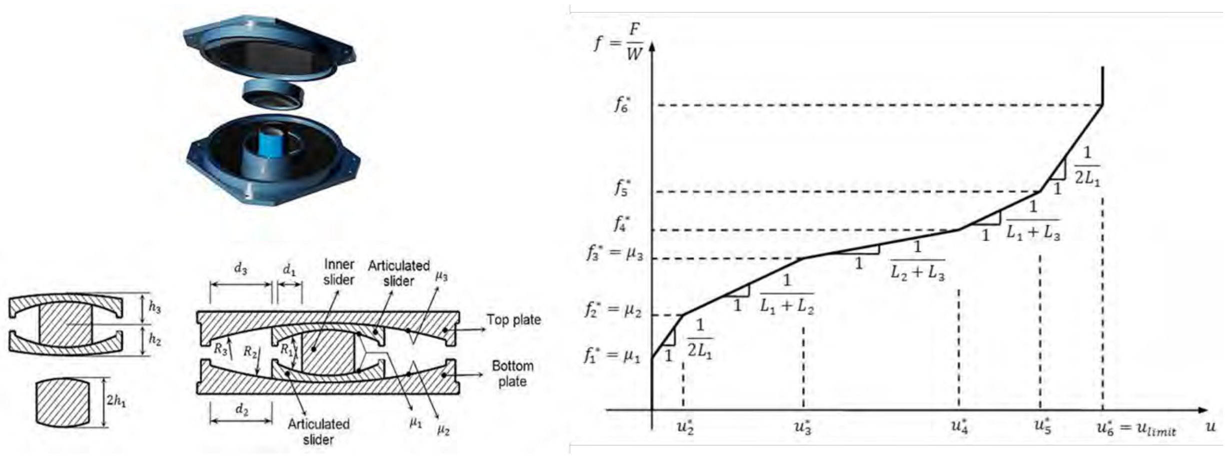


Figure 14. On the left: Three Dimensional view of TPB bearing (top) and vertical sections with dimensional parameters (bottom) and the backbone curve of the resulting friction deformation relation (right). Figure from: http://opensees.berkeley.edu/wiki/index.php/Triple_Friction_Pendulum

CONCLUSIONS AND RECOMMENDATIONS FOR THE ROADMAP

The first investigation of the proposed rehabilitation method, using simple models and seismic calculations as well as time domain models, indicate that the retrofit method may provide very good opportunities for seismic upgrading and rehabilitation. Technically the method proofs to be feasible. It has some clear advantages, in terms of economics and energy performance, over other approaches, by combining the seismic retrofit with thermal upgrading of the ground floor.

Contributes to the Roadmap

Further development of the proposed seismic isolation method for the existing masonry houses in Groningen/NL clearly contributes to the main goals and the proposed roadmap for the resilient transformation of the existing building stock. It involves and considers occupants safety in this area with increased seismic hazard, it provides solutions honoring architectural/heritage value. Further development is needed, but by combining the seismic retrofit with thermal insulation, the retrofit approach clearly has an economic rationale. It thus contributes to improving overall energy and functional (comfort) performance.

Open Issues

A number of different aspects, covering technical as well as economic and social cultural aspects, need further investigation. The technical aspects involve further research and (3D-) modelling. The extend of the influence on vertical/ radial ground motions and ground accelerations (apart from the horizontal) on this approach needs investigation. Also the plastic (3D-) behavior of masonry should be investigated further. Non-linear final element calculations that including hysteresis damping are seen as essential next steps. Detailing solutions have to be found for flexible connections of the building services to account for the possible enlarged horizontal movements of the house, (although this might not be very different from other seismic upgrading solutions).

The economic feasibility would involve test designs on existing buildings including construction detailing, and solving the logistics of the construction process, and thus optimizing the involved cost aspects. Estimation of the changed thermal energy behavior by the insulated ground floor can provide more insight in the advantages of this approach in terms of financial and sustainability energy gains.

The social cultural advantages or disadvantages of upgrading the existing buildings over demolition need careful consideration, including discussion amongst involved parties on how aspects should be weighted. Some of the existing buildings have considerable architectural and heritage value, some houses are just dear to their owners and occupants. The comparison of upgrading versus demolition of the buildings (and creating new urban of rural housing) is an area in which stakeholders may have different opinions depending on their interests and point of view.

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Role of seismic vulnerability on the environmental impact of existing buildings

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ABSTRACT

In earthquake prone areas, the benefits derived from the thermal and energy refurbishment of existing buildings could be jeopardized by the damage associated to seismic events, especially for buildings not designed according to modern building standards. This could lead to an unexpected and reduced environmental load, besides representing a safety hazard.

In the present paper an attempt is made to investigate available procedures in earthquake engineering in order to include environmental effects related to seismic damage and collapse of buildings. In particular, the PEER-PBEE framework is herein adopted to address the embodied carbon related to seismic events of an existing building after thermal refurbishment. The application of the procedure to a selected case study shows how the site seismicity influences the environmental impact evaluation of the considered building.

Keywords

Environmental impact assessment, Embodied carbon, operational carbon, seismic risk, sustainable refurbishment.

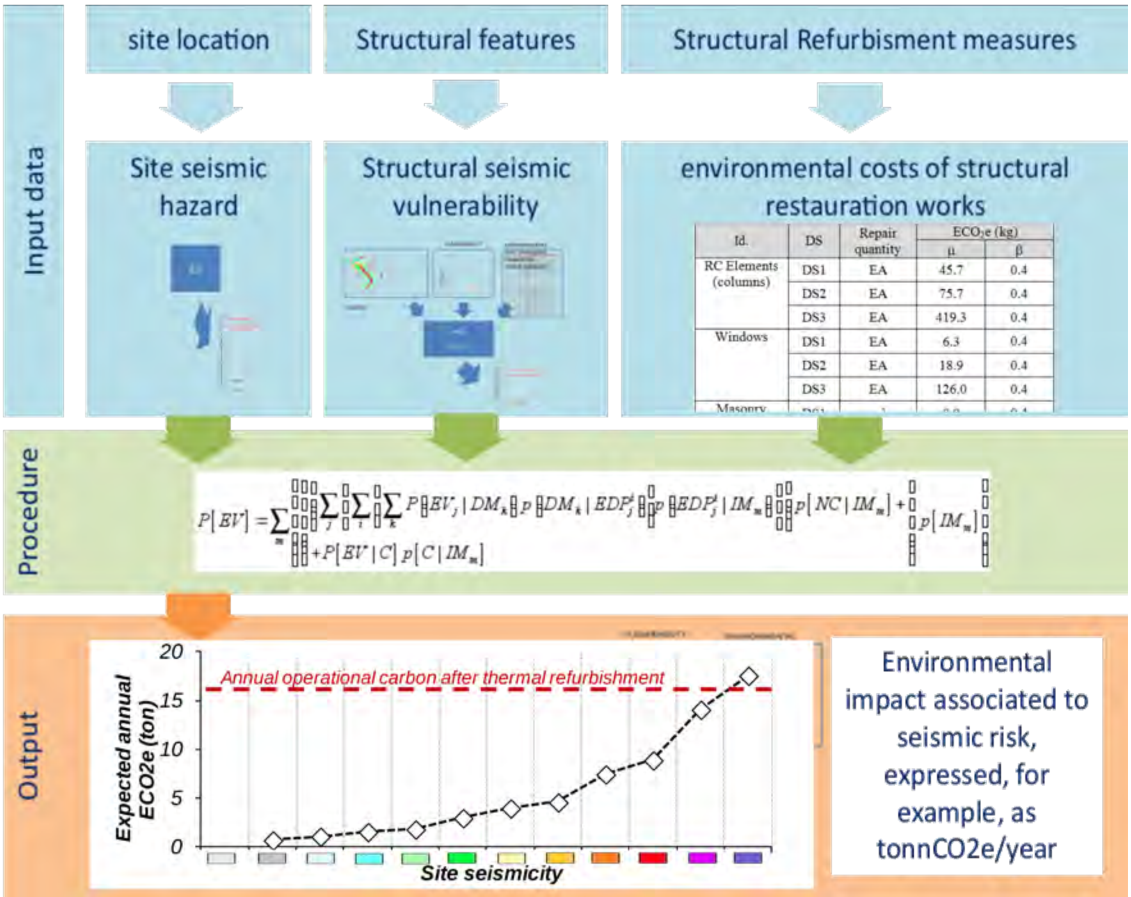
SEISMIC VULNERABILITY AND ENVIRONMENTAL IMPACT

The structural vulnerability of existing buildings, resulting in major damage or even collapse following a seismic event, can jeopardize the energy savings obtained acting solely on the energy enhancement side (Belleri and Marini 2015). Disregarding the seismic impact may result in misleading expectations on the actual effect of energy saving measures carried out at district or urban level. In this scenario a procedure is investigated in order to include sustainability issues in the seismic risk evaluation, complementing the classical loss analysis in terms of human losses, direct economic losses and indirect losses with an environmental impact assessment. This in turn results in the possibility to account for the environmental impact associated to the seismic risk in the global sustainability analyses, such as those carried out with a life cycle assessment (LCA) and life cycle cost (LCC) procedures.

The selected procedure is taken directly from existing frameworks adopted in earthquake engineering. The probabilistic performance based earthquake engineering (PBEE) methodology developed at the Pacific Earthquake Engineering Research (PEER) Centre is selected, referred to as PEER-PBEE. The PEER-PBEE procedure (Günay and Mosalam, 2013) accounts directly for various sources of uncertainties and provides as output the prevision, in terms of repair costs, downtime and casualties, of the influence of possible seismic events on a given building at a given location. To include environmental aspects in the procedure it is possible to directly substitute the typical decision variables adopted in earthquake engineering (i.e. repair costs, downtime and casualties) with environmental variables such as global warming potential, ozone depletion potential, acidification and eutrophication potential among others.

The procedure involves as input data: the seismic hazard analysis for the site where the building is located; the structural seismic vulnerability of the considered building; the definition of the environmental costs of structural and non-structural repair works. The input data are combined together in a probabilistic manner to account for uncertainties related to each of the data set. The combination of the data is carried out automatically through the freely available software PACT (Performance Assessment Calculation Tool) developed as a result of the ATC-58 project (ATC 2012). The output of the procedure is the expected annual value of a chosen environmental variable, such as the embodied equivalent carbon dioxide (ECO_2e), related to structural and non-structural repair works following a seismic event. The results could be compared directly to the annual operational carbon after the solely energy and thermal refurbishment. A conceptual map of the investigated procedure is shown in Figure 1.

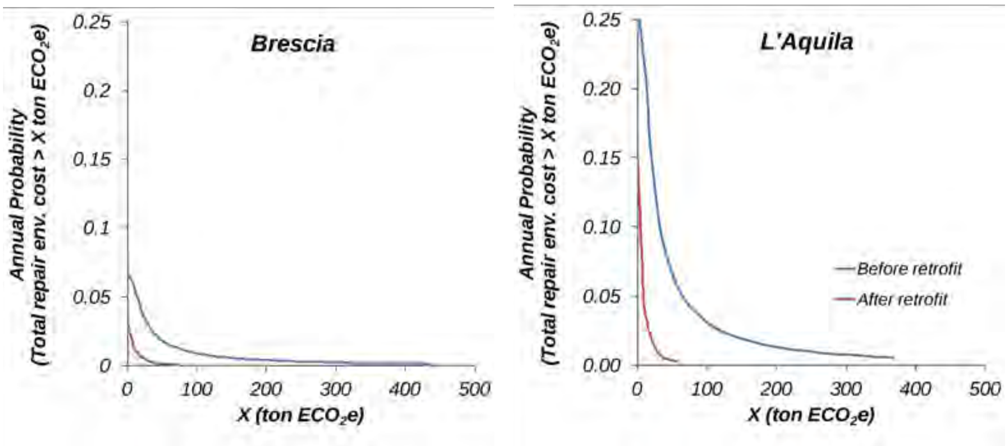
Figure 1. Conceptual maps of the investigated procedure.



The investigated procedure is applied to a selected case study representative of reinforced concrete residential buildings constructed in the Italian territory after the Second World War, which represent about 50% of the Italian building stock (Marini, Passoni, Riva, Negro, Romano and Taucer, 2014). These buildings show structural and energy deficiencies and a sustainable renewal is required under multiple perspectives such as energy efficiency upgrade, structural strengthening and architectural renewal among others: engineered double skin façade (Feroldi, Marini, Badiani, Plizzari, Giuriani, Riva and Belleri, 2013) represents a possible integrated retrofit solution accounting for all such requirements.

By applying the procedure to the selected building it is observed how the environmental impact is dependent on the site seismicity and how the structural retrofit, coupled with a thermal refurbishment, contributes in reducing the influence of seismic environmental impact on the retrofitted building. An example of the results of the procedure is represented in Figure 2 for two Italian cities with moderate, Brescia, and high seismicity, L'Aquila, after the sole energy efficiency refurbishment and after a combined energy efficiency refurbishment and seismic retrofit. The results are expressed in terms of the annual probability of exceeding a determined value of ECO_2e, indicated in the abscissa, associated to the repair measures required to restore the building in the before-earthquake conditions. Another way to present the results is included in Figure 1, where the expected annual ECO_2e for the selected building is shown as a function of the site seismicity. It is worth noting that in the absence of seismic retrofit the expected annual ECO_2e could be as high as the annual operational carbon after thermal refurbishment.

Figure 2. Investigated procedure results before and after seismic retrofit in terms of annual probability of exceeding the ECO_2e value reported in the abscissa: (a) Building located in Brescia; (b) Building located in L'Aquila (Italy)



CONCLUSION

The influence of seismic vulnerability on the environmental impact of existing buildings was highlighted herein. A procedure derived from the available probabilistic framework in earthquake engineering was investigated through the application on a selected case study: an existing building in the Italian territory built before the enforcement of modern anti-seismic building codes. Based on the site seismicity, it is observed that the solely energy-upgrade interventions on vulnerable buildings in seismic prone areas could lead to an unexpected and reduced environmental efficiency, besides representing a safety hazard.

The procedure investigated allows to account for the environmental impact associated to the seismic vulnerability in global sustainability analyses, as for instance life cycle assessment (LCA) and life cycle cost (LCC) procedures.

Contributes to the Roadmap

A probabilistic procedure derived form typical earthquake engineering approach was selected in order to account for environmental variables, such as embodied carbon, associated to building repair actions after a seismic event.

The structural vulnerability of existing buildings, resulting in major damage or even collapse during a seismic event, affects the energy savings obtained with energy retrofit interventions, beside being a safety hazard.

Depending on the site seismicity, the target of nearly-zero-energy buildings can only be achieved if the appropriate energy efficiency interventions are carried out on structurally safe constructions.

Remarks on single buildings are even more critical when expanded at district and city level, where the vulnerability of entire districts may jeopardise the effectiveness of extensive energy saving measures.

Open Issues

The influence of seismic risk is not actually included in the evaluation of environmental impact of existing buildings. How could the seismic risk be included in life cycle assessment (LCA) and life cycle cost (LCC) procedures?

Disregarding seismic risk may result in erroneous expectations on the actual effect of extensive energy saving measures. Should the current way to assign national subsides for energy refurbishment be changed?

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Earthquake Damage Cost Analysis of Resilient Steel Buildings

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ABSTRACT

There is an increasing recognition that the conventional approach of ductile design of steel buildings for collapse prevention, which is necessary, may not be sufficient for the necessities of the present society. Structural designs that provide minimizing the disruption and cost of repairs following major earthquakes are required. Earthquake damage cost analysis is one of the suitable tools for evaluating the performance of steel buildings. In this study, a methodology is presented for improving performance-based engineering aspects from seismic resilience perspective. In this approach, alternative designs of a steel building are accounted with different level of safety or reliability and the probability of exceeding the various damage levels under a given earthquake intensity are determined. Initial costs and earthquake damage costs that are expected during the design life of the steel building are estimated and the minimum expected life cycle cost is identified by underlying its safety.

Keywords (Required)

Earthquake damage cost, life cycle cost, resilient steel buildings, pushover analysis.

INTRODUCTION

The general principle of earthquake resistant design codes are to prevent structural and non-structural elements of buildings from any damage in low intensity earthquakes; to limit the damage in structural and non-structural elements to repairable levels in medium-intensity earthquakes, and to prevent the overall or partial collapse of buildings in high-intensity earthquakes in order to avoid the loss of life (TERDC, 2007). Although earthquake resistant design codes aim to protect life and reduce damage, the costs from possible future earthquakes and the difficulty in repairing the post-earthquake damage, suggest the need for consideration of damage control in the design rather than life loss prevention. Life safety is obviously essential and important in seismic design and should be conserved. However, cost feature has long been recognized to be important, but the issue has not been explicitly included in the structural design requirements. Direct and indirect large scale economic losses due to structural as well as non-structural damages in the recent earthquakes caused considerable concerns among structural engineering community as well as in society (Erdik, 2000). Therefore, it is important to incorporate damage control explicitly into the design process so that tremendous economic impacts due to earthquake damages can be reduced to an acceptable level. This can be taken into account by the development of a design criterion which balances the initial cost of the steel building with the expected potential losses from future earthquake damages.

Earthquake resistant design solutions with more economical use of resources while satisfying conventional code requirements become a particular interest among the structural engineers (Jarmai, Farkas and Kurobane, 2006). Seismic resistant design of steel moment frame buildings in an economic perspective requires a balanced minimization of two general competing objectives; the initial capital investment and the future seismic risk. Many of the existing seismic design optimization procedures use single objective functions of either the conventional minimum material usage or the recent minimum expected life cycle cost criterion while following the related design code specifications as well as additional seismic performance regulations. Research efforts are mainly focused on efficient implementation of single objective based structural material usage with imposing constraints from relevant code specifications however does not completely reflect the requirements of the design practice. In contrast to strict constraints in conventional seismic design codes, acceptable performance parameters recommended in recent performance based seismic design guidelines illustrates performance ranges that a building may sustain when responding to different performance levels. The damage condition associated with each performance level is illustrated quantitatively by deformation indices as a measure of damage level that a steel building will experience during significant earthquake events of that particular level. Thus, in addition to designing a steel building for severe damage states such as life safety as required in conventional design codes, performance based design concept also enables damage control for reducing future economical loses in the design state.

In this study, a methodology based on cost effective and earthquake resistant steel building design is aimed to be investigated in order to fulfil the aspects of life time structural engineering. Initial costs, earthquake damage costs that are expected during the design life of the steel building are explained. The methodology is based on the performance based design concept, where pushover analysis is performed to determine the capacity of each candidate design. It is exposed that an optimum design with respect to the minimum initial cost is far from being optimum with respect to the total lifetime cost of the building. Also, life cycle cost analysis results serve as an objective function in order to take into account the level of damage caused by future earthquakes.

PERFORMANCE BASED DESIGN CONCEPT

Performance based building design is a general structural design philosophy in which the design criteria is chosen with respect to the selected performance level under various seismic motions. The most important aim of the contemporary seismic design is not only protecting the human life but also accounting the additional performance targets. The developments in computer technology within the last decades made possible to employ more complex and realistic design procedures based on nonlinear analysis instead of conventional linear analysis.

Performance based design concepts have been introduced by various guidelines (SEAOC Vision 2000, 1994; ATC 40, 1996; FEMA 356, 2000; FEMA 440, 2000). The main objective of the guidelines is to increase the safety against earthquakes, to make them have a predictable and reliable performance. There are various types of analysis methods for assessing the structural performance level of buildings. Guidelines generally suggest the use of linear static, nonlinear static, linear dynamic, and nonlinear dynamic analysis procedures. However, the most popular analysis method is the nonlinear static analysis which is also known as pushover analysis. Pushover analysis is a very efficient method for the direct evaluation of the structural performance at each limit-state. The aim of the pushover analysis is to assess the structural performance in terms of strength and deformation capacity. Pushover analysis is based on the assumption that the response of the building is related to the response of an equivalent single degree of freedom system with properties proportional to the fundamental mode of the building. Using the analysis results, the sequence of member yielding, inelastic deformation amount of critical members, maximum inter storey drifts and the possible collapse mechanisms of the building can be identified.

The pushover analysis which begins after the application of gravity loads uses a lateral load distribution generally proportional to the fundamental mode of the building. The building model is pushed using the predefined fixed lateral load pattern and total lateral load is incremented up to the lateral displacement of the control node reaches to the displacement demand of the selected earthquake level. The displacement demand of earthquake which is also called the target displacement can be obtained depending on the performance level considered (FEMA 356, 2000).

The pushover curve, which is obtained with the end of the pushover analysis, is converted to a bilinear curve with a horizontal post-yield branch that balances the area below and above the pushover curve and the yield base shear of building is determined. Using a single fundamental mode dominated load pattern in a pushover analysis may provide satisfactory estimation of the maximum inter storey drift when it occurs at the lower storey levels for regular buildings.

EVALUATION OF LIFE CYCLE COST

The life cycle cost of a steel building can be considered as the sum of many different cost components. Cost of planning and design, cost of structural materials, cost of fabrication such as connection of members, cost of transporting fabricated pieces to the construction field, cost of handling and storage costs of rolled sections are basic initial costs. Erection cost, cost of tool operations and machinery on the construction site, cost of preparing the project site including the cost of preparing the foundations are also parts of the initial cost functions. In general, initial cost functions highly depend on the design intensity. The non-structural component costs, such as those of partitioning, which may be high but do not depend on design intensity, were therefore, generally not considered as initial cost components.

There are other cost components which are generally accounted in life cycle cost calculations. Maintenance cost such as painting of exposed members of a steel building, inspection cost to prevent a potentially major damage to the building, repair cost, operating cost required for proper functional use of the building such as heating and electricity, damage cost based on an acceptable probability of failure, demolishing costs are some of the other cost components beside the initial costs.

In recent years, the limit state cost functions which is also an important part of the life cycle cost analysis have gained importance. The term limit state cost functions consist of potential damage cost from earthquakes that may occur during the lifespan of the building. Limit state cost functions neglects other expenses which are not related to earthquake damages, such as maintenance costs. The limit state dependent cost functions mainly consists of damage cost, loss of contents, relocation cost, economic loss which is the sum of rental and income loss, cost of injury, and cost of human fatality, and other direct or indirect economic losses (Secer and Bozdag, 2011). Limit state dependent cost functions are specified in numerous documents (FEMA 227, 1994; FEMA 228, 1994; ATC 13, 1987).

CONCLUSION

Structural engineers almost generally tend to design cost effective seismic resistant buildings that favourably balance initial investments and future seismic risk. However, designers may sometimes make a decision either designing with the least initial expense limited by the maximum acceptable risk or finding a design solution with the lowest risk measure not to exceed a prescribed amount of initial cost. When the life cycle cost curve for the alternative designs are plotted, the designer will be able to monitor the desired design in an economic perspective.

In this study, cost effective and earthquake resistant steel building design is aimed to be investigated in order to fulfil the aspects of life time structural engineering. Static pushover analyses are advised to be used for practically determining the earthquake damage cost and calculating the level of damage for different earthquake intensities. If base shear values versus total cost graphics are plotted accounting life cycle cost analysis, optimal system yield force coefficient can be determined for the steel building. Life cycle cost curve shows that, when only the material weight is minimized then the resulting design may easily be damaged with future earthquakes. Likewise, these earthquake damages may lead to higher cost in the lifetime of the steel building. Finally, the results of these analyses can be easily evaluated, since the performance of a building is specified in economic terms.

Contributes to the Roadmap

In order to derive the roadmap for the improvement of earthquake resistance and eco-efficiency of existing buildings and cities, many researchers and practitioners worldwide are working to develop economical systems that can dependably permit engineered facilities to continue functioning even following a large seismic event. In this study, a methodology is outlined for determining earthquake damage cost of a steel building during the planning phase accounting performance based design procedures. In this manner, structural engineers and building owners may be able to decide the building performance level accounting initial cost and earthquake damage cost. Correspondingly, the outcomes of these analyses are easy to be understood for public, especially for building owners, when the reliability and performance of a building is indicated in economic terms.

Open Issues

The value and effectiveness of this methodology should be judged in the context of how efficiently it manages direct losses and improve seismic resilience. Likewise, cost components other than the earthquake damage cost should be evaluated and their effects on total life cycle cost should be reported.

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We are far away…

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ABSTRACT

Is Europe prepared to solve the seismic risk problem? How far are we from reaching Japan or Chile's resilience? These are two questions with possible solutions not only from Brussels politicians, but also from scientific communities.

Keywords

Eurocodes, seismic risk, legislation.

INTRODUCTION

The paper is focused on two directions for reduction of the seismic risk in Europe: European building codes for construction design and budgetary allocation for research from the European Commission.

EUROCODES

Starting with the first document Directive 73/23/EEC, *The Low Voltage Directive*, the EU finds the way for abolition of technical barriers to trade in Europe. CEN –European Committee for Standardization has the following role in EU: "European Standardization plays an important role in the development and consolidation of the European Single Market. Governments can be users of standards both for their procurement and in support for their legislative or other policies. They are therefore interested in having good standards available for use. The European Standards published by CEN are developed by experts, established by consensus and adopted by the Members of CEN. It is important to note that the use of standards is ***voluntary***, and so there is no legal obligation to apply them", but at the same time "unavoidable" in practice.

The European Commission has a dedicated unit dealing specifically with standardization policy for the EU but ***the European Commission plays no role*** in relation to the technical choices made in the European Standards; it is only interested in ensuring that the standardization structures and procedures remain ***efficient, accountable and transparent***. The General Guidelines for the Cooperation between CEN, Cenelec and ETSI (European Standards Organisations) and the European Commission and the European Free Trade Association was signed in 28 March 2003, and published on Official Journal C 091 , 16/04/2003 P. 0007 – 0011. The European Committee for Standardization (CEN) and the European Committee for Electrotechnical Standardization (CENELEC) are ***two distinct private international non-profit organizations*** based in Brussels.

In CEN, the preparation of the standards is made by 420 Technical Committees (TC's) that each have their own field of operation (scope) within which a 1633 Working Groups (WG's) work programme of identified standards is developed and executed.

Only 1 from 420, the TC 250 is dealing with "Standardization of structural design rules for building and civil engineering works". Within this TC are established the rules of making constructions that can withstand the natural or human hazards, so called EUROCODES.

Since the 1970's Europe has invested from the European taxpayer a lot of public money in European standardization. For example, Horizon 2020, the biggest EU research and innovation programme ever has €79 billion available over 7 years (2014-2020). The Joint Research Centre's the Commission's in-house science service and the only service responsible for direct research, through Horizon 2020 has a budget of €2 billion, will contribute with developing standards and providing references in support of European competitiveness. In comparison, with only €0.07 billion budget (1999), CEN has the copyrights on all European Standards (EN) including the EUROCODES. As a fact, only for the structural design, a civil engineer must spend more than 10.000 Euros on EUROCODES. This is a big mistake, and the European engineering/consultancy cannot promote that knowledge outside Europe. In comparison, let's look at the United States of America: public money = free access to the results to anyone. Maybe, that is why in many countries from all the continents, the engineers are using the American building code models.

The solution found in the European Union, through the legislative technique of the 'New Approach', demonstrates perfectly that ***the responsibility for safety and other public interest matters lies with governments.*** Now, a question can be raised:

How can we let an NGO (i.e. CEN) to establish the rules of how to build houses, but in the case of disaster the governments are responsible if they will fall apart? Where is the responsibility? Why is Europe different and why there is no action taken? This is an issue of the politicians.

The results of the implementation of EUROCODE regulations can be observed in Figure 1, where the differences between the seismic performances of the buildings will be very different in the case of a strong earthquake. In Figure 1 are presented two structures located in a high seismic area of a Mediterranean country. We can notice the outstanding engineering for the airport building, but in the same time in the opposite situation is the design and construction of the apartment building.

Figure 1. Building structure built in high seismic areas (apartment bldg.-left; airport bldg.-right)

The apartment building will be the tomb for the future inhabitants in the case of an earthquake, and the European scientific community knows that from many years ago.

Figure 2 (Italy, April 6, 2009 earthquake) provides evidence of the "good behaviour" since the RC frame structure is not damaged and no "plastic hinges" were developed. But the taxpayer, owner of the apartment from Figure 2 will not agree with the engineering point of view. The owner lost his property/money without any fault. This is an issue of the engineers.

Why in seismic areas of Europe the EUROCODES allow the design engineers to recommend ceramic blocks, even, we have many damaging lessons from disasters?

Are the European citizens of damaged properties guilty because they believe in the quality assurance system provided by EUROCODES? Maybe yes, they are guilty for not being insured - this is a policy maker's point of view (mainly from seismic free countries). But after a large disaster the experience show that the insurers or reinsurers companies get bankrupts (see Kobe, Katrina, San Francisco, etc. disasters) and the citizens are not covered.

Figure 2. Damage of apartment building in l'Aquila

In the case of ***moderate*** Italy, April 6, 2009 earthquake, magnitude M_w=6.3, 308 people lost their lives in a ***very small affected area*** (the city of L'Aquila capital city of Abruzzo and nearby 26 villages). The estimated financial losses reach €16 billion. After 6 years, Italian governments have spent more than €8 billion constructing a new town for residents of city centre and also for reconstruction of the old city. The town, financed in part with European funds €0.5 billion, has been hit by a number of scandals. According to the EU Court of Auditors, more than 4,000 apartments were bought at 158 percent above the market value. Many residents described the houses as being of "poor quality." The European reality is more cruel and the differences between EU and Japan, USA or Chile is that "in California, an earthquake like this one would not have killed a single person"-Franco Barberi (head of Italian Civil Protection). Maybe, one solution is to follow east European experience in implementing the construction regulations. Why? Let's have a look at the number of illegal constructions in Italy, Spain, and Greece in comparison to Romania, Bulgaria or Slovenia. If not, follow the Chilean or American quality control and responsibilities systems in the field of construction.

The developer, the structural engineer, the construction company and the official from the city hall, who make the verifications, have to be life responsible for the quality of their product.

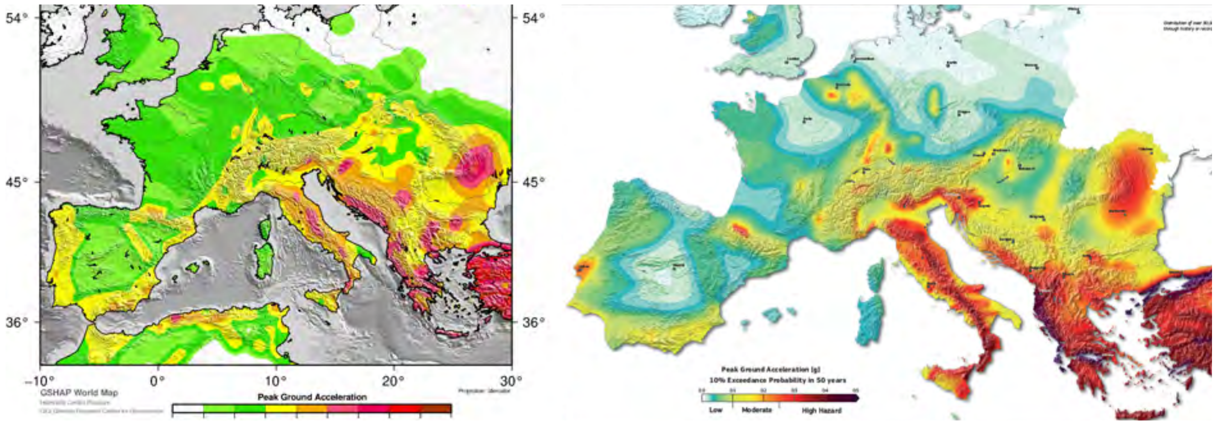
RESEARCH ACTIVITIES

How far away are we in the field of structural testing facilities? We have to compare the budgets spend by Japan and the US in the field of structural testing with European one. Only for the E-Defense testing facility from MIKI/ Kobe, Japan paid €0.5 billion. Also, in comparison with Japan, the European Commission might act as the main investor while the big European construction companies do not invest in research facilities or in research programs. This is why in Europe, even from the project phase, constructions are vulnerable to earthquakes.

In the Figure 3 (left side) is presented one of the results of the Global Seismic Hazard Assessment Program (GSHAP). The European population affected by strong earthquakes is similar with the Japanese one and is more than double of all the affected Americans.

The last research program for estimating the seismic hazard is: ***SHARE*** European Seismic Hazard Map 2013. SHARE has published recently, 2014, the European Seismic Hazard Map showing the 10% exceedance probability in 50 years for Peak Ground Acceleration, Figure 3 (right side). The differences between the maps presented in Figure 3 can be noticed.

Figure 3. Damage Global Seismic Hazard Assessment Program (GSHAP) and results for Europe (left) and SHARE European Seismic Hazard Map 2013 (right)



In the SHARE European Seismic Hazard Map 2013, the hazard values are referenced to a rock velocity of v_{s30}=800m/s. One question might be for the case of cities like Bucharest where the rock is at depths of around 1 km. And if we take into account that during the last century the largest magnitude earthquakes occurred in Romania (10.11.1940 M_w=7.7; 4.03.1977 M_w=7.5), how is SHARE going to be used?

The proposal to use the results from SHARE research project in the future hazard maps of EUROCODE 8 without any verifications, discussions at national level is maybe the easy way to show to the European Commission the use of the output. Also, another vulnerability is the understanding the effect of surface geology on ground motion parameters, which is correlated with the prediction of seismic hazard. The experience of European researchers in testing the dynamic soil parameters is rather limited in comparing with the one from Japan or USA. A European program for investigating the surface geology is needed.

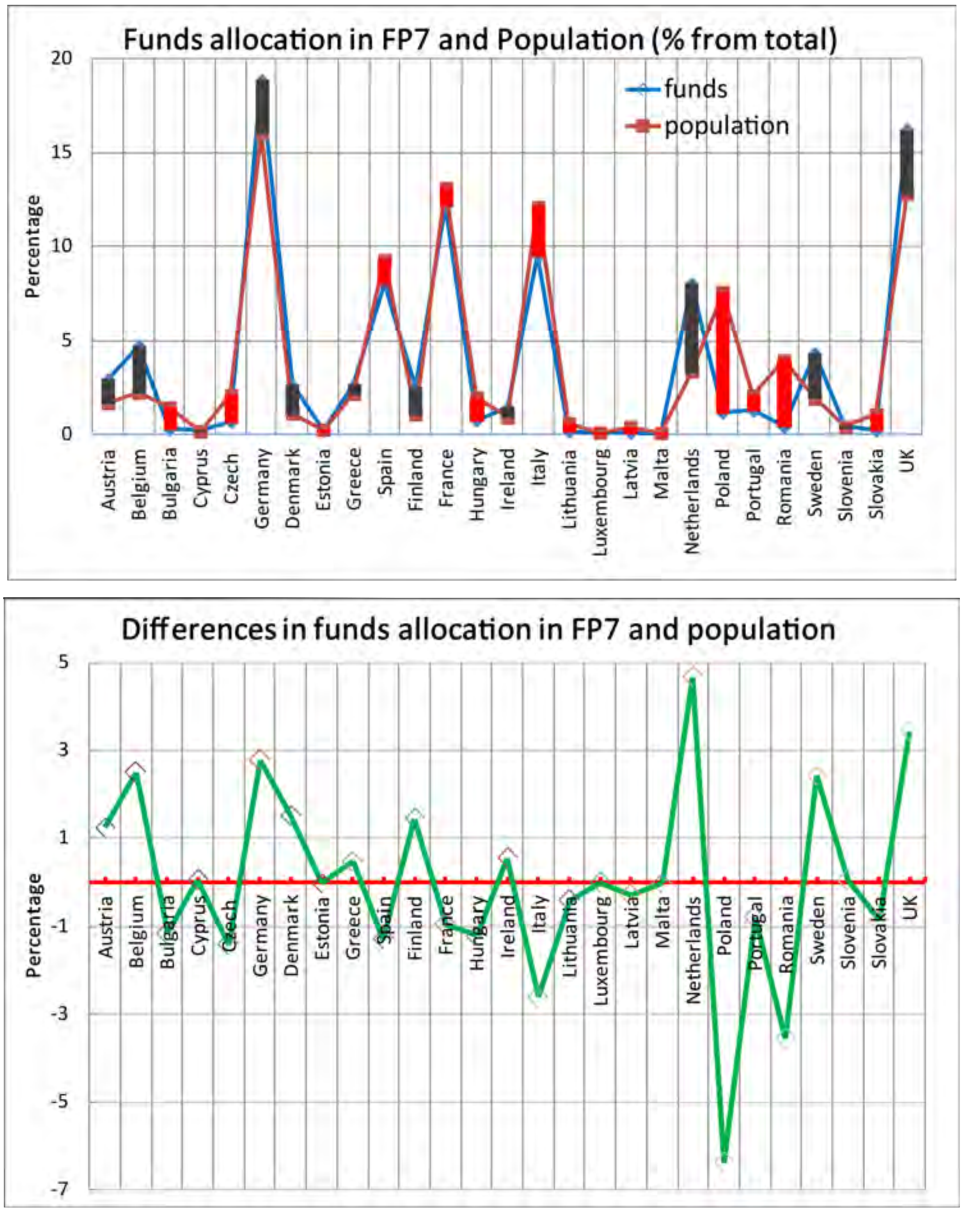
Another use of SHARE research project is the incorporation in the GEM (Global Earthquake Model). One example is in the paper “Exploring Risk-targeted Hazard Maps for Europe” by Silva et al. published recently (September 2015) in Earthquake Spectra; Romania has a seismic risk for new buildings similar with the one of low seismicity zones or high seismicity zones (alternatively without any pattern). Another example from the same authors shows that the probability of collapse of new buildings in Slatina is 6 times smaller than the probability of collapse of new buildings in Catanzaro, although the seismic hazard from SHARE is the same and the construction regulations are similar for both cities. What is the solution?

FINANCING THE RESEARCH ACTIVITIES FROM EU BUDGET

A review of the “Sixth FP7 Monitoring Report, 2013, European Commission” and of the “Study on Network Analysis of the 7 Framework Programme Participation Final Report” shows huge differences among European countries. The total budget of FP7 was €29.3 billion. An invisible line almost similar with the delimitation between seismic areas of Europe divides Europe in: “North Countries – low seismicity”’ and “South Countries – high seismicity”. In Figure 4 are presented the allocation (in percentage from total) of FP7 budget in each EU country (blue line) and also the population (in percentage from total) of each EU country (brown line). The size of red and black rectangles shows the differences between the two lines, and are calculated and represented by the green line.

In the red team we found all the former eastern countries and the south team: Italy, Spain, Portugal and France. Only one exception: Greece.

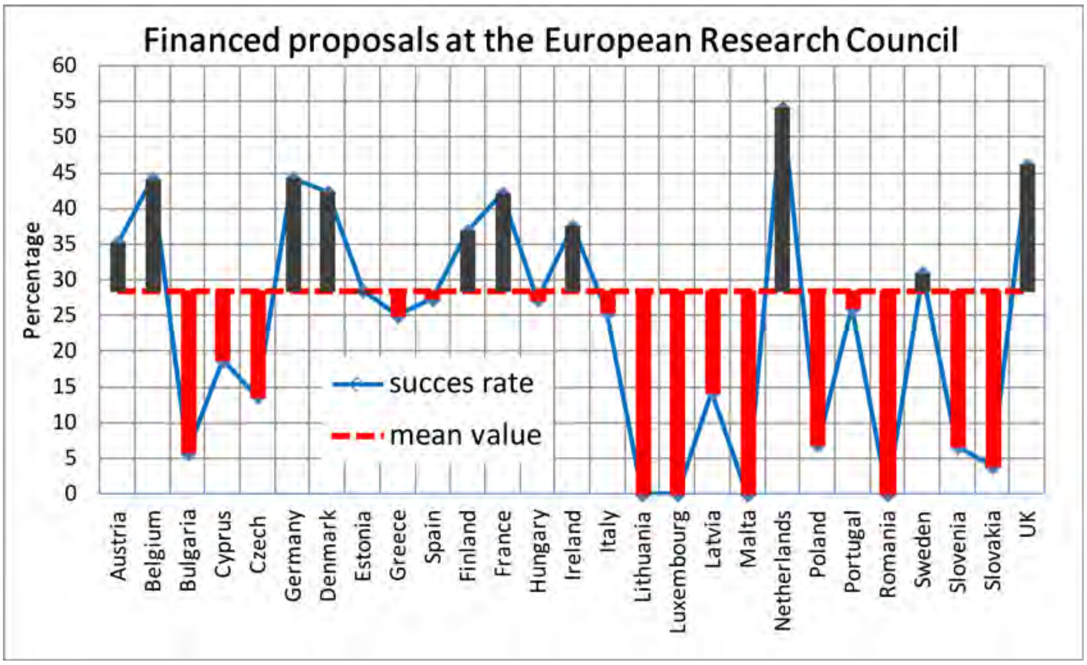
Figure 4. Funds allocation in FP7 by country and by population



Another funding scheme is The European Research Council, ERC. The ERC has a budget of over €13 billion from 2014 to 2020 and is part of the EU research and innovation programme, Horizon 2020. A short description of the ERC is done by Jean-Pierre Bourguignon, President of ERC: "ERC has, in a short time, achieved world-class status as a funding body for excellent curiosity-driven frontier research. With its special emphasis on allowing top young talent to thrive, the ERC Scientific Council is committed to keeping to this course. The ERC will continue to help make Europe a power house for science and a place where innovation is fuelled by a new generation". Unfortunately the funded research proposals follow the same pattern like in Figure 4.

In Figure 5 are represented the rate of success (blue line) for a proposal in each European country. Also is represented the average success rate (dotted red line), i.e. 28%. Similar with Figure 4, the size of red and black rectangles shows the differences between the two lines (rate of success and the average).

Figure 5. Rate of success of the research proposal at ERC for European countries and the comparison with the average rate



CONCLUSION

The policies of EU become more like the ones from former communist states. For example, the similitude's with Romania: in May 14, 1981 the first Romanian person goes to space, but in the same time, with the infant mortality rate of 29.3 ‰ Romania was the first in Europe. Now in 2015, the Europe is financing the project "Gas and Dust from the stars to the Laboratory: Exploring the Nanocosmos" but in the same time on the Earth, the European citizens are in danger in losing their life or properties due to small magnitude earthquakes.

The pattern of the European seismic hazard shows large differences between North and South. Unfortunately, not only the population from South is exposed to seismic hazard. The long term or short term vacations, business or study trips might be the reason that the citizens from North countries might be also get exposed to earthquakes. Reducing the seismic risk in the South part of Europe must be the top priority on the European agenda. Let's make Europe a "low seismic risk" place to live, travel or study.

Contributes to the Roadmap

The legal frame for quality control and responsibilities systems in the field of construction must be improved. Investments in dynamic soil investigations (field and laboratory testing) are needed. Dedicated programs for earthquake disaster mitigation in Europe are needed.

The scientific community and the politicians must have the priority in protecting the lives and the properties of the European taxpayer. Today, November 11, 2015 at the European Council there aren't any policies related with reduction of seismic risk.

Open Issues

If no actions will be taken by all partners (policy makers, European Council, scientist) the proposed alternative might be in Figure 6. The construction is resilient to earthquakes and eco efficient. It is not used anymore in Romania but can be an alternative…

Figure 6. Traditional house in Romania (Village Museum in Bucharest)

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Energy Session

Session Rapporteur: **Roberto Lollini**

Breakthrough Solutions for Adaptable Envelopes in building Refurbishments

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ABSTRACT

The overall objective of BRESAER project is to design, develop and demonstrate an innovative, cost-effective, adaptable and industrialized envelope system for buildings refurbishment including combined active and passive pre-fabricated solutions integrated in a versatile lightweight structural mesh. The components which form the BRESAER system are: i) dynamic window with automatic and controlled air-tightness and insulated solar blinds complementing energy saving and visual comfort strategies; ii) multifunctional and multilayer insulation panels made of UHPFRC to be used as rigid shells integrating an insulation material; iii) combined solar thermal air and PV envelope component for indoor space heating and ventilation; iv) multifunctional lightweight ventilated façade module; v) BIPV and Combined thermo-reflexive (improving fire resistance) and self-cleaning coating (through photo-catalytic nanoparticles). Additionally, through an innovative BEMS covering a specific control system both the envelope active components and the energy use of the building will be governed. A real demonstration will be performed in an educational building in Turkey.

Keywords

Innovation, Renewable Energy Sources, Demonstration, Collaborative project.

BACKGROUND

The current building stock of the EU has an enormous potential for improvement of the energy efficiency and the application of renewable energy systems so that the transformation of that building stock into energy efficient buildings is a must in order to contribute to the objective established in the European 2020 Strategy.

33. 20% target for GHG reductions.
34. 20% of EU energy to be sourced from renewables.
35. 20% reduction in energy use

The industry sector must increase its technological competence, particularly aiming at producing solutions that require less energy. Only by doing so, the industry sector becomes ready to reach these environmental goals. In addition, this will also contribute to increase the competitiveness of the European construction sector in a global competitive environment. The construction industry however, due to its economic model and long time needed to finish a product and obtain payback, has the particularity that it cannot experiment widely with new technologies. It will do so unless they have been proven, there are guarantees they will perform better than traditional ones in the long term, that they comply with regulations and that there are incentives for their application (reduced costs when compared to traditional technologies).

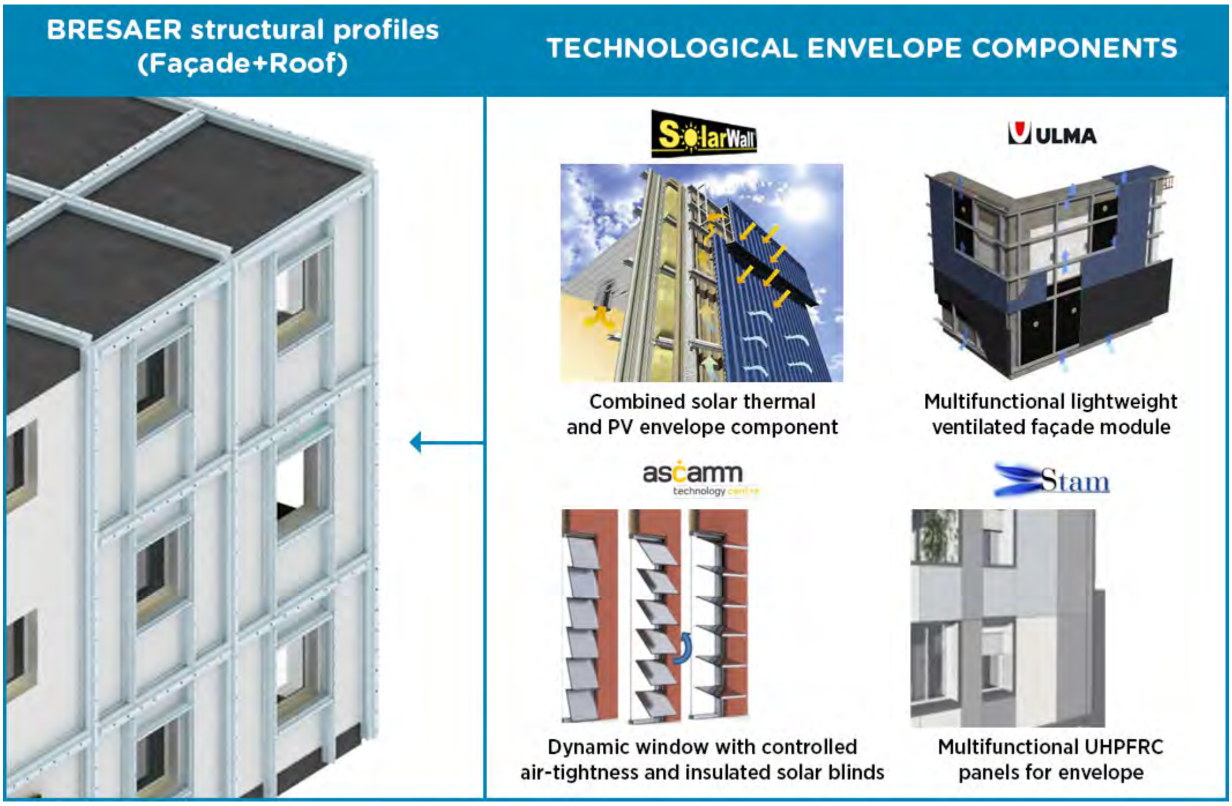
BRESAER has the potential to solve this gap for innovation by using a combination of known and novel technologies, having potential for success when applied in building refurbishment projects. Since the building envelope (façade and roof) is usually a passive boundary between the indoor and outdoor climate, an 'active' envelope responds to (and anticipates on) changes in indoor and outdoor conditions. Therefore the envelope is key element to address in order to significantly increase the energy efficiency and the use of renewable energy in the building sector.

Advanced technologies achieve considerable gains concerning the energetic efficiency of building envelopes. This concerns both new buildings and the energetic retrofitting of existing ones. Better insulation of buildings is not only increasing their energy efficiency in cold climates but also in warm and hot regions due to the reduction of cooling (AC) power. The use of renewable energy in the building sector has been traditionally dominated by the application of solar domestic hot water and PV systems in new buildings for single-family houses and small non-residential buildings, omitting the existing building stock. Hence, integrated retrofitting concepts must be developed to harvest the potential in the existing stock of both residential and non-residential buildings. Concepts easily adaptable as building envelope to integrate both active and passive solutions using adapted existing technologies, as well as technologies tailored for the building use, are needed.

PROJECT DESCRIPTION

An innovative, cost-effective, adaptable and industrialized envelope system (façades and roofs) for buildings refurbishment including combined active and passive pre-fabricated solutions integrated in a versatile lightweight structural mesh for reducing drastically the primary energy and the Greenhouse emissions while improving indoor environment quality (IEQ) comprising thermal, acoustic and lighting comfort, and indoor air quality (IAQ). The whole building will be governed by an innovative Building Energy Management System covering a specific control system for governing several envelope functions and the energy facilities of the building, including the energy generated by the BRESAER system.

Figure 1. BRESAER solutions



Technological solutions under development:

i) For opaque surfaces:

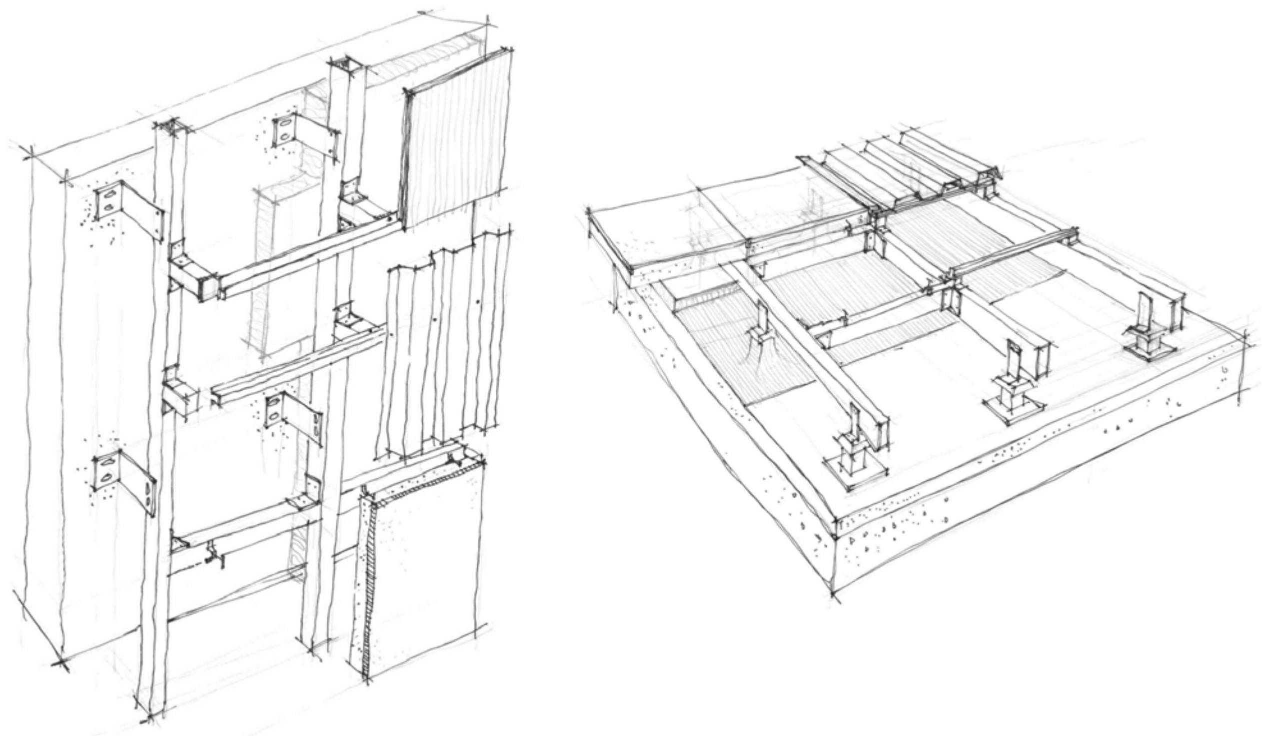
– Multifunctional and multilayer insulation panels made of Ultra High Performance Fibre Reinforced Concrete (UHPFRC), to be used as rigid shells integrating an insulation material

- Multilayer panel to reach better performance in terms of insulating capacity, lightness, thinness, manufacturing process, installation, and environmental aspects, with appropriated mechanical resistance to work as external panel.
- Multifunctional because can be used as insulation panel combined with several external coatings providing different capabilities:
  - BIPV for electricity generation
  - Combined thermo-reflexive (improving fire resistance) and self-cleaning coating (through photo-catalytic nanoparticles)

– Combined solar thermal air and PV envelope component for indoor space heating and ventilation, thermal insulation and electricity generation
- Preheated air to be used in building applications:
  - Indoor space heating through mechanical ventilation while improving IAQ and energy efficiency
  - Dehumidification through thermal regeneration of desiccant dehumidifiers
- Thermal insulation: able to reduce thermal loads of the indoor space through thermal conduction
- PV modules directly integrated on the flat metal panel of the air solar thermal envelop component:
  - Facilitates the integration and manufacturing process
  - Improves the PV cells efficiency
  - Lightens the solution

– Multifunctional lightweight ventilated façade module:
- BIPV for electricity generation integrated on the cladding panel
- Combined thermo-reflexive (improving fire resistance) and self-cleaning coating (through photo-catalytic nanoparticles) applied on the cladding panel

Figure 2. *General solution of BRESAER concept for façade (left) and roof (right)*

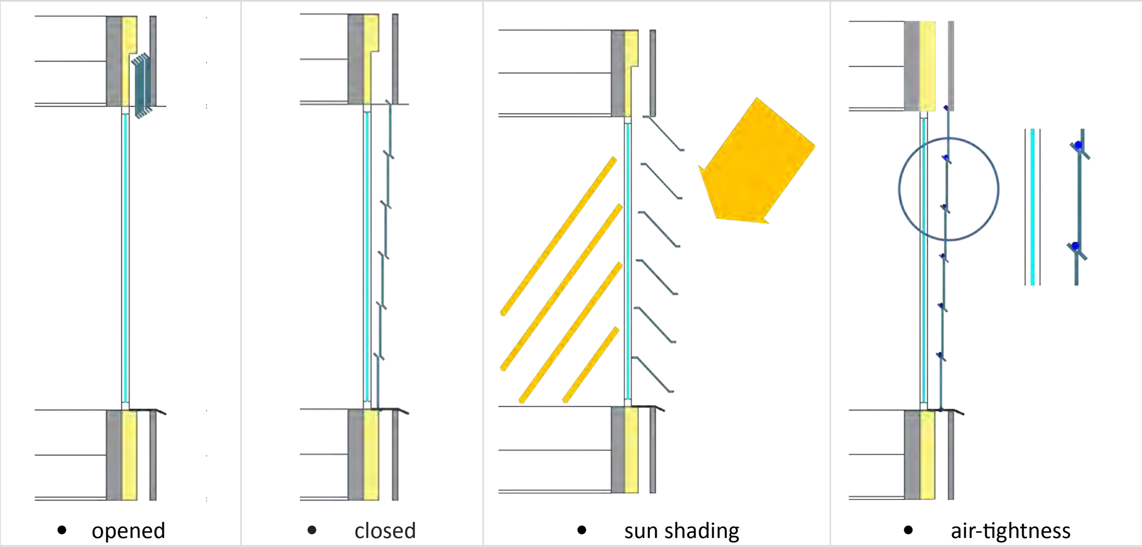


ii) For openings:

– Dynamic window with automatic and controlled air-tightness and insulated solar blinds complementing energy saving and visual comfort strategies, such as light redirection and response to solar radiation.

- Solar blinds will be automatically controlled according to indoor comfort and sun position under a logical control system for its position and inclination
- Insulation and air-tightness component self-adjustable to Day-Night cycles

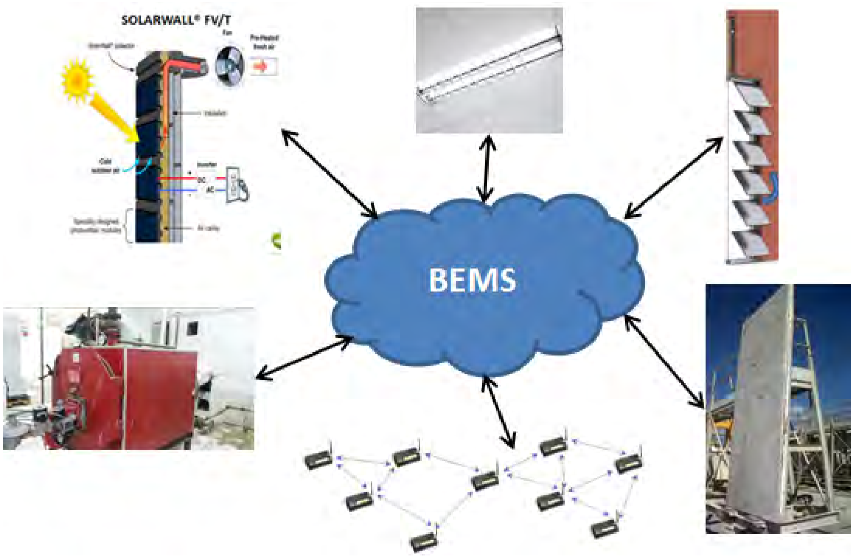
Figure 3. *Dynamic window concept*



iii) For governing the building

– Cutting-edge Building Energy Management System able to measure and control both the envelope and hungry consuming devices using integrated simulation-based control techniques for automating the establishment of optimal operational plans related to:
  - Automated solar blinds
  - Envelope electrical energy generation by PV modules and its associated strategies for use and storage (if needed)
  - Envelope air solar thermal energy generation
  - HVAC energy flows

Figure 4. *BEMS concept*



INNOVATIVE ASPECTS

BRESAER project is a research and innovation action in which the innovation capacity of the participants will be improved because there are a good number of innovative technological solutions that implies integration of new knowledge within a consortium that combines research institution companies and end users.

In that sense, BRESAER proposes a new prefabricated retrofitting system that will try to lead existing prefabrication market according to the following innovative aspects:

- ***Adaptability***:
  - Focused on both façade and roof
  - Prefabricated and standardized aluminum structure elements easily re-configurable along building's life
  - Able to integrate new developments for future renovations
  - Able to perform accordingly by measuring and processing multi source information on real time
  - Adjustable to different typologies and building's use (housing, office, schools, etc.)
  - Adaptable to different European climatic conditions and energy needs
  - Adaptable to different size and shapes of the buildings and aesthetical requirements
  - Compatible with the existing building systems
  - Easy assembly, quick and low intrusive installation in construction process
  - Low maintenance
- ***Design and planning***: Customization providing greater flexibility which respond to particular weather conditions and architectural requirements
- ***Technologies***: Fully integrated RES and BEMS to the new resilient building envelope.
- ***On-site work***: Easy assembly minimizing skilled labour needs and on-site phase. Low transportation cost-modular system, lightweight components.
- ***Sustainability***: System energy efficiency will be a priority goal considered on its design and verified through LCA.
- ***Other***: BRESAER system will develop a competitive business model and dissemination plan to attract potential end users. Reduced payback integrating RES

PROPOSED DEMONSTRATION

In order to validate the proposed system, a real demo will be performed in an education building in Ankara (Turkey) owned by the National Ministry of Education which consists of one building block with a gross area around 1.800 m^2 (4 storeys with 450 m^2 each). The building will be monitored before and after the refurbishment intervention in order to establish the baseline energy consumption, the achieved energy savings and the comfort improvement. The BRESAER's expected impact is to reach a near zero energy building (total primary energy consumption below 60 kWh/m^2 per year) by the reduction of the energy demand for space heating and cooling around 30%, a contribution of solar thermal energy for space conditioning around 35%, and a contribution of RES for electricity generation around 10%. The estimated payback time is expected to be 7 years. Furthermore, the real achievements in terms of primary energy savings, comfort, CO_2 emissions, costs, and payback period will be compared with that one coming from simulation tools.

Figure 5. Proposed demo building

CONCLUSION

Following global market needs for the improvement of eco-efficiency of existing buildings, BRESAER system puts forward ground-breaking solutions be adopted throughout Europe and beyond in order to meet global targets for reduced energy use and greenhouse gas emissions. In that sense, BRESAER system is designed to turn the building envelope into an active element rather than a passive, meeting more functions than just the separation of the outer space from the interior with insulation. On the other hand, it is conceived to accommodate further modifications enabling also to adapt to a dynamic environment and to building occupant's requirements during its lifetime.

However, there are still some open issues to be solved within the project. One of them is the sizing of the structural elements that must support the external claddings to the existing envelope and resist the different loads, and also must provide an alignment of the different claddings ensuring a good aesthetics from the architectural point of view. On the other hand, the integration of the PV modules on the external face of the different claddings is being analysed through multiple BIPV solutions providers.

ACKNOWLEDGEMENT

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Lime plastering systems for energy-efficient and seismic retrofitting

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ABSTRACT

Buildings which undergo energetic retrofitting often require also a structural consolidation. This actually implies two separate operations, materials and related quality issues. Scope of the work was to investigate possible lime-plaster systems, with combined thermal and mechanical improvements. Different recipes and types of binders and fillers of lime-plastering-systems were tested to assess thermal and mechanical properties. The study was developed in the framework of a novel innovation method, designed to generate market-driven-innovations in SMEs.

Keywords

Retrofitting, hystorical building retrofitting, energy efficiency, seismic performance, thermal insulation, lime plastering system, plaster, structural retrofitting, structural consolidation, concrete, structural fibre net, structural mesh, market-driven-innovation, innovative construction materials, innovative envelope insulation.

INTRODUCTION

In these last years, a growing number of buildings undergoing energy retrofitting operations require structural improvements, because of aging of materials and because of additional loads, e.g. storey addition due to cubage bonus incentive policies.

A large variety of systems and materials for energy efficiency improvement of building envelopes, as well as effective systems for seismic retrofitting, exists. Plastering systems have the main scope to provide a proper surface finish. Nowadays, special types of plastering systems exists, which provide additional functions, such as acting as mechanical matrix for structural fibre meshes application, or providing additional thermal insulation.

On the actual construction product market, however, no plastering system can be found, which can provide good thermal insulation, and at the same time, enough mechanical properties for seismic retrofitting.

A product having combined properties would lead to more cost-effective and efficient seismic and energetic retrofitting, because just one application procedure and one material type would be needed. Moreover, a combined single-layer system would also avoid issues between interfaces and application procedure uncertainties; the overall thickness of the main envelope insulation system could also be reduced, due to additional insulation provided by the external insulating plaster layer. These advantages simplify the complexity of works; this could lead building owners and construction professional to more frequently consider a combined energy-efficient and seismic retrofitting. The study is structured in two steps.

The first part investigates the mechanical improvement of the binding agent, by testing different recipes until enough mechanical performances needed for structural purposes are reached.

In the second part, different low-density, thermal-insulating fillers are mixed with the binding agents, and mechanical and thermal properties are measured, also against an actual structural plastering system available on the market.

The authors wish to highlight that this study was generated and developed, in just two weeks, under the framework of "Under Construction" Innovation Accelerator Initiative. "Under Construction" is focused on SMEs and foresees intense and quick R&D programs, putting young researchers and experts together with well-established companies in the sustainable construction sector. The scope is to promote quick and effective innovation projects with short time-to-market phase. This novel innovation method was developed by the Construction Cluster of TIS Innovation Park in cooperation with the Energy-Efficient-Buildings research group of the Renewable Energies Institute of European Research Academy (EURAC).

MECHANICAL IMPROVEMENT OF BINDING AGENT

A set of 3 OPC (Ordinary Portland Concrete)-based binders and 2 OPC-free binders were prepared and aged.

OPC-free binders are allowed in renovation of historical buildings; in absence of concrete, mechanical strenght is provided by lime and metakaolin components.

Note: only general recipe data is showed, in order to protect intellectual property of the company.

Samples 1 and 2 differ in the proportion of several other addictive agents.

Samples 3, 4, 5 have decreasing OPC content.

After aging, the samples were mechanically tested (3-point flexural resistance and compression resistance).

OPC-free samples 1 and 2 showed cracks during aging, showing that mechanical properties were really poor, therefore no further thermal testing was made.

Thermal conductivity was evaluated only on the best mechanical performer, binder 3.

Mechanical and thermal performances of binder 3 were then compared with those of further two binders:

- binder "Th": a special binder optimized by the company for a high-thermal-insulation plastering system
- binder "Str": a traditional structural binder available on the market.

Results are showed in table 1.

Table 1. Binder characteristics and properties comparison (references for test methods: [1] to [7]).

Binder Type	OPC [%]	Metakaolin + Lime [%]	R(fl) [N/mm2]	R(comp) [N/mm2]	λ W/(mK)]
1	none	very high	N.A. (spontaneous cracks)		N.A.
2	none	very high			
3	high	low	2,6	11,2	0,33
4	medium	medium	1,2	4,3	N.A.
5	low	high	0,7	1,7	
Th	N.A.		0,3	0,6	0,21
Str			9,5	53,1	0,62

At the end of the first phase, it was concluded that:

- Mechanical properties of OPC-free binders are very low, and are sufficient just as basic plaster adherence purpose and filler-matrix function.
- Required mechanical properties for seismic renovation require OPC-based binders.
- OPC-based binders are not allowed for historical building renovation
- Binder 3 satisfies minimal mechanical properties for seismic renovation, while doubling thermal insulation performance in comparison with traditional seismic plastering products on the market.
- Binder 3 thermal insulation performance is not too far from value of specialized binder used in plastering systems for thermal insulation purposes.
- Binder 3 is therefore chosen for the thermal properties optimization phase.

THERMAL AND MECHANICAL COMPARISON OF PLASTERING SYSTEMS

In the second phase, binder 3 was mixed with three different thermal-insulating fillers, with increasing thermal insulation properties. Mixing proportion of filler weight / total weight varied from 60% (F1 and F2) down to 40% (F3). A lower quantity of F3 was used because of its very good thermal insulation properties, compared to F1 and F2.

After aging, the samples were mechanically tested (3-point flexural resistance and compression resistance).

Thermal insulation performances were not tested on 3+F1 and 3+F2 because of their poor mechanical performances.

Results are showed in table 2.

Table 2. Comparison of properties variation after addition of different fillers (references for test methods: [1] to [7]).

Systems (binder + filler)	Wt. filler/tot wt. [%]	R(flex) [N/mm2]	Mech. performance compared to binder 3 [%]	R(compr) [N/mm2]	Mech. performance compared to binder 3 [%]	λ [W/(mK)]
3 (only binder)	No filler	2,6	-	11,2	-	0,33
3 + F1	60%	0,2	8%	0,2	6%	N.A
3 + F2	60%	0,2	8%	0,2	8%	N.A
3 + F3	40%	0,4	15%	0,9	34%	0,19

At the end of the first phase, it was concluded that:

- Addition of a thermal-insulating filler drastically reduces mechanical properties of lime-plastering system. Mechanical properties of the binder + filler system drop to values between 34% and 6% of original binder properties.
- Mechanical properties reduction is strongly dependent on weight percentage of filler in the plastering system.
- System 3+F3 has the best mechanical resistance, because the high termal insulation properties of F3 permit to reduce the percentage of filler in the mix.
- However, the performance of 3+F3 drops below the minimum limit of 4MPa for compression resistance.
- Moreover, thermal insulation properties of 3+F3, even if a sligh improvement was achieved, are still not sufficient to reach the requirement of λ = 0,09 W/(mK).

- System 3+F3 is a candidate to be optimized in future investigations.

CONCLUSION

In a strict time-frame of 2 weeks, a set of different lime-based plastering systems was studied, with the aim of improving, at the same time, both thermal and mechanical properties.

In the first phase, 5 optimized binders were tested, belonging to two different application categories: OPC-based (general renovation use) and OPC-free (for hystorical building renovation purpose)

The optimized binder (3) satisfied minimal mechanical properties for seismic renovation, while doubling thermal insulation performance in comparison with traditional seismic plastering products on the market.

In the second phase, a series of 3 fillers with high thermal insulation properties were added.

Even if enough mechanical properties of binder 3 were reached in the first phase, these were drastically reduced by the addition of insulating filler.

The best performer was System 3+F3, however target thermal and mechanical properties were not reached.

System 3+F3 must be optimized in future investigations.

Contributes to the Roadmap

This work aims to contribute on both technical and market implementation objectives of the Roadmap.

In fact, this work was originated by a precise and actual requirement of renovation market. Construction materials for combined structural and thermal performances can therefore promote a growth in seismic and energy-efficient renovation, due to simplified and potentially more cost-effective renovation works.

This paper shows that further research in material science and technology is required to find innovative solution for combined improvement of both mechanical and thermal insulation properties of construction materials. The simultaneous improvement of these two properties is difficult, because both properties are affected by the same material characteristics, such as density, but with concurrent behaviour.

This work demonstrates also that a method based on small and rapid R&D optimization steps can activate SMEs to invest in quick adaptation and optimization of their actual products. This will reduce time-to-market cycles and involve SMEs (and not just large enterprises) in more effective market-driven research activities.

Small and medium-sized enterprises (SMEs) are the backbone of Europe's economy. They represent 99% of all businesses in the EU [8]. For this reason, methods for activation and increase of SMEs research activities, such as "Under construction" which supported this work, are an effective mean of driving a realistic market and technical change.

Open Issues

The simultaneous improvement of mechanical and thermal properties is known to be difficult, because both properties are affected by the same material characteristics, such as density, but with concurrent behaviour. High-strength binders and high-insulating fillers must be developed to close the performance gap. Plastering systems must also satisfy requirements for historical building renovation, which currently do not admit OPC-based systems.

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Taxonomy of the redevelopment methods for non-listed architecture: from façade refurbishment to the *exoskeleton system*

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ABSTRACT

In the context of building requalification, in which sustainability must be considered in the three perspectives of environment, society and economics, it is important to introduce the possibility of effectuating an integrated intervention. Today, the taxonomy of interventions in the field of requalification of non-listed buildings can be technologically classified and represented in a synoptic diagram. Moreover, it seems that several examples show the same approach, with the introduction of an added, external, independent structure that allows for more than a purely energetic retrofit intervention. This is identified as an "exoskeleton system". Through a classification of the strategies of retrofit interventions, the aim of the paper is to delineate a definition of the "exoskeleton system" in order to classify it among the strategies of intervention on non-listed buildings. In particular, it could constitute a future proposal for those cases that necessitate a retrofit intervention that integrates energetic, structural, architectural and functional issues.

Keywords (Required)

Taxonomy of requalification methods, integrated requalification, *exoskeleton system*, socio-technical device

INTRODUCTION

The approach to sustainability in the building sector requires the combined consideration of environmental, economic and social aspects[4], with regard to the entire building life-cycle. The requirements in terms of building sustainability relates to environmental safeguarding, rational use of resources and user welfare and health, as described by standards[5]. Redevelopment, among the main areas of interest for the reduction of CO_2 emissions, is the only construction business sector that still shows a growth of investments, and it is a driving force for the intervention plan, in particular for the second post-war buildings. Working on this kind of structures could reduce the consumption of the entire construction sector.[6] In this context it is necessary to consider redevelopment projects as being able to integrate the various aspects of "sustainable redevelopment" for a complete upgrade of the building, which often has only one chance of intervention during its life cycle. Moreover, the current European Directives give priority to energy retrofit interventions.[7] The CRESME

[4] According to ISO/DIS 15392 - *Sustainability in building construction – general principles*.

[5] UNI 11277:2008 *Building Sustainability – Eco-compatibility Requirements And Needs Of New And Renovated Residential And Office Buildings Design.*

[6] According to CRESME research, the area of new buildings is now in crisis, registering an investment decrease from 44,3% in 2006 to 29,3% in 2013, while the field of upgrading registers an increase in investment from 55,4 to 66,4%, thanks to tax reduction. The CRESME research shows that intervening only on 20% of the more energy-intensive buildings, it is possible to reduce the consumption of the entire construction sector by 12.8% (*Servizio Studi-Dipartimento Ambiente della Camera dei Deputati, CRESME. 24 febbraio 2014. Estratto della ricerca CRESME, ristrutturazione edilizia riqualificazione energetica rigenerazione urbana*).

[7] Reference is made to 2002/91/CE Directive on the energy performance of buildings, 2006/32/CE on Energy end-use efficiency and energy services, 2010/31/UE Energy performance of buildings, 2012/27/UE The Energy Efficiency Directive.

studies reveal that the building sector that is responsible for the highest energy consumption is that of non-listed buildings, which in Italy is the most heterogeneous. However, the study of building techniques illustrates how residential architecture built after World War II uses R.C. construction systems, as for example tunnel or banche-tables precast systems (Zaffagnini, 1981). This is the case of the multi-storey residential typology: 40% of residence buildings in Italy have three to five floors, and 14% have more than five floors.[8]

TOWARDS THE TAXONOMY OF REQUALIFICATION STRATEGIES

The methods for the rehabilitation of these buildings are differentiated according to requirements and the cost-benefit ratio. The evaluation of these issues has led to an analysis of the state of the art in Italy and Europe, with the aim of identifying a classification methodology of intervention based on the requirements/performances approach: in accordance with the technology and the typological classes differentiation (Belatti, 2012), or taking into consideration the morphological strategies (Antonini et al., 2012) or considering social, demographic and architectural problems (Malighetti, 2004; MVRDV, 2013). The interventions identified in the case history have been classified on the typo-morphological and performance issues, leading to the definition of a synopsis of the interventions.

Figure 1. Figure 1. The taxonomy of intervention methods (F. Guidolin, 2014).

A distinction is made between two-dimensional actions, that can be recognized in the façade refurbishment interventions (recladding, refitting, overcladding) and three-dimensional actions, such as volumetric addition (of punctual boxes, towers, continuous and global spaces). The taxonomy of requalification methods (Zambelli, 2004) has a correspondence with the structural and technological case history examination, as in the case of:

- The *Tour Bois le Prêtre* requalification by F. Druot, A. Lacaton e J.P. Vassal (Paris, 2008-2012).
- The *Westerpark* intervention by Van Hoogmoed Architecten (Tilburg, 2008).
- The *Leeuw Van Vlaanderen* intervention by Heren 5 Architecten (Amsterdam, 2007).
- The *Rathenow* building renewal by Klaus Sill e Jochen Keim (Rathenow, 1997).
- The *Ipostudio Architetti* project for the European Research Sure-Fit, Le Navi, 2006.

[8] CRESME, ibidem p. 30

Figure 2. Tour Bois-le-Pretre transformation, F.Druot, A.Lacaton, J.P. Vassal in Paris (2009-2011). (credits Matteo Busa).

THE "EXOSKELETON SYSTEM": A SOCIO-TECHNICAL DEVICE FOR INTEGRATED REQUALIFICATION

The requirements/performances approach (with the decomposition of requirements in technological system, sub-system and technical elements) has shown that the best qualities of integrability occur in the case of global envelope volumetric addition that is structurally independent and is recognizable and definable as "exoskeleton system"[9]. It is a technological device for the integrated regeneration of non-listed architecture, consisting of an independent structure and cladding system, with its own foundations and arranged at a suitable distance from the façade of the building around which it stands, in order to create spaces. It is technologically and morphologically definable according to the necessities of use of the spaces.

A definition

Currently, several studies are investigating the theme of redevelopment through independent external structures. The exoskeleton is defined as: a*daptive* (Montuori et al., 2014), considering the design approach that takes into account the adaptability of the existing spaces for renewal processes[10]; *active*, with the dual objective of energy and architectural renewal for social housing following the logic of the Smart City, for the installation of capturing and shading systems and for the structural seismic efficiency[11]; *structural*, for the relevant interest of this device in the field of seismic structural upgrading of buildings.

[9] It is considered as necessary to define the technological device as a "system" because it is constituted by a set of technical elements that belong to different technological units: the structure, external vertical closures, horizontal closures and plant design system, which also confer efficiency to multiple needs. (F.Guidolin, *Sistemi per la riqualificazione semplificata del costruito: dal façade refurbishment al "sistema esoscheletro" in Abitare Insieme 2015, Atti del Covegno DiARC, Università di Napoli Federico II*, in corso di pubblicazione).

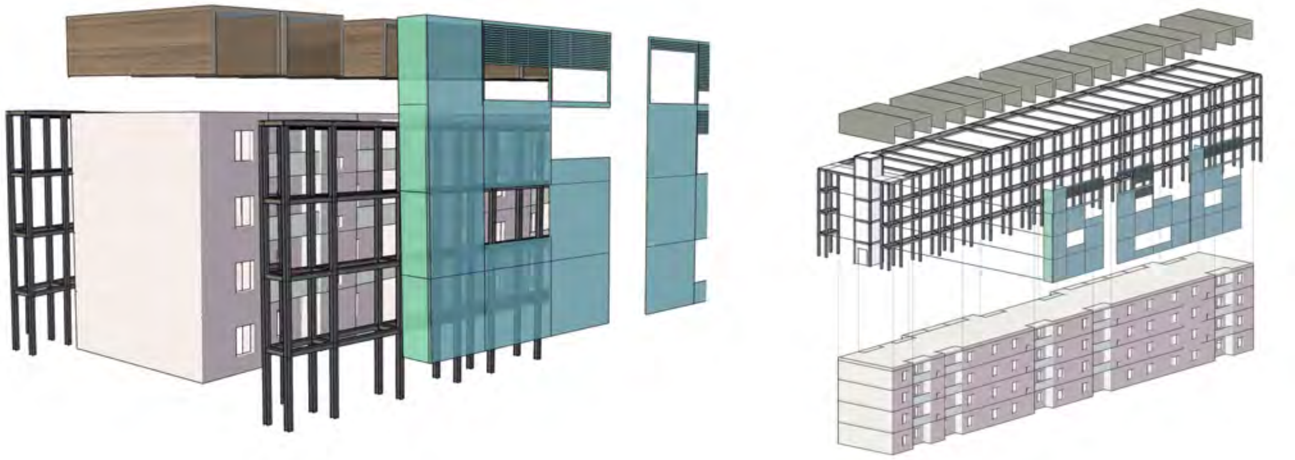
[10] The research is PRIN 2009 (MIUR) "*Strategie di rimodellazione e riqualificazione architettonica dell'Housing sociale*", (Unità di ricerca dell'Università degli studi di Brescia: Marina Montuori (National scientific coordinator), Barbara Angi, Massimiliano Botti, Olivia Longo, Giulio Lupo, Alessandro Muraca. Seconda Università degli Studi di NAPOLI (Pasquale Belfiore, con Raffaele Marone, Maria Dolores Morelli), Università degli Studi di SALERNO (Roberto Vanacore, con Alessandra Como), Università degli Studi di BOLOGNA Alma Mater Studiorum (Valter Balducci, con Valentina Orioli).

[11] It refers to some theses conducted by prof. Roberto Pagani at the Politecnico di Torino.

The integrative qualities of the system are recognized in its redevelopment responsiveness from many points of view:

- Structural, as an S/R system, independent from the original artefact, its stiffening and dissipative action offers significant advantages in the event of an earthquake (Feroldi et al., 2014)[12].
- Energetic, as an evolution of façade refurbishment systems (Zappa, 2011).
- Architectural, equipping the building with a new indoor/outdoor interface, modular and customisable to the needs of the inhabitant (Battaino, Zecchin 2013; Martinelli, 2009).
- Typological/functional, since the added spatiality in the façade can implement the usability of the building, in terms of accessibility and inclusiveness of architectural and urban spaces.

Figure 3. The "exoskeleton system" (F.Guidolin, 2015) is composed by by a set of technical elements that belong to different technological units: the structure, external vertical closures, horizontal closures and plant design system.



The external structure of the exoskeleton system in fact can be applied to those buildings that don't have a high potential of internal reversibility because of the precast construction techniques of the second post-war years[13]. In particular, for architectural and urban quality upgrade, this last function of the exoskeleton system plays an important role for the efficiency of buildings with regard to accessibility: additional spaces can be private or collective as in the case of the vertical connective additions (stairwells, lifts, areas of refuge for the evacuation management in emergency situations) as well as the horizontal housing connective, that determines therefore a typological renewal of the units accesses. All the examples considered show a functional upgrade of the building in terms of accessibility and circulation which is planned and executed through the use of the exoskeleton system. In addition, this feature may be the reason for a larger application of this device to a wider range of building types, such as the public buildings (hospitals and schools).

[12] Among these, the research of the University of Bergamo and Brescia group "*Riqualificazione sostenibile del patrimonio edilizio del secondo dopo guerra mediante doppia pelle ingegnerizzata ed adattiva per il rinforzo strutturale, l'efficientamento energetico, la riqualificazione architettonica ed urbana*" of Ing. Paolo Riva, as for G.Scuderi research, *Adaptive Building Exoskeletons, a biomimetic model for the rehabilitation of social housing*, Archnet - UAR, volume 9, 2015.

[13] It is useful to refer to some examples of redevelopment that aim to move some technical spaces toward the façade of the building, as the research carried out in the 80's by Yves Lion on *Bande Active* as a principle for the typological redevelopment through the addition of services on the façades. (Yves Lion, 1984, *Domus Demain*, AA n.252,p.16-20). Or the latest achievements of "inhabiting the walls" made by Aires Mateus (*Casa en Azeitao*, Setubal Portugal, 2000-2003).

CONCLUSION

This research aims to present the series of case histories that led to the classification of the redevelopment taxonomy, leading to the definition of the exoskeleton system for an integrated building redevelopment. It focuses on the analysis of the space inclusiveness quality for an architectural upgrade of buildings and the surrounding circulation. The use of the exoskeleton system as a technological device will be examined in relation to its possible applications, as a *socio-technical device*[14] (Vermaas P. et al., 2013): the technical identity of this system is associated with a function of use, customization and management of social type. This flexibility is made possible in the design phase, thanks to the use of materials and components with a high potential for customization in terms of the function of use and materials, but also in the participatory management of the construction site. The constructive configuration (with the system S/R) of the exoskeleton device in fact, can allow the management of a participatory and inclusive construction site, since the intervention can be performed completely from the outside and without the displacement of the users, thus saving on moving costs.

Contributes to the Roadmap

The introduction of requalification systems that integrate the energetic, structural, functional/social and architectonical aspects, as the *exoskeleton system* does, could constitute a new strategy for the intervention in non-listed buildings.

The importance of providing strategies for requalification not only in terms of technical solutions but also social and programmatic requisites could promote the possibility of operating in cases of high social and urban complexity.

The introduction of technological systems such as the exoskeleton that allows energetic requalification site management and avoids the interruption of fruition and activities allows for saving on site costs. This perspective must be discussed in reference to a detailed planning operative program and appropriate communication strategies for participatory site management.

Open Issues

The current regulations in terms of integrated intervention strategies, such as the exoskeleton system, should be revised in order to introduce some issues that promote a conjunct energetic and functional upgrade. At the moment, only a small increase in volume is allowed in order to execute an energetic refurbishment. But a more significant increase in volume should be useful in order to integrate functional and structural renewal as well.

Usually we hear of participatory planning in urban settings. The exoskeleton could provide the possibility to implement it at a lower scale. This requires the implementation of certain measures of communicative and future programming lines.

[14] In this case the exoskeleton system is a declination of socio-technical device for envelopes, since it is not only a technical artifact for the physical regeneration, but also a social device, capable of triggering integrated and sustainable mechanisms also in terms of user management.

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A New Model to Evaluate the Performance of the Building Envelope: the Case study of *Energy Park*

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ABSTRACT

The rating system of the building envelope is sustained and is a completion of the BRaVe system (Building Rating Value) offered by the Polytechnic of Milan and is the result of a working group of the laboratory Gesti.Tec.

The rating of the envelope represents an analytic system through which it is possible to examine in depth the elements that contribute to identifying objectively the level of "quality" of a building envelope with the aim of aiding the design of the systems of vertical closure so that it is possible to identify (clearly state) if a specific enhancement can or cannot be functional with regard to the technological aspect.

Keywords

Rating system, building envelope, performance of building envelope, enhancement of buildings, curtain wall, intelligence systems.

INTRODUCTION

A building's envelope, in modern architecture and in the construction market, is now not thought of as a simple division from the outside, but has acquired multiple functions due to the evolution of both buildings and materials (Puglisi, 2014).

“It is more and more significant the fact that the building envelope is defined not as an isolated object that is self-related, but as a “skin” or “membrane”, something that breathes and controls the mechanisms of exchange with the outside environment, in the sense of a building, as a living entity, guaranteeing the upkeep of optimal living conditions inside it, thanks to a metabolic exchange of mass and energy with the surroundings” (Altomonte, 2005).

The enhancement of buildings now represents an innovative approach that pays particular attention to the potential for transformation of the property, placing it in relation to the urban context and the needs of the market, increasing its profitability (Tronconi and Baiardi, 2010).

THE BUILDING ENVELOPE IN THE ITALIAN MARKET

According to the Uncsaal report, the sector related to the production of façade components, despite a physical decrease in production due to the ongoing economic crisis, is following a path towards a constant evolution and innovation of products, which aims to produce innovative and energy-efficient components (Uncsaal n.ro 2, 2013).

Today the sector of the building envelope is characterised by a high fragmentation of supply and by the predominance of small companies, often generic ones. Data supplied by the *Agenzia delle Entrate* (Inland Revenue) in 2011 indicate that there are 12,068 companies in clusters related to the production of metal doors and windows. In the majority of cases, these were individual firms (6,687 companies) or small artisan companies (3,525 companies). Only 1,857 companies (15% of the population) are corporations, of which most are small. The companies that operate in the sector of metallic doors and windows are of two types: non-specialised producers of doors and windows (generic companies that produce doors and windows) and companies focused on the continuous façade (curtain wall companies). The average size of the curtain wall companies are considerably larger than those of companies producing doors and windows, with an average production turnover over 11 million euros with approximately 50 employees, versus 3.7 million euro production and around 25 employees for generic door and window producers (Uncsaal n.ro 1, 2013).

ACTIVITY	NUMBER OF COMPANIES
Manufacturers of metal frames and curtain walls:	***12.086***
✓ Company capital	1.857
36. Partnership	3.525
✓ Sole traders	6.687

Table 1. Breakdown of companies in cluster linked to the production of windows.

	AVERAGE VALUE OF PRODUCTION	AVERAGE NUMBER OF EMPLOYEES
Manufacturers of windows and facades	***5,6***	***30***
- Manufacturers of windows	3,7	25
✓ Manufacturers of facades	11,4	47

Table 2. The size and the numeber of employees in companies operating in the field of frames.

RATING SYSTEMS IN USE TODAY

Today the valuation methods that are used are very varied and not well known; very often, especially in small companies, there is no knowledge of such methods. The reason for this is probably that the market itself does not contain systems that are recognised on an international level: in fact, some of these methods are strongly based on the national context where they have been developed.

"The majority of systems deal only with some of the variables considered fundamental for an overall valuation of the performance of a building: particularly spread are the aspects related to the containment of energy consuming and the compatibility with the environment” (Ciaramella and Tronconi, 2011).

None of the analysed systems has the aim of evaluating the performance according to "transversal" criteria, regarding different thematic or scientific areas of the building envelope.

Fueling the uncertainty of companies who undergo the selection of a valuation method is the presence on the market of two types of methods:

Figure 15. the "standards" : are systems that evaluate the presence of building services, types of services, infrastructure, etc. and are derived from ‘best practices’ in the selection of building adopted by the major companies in the property market.

Figure 16. the "labels": are tags recognised by the market but, very often, evaluate only the environmental aspects of the building and can be applied to all buildings.

	Location	Architecture	Technological flexibility	Furniture interior design	Structure	Building comfort	Care facility staff	Energy performance	Securety	Safety	Rental value	Facility & building management	Year	Classification methods	Total number of parameters	Web based system	Benchmarking of buildings
BOSTI	■	■	■	■		■							1980	Different from building to building			
BQA		■	■		■	■	■		■	■		■	1985	Numerical scale	137		■
BQI						■				■			2004	A, B, C, U			
BOMA	■	■	■	■							■	■		A, B, C			
DQI	■	■	■	■	■	■				■			2002	Graphics	100	■	
International classification office		■	■		■	■	■		■	■				A, B, C			
Logometrix			■			■			■	■		■	2006	Report indicating score		■	
Office class Bulgaria	■	■	■								■		2006	A, B, C	26		■
Office classification ABCD			■		■	■	■	■	■				2006	A, B, C, D	50		
REN	■	■	■		■	■	■	■	■		■		1990	Comparison with examples	150		■
Star office rating	■			■			■		■			■		Stars from 3 to 5		■	■
Politecnico di milano	■		■	■	■	■	■	■				■	2008	AAA, AA, A, BBB, BB, B, CCC, CC, C, D			

Figure 6. The standards systems.

	Location	Architecture	Technological flexibility	Furniture interior design	Structure	Building comfort	Care facility staff	Energy performance	Securety	Safety	Rental value	Facility & building management	Year	Classification methods	Total number of parameters	Web based system	Benchmarking of buildings
3*system	■							■		■		■	2006	Stars from 1 to 3			
BREEAM	■					■		■		■			1990	Sufficient, good, very good, excellent			
DGNB	■							■		■		■	2008	Gold, silver, bronze			
EU Energy Pass	■							■					2002	A+, A, B, C, D, E, F, G			
Green building challenge	■							■			■		2000	Score scale			
HK BEAM	■					■		■		■		■	2003	Platinum, gold, silver, bronze			
LEED	■							■		■			2000	Platinum, gold, silver, certified			
NABERS	■							■		■			2009	Stars from 1 to 5		■	
Protocollo ITACA			■					■		■			2002	Scale scores and examples of buildings			

Figure 7. The labels systems.

RATING SYSTEM OF THE BUILDING ENVELOPE

The rating system of the building envelope is sustained and is a completion of the BRaVe system (Building Rating Value) offered by the Polytechnic of Milan and is the result of a working group of the laboratory Gesti.Tec.

The rating of the envelope represents an analytic system through which it is possible to examine in depth the elements that contribute to identifying objectively the level of "quality" of a building envelope with the aim of aiding the design of the systems of vertical closure so that it is possible to identify (clearly state) if a specific enhancement can or cannot be functional with regard to the technological aspect.

The system identifies different areas of analysis, each of them distinguished by variables that contribute to determining the "performance" level of the envelope (Puglisi, 2012).

Areas of applications

The system can be applied on tertiary building envelopes and, particularly on:

a. Envelope enhancements in order to evaluate achieved improvements or reduction in performance;

b. Pre-existing buildings to evaluate the performance characteristics of the envelope;

c. Buildings in design phase with the purpose of simulating various scenarios and implement the most suitable type of envelope.

The survey questionnaire

The system requires the completion of a questionnaire that, for each item, offers a choice of responses or the simple indication of "yes/no". The survey questionnaire is filled in directly by the designer or by the person who has at his/her disposal the data of the original project and of the enhancement project. It is composed of two parts:

Figure 17. A descriptive sheet that contains the general data of the property to be analysed.

Figure 18. A series of sheets regarding the technological/descriptive aspects of the envelope, its performance, intelligent characteristics, the security and maintenance regarding the property before and after the enhancement.

The system of point attribution

The rating system that is proposed considers 5 families (envelope, technological performance, intelligence, security and maintenance), each of which is divided into different groups (factors) and subgroups (parameters), for a total of 45 entries examined.

Specific scores are allocated for each family, factor and parameter, each of them weighted by its level of importance. The criteria that led to the definition of the scores was that of pairwise comparison, that has allowed the classification of families, factors and parameters in relation to the importance attributed to them in contributing to the determination of the quality of the building envelope of a tertiary building, in terms of performance. Specifically, the envelope has received a score of 30 points, with 35 points for technological performance, 14.50 points for intelligence, 10.50 points for security and 10.00 points for maintenance. The sum of these points is equal to 100.

Rating system output

Upon receipt of the completed questionnaire, the data is entered into a database from which an output is generated that allows you to represent numerically and graphically, the result of the evaluation. In the tables generated by the system for each factor and parameter the following are represented:

- The maximum achievable score.
- The score the building has achieved before the valorisation (enhancement) operation.
- The score the building has obtained after the requalification operation.

The total mark generated by the rating system, expressed as a percentage, classifies the "quality" level of the building envelope.

On the basis of the score obtained it is possible to associate the analysed building to a marking scheme that defines the value of the rating (AAA, AA, A, BBB, BB, B, CCC, CC, C, D).

This score is then described by a radar chart that represents the result obtained for each family in percentages.

The representation of the results of the rating system is derived from histogram charts where are highlighted as an absolute value: the maximum score that can be obtained (left column), the markings that are actually obtained by every factor and parameter that have been analysed before (central column) and after (right column) the valorisation operation.

This allows a clearer view of the improvements/worsening that have occurred as a result of the enhancement operation for the five analysed families.

THE ENERGY PARK

One application of the building envelope rating system are proposed below: the Energy Park - Segro in Vimercate, a recently built building where the method is applied to evaluate the characteristics of the performance of the envelope.

Figure 8. The property of Segro in Vimercate (MI). Source: Garretti Associati srl.

Location	Vimercate (MB)
Functions	Tertiary, laboratories, IT rooms, training rooms, auditoriums, testing rooms
Building time	November 2008 - November 2009
Customer	SEGRO
Designer	Garretti Associati srl
Stakeholders	
Construction management	Garretti Associati srl
Security manager	Garretti Associati srl
Structural engineers	B.M.S. Progetti
Plant engineer	Lombardini 22 srl
Construction company	CESI
Facades and windows	Teleya
Project landscape	Garretti Associati srl
Design Features	
Surface	11.500 mq
Number jobs	About 900
Energetic class	A+
parking lots	559
Amount	15 million euro

Table 3. Some data of Energy Park.

Energy Park is located in the heart of the well known Polo Tecnologico della Brianza (the Science Hub of Brianza) approximately 20 km from down town Milan. It is strategically located for easy access to the traffic arteries of Northern Italy, and it is connected to Milan via the Ring Road East, with a dedicated junction at only a 200 metres distance. Excellent accessibility as well to the A4 (Turin-Milan-Venice) Motorway Junction of Agrate. Besides Building 03 and the new Alcatel-Lucent Campus on the west side, the development of Energy Park includes the completion of 4 additional buildings. Buildings P1, P2 and P3, looking onto the ring road, will be subjected to radical renovations. Moreover, once completed, ENERGY PARK will have over 100,000 sq m. of working spaces and research labs.

Energy Park was developed with a special commitment to deliver against the most ambitious sustainability goals. Each of the new buildings is planned with a 22 metres core depth, with a façade system in precast concrete panels and a shell system which provides for a reversed insulation and a steel ventilated front. The size of the windows is such as to guarantee a good natural lighting factor, even though maintaining a high protection from direct irradiation. Façades have in fact a balanced opaque and transparent bodies ratio with elements fully in glass, concentrated in a highly visible part of the buildings: the entrance halls and the bioclimatic glasshouses, strengthening further their architectural character. It is this way possible to achieve a balance between the winter and summer's energy savings and the optimization of natural lighting contribution.

The rating system of the building envelope applied to Energy Park reaches peaks of excellence in the most households with particular reference to the building envelope, the technological performance, the security and the maintenance, achieving a very good score in the rating system ("AAA").

				MAX	AS BUILT	
	Type 1	**Type 2**		**Max Score**	**%**	**Score**
1	ENVELOPE	1.1	Relationship with Form	3	100%	3
		1.2	Type of envelope	7,5	100%	7,5
		1.3	Openings	9,5	95%	9
		1.4	Facade Shading	9	94%	9
		1.5	Roof Shading	1	100%	1
2	TECHOLOGICAL PERFORMANCE	2.1	Energy Class of the Building	4	100%	4
		2.2	Thermal Conductivity	20,5	100%	20,5
		2.3	Light Transmission	3	100%	3
		2.4	Sound Insulation	5,5	100%	5,5
		2.5	Meccanical ventilation	2	100%	2
3	INTELLIGENCE	3.1	Intelligent Systems	6	100%	6
		3.2	Photovoltaic system and presence of renewable energies	7	50%	3,5
		3.3	Comunication	1,5	67%	1
4	SECURITY	4.1	Security glass	8,5	100%	8,5
		4.2	Control systems	2	100%	2
5	MAINTENANCE	5.1	Ordinary maintenance	5	90%	4,5
		5.2	Maintenance Systems and tools	5	80%	5
			TOTALE	***100***	***94%***	***95***

Table 4. The results of the rating system *applied to Energy Park.*

RATING	SCORE
AAA	100 - 95
AA	94 -90
A	89 - 80
BBB	79 - 70
BB	69 - 60
B	59 - 50
CCC	49 - 40
CC	39 - 30
C	29 - 20
D	< 20

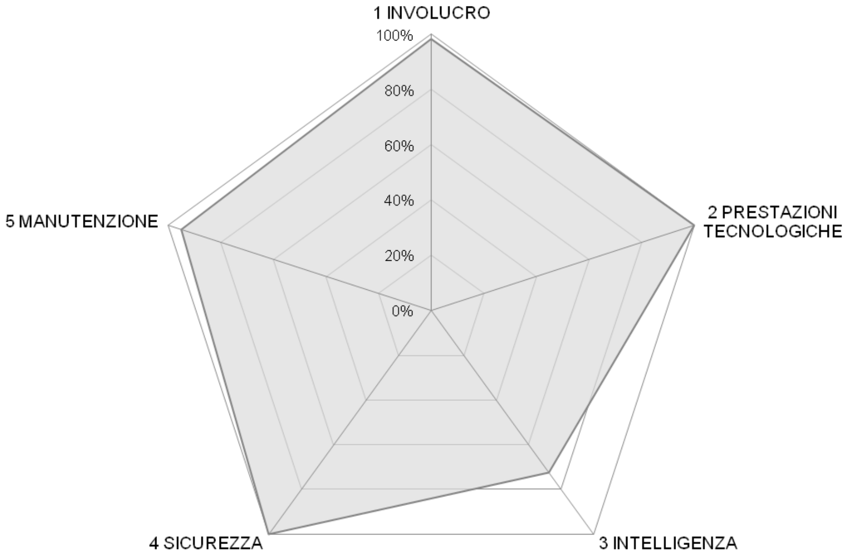

Figure 9. The results of the rating system applied to Energy Park.

The quality level of the envelope up to 98% and it is it is characterized by:

- Type of envelope: it is characterized by various types of façade (structural, ventilated and continuous).
- Openings: the windows are equipped with thermal break and low-emissivity glasses are installed.
- façade shading: are characterized by a combination of shading in the horizontal and vertical shields. In particular the shields are hyper performance, in fact the tents have low emitting characteristics.

The building thanks to the characteristics described above, achieves the maximum scores in all parameters analyzed.

The quality level of technological performance of the building envelope the maximum score possible. The building, in fact, lies in A+ energy class, is designed to provide a lot of number of air changes per hour, is characterized by very low transmittance and by a good level of acoustic-sided glossy. Façade sound insulation has also met legal requirements (DPCM 5/12/1997 “Determination of passive acoustic requirements of buildings”). The number of air changes per hour to meet the current legal requirements (Building Research Establishment Environmental Assessment Method, RICS).

The quality level of intelligence of the envelope reaches 72%. The building achieve excellent scores in the following areas:

- the clever features: the building has solar trackers, artificial lighting reactive systems for heat recovery systems, different for every area (foyer, interior and perimeter areas, CED) directly connected to the internal network through wiring;
- control systems: for cooling, ventilation, heating, humidity and solar shading;
- use systems that use geothermal energy.

Instead constitute points of weakness the following areas the absence of the photovoltaic system and the absence of systems that contribute to the communication capacity of the building with the external environment.

The quality level achieved by the family of security around the envelope is equal to 100%. The building, in fact, is characterized by the using of security glass like anti-injury, anti-fall and anti-burglar-vandalism-crime and the CE branding of the glass.

The quality level of the family regarding maintenance up to 85% and it is it is characterized by:

- The constant implementation of a maintenance program during the years considered.
- The possibility of lowering mobile scaffolding from the roof and allowing a ladder within 5m of the building so that some external maintenance can be easily done.
- A high availability on the market of replacement components for the envelope.

Instead constitute point of weakness the absence of self-cleaning glass integrated into the facade.

CONCLUSION

In the enhancement process, the renovation of the building envelope has a decisive role. A product that is correctly enhanced is subject to a simple insertion in the market and it adds value to the investor and to the context where it is set. High quality buildings are usually qualified by the real estate market with the term "Class A". This definition, taken from models of financial rating, doesn't correspond to a precise, objective and scientific identification of the elements that determine it: elements as the "flexibility of the surfaces", "high standard plants", the presence of "raised floors" or other features that characterize the building's equipment, are generically listed.The envelope rating system's aim is to spot elements that can objectively identify the level of "quality" of a building envelope. In particular, this system wants to clarify if indeed a redevelopment, only limited to the building's envelope, may or may not be functional in terms of technology and function.

Contributes to the Roadmap

The rating system of the building envelope should be applied to any enhancement of the building in order to improve its performance.

Open Issues

The rating system of the building envelope should be applied not only to the tertiary buildings, but to all types of building.

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Materials Session

Session Rapporteur: **Koji Sakai**

Sustainable Recycling of Concrete with Environmental Impact Minimization

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ABSTRACT

The paper outlines the history of quality requirements for recycled concrete aggregate in Japan and introduces the framework of "Guideline for Mix Design, Production and Construction Practice of Concrete with Recycled Concrete Aggregate" established by Architectural Institute of Japan. Then the paper proposes a design concept for closed-loop recycling and presents the outline of completely recyclable concrete, with which closed-loop circulation of component materials is realized. The paper also introduces a newly developed technology realizing sustainable resource recycling with low energy consumption in concrete structures.

Keywords

Recycling, concrete, closed-loop, low energy consumption, guideline.

INTRODUCTION

Providing excellent performance as a structural material, concrete has long been deemed essential for modern civilization and recognized as a material that will continue to maintain and support the development of human society. The sheer amount of concrete in use and in stock compared with other building materials brings up the issue of the enormous amount of waste generated when concrete is disposed of. Besides, aggregate resources are beginning to be depleted at a high speed. Concrete has conventionally been regarded as being difficult to recycle. The construction industry has addressed these problems and carried out research and development regarding the recycling of concrete since the 1970s.

JAPANESE STANDARDS AND GUIDELINE FOR RECYCLED AGGREGATE CONCRETE

After a three-year study aiming at using demolished concrete as recycled aggregate for concrete, the Building Contractors Society established "Draft standard for the use of recycled aggregate and recycled concrete" in 1977. This standard required that the oven-dry density and water absorption of recycled coarse aggregate be not less than 2.2g/cm^3 and not more than 7%, respectively, and those of recycled fine aggregate be not less than 2.0g/cm^3 and not more than 13%, respectively. This was followed by researches and developments under some projects promoted by the Ministry of Construction (1981-1985 and 1992-1996) or semi-public research institutes, through which standards for recycled aggregate have been established. The development history of concrete recycling is summarized in Table 1 from the viewpoint of the properties of recycled aggregate. Table 1 shows the progressive improvement in the properties of recycled aggregate achieved by advances in the technology for producing recycled aggregate, finally reaching a level comparable to natural aggregate. The Recycled Aggregate Standardization Committee was set up in Japan Concrete Institute in 2002, which was tasked with formulating Japan Industrial Standards for recycled aggregate for concrete.

The committee established three standards as follows:

- JIS A 5021 (Recycled aggregate for concrete, Class H)
- JIS A 5022 (Recycled concrete using recycled aggregate, Class M) with Annex
- JIS A 5023 (Recycled concrete using recycled aggregate, Class L) with Annex

Three types of recycled aggregate are classified by water absorption and oven-dry density, each being recommended for concrete structures and segments as given in Table 2.

Table 1. History of Quality Requirements for Recycled Aggregate

Year	Formulator and Name of Standard		Coarse aggregate		Fine aggregate	
			Density (g/cm^3)	Absorption (%)	Density (g/cm^3)	Absorption (%)
1977	Building Contractors Society Draft standard for the use of recycled aggregate and recycled concrete		2.2 or more	7 or less	2.0 or more	13 or less
1994	Ministry of Construction Provisional quality standard for reuse of concrete by-products	Type 1	-	3 or less	-	5 or less
		Type 2	-	5 or less	-	10 or less
		Type 3	-	7 or less	-	
1999	Building Center of Japan Accreditation criteria of recycled aggregate for building concrete		2.5 or more	3.0 or less	2.5 or more	3.5 or less
2000	Ministry of International Trade and Industry TR A0006 (Low quality recycled aggregate concrete)			7 or less		10 or less
2005	Japan Industrial Standards Committee Recycled aggregate for concrete	JIS A 5021 (Class H)	2.5 or more	3.0 or less	2.5 or more	3.5 or less
2006		JIS A 5022 (Class M)	2.3 or more	5.0 or less	2.2 or more	7.0 or less
2007		JIS A 5023 (Class L)		7.0 or less		13.0 or less
	Japan Industrial Standards Committee JIS A5005 (Crushed stone and manufactured sand for concrete)		2.5 or more	3.0 or less	2.5 or more	3.0 or less

Table 2. Recommended application of recycled aggregate

Class	Structural concrete		Non-structural concrete	
	Affected by drying	Not affected by drying	With reinforcements	Without reinforcements
H	Applicable range with no need for special consideration			
M		Applicable range with no need for special consideration		
L				Applicable range with no need for special consideration

Table 3. Contents of the AIJ Guideline for Recycled Aggregate Concrete

Chapter	Title
Chapter 1	General
Chapter 2	Types and applicable members of RAC
Chapter 3	Qualities of RAC
Chapter 4	Materials
Chapter 5	Production of RA
Chapter 6	Proportioning
Chapter 7	Order placement, production, and acceptance of RAC
Chapter 8	Transportation, deposition, consolidation, and curing of RAC
Chapter 9	Quality control/inspection
Chapter 10	RAC M for structural members subjected to the effect of drying
Chapter 11	RAC L for reinforced concrete members
Appendix 1	RA and RAC that received JIS accreditation and Ministry certification
Appendix 2	Application examples of closed-circuit concrete recycling technology
Appendix 3	Placement examples of concrete made using RA H produced by equipment with an eccentric rotor
Appendix 4	Application examples of RAC H and M to buildings
Appendix 5	Application examples of RAC by aggregate replacement
Appendix 6	Methods of reutilizing by-product fine powder

Architectural Institute of Japan (AIJ) established and published "Guideline for Mix Design, Production and Construction Practice of Concrete with Recycled Concrete Aggregate" (AIJ Guideline) in October 2014 based on the Japan Industrial Standards for recycled aggregate and recycled aggregate concrete. The table of contents of AIJ Guideline is shown in Table 3. The guideline shows the standard specifications for the investigation of demolished reinforced concrete structures which become the resource of recycled aggregate and the production and quality control of recycled aggregate. It also recommends the appropriate type of recycled aggregate concrete according to the condition of the part or the component of a building, and prescribes the mix proportioning, production technique, transportation method, execution technique, quality control method for recycled aggregate concrete. In the appendices, lists of recycled aggregates and recycled aggregate concretes certified by the Japanese government are shown, and typical application cases of these recycled aggregate concretes to buildings are outlined.

STATE OF THE RECYCLING TECHNOLOGIES FOR CONCRETE

Recycling technology shown in Figure 1 has been shifting from simple crushing into advanced techniques, i.e. scrubbing with some preparations such as heating (Shima et al., 1999; Yanagibashi et al., 2004) to produce high-quality recycled aggregate for structural concrete. These techniques avoid down cycling and recovers recycled aggregate, or a material, having the same quality as natural aggregate from waste concrete, forming a closed-loop in terms of the resource circulation of concrete materials. However the problems are remained in these techniques regarding thermal-energy-induced environmental impact and cost increase.

The time has come when establishment of a new design concept for complete recycling of structural concrete is definitely necessary. The principle of complete recycling is that the concrete is subject to material design to reduce waste generation and facilitate resource circulation in a closed-loop system (Noguchi et al., 2011). Development technology based on such material design is regarded as proactive technology. The materials of concrete should be used as parts of concrete during the service life of concrete and remain usable after demolition as parts of similar or other products without quality deterioration, continuing circulation in various products as the media. This is defined as a performance called resource conservability. If concrete produced with due consideration to the resource conservability at the stage of material design is applied to structures, then the components of the concrete can be completely recycled at the time of demolition as shown in Figure 2. What should be done in the future is to introduce material design that permits complete recycling for at least the components of concrete, i.e., aggregate and cement materials, to ensure the material conservability in concrete as the medium and then to achieve high strength and high durability of structures.

IDEAL COMPLETE RECYCLING OF CONCRETE IN THE FUTURE

Concrete shall have the same characteristics as steel and aluminum in order to realize a closed-loop complete recycling in concrete. The author has been involving the development of completely recyclable concrete (CRC) since 1994 and proposed two types of CRC. One is the cement recovery-type (Tomosawa and Noguchi, 1996) and another the aggregate recovery-type (Tsujino et al., 2008).

Figure 1. Categorization of Concrete Recycling Technology

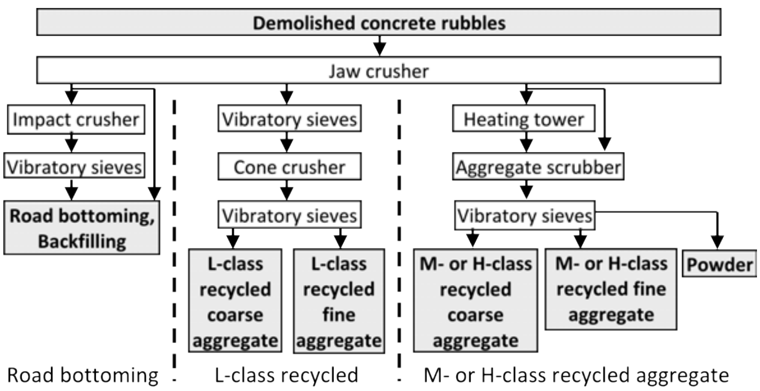
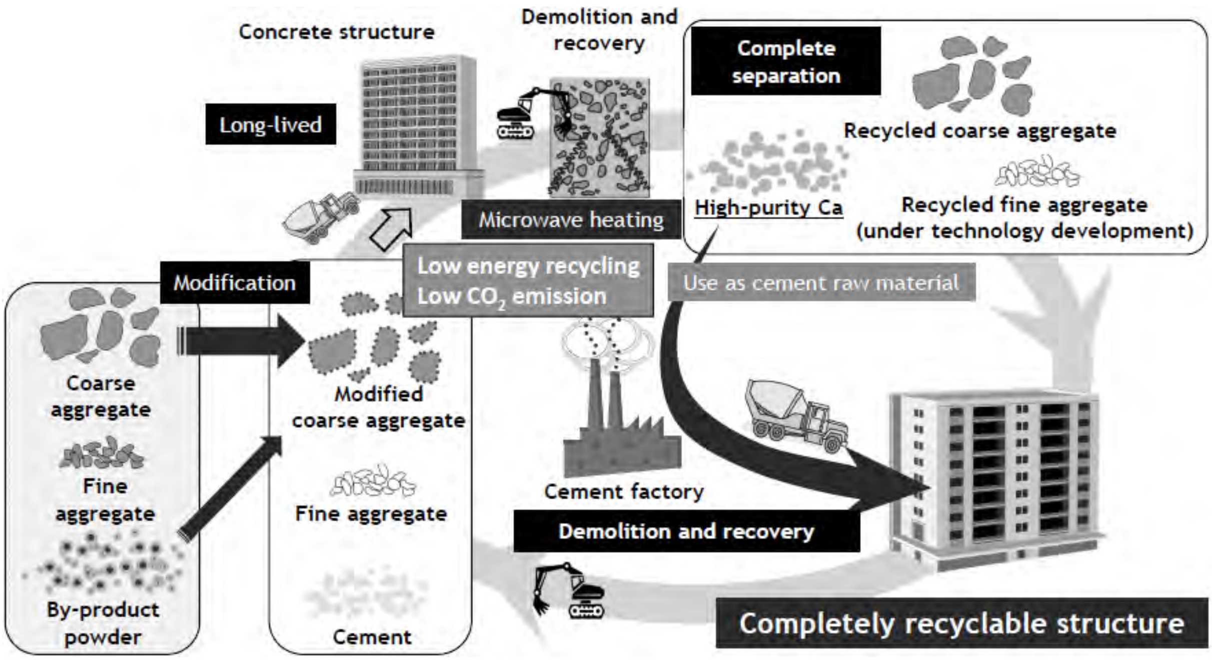


Figure 2. Society of Closed-loop Concrete Recycling



Cement Recovery-type CRC

Cement recovery-type CRC was defined as "concrete whose materials are entirely usable after hardening as materials of cement, since all the binders, additions, and aggregate are made of cement or materials for cement". Blast-furnace slag, fly ash, etc., generated as by-products from industries other than construction have been actively reused as materials for cement and cementitious materials for concrete. Since these contain adequate amounts of SiO_2, Al_2O_3, and Fe_2O_3 that are necessary for materials of cement, concrete containing several types of these industrial by-products in combination achieves complete recyclability as clinker material after demolition without adding any other ingredients. The experiments revealed that the recycled cement had the same properties as one available on the market and no problem was observed in fresh and mechanical properties of the concrete made using this cement as shown in Table 4. Cement recovery-type CRC can formulate a semi-closed-loop circulation material flow as shown in Figure 3. Conversion from conventional concrete to cement recovery-type CRC will substantially mitigate the environmental problem of concrete waste generation, while permanently preserving and storing the limestone resource in the form of structures. Besides, CO_2 emission during cement production can be reduced by the utilization of cement recovery-type CRC as a raw material of cement since cement made from calcined limestone never emits CO_2.

Aggregate Recovery-type CRC

Aggregate recovery-type CRC was defined as "concrete in which the aggregate surfaces are modified without excessively reducing the mechanical properties of the concrete, in order to reduce the bond between aggregate and the matrix, thereby permitting easy recovery of original aggregate". It can also form a closed circulating material flow as shown in Figure 4. In order to achieve 100% circulation of concrete in a closed system, a structure is necessary as an aggregate-supplier in addition to one as a cement material supplier.

Table 4. Properties of Recycled Cement and Recycled Concrete

	Density (g/cm^3)	Specific surface area (cm^2/g)	Setting time		Compressive strength at 28days (MPa)
			Initial	Final	
Recycled cement	3.13	3,340	2h-00m	2h-50m	43.0
Recycled concrete	W/C	Compressive strength at 28 days		Modulus of elasticity at 28 days	
	0.58	35.2 MPa		39.0 GPa	

Figure 3. Cement Recovery-type CRC

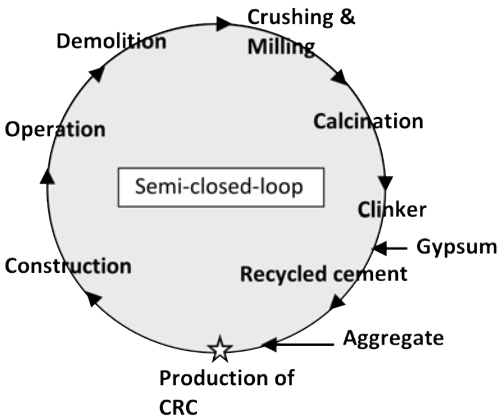
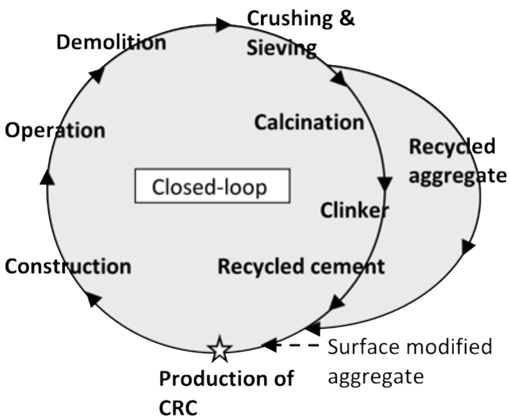


Figure 4. Aggregate Recovery-type CRC



By building a stock of structures keeping such an appropriate balance, all cement and aggregate can be exploited from built structures in the future.

Aggregate recovery-type CRC has to ensure compatibility of the performances in a trade-off relationship between mechanical properties of the concrete and aggregate recoverability. Aggregate recovery-type CRC consists of two technologies as shown in Figure 5, i.e. concrete strength enhancement technology and aggregate recovery technology. The former involves, differing from conventional technologies, aggregate surface modification to increase the bonding force between the coarse aggregate and the mortar by coating a binder evenly on the surface of the coarse aggregate. Silica fume and by-product powder were contained in the binder expecting to enhance chemical and physical bonding force due to pozzolanic reaction and mechanical friction. The latter aims at recycling aggregate with low energy, which involves inclusion of dielectric material in the binder. When applied with microwave radiation, the dielectric material on the surface of the aggregate is heated and the interface between the aggregate and mortar matrix is weakened locally and thus the separability of the aggregate and mortar matrix is improved. Experiments were conducted using different types of surface modified coarse aggregate shown in Table 5. Figure 6 shows that the strength of the concrete (SP80, SP90) is increased by 20% or more compared to that of normal aggregate concrete (O) because of the combination of the increase in the mechanical friction force and the increase in the chemical bonding force. After heated as shown in Table 6, the specimens were roughly crushed with a jaw crusher, and subjected to a rubbing treatment with the Los Angeles Abrasion Machine to remove cement mortar. The recovery ratio of the recycled coarse aggregate is shown in Figure 7. The specimen O1 (not heated) contains much cement paste in spite of undergoing rubbing treatment. With respect to the specimen O2 heated by microwave radiation and O3 heated in the electric oven, more cement paste is removed than that without heating, but it is not so much compared to that of specimen undergone heated-scrubbing as reported in the past papers. The aggregate recovery rate of the specimen SP80 heated by microwave radiation was around 93%, indicating small amount of the paste and fine aggregate remained, proved a high quality of the recycled coarse aggregate. The CO_2 emission during the treatment of 1 ton of waste concrete mass is shown in Figure 8. The CO_2 emitted using the microwave heating is extremely small compared to that from the aggregate production process based on the heated-scrubbing. When compared to the mechanical-scrubbing that could produce moderately high quality aggregate, CO_2 emission was almost the same. Considering the extremely high quality of recycled aggregate obtained by the new technology, it seems highly advantageous than conventional ones.

Figure 5. Concept of New Technology for Aggregate Recovery-type CRC

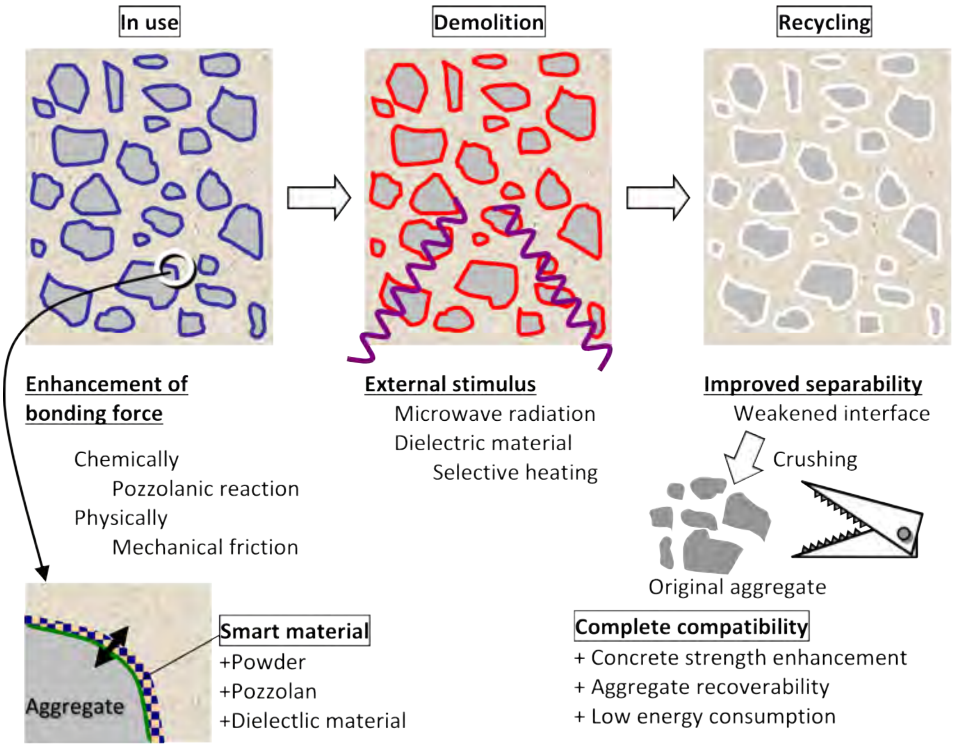


Table 5. Surface Modified Coarse Aggregates

Symbol	Silica fume (%)	By-product powder (%)	Epoxy resin & dielectric material
O	0	0	Not applied
N	0	0	Applied
SP70	30	70	
SP80	20	80	
SP90	10	90	
P	0	100	

Figure 6. Compressive Strength and Modulus of Elasticity in Aggregate Recovery-type CRC

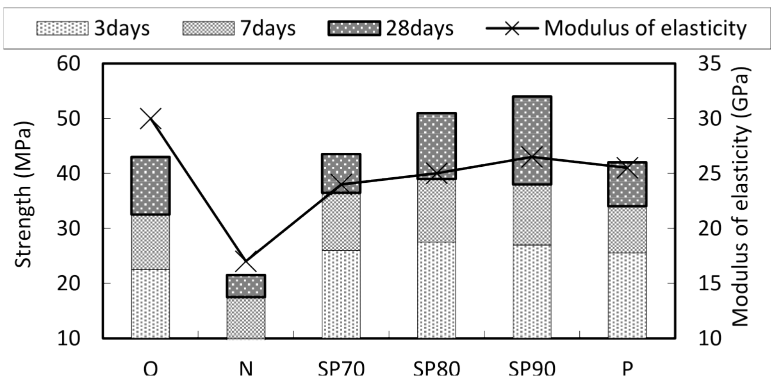


Table 6. Heating Conditions

Symbol	Dielectric material	Microwave heating	Electric oven heating
O1	Not applied	-	
O2		2.45GHz, 1800W, 90sec	-
O3		-	300°C, 60min
SP80	Applied	2.45GHz, 1800W, 90sec	-

Figure 7. Recovery Ratio in Aggregate Recovery-type CRC

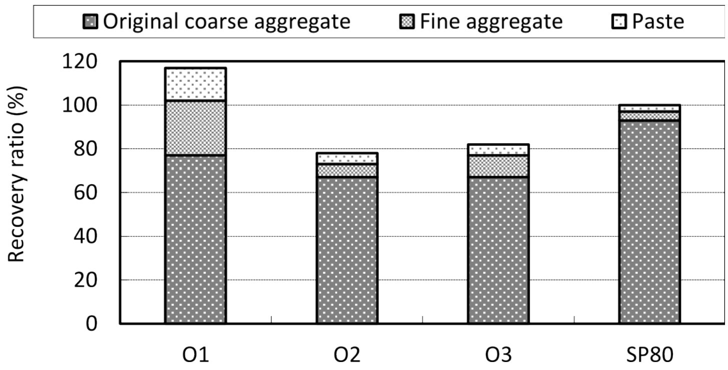
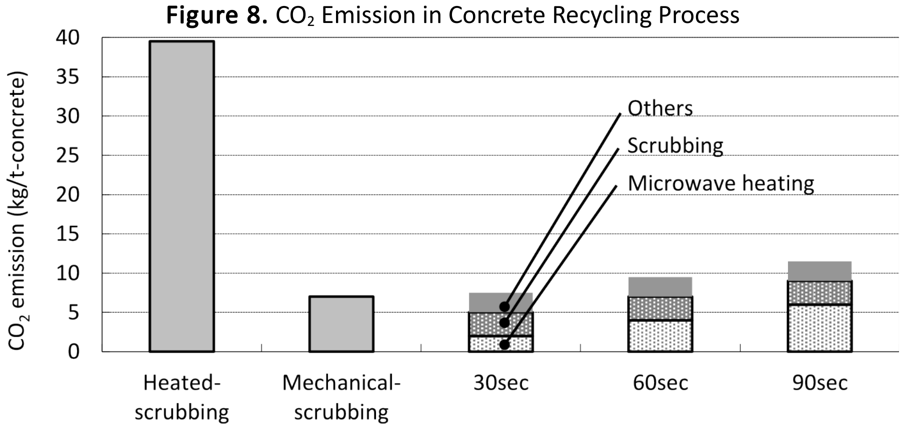


Figure 8. CO_2 Emission in Concrete Recycling Process



CONCLUSION

A recycling-oriented society is a society that continues to use resources, once they are taken from nature into the society, without returning them unless they do not represent an environmental load. In such a society, the intake of resources from nature is minimized and products and materials that cannot be recycled repeatedly are rejected. Recycling should be of high quality because recycled products are not marketable unless they are of a quality that satisfies users. Recycling should be repeatable. If a recycled product has to be dumped in a landfill after use with no chance of recycling, then the recycling is no better than producing waste of the following generation. To establish a recycling-oriented society, it is vital to materialize a new production system whereby new stock serves as resources and it is important to adopt a technology of enhancing the resource conservability of concrete and its components, at the stage of designing the structure by incorporating the concept of upstream-process system. Completely recyclable concrete (CRC) is one of the technologies which can recover materials for cement and aggregate to realize the formulation of resource circulation. Though the cement recovery-type CRC cannot completely achieve closed-loop resource circulation, the aggregate recovery-type CRC is proved to become such like steel and aluminium. It also achieves smaller CO_2 emission in recycling compared to conventional technologies.

Contributes to the Roadmap (Required)

The target values should be determined for several parameters such as a resource efficiency (=GDP/Resource consumption) and a recycling efficiency (=Utilization of recycled or reused resource/Utilization of recycled resources and natural resources) in order to reserve abiotic natural resources.

Open Issues

Clients have little intention of investing recyclable materials and/or reusable components used in structures which are costly at the stages of production and construction but will become beneficial at the stages of demolition and recycling in the future. How can we actualize a paradigm shift?

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Sustainable Concrete Structures – Contribution to the Development of a Sustainably Built Environment

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ABSTRACT

Concrete is used in construction of buildings, bridges, dams, roads, tunnels – basically every contemporary construction contains concrete. The special properties of concrete are, among others, affordability, availability and variability in connection with strength and potential durability, which has made concrete the most used man-made material in the world. More over high amount of concrete use is associated with high transport needs and demands on production and demolition processes within the entire life cycle. This all has significant impact on the environment. The presentation shows and discusses advantages of concrete structures from the viewpoints of sustainability. The general methodology for ILCA of concrete structures based on ISO and CEN standards and other specifics applied to different life cycle phases, different types of concrete structures and to different regional conditions will be also presented.

Keywords

sustainability, life cycle assessment, concrete structure, environmental impact

INTRODUCTION

The production of concrete in the industrialized world annually amounts to 1.5-3 tone. In consequence of a fact that world cement production has been 12 times increased in the second half of the last century, the cement industry produces at present about 5 - 7% of global man-made CO2 emissions. More over high amount of concrete use is associated with high transport needs and demands on production and demolition processes within the entire life cycle. This all has significant impact on the environment.

Current development of concrete, production technology and development of concrete constructions during last twenty years have lead to quality shift of technical parameters and also of related environmental impacts. New types of concrete have due to mix optimization significantly better characteristics from the perspective of strength, mechanical resistance, durability and resistance to extreme loads.

The rapid development in the construction industries leads to the replacement of old existing buildings with new buildings. Consequently, the amount of demolished concrete structures is very high and is gradually increasing. This creates needs and potential for replacement of natural aggregate by recycled aggregated. The use of recycled concrete - as an aggregate for new concrete mixes, leads to saving of natural resources and helps to reduce the pressure on landfilling sites.

Concrete gradually becomes building material with high potential for expectant environmental impact reduction. This needs better knowledge about technological processes and their impacts from wide variety of sustainability aspects within entire life cycle – from acquisition of materials, through production of concrete and concrete components, construction, use, up to demolition of concrete structure and recycling (Hajek, Fiala and Novotna, 2014).

ADVANTAGES OF CONCRETE STRUCTURES

Main advantages of concrete structures from the viewpoints of sustainability are: (i) thermal mass (contributing to energy savings associated with cooling and heating), (ii) acoustic properties (improving air-born sound insulation), (iii) fire resistance, (iv) long term durability, (v) structural safety, including high resistance to natural effects during exceptional effects like natural disasters comprising good resistance to earthquakes. These advantages could be significant in designing new constructions as well as in old structures reconstructed for the new use (Hajek, Fiala and Kynclova, 2011; Hajek, Novotna and Fiala, 2013).

Specific advantages of concrete structures from environmental viewpoint

- Secondary materials utilization - Utilizing supplementary cementitious materials in a composition of concrete mixture (fly-ash, granulated blast furnace, microsilica) it is possible to reduce the amount of embodied energy and embodied CO2 and SOx emissions.
- Recycled concrete can be utilized as aggregate substitutes in earthwork construction and up to some extent as an aggregate substitute in a new concrete production.
- Precast concrete elements in “tailor-made” manner enable waste reduction in production and also on construction site.
- Thermal mass of concrete can contribute to energy savings associated with cooling and heating.

Specific advantages of concrete structures from economy viewpoint

- Long-term durability - Concrete in comparison to other materials (timber, steel etc.) enables longer service life of buildings. Concrete structures are usually more resistant to atmospheric action, they have a good capability of withstanding wear, and they do not subject easily to degradation processes. This also results in lower operating, maintenance and demolition cost.
- Lower material cost, lower manipulation and transportation cost - Subtle concrete structures utilizing lesser amount of higher quality concrete could be cheaper, even though the unit cost of this type of concrete is higher than the unit cost of standard concrete types.
- Dismountable structures: Precast concrete structures can be designed as dismountable enabling consequential utilization of structural elements.
- Smaller thickness of peripheral structures can have a positive effect on construction economic efficiency (especially in areas with regulated size of built-up area).
- Thermal mass - Concrete structures due to their accumulative properties can in some cases contribute to decrease of operating cost for cooling and heating.

Specific advantages of concrete structures from social viewpoint

- High structural safety and reliability, higher fire resistance – This includes also high resistance to natural effects during exceptional cases of natural disasters (floods, storms, winds, hurricanes, tornados, fires, earthquakes, etc.) and terrorist attacks.
- Acoustic properties – Due to high specific weight of concrete there can by improved air-born sound insulation of structure (floors and/or walls separating different operational areas);
- Thermal mass – Concrete (material with high specific weight) can contribute to thermal stability of internal environment and consequently to energy savings.
- Maintainability - High quality concrete surface can be easily maintained, cleaned and it has long durability.
- Flexibility – Character of concrete technology enables significant design flexibility due to the possibility of forming almost any element shape limited only by structural reliability requirements.
- Healthiness - Concrete is not the source of toxic emissions or volatile organic compounds.

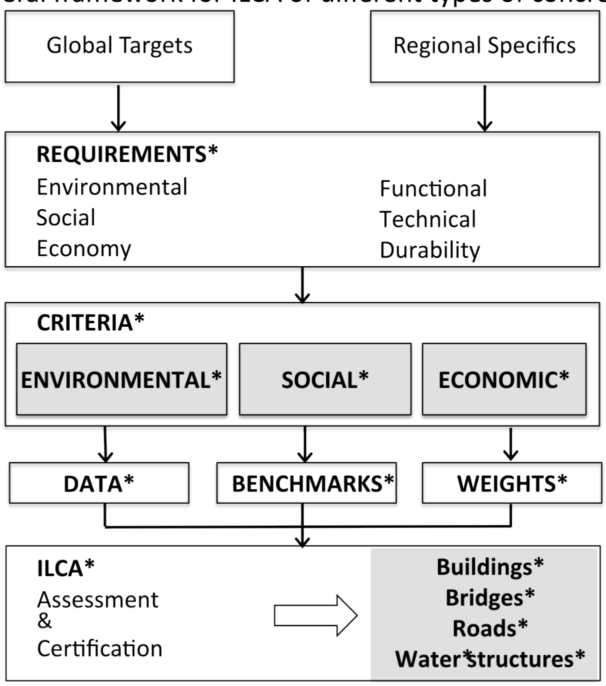
INTEGRATED LIFE CYCLE ASSESSMENT OF CONCRETE STRUCTURES

Integrated design is a complex approach implementing all relevant and significant requirements into one single design process. This approach integrates material, component, and structure design and considers selected relevant criterions from a wide range of sustainability criterions sorted in three basic groups: environmental, economic and social and considering entire life cycle of structure (Fib Bulletin 28, 2004). Complex integrated approach is based on simultaneous and interactive consideration of different aspects:

– sustainability requirements (environmental criteria, economic criteria and social criteria);
– technical and functional requirements (technical performance, functional performance, durability);
– life cycle phases throughout the entire life of the structure;
– various functional units (material, component, entire structure).

Concrete is used in a wide variety of structures (buildings, bridges, roads, dams etc.), each designed with a specific kind of functionality and life span in mind. For all these reasons no single outline for an ILCA for a given concrete structure can be specified. A chart in the "Figure 1" shows ILCA process applied to different types of concrete structures (Fib Bulletin 71, 2013). In this process the key importance play regional specifics, because concrete is typically produced from regionally available materials using regionally available techniques and transport systems.

Figure 1. General framework for ILCA of different types of concrete structures.



CONCLUSION

Already implemented realizations give clear signal that in the forthcoming era there will be necessary to take into account new requirements and criteria for design and construction of concrete structures following from global aspects on sustainable development. The results show that the high quality of mechanical and environmental performance of new silicate composites creates the potential for wider application of High Performance Concrete in building construction focused on sustainability issues.

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Contributes to the Roadmap

Concrete gradually becomes building material with high potential for expectant environmental impact reduction. Especially optimized concrete structures using new types of concrete in advanced technologies can significantly contribute to needed reduction of global environmental impacts. One possible way is utilizing of ultra high performance concrete in optimized structural shapes. Mechanical properties of these materials such as high compressive strength, durability, water tightness etc. create conditions for designing subtle structures that leads to saving up to 70% of material in comparison with ordinary concrete, and consequently to reduction of embodied CO2 emissions.

Open Issues

Efficiency of new concrete technologies to be used in sustainable construction of buildings in the changing world (considering global climate changes and global social changes).

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LCA-Based Sustainability Assessment Approach Applied to Structural Retrofit of Masonry Buildings

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ABSTRACT

Over the last decade, the rehabilitation/renovation of existing buildings has progressively attracted the attention of the scientific community and government institutions. Many studies focus intensely on the mechanical and energy performance of retrofitted/renovated existing structures, while few works deal with the environmental impacts of such interventions. The environmental impacts related to a structural retrofit option can be successfully evaluated by means of a life-cycle assessment (LCA) based approach. In particular, a cradle to gate (or grave) system boundary can be considered for each retrofit technique in order to compute substance flows throughout the entire or partial life cycle of the existing building. On the basis of a methodological framework based on LCA, the present study evaluates the life cycle environmental impacts of typical retrofit techniques applied to masonry walls belonging to exiting masonry structures.

Keywords

Existing masonry structures, retrofit techniques, LCA.

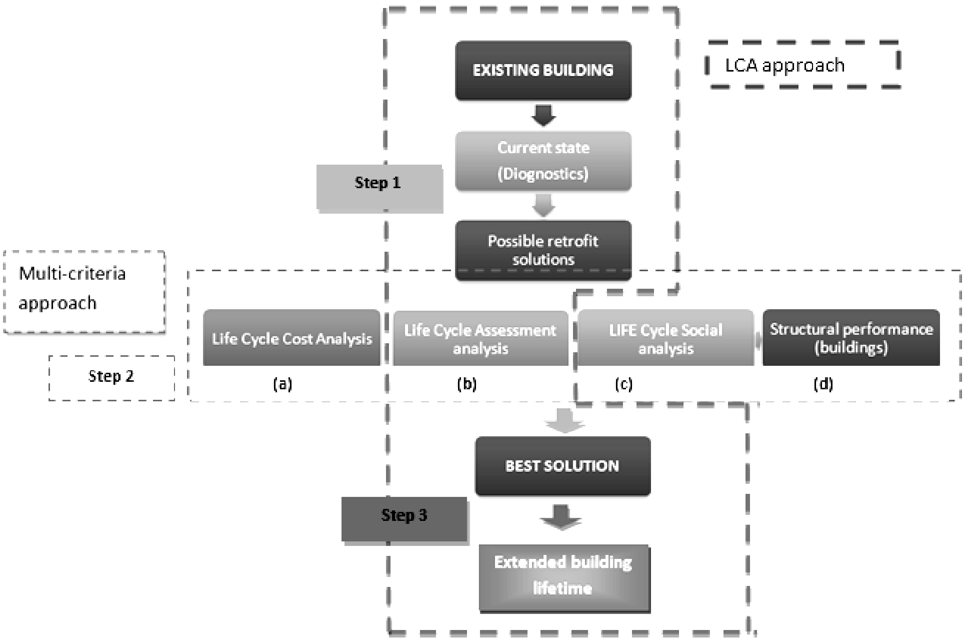
INTRODUCTION

In many European countries, such as Italy, masonry buildings constitute a significant portion of existing building stock; in addition, many of them are characterized by an important historical and cultural value. In general, these structures do not comply with current/national engineering standards and are sometimes subjected to physical and functional degradation over time as well as structural damage from hazardous events. Despite these drawbacks, building renovation has gained increasing attention as a valuable alternative to demolition, providing opportunities to upgrade the internal and external building environment, reach energy efficiency, align with more modern accommodations with respect to new standards, and increase the value and safety of the existing building. Large-scale retrofitting studies have focused deeply on the mechanical, functional, and energy performance of retrofitted/renovated existing structures, while few works have dealt with the environmental sustainability assessment of such interventions (Asadi et al. (2012), Ascione et al. (2011)). In addition, recent research activities have also included other sustainability criteria, such as economic benefits of refurbishment (Kanapeckiene et al. 2011) and social aspects (Raslanasa et al. 2011), often considering the structural and functional performance of a building after earthquake damage. From an environmental sustainability perspective, the environmental impacts related to a structural retrofit option can be successfully evaluated by means of a life-cycle assessment (LCA) based approach. However, if the LCA of a single construction component or process can be effectively conducted according to process/manufacturing data, on the other hand, a retrofitted building/structure is a system that is too complex to be assessed, with a long lifespan that involves multifaceted procedures, hypotheses, data collection, and interpretations. Nevertheless, moving the LCA focus from single components to retrofitted buildings and structures would significantly contribute to sustainability from the design phase onward, orienting the decision-making towards low-impact solutions. The purpose of this paper is to analyze different structural retrofit techniques applied to masonry structures. In particular, the present study aims to quantify the environmental footprint of different structural retrofit interventions, conducted on a masonry structure, once structural requirements are established and satisfied. Four different structural options are examined from the environmental point of view by means of a LCA approach (ISO:14040 2006; ISO:14044 2006): local replacement of damaged masonry (LRDM), mortar injection (MI), steel chain installation (SCI), and application of grid-reinforced mortar (GRM) made of a glass fiber composite grid.

METHODS

Given the wide set of possible scenarios and solutions, it should be emphasized that refurbishment and retrofit of existing buildings often require, as mandatory requirement, the fulfilment of several mechanical and functional requests (sometimes prescribed by national laws/standards) that have to be properly taken into account during the design of the retrofit itself. Among these requirements, a selection of a set of actions should be pursuit also in the light of common goals of sustainable development in the construction sector. Each solution should be analysed by using appropriate criteria (quantitatively expressed by proper indicators) considering financial, environmental, social, and structural aspects, in order to implement the optimal retrofit solution. According to this approach, sustainability and structural requirements might be incorporated within the design stage of retrofit of existing structures. In other words, a comparison between the environmental performance of different retrofit options could be properly carried out by (Figure 1): (1) designing different retrofit configurations following current/local engineering practice; (2) verifying that each retrofit configuration satisfies some performance requirement defined at the design stages, e.g. structural properties, thermal insulation properties, space availability; (3) performing an LCA of the different retrofit configurations within a standardized LCA framework; and (4) interpreting and comparing the results according to such a framework.

Figure 1. Schematic approach for environmental sustainability assessment of retrofit options



Four different structural options are investigated in the present study by following the mentioned step by step procedure (Figure 1): LRDM, MI, SCI, and GRM. These techniques have been often employed to repair the damages linked to mechanism of collapse occurred, for example, during seismic events which typically involve the partial or total collapse of the wall (out-of-plane mechanisms) and cracks formations. The proposed approach, based on the LCA logical scheme reported in Figure 1, aims at contributing to sustainable design of retrofit interventions in construction sector. This approach has been selected coherently with the requirements of the international Environmental Product Declaration (EPD) system according to ISO 14025 (ISO: 14025 2006). Each different option reported in Figure 2 is analysed with reference to proper normalized quantities based on mechanical performance targets that characterize each technique: 1 m long of local replacement and crack binding on 1 m^2 of masonry wall in the case of LRDM and MI, respectively; 1 m^2 of masonry wall where GRM is applied and 1 m of steel chain in the case of SCI. These investigated scenarios are designed in order to achieve the same structural performance in terms of shear strength for the retrofitted masonry wall. This condition is achieved by applying a proper number of grid reinforcement layers to obtain the same tensile strength according to Circolare n.617 2009. The environmental impacts of the structural retrofit options are assessed by means of an LCA approach. A cradle to grave system boundary is considered for each retrofit process. The results of the environmental analysis are presented according to the data format of the Environmental Product Declaration (EPD) standard. Indeed, the environmental outcomes are expressed through six impact categories: global warming, ozone depletion, eutrophication, acidification, photochemical oxidation, and non-renewable energy.

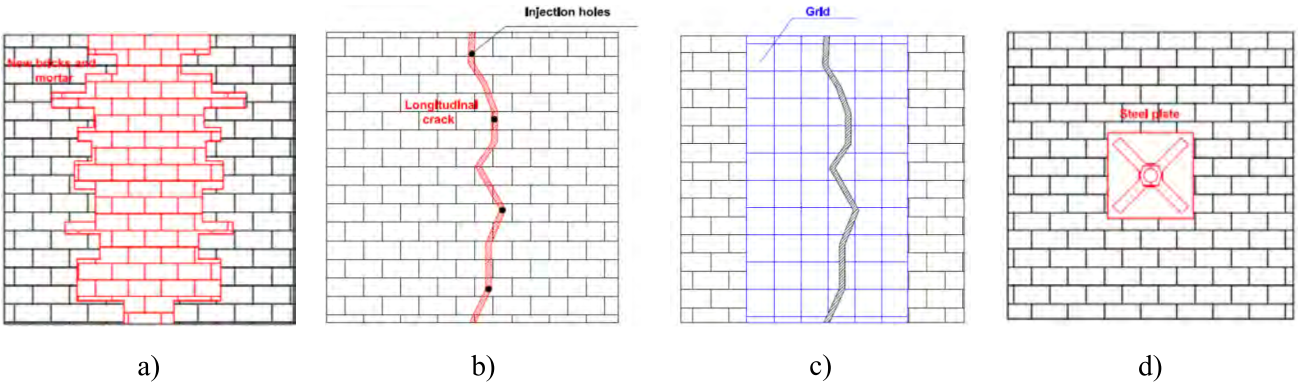


Figure 2. Retrofit options herein investigated: a) local replacement of damaged masonry, b) mortar injection, c) grid-reinforced mortar application, and 4) steel chain installation.

RESULTS

The EPD environmental indicators are adopted to quantify the environmental impacts of the structural retrofit options. In particular, the environmental impacts on global warming, ozone depletion, photochemical oxidation, acidification, eutrophication and non-renewable energy are evaluated. The results for all the retrofit options and referred to the entire life cycle are reported in Tables 1, 2, 3 for LRDM and MI, GRM, SCI, respectively.

In the LRDM and MI retrofit options, the use of light mortar (construction phase) is responsible for the major environmental impact in all LCA categories. When the LRDM and MI options are compared, the results show that the LRDM option is the major responsible for the environmental impacts in all the categories. In the SCI retrofit option, the use of steel along with possible end of life scenarios (i.e. steel recycling) are able to influence the overall results of the retrofit option. In the GRM retrofit option, the production process of the glass reinforcing grid is responsible for the highest environmental impact in all LCA categories.

Table 1.LCA results for LRDM and MI retrofit techniques.

Impact category	Unit	LRDM - 1 mq	MI - 1 mq
Global warming (GWP100)	kg CO2 eq	63,5	25,6
Ozone layer depletion (ODP)	kg CFC-11 eq	6,9E-06	2,6E-06
Photochemical oxidation	kg C2H4 eq	6,0E-02	2,9E-02
Acidification	kg SO2 eq	1,5E-01	7,7E-02
Eutrophication	kg PO4--- eq	5,3E-02	2,5E-02
Non renewable, fossil	MJ eq	798,0	354,2

Table 2.LCA results for GRM retrofit technique.

Impact category	Unit	GRM - 1 mq
Global warming (GWP100)	kg CO2 eq	34,7
Ozone layer depletion (ODP)	kg CFC-11 eq	4,3E-06
Photochemical oxidation	kg C2H4 eq	5,0E-02
Acidification	kg SO2 eq	1,2E-01
Eutrophication	kg PO4--- eq	4,1E-02
Non renewable, fossil	MJ eq	581,2

Table 3.LCA results for SCI retrofit technique.

Impact category	Unit	SCI - 1 m
Global warming (GWP100)	kg CO2 eq	132,7
Ozone layer depletion (ODP)	kg CFC-11 eq	9,5E-06
Photochemical oxidation	kg C2H4 eq	1,2E-01
Acidification	kg SO2 eq	5,3E-01
Eutrophication	kg PO4--- eq	4,2E-01
Non renewable, fossil	MJ eq	2123,1

The results of this analysis in the form of normalized input quantities can be used to compute the environmental impacts of real large-scale retrofit operations, once the amount/extension of them was determined and established (as target) in the design stage. The study provides a systematic approach and environmental data to drive the selection and identification of structural retrofit options for existing buildings, in terms of sustainability performance.

CONCLUSION

An effective environmental comparison between retrofit options would be meaningful only once the exact amount of each operation (i.e. number of m^2 of masonry wall in the case of LRDM and GRM, number of m of crack in the case of MI and number of m of steel chain in the case of SCI) and the corresponding mechanical performance are defined for a specific retrofit case that requires a pre-defined structural improvement. Then, based on the results of the LCA analysis, it is possible to compare the total environmental impact related to a large scale retrofit intervention on an existing masonry building (through the investigated techniques), guaranteeing an equivalent structural response of the retrofitted building. Finally, the environmental impacts of the retrofit options herein investigated can be used for future research/practical activities, to monitor and control the environmental impact of structural retrofit operations of existing masonry buildings.

Contributes to the Roadmap

With regard to the specific application to masonry structures, it should be highlighted that in recent years and especially in Italy, historic centres severely damaged by earthquakes were mainly made of masonry structures. As a consequence of this, different retrofit techniques were largely employed to repair the previous mentioned types of damage and improve the earthquake resistance. Given the wide set of possible scenarios and solutions, the combined improvement of earthquake resistance and eco-efficiency of existing buildings can be achieved by means of a systematic approach based on LCA which is able to link environmental performances of retrofit techniques with mandatory structural and functional requirements (sometimes prescribed by national laws/standards) of the building.

Open Issues

Besides the definitions of standards for a systematic approach based on LCA and applied to structural retrofit of existing masonry buildings, the major issues regard the availability and quality of primary inventory data linked to different retrofitting techniques.

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Self-healing cement based construction materials: a new value for sustainable concrete. Five years of research experience at Politecnico di Milano

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ABSTRACT

Worldwide increasing consciousness for sustainable use of natural resources has made "overcoming the apparent contradictory requirements of low cost and high performance a challenging task" as well as a major concern. The importance of sustainability as a requisite which has to inform structure concept and design has been also recently highlighted in Model Code 2010. In this context, the availability of self-healing technologies, by controlling and repairing "early-stage cracks in concrete structures, where possible", could, on the one, hand prevent "permeation of driving factors for deterioration", thus extending the structure service life, and, on the other hand, even provide partial recovery of engineering properties relevant to the application

The author's research group has undertaken a comprehensive research project, focusing on both experimental characterization and numerical predictive modelling of the self-healing capacity of a broad category of cementitious composites, ranging from normal strength concrete to high performance cementitious composites reinforced with different kinds of industrial (steel) and natural fibres. Both autogenous healing capacity has been considered and self-healing engineered techniques, including the use of pre-saturated natural fibres as well as of tailored admixtures.

Tailored methodologies have been employed to characterize the healing capacity of the different investigated cement based materials. These methodologies are based on comparative evaluation of the mechanical performance measured through 3- or 4- point bending tests. Tests have been performed to pre-crack the specimens to target values of crack opening, and after scheduled conditioning times to selected exposure conditions, ranging from water immersion to wet and dry cycles to exposure to humid and dry climates.

The healing capacity has been quantified by means of the definition and calculation of suitably defined "healing indices", based on the recovery of the load bearing capacity, stiffness, ductility, toughness etc. and correlated to the amount of crack closure, measured by means of optical microscopy and also "estimated" through suitable indirect methodology. As a further step a predictive modelling approach, based on modified micro-plane model, has been formulated. The approach incorporates the self-healing effects, in particular, the delayed cement hydration, as well as the effects of cracking on the diffusivity and the opposite repairing effect of the self-healing on the micro-plane model constitutive laws.

The whole experimental and numerical investigation represents a comprehensive and solid step towards the reliable and consistent incorporation of self-healing concepts and effects into a durability-based design framework for engineering applications made of or retrofitted with self- healing concrete and cementitious composites.

Keywords

Self-healing, normal strength concrete, high performance fiber reinforced cementitious composites, modelling, durability-based design

Environmental Sustainability Assessment of an Innovative Hemp Fibre Composite System for the Retrofit of Masonry Structures

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ABSTRACT

Sustainability goals are essential driving principles for the development of innovative materials and technologies devoted to the retrofit/renovation of existing buildings. Natural fibres are an attractive alternative as reinforcing material due to both good mechanical properties and sustainability prerequisites. In addition, natural fibre reinforced composites are widely investigated in the research community, trying to exploit their potential to reduce or eliminate some of the problems associated with the poor recyclability of glass and carbon fibres in conventional composites. In the present work, we investigate the environmental performance of an innovative hemp fibre composite grid used in a previous experimental campaign investigating the shear behaviour of masonry panels strengthened with this system. In order to quantify the level of environmental sustainability of the developed strengthening technique, we have compared the environmental performance of this system with that of typical FRP-mortar systems which are commonly used for retrofitting purposes.

Keywords

Existing masonry structures, Hemp fibres, retrofit, LCA.

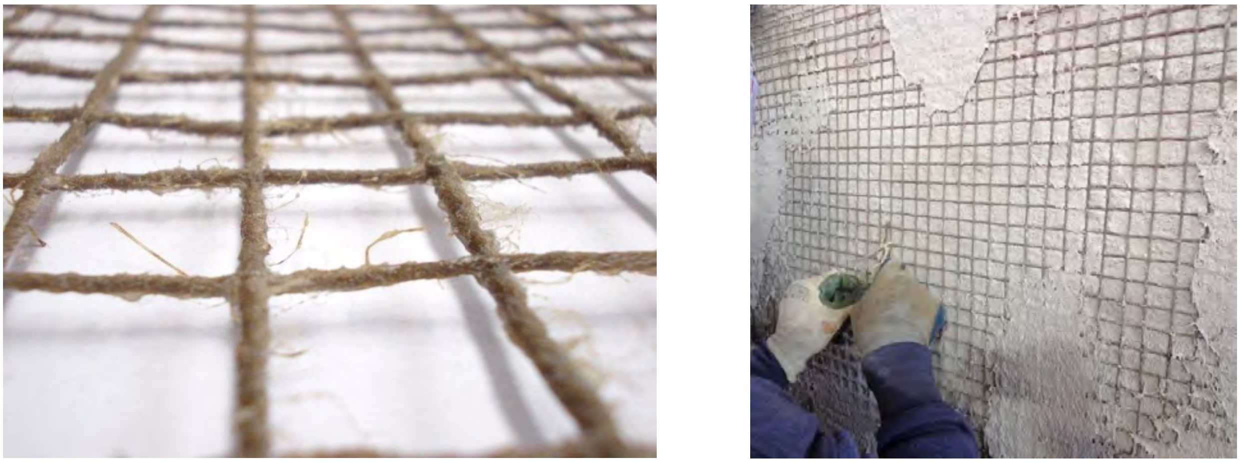
INTRODUCTION

A large number of existing masonry structures is prone to damage as a consequence of possible actions, including earthquakes, environmental deterioration/aging, and other hazardous events. Several retrofit/strengthening techniques have been developed for these type of structures, often considering reversibility, compatibility and sustainability as beneficial prerequisites for the retrofit/strengthening process. Among new strengthening strategies, the employment of Fibre-Reinforced Polymers (FRPs) provides a series of advantages, including high strength-to-weight ratios, corrosion and fatigue resistance, negligible influence on global structural mass, easy handling and installation, and low architectural impact. Recently, natural fibres (such as hemp, flax jute, sisal etc.) have emerged as possible alternatives to FRP systems since they exhibit tensile strengths comparable with those exhibited by synthetic fibres. Other benefits related to the use of natural fibres include the production process which consumes globally less energy compared to typical fibres used in composite technology. In the present study, we propose a strengthening system for external retrofit of existing masonry walls based on natural hemp fibres. The comparison between this system and FRP based ones is conducted on the basis of a life cycle assessment (LCA) approach that allows the identification of the solution that minimizes the consumption of materials, energy, emissions and waste related to the different phases of the life cycle. In particular, the following different reinforcing options are investigated: steel grid, glass fibre grid, basalt grid and hemp composite grid combined with cement mortars.

MATERIALS AND METHODS

The hemp fibre composite grid investigated in this study is used as external reinforcing system in the form of a 20 mm x 20 mm bi-directional mesh made of hemp cords impregnated with a low viscosity epoxy resin. Each cord (or strand) is obtained by twisting three single hemp yarns of size equal to 400 tex, resulting in a final cord size of 3 x 400 tex (Figure 1a,b). The fully description of the hemp based grid along with the experimental results of the experimental investigation conducted on retrofitted masonry walls is reported in the work by Menna et al. 2015 (Menna et al. 2015).
With regard to the environmental assessment of the hemp fibre composite grid, the environmental impacts of the reinforcing options are assessed by means of an LCA approach. A cradle to grave system boundary is considered for each retrofit process: steel grid, glass fibre grid, basalt grid and hemp composite grid. The results of the environmental analysis are presented according to the data format of the Environmental Product Declaration (EPD) standard (ISO ISO:14025 2006). The functional unit chosen for the comparison of the different alternatives is 1 m^2 of reinforced mortar/plaster designed in such a way as to ensure the same shear strength (at least 60 kN) of the retrofitted masonry structure.

Figure 1. a) hemp fiber composite grid; b) application of the hemp fiber composite grid on masonry panels.



a) b)

RESULTS

The results of the LCA pointed out that the retrofit technique employing the basalt fibre reinforced grid was characterized by a greater environmental impact than other solutions investigated. In particular, the production of basalt fibres requires a high consumption of energy, which would affect adversely the overall environmental performance. On the contrary, the solution employing hemp fibres results in a reduction of the environmental loads of about 50-70% compared to other technologies, mainly linked to the CO_2 absorbed by the plant species from which the fibres of the grid are obtained.

CONCLUSION

The LCA framework was able to provide useful results with regard to the environmental performance of an innovative strengthening system applied on existing buildings. In particular, LCA was applied to evaluate the environmental impacts of different retrofit techniques employing synthetic and natural fibres. The analysis conducted from cradle to grave, pointed out that the environmental benefits linked to the use of natural fibers were mainly related to the CO_2 absorption during the plant species lifetime and low production environmental loads.

Contributes to the Roadmap

LCA results of new materials and technologies can be successfully used as a tool for decision support of retrofit actions on existing buildings and in the selection of the most sustainable solution which guarantees at the same time proper mechanical performances.

Open Issues

Besides the definitions of standards for a systematic approach based on LCA and applied to structural retrofit of existing masonry buildings, the major issues regard the availability and quality of primary inventory data linked to different retrofitting techniques especially those based on innovative materials.

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Financial Session

Session Rapporteur: **Marco Castagna**

The tension between competition and regulation on European real estate markets

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ABSTRACT

The abstract "The tension between competition and regulation on European real estate markets" is intended to provide an insight into today´s European real estate markets and their main emerging trends. The explanation of the current situation of investors and real estate companies helps to clarify the circumstances. The abstract combined with a brief case study to be shown in the presentation further aims to create an awareness of the complex relationships between governmental regulation, costs of construction and the increasing property prices on real estate markets. These matters of fact have to be deliberately considered when looking at how sustainable regulations may eventually prevent high quality architecture and city planning measures, such as refurbishments, being taken under careful consideration of the financial demands.

Keywords

Real estate markets, trends in real estate, increasing property prices, fierce competition, real estate investment, refurbishments, city planning, sustainable regulations, high-quality architecture, construction costs, financial limits.

INTRODUCTION

Years after the global financial crisis the effects can still be felt in many European economies. Nonetheless, there are some positive signs to be recognized in the real estate markets – one of the best examples is the renewed increase in construction activity due to increasing demand. For instance, Norway currently shows the highest increase in new construction, followed by France and Ireland.

Strong and increasing competition characterizes the situation within property markets throughout Europe. On the one hand, and from the perspective of institutional investors, this means lower yields in an already difficult market, and situations such as the low interest rate which still persists to yield at historical lows. On the other hand operators in the real estate markets - for example real estate development companies - face strong competition in highly sought after locations with property prices that have recently soared over the last few years.

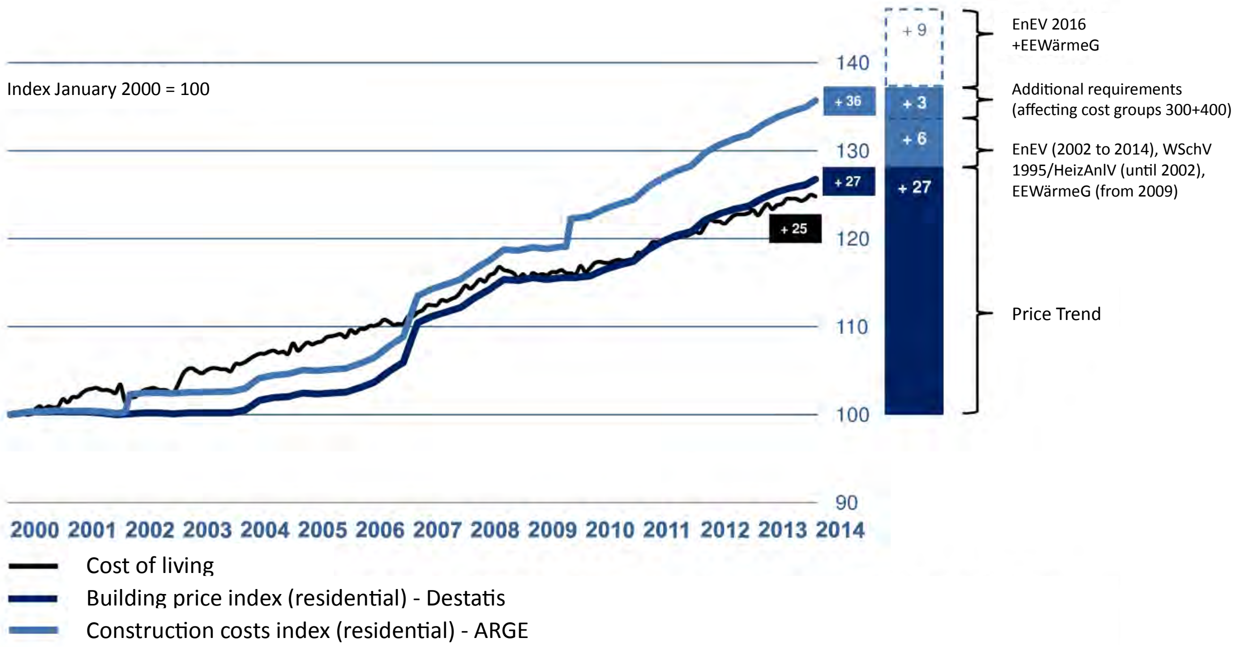
TRENDS ON REAL ESTATE MARKETS

During the current re-urbanization process the increasing demand for residential real estate, especially in metropolitan areas, comes from a strong lack of supply alongside rising population numbers and changing demographics. This trend is expected to continue within the years to come. High quality new construction projects in core locations are in demand by competing investors. This situation emphasizes the current trend of converting existing inner city commercial properties into residential real estate and thereby decreasing existing vacancies expeditiously.

With regards to commercial real estate segments, such as office and retail, several significant points should be highlighted. The demand for office space is highly dependent upon the regional labour market. Due to the above mentioned re-urbanization the amount of highly qualified workers in major cities has drastically increased. This has attracted an ever growing number of companies which has led to a greater variety of different industries in the metropolitan areas and in turn has a direct impact on the demand for office space. Post 2012 office rents have shown less volatility than in the previous decade. More precisely the prime rents of office properties in Europe have increased by no more than 7 % and fallen by no less than 5 % since 2012. This requires investors in office properties to reconsider their investment strategies, especially when it comes to core risk profiles with lower yields due to a higher investment volume.

The retail sector offers more stability to investors, as it is characterized lower volatility and a more reliable foundation in rents and yields with a steady growth rate over the last 20 years. However, even within the retail markets investors should consider an in-depth analysis of emerging demographic and trends, for example, the above mentioned urbanization process or the ageing population.

COMPETITION ON REAL ESTATE MARKETS



The real estate companies acting as investors themselves or as direct agents to institutions are competing for the few remaining inner city development sites. This fierce competition on the real estate markets further boosts the increasing price of land and in turn contributes to growing rents and sale prices in prime cities. This trend is also visible in locations with less demand. In addition, real estate companies additionally have the claim on developing distinct architecture as a significant contribution to sustainable urban development as a marketing advantage during such competitions.

Moreover, real estate companies face increasing regulations throughout Europe. Germany has assumed a pioneering role with regards to the regulation of property markets while these rules are being reduced in other European countries. German rent control – for example – provides stricter governmental regulation but can still be seen as an exception in Europe while legal regulation measures concerning energy saving is far more widespread and continues to increase throughout Europe.

REGULATION ON REAL ESTATE MARKETS

The amendments of the German Energy Saving Ordinance (EnEV) are expected to take place with increasing costs for construction. This is underlined by the fact that from the year 2000 to 2014 the construction cost relation between the construction of the shell (2000: 54%, 2014: 46%) and the interior work (2000: 46%, 2014: 54%) shifted significantly. Long term studies have confirmed this effect: from 2000 until the year 2014 construction costs in Germany rose by 36% due to energy efficiency regulations. The following diagram illustrates the increase of construction costs in Germany.

In addition to energy saving rules, the residential real estate market faces some serious regulations concerning the increasing rents and sales prices as well as supervision for affordable housing. While these controls have a minor effect on the investor´s returns they indirectly decrease the urgently needed supply on the residential markets. Therefore they create an increasing dynamic concerning rents and sales prices that limit the effects on the grievances they are designed to control.

A brief case study has combined all of these circumstances. It illustrates the significant confrontation between ever increasing property prices and strict building regulations which require sustainable materials and procedures as well as distinct architecture. The oral presentation will discuss the market and also the financial aspects, referring to sustainability regulations, for example, the construction costs. In addition the presentation will highlight selected project references to further emphasize the discussion.

CONCLUSION

Real estate markets throughout Europe are characterized by a strong and still increasing competition. Financial investors and real estate companies compete for the last development sites in inner city locations. In addition the amendments of governmental regulation measures, for example energy saving ordinances or rent control regulations, contribute to the increasing prices of land, rents and sales prices. These circumstances (increasing property prices and strict building regulations) therefore impede the development of high quality architecture utilizing ever more sustainable materials and procedures.

Contributes to the Roadmap

In regards to the eco-efficiency of existing buildings and cities, it is important to take into account the interdependence between economic sectors such as the real estate industry and governmental regulations. The necessity of these regulations has to be carefully considered, and for this consideration the situation on the affected markets has to be known. Future investments in properties combined with high architectural quality under consideration of the investor´s financial leeway may otherwise be severely restricted.

Open Issues

Issues to be discussed are the difficult conditions concerning real estate markets, i.e. the low interest rates, the compatibility of increasing property prices due to a lack of supply combined with increasing construction costs caused by governmental regulations, such as energy efficiency requirements. Yet there is no satisfactory solution on how governmental regulations will not affect the increasing prices on property markets avoiding for example the prevention of high quality design by considering the yield requirements of financial investors.

An extended financial dimension of sustainability

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ABSTRACT

A proper sustainable assessment of construction works should be holistic: performed at the building or infrastructure level, during the whole life cycle (from cradle to grave) and considering the three pillars: People, Profit and Planet. Buildings and infrastructure are designed and built to fulfil people's needs. Safety, comfort and resilience considerations (amongst others) should remain the key objective, to be achieved with the lesser impact to the environment and in an affordable way throughout the whole life cycle.

The economic dimension of sustainability goes beyond acquisition and running costs: the end-of-life stage costs as well as the income associated to the construction work should be considered for drafting the whole picture. Even further, a study demonstrated the multiplier effect on the economy of a value chain with a strong local dimension, as well as the benefits of a long service life, like in the case of concrete.

Keywords

Sustainability, Holistic approach, Economic pillar, Multiplier effect, Service life, Concrete.

INTRODUCTION

The sustainable assessment of a construction work (being it a building or a civil engineering work) is performed during its whole life cycle, thus including the three main stages: Construction (stage A), Use (stage B) and End-of-life (stage C). Additional information outside the system boundaries (stage D) may also be considered.

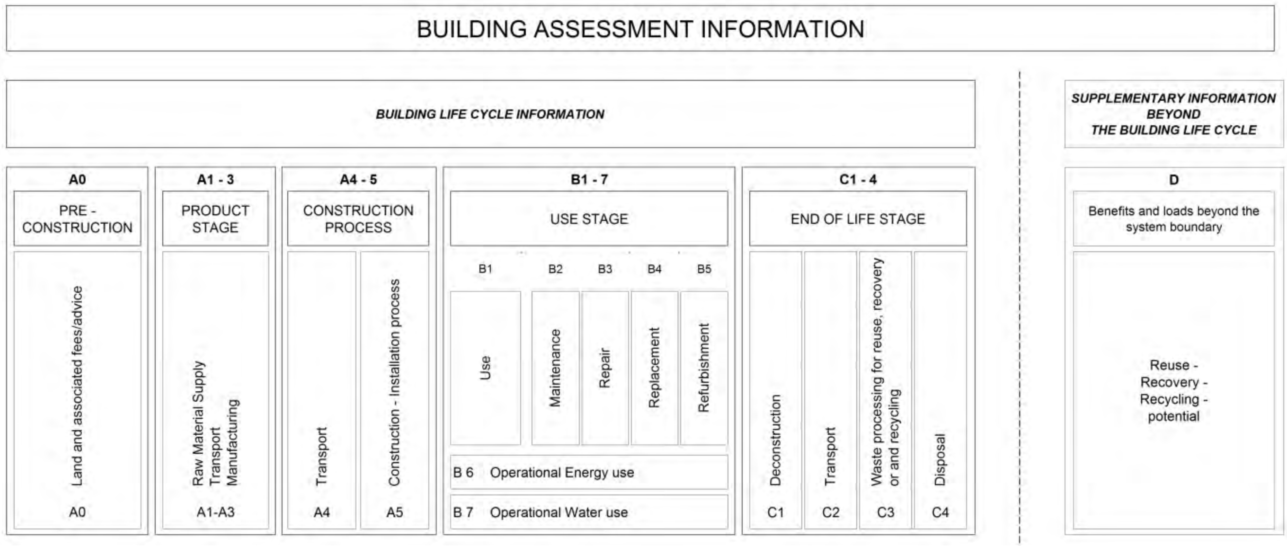

Figure 1 - Display of modular information for the different stages of the building assessment as defined in CEN/TC 350

This assessment is commonly addressed looking at the so called "three pillars": the social, the environmental and the economic one (also known as the "3Ps": People – Profit – Planet).This approach might look complex to some people or simplistic to others (aspects like e.g. cultural heritage, policy and ethics are neglected). Anyhow, it has the merit of expanding the criteria of "lowest cost" which has dominated the decision making process in the field of construction during the last century. The client (being a business, an administration, a property developer, a consumer etc.) is today in a position to make an informed decision based on a (limited) number of key parameters. His main task has become weighting the different features to come to a final decision.

THE THREE PILLARS

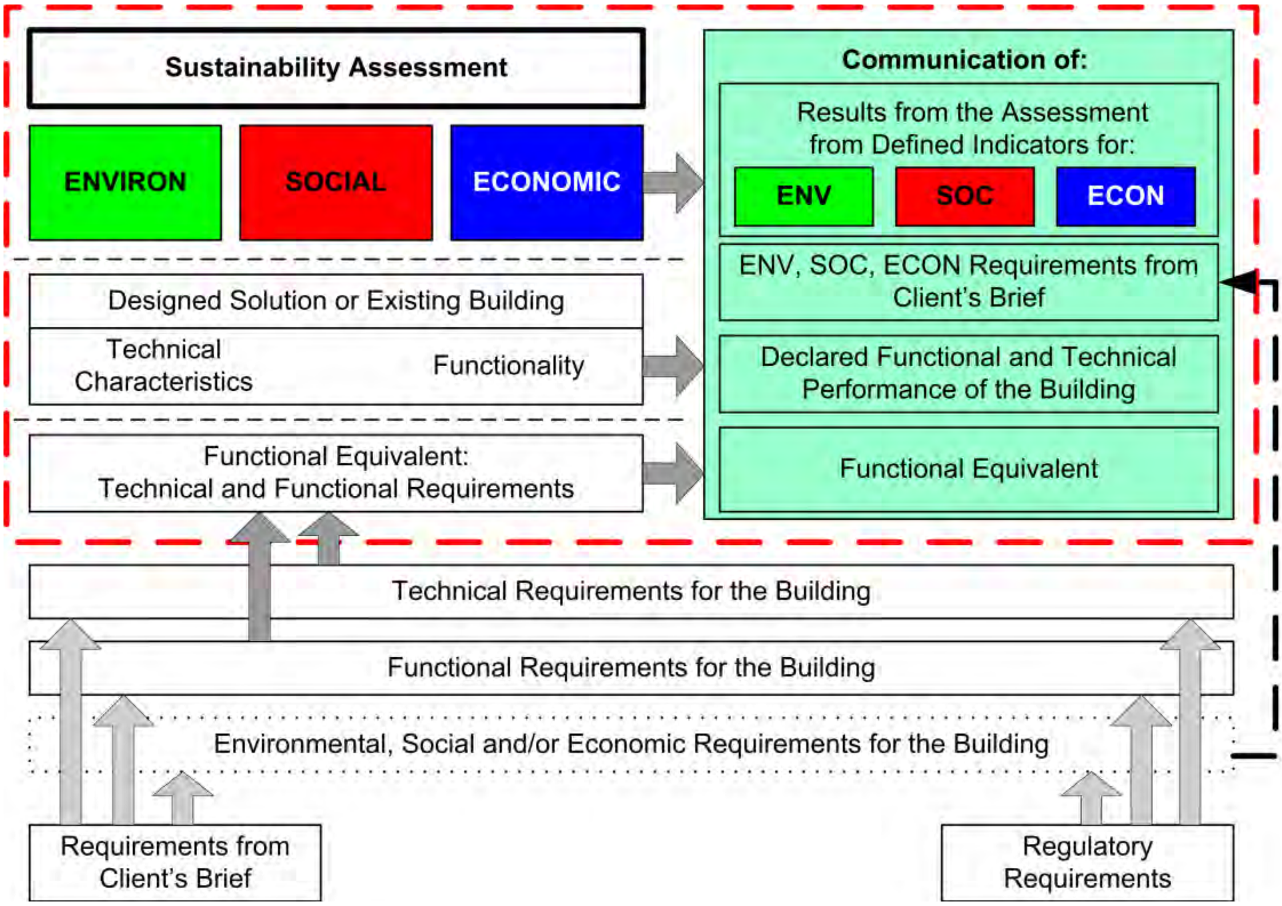

Figure 2 — Concept of sustainability assessment of buildings as defined in CEN/TC 350

Environmental aspects have today a very high profile and consideration. Ecosystem preservation (land, forests, seas, biodiversity etc.) is the main objective of environmental considerations. Mitigation of and adaptation to climate change are often identified as the main environmental concern for most of the human activities. Achieving resource efficiency in a circular economy model is gaining more and more consideration in parallel with the awareness of the finite reserves of our planet.

The social facets of sustainability are probably the more undervalued of the three pillars today. But isn't the preservation and improvement of the living conditions the primary objective of sustainability? For sure we have to respect the limited resources and fragile environment of the planet we live in. For sure we have to build economically sustainable models for growth. But these are maybe to be considered the means to achieve a human development for present and future generations.

Energy is an issue a bit on its own because it has a direct influence on each of the three pillars: on comfort and quality of life, for the impact of its production on the environment and on the running costs of a construction work.

And finally we come to the economic side. Clearly the direct costs of a construction work are always considered. Being it spot (construction, replacement etc.) or recurrent (energy, water etc.), they represent the most immediate indicator of the economic impact of a construction work. Combined to the environmental and social aspects mentioned before, they could be seen as the final indicator for the assessment of the “best value for money” option.

THE ECONOMIC PILLAR EXTENDED

The Assessment of economic performance of buildings (EN 16627)

However these are only the surface of the “economic” pillar. An in-depth analysis of the European standard “EN 16627 Sustainability of Construction Works – Assessment of economic performance of buildings – Calculation methods” highlights at least two factors that are usually neglected.

The first is the impact of the “end-of-life” stage. Without speaking about the extreme example of nuclear power plants, the impact of the end-of-life stage of a construction work is growing more and more in the future compared to the construction and use stages. The increased focus on resources (as mentioned before) is indeed focusing the attention of the clients to this life stage, being sure that its economic impact will increase with time. Easily demountable buildings made of easily recyclable materials have a bright future in front of them.

The second is the “income” associated to construction works. If this may appear clear from an investor’s point of view, it is too often forgotten in a sustainable assessment, where only the costs are put on the scale. This income may come from the use phase (including the export of energy in case the generation exceed the consumption) but also from the end-of-life, where the material may be mined for a second, third etc. life.

The Multiplier effect – A study by “Le BIPE”

Within “The Concrete Initiative” (see below) we have been even further the direct costs and income linked to a construction work. In a study commissioned to “Le BIPE”, we have analysed the indirect and induced impacts of the concrete sector, a key industry in the construction field. “Indirect impact” means the added value at the level of companies providing materials and services to the concrete industry. “Induced impact” means the added value generated by the spending of the employees of all actors implicated.

The study shows that when these aspects are taken into account, we have a multiplier effect of 2,8: for each euro invested in the concrete sector, 2,8 € are generated in the economy.

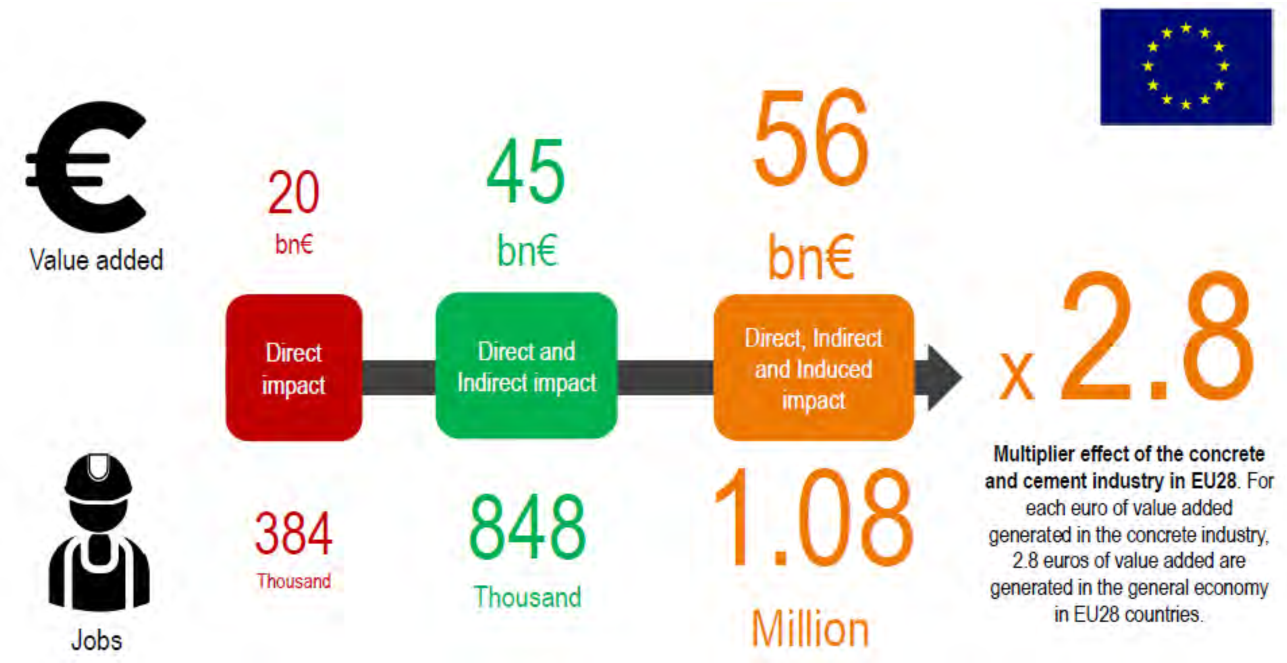

Figure 3 — The multiplier effect of the concrete and cement industry in EU28

These conclusions can easily be extended to other sectors which are characterised by a very high level of domestic intermediate consumption, in one word to other "local" businesses. At the level of a construction work, these aspects may be considered if the level of economics benefits targeted goes beyond the mere system boundaries of the work itself.

Service life

Finally a last consideration on one parameter which is also too often neglected due to its "long term perspective": the service life of a construction work. The longer a work keep on fulfilling its function (in particular if limited repair, replacement and refurbishment are needed), the lower are the yearly costs for a given function. And consequently the higher the incomes are.

ABOUT US

Concrete is the most widely-used construction material in the world. It is part of our everyday lives. However, its ubiquitous nature often means it is taken for granted.

The Concrete Initiative aims to increase awareness of its essential role in creating a sustainable construction sector in Europe. The initiative wishes to engage in a Concrete Dialogue with stakeholders on the issue of sustainable construction, and in particular the barriers and solutions to harness concrete's multiple benefits.

The Concrete Initiative is a project led by CEMBUREAU (the European Cement Association), BIBM (the European Federation of Precast Concrete) and ERMCO (the European Ready-Mixed Concrete Organisation).

CONCLUSION

It is recognised that not all these "economic" aspects of a construction work may be relevant for everybody. A private person renting an apartment is probably interested in the yearly functioning costs and nothing more. But as soon as one wants to have a more complete assessment of the financial performances, he may use these drivers for a more comprehensive approach to the economic pillar of sustainability. Public authorities and decision makers should integrate these aspects in a long term perspective benefitting the society they are responsible for.

Contributes to the Roadmap

Extend the assessment of the economic dimension of construction works following the ideas presented in this paper.

Keep on using a holistic approach, integrating social, environmental and economic aspects to fulfil clients' and users' needs

Open Issues (Required)

Extend the "safety" concept from earthquake to other social aspects like fire safety and protection against extreme events.

REFERENCES

1. EN 16627 Sustainability of Construction Works – Assessment of economic performance of buildings – Calculation methods. Developed by CEN/TC 350 "Sustainability of Construction Works"
2. Cement and Concrete Industry: Multiplier Effect and Contribution to Low Carbon Economy. A study by Le BIPE (available on www.theconcreteinitiative.eu)

"Common Efficacy": from what we "have and know" to what we "need and expect"

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ABSTRACT

This contribution for a roadmap for the resilience and eco-efficiency improvement of existing buildings and cities proposes that it is necessary evaluate what has been done and why, identify the expectations of those attracted by this journey and, with these results, execute the necessary adaptations to render it attractive, useful and replicable by others: in short, the objective of a roadmap is to "sell" a path, not a destination.

Awareness is necessary to anticipate, there and elsewhere, the underlying factors and actors that may help to re-read what we "need and expect" in the perspective of what we already "have and know": by adapting known ways (techniques, technologies, strategies and existing scenarios), the learning curve is compressed, partners are more comfortable to join in and risks reduced along the road.

Energy Efficiency and Climate Change Mitigation goals are a new chance for inclusive win-win interventions that will only make sense guaranteeing the (clients / investment) safety, well being and resilience.

Keywords

Historic Centres, ESCOs, Financing, Climate Change Mitigation, Energy Efficiency, Energy Efficacy.

INTRODUCTION

Historic Centres embody centuries of "fabrica" (labour) and "ratiocinatio" (search of "proportion"), but not often enough the existing relations were systematized into "authoritas", the deep-and-written reasoning that unifies theory and practice into knowledge, making it useful beyond the place and time of its beholder[15].

Historic Centres recent history of rehabilitation actions is full of "fabrica" and displays some "ratiocinatio" but, in the opinion of the author, had not enough "authoritas" to go on from: errors are consistently repeated, and victories scarce and brief.

Starting from a presentation video produced by the 2020 Global Climate Challenge team of (VINCI, 2015), in which the authors achieved the first prize in "Urban Services and the Connected City", the proposal is demounted to illustrate that all the necessary tools are available.

It is proposed that long lasting change in the existing buildings an cities requires an effort to evaluate what has been done and why, to clarify what we "have and know", and further effort to identify the "needs and expectations" of the local actors to adjust the proposals to a larger base, able to execute the needed adaptations to render it attractive, useful and replicable.

An annotated glossary

Having in mind that this workshop will aggregate a large number of non-native English speakers, a small glossary of the less usual terms is provided using extracts from the Merriam Webster dictionary (in http://www.merriam-webster.com/dictionary) and and intended uses of expressions for a small context:

[15] Using the terms of Vitruvius' "De Architectura" according to (McEwen, 2002) remarkable approach

"Common":
"(...) *belonging to or shared by two or more individuals or things or by all members of a group"*

"Efficacy":
"the power to produce an effect"

"have and know":
acknowledges the fact that any intention to act on a given building or area requires some degree of control and access to retrieve the necessary information, and that the quality of the information is highly dependent on the used tools and depiction methods (Brito & Gameiro da Silva, 2014). In most of the European settings, ownership may be protected by stronger rights than collective or individuals' protection would advise, until something goes terribly wrong. "Have and know" acknowledges these limitations, assuming the embedded limitations whilst enforcing that there are ways to gain the right to access this information (see Conclusions).

"need and expect"
acknowledges that what is needed not always coincides with the normal expectations, moreover in the cases when such expectations are proven erroneous. A good example are the double glazing windows that are still proposed as essential for increased energy efficiency and Climate change mitigation in ancient buildings, As referred ahead, (Baker, 2010) proves that single glazing sash windows can achieve the same degree of comfort as double glazing windows if properly operated, maintained and upgraded, while (Brito, 2015) demonstrates that changing windows and isolating masonry stone walls has greater environmental impact than simply placing heat pump units; and here "art" will be necessary to demonstrate that what "science" and Industry were proposing for all buildings, ancient and new alike, might not suit their specific case.

"other needs"
Earthquake resistance and eco-efficiency of existing buildings and cities are only a few of the many problems that endure in our city centres, and the connection this workshop proposes states the advantages of solving more than one problem at a time. In this sense it is necessary. So, beyond structural stability and seismic resilience, issues like energy security and climate change mitigation, fire risk, water (and waste water) reuse, composting and recycling are topics that have direct and indirect impacts in environment.

Moreover it is known that single objective solutions have inherent risks: the Montarroio case study demonstrates that some currently incentivized Energy Efficiency measures like interior insulation of existing masonry walls can favour inner wall frost cycles, and thus weaken supporting walls (Brito, 2015).

Objective

This paper acknowledges the tangible and intangible advantages of safeguarding eco-efficient investments with increased earthquake resistance, and of optimizing the resilience of our built heritage to the forthcoming risks of Climate Change and Energy Security.

It states that change will only happen, and be cost effective, when more variables are included from the interior threshold (safety, indoor environmental quality, accessibility, social and energy poverty issues, to name a few), the neighbourhood scale (fire-risk mitigation) and the collective sphere. Basilar questions emerge: do European citizens have the right to know the probability of dying at home in the occurrence of a seismic event? Or to be aware of the risk level of pulmonary diseases due to poor indoor air quality?

Acknowledging that the problem is **more societal than financial** –as the money and will to invest exist–, this paper revisits **crossed perspectives between stakeholders, and between themselves**, to propose that the resolution of the existing buildings and cities lies on the clarification of the rights of the building consumers and, from there, by the promotion of neighbourhood scale multi-stakeholders' investments.

SLICING "COMMON EFFICACY": THE EXISTING LAYERS

The proposal presented in the video (VINCI, 2015) reads from the investigation developed in the ongoing Ph.D. thesis on "Upgrade Opportunities for Ancient Buildings (in City Centres)", on the participation on the International Energy Agency EBC Annex 50 on "Prefabricated Systems for Low Energy Renovation of Residential Buildings" and Annex 56 on "Cost-Effective Energy and CO_2 Emission Optimization in Building Renovation" investigation projects and practical on-site experience.

Starting from a general assumption that well built ancient buildings were able to provide adequate indoor comfort to its users in a time when fossil fuel availability was scarce, the investigation extended the commonly developed methodology in Annex 56 to compare Initial Investment Costs (IIC), Life Cycle Costs (LCC) and Life Cycle Impact Assessment (LCIA) of intervention options that range from the minimum necessary non-energy efficiency related "Anyway measures" as defined by (Morck, Almeida, Ferreira, Brito, Thomsen, Østergaard, 2015) to "business as usual" Energy Performance Certificates regulatory compliance solutions, demolition and reconstruction and two "upgrade" interventions (Brito, 2016), replicated here from the ECEEE paper (Brito, Fonseca, Gameiro da Silva, De Almeida, Brites, Cardoso, Castela, 2015), which should be consulted for further detail:

- **Opt.0_*_Reference Case**: The building "as it is", with the works to render it inhabitable, tagged as "Anyway Measures" (IEA A56, 2014), including materials/equipments maintenance and replacement;
- **Opt.1_*_Common "rehabilitation":** "Business as usual" (BAU) neighbourhood practices where interior insulation under plasterboard is placed to hide existing pathologies, with serious Indoor Air Quality risks;
- **Opt.2_*_Demolition & Reconstruction**: the primary choice for many, as it reduces surprise factors, uses common new construction techniques and increases useful space: economically unviable in most locations;
- **Opt.3_*_Upgrade without extension**: Detailed assessment to optimize the inherent building characteristics to achieve efficacy with users. Solar thermal heating and DHW require primary energy only for backup;
- **Opt.4_*_Upgrade with extension**: previous strategy (**Opt.3)** with structural seismic reinforcement made financially viable with an area extension (IEA A50): safer users / investment, and space for a small family.

Equipments, accounted with full installation on site, are denoted by suffix notations: "**bio**" for biomass; "**erh**" for electric resistance heater; "**hp**" for heat pump; "**gas**" for gas combustion; "**st**" for solar thermal, and conjunctions like "**st-bio**" when the backup is provided by biomass.

Figure 3: Montarroio Case Study intervention options scheme of studied options (source: Brito, 2015)

Table 1 compares energy efficiency (**EE.**) related renovation options (**EE.Ren.Options**) describing their non-energy efficiency related costs (**Non-EE.costs**), necessary to render the building inhabitable, and Initial Investment Costs for the building envelope (**IIC_EE.Envel.**) and energy efficient equipment (**IIC_EE.Equip**).

Table 1: Renovation options: Initial investment (IIC) and lifecycle costs (LCC) per option and equipment

EE.Ren.Options:	**Opt.0**		**Opt.1**		**Opt.2**		**Opt.3**		**Opt.4**	
Equipment type:	_erh:	_hp:	_erh:	_hp:	_erh:	_hp:	_st-bio:	_st-erh:	_st-bio:	_st-erh:
Useful area	*36 m^2*	*36 m^2*	*31 m^2*	*31 m^2*	*63 m^2*	*63 m^2*	*36 m^2*	*36 m^2*	*46 m^2*	*46 m^2*
Non-EE.costs (€/y)	7 801	7 801	7 801	7 801	45 039	45 039	7 801	7 801	12 545	12 545
IIC_EE.Envel. (€/y)			6 906	6 906	4 957	4 957	1 188	1 188	2 733	2 733
IIC_EE.Equip (€/y)		2 120		2 120	1 874	3 719	4 840	2 975	5 490	3 475
%EE.OverCost/m²	**0%**	**27%**	**119%**	**150%**	**280%**	**293%**	**77%**	**53%**	**108%**	**88%**
Energy costs (€/y)	1 546	423	811	218	160	44	36	92	32	82
Yearly LCC (€/y)	2 321	1 642	2 192	2 042	5 724	5 735	1 924	1 591	2 686	2 314
EE. Payback (y)	**no ROI**	**2y**	**9y**	**7y**	**5y**	**6y**	**4y**	**3y**	**5y**	**4y**
50% EE. incentive?	no fund	1 060	3 453	4 513	3 415	4 338	3 014	2 082	4 112	3 104

The energy costs and the return of investment calculations are based in the Portuguese Energy Performance Certification process that assume a full occupation and comfort levels maintenance across the seasons. Statistical data tells otherwise, and local interviews confirm that the table values per person are significantly lower in reality. The over cost of EE. related measures (**%EE.OverCost/m^2**) compares the **investment on EE measures** with the **Reference Case** Opt.0_erh (217€/m^2), the local non-energy efficiency related renovation current practice.

Figure 3 graphs the Initial Investment Costs (**IIC**) per square meter of renovation area, the value payed upfront, and the Life Cycle Costs (**LCC**) comprising the IIC, the equipments maintenance / replacement costs (each 15 years) and the energy costs during 30 years, divided by 30 as if paid annually.

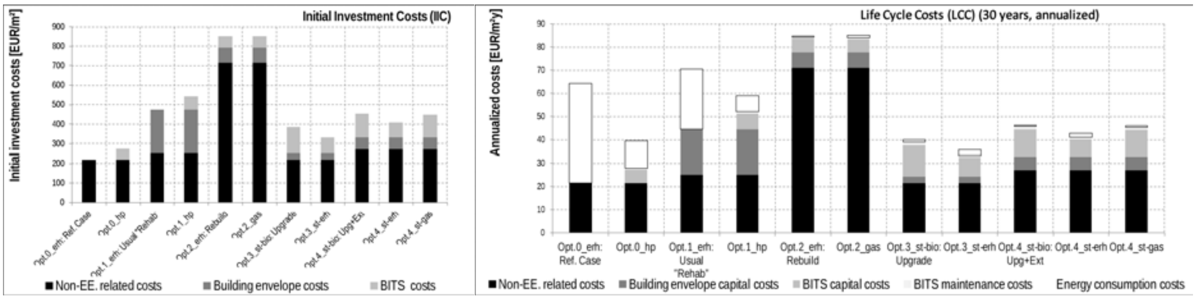

Figure 4: Initial Investment (IIC) and Life Cycle Costs (LCC) in 30 years, annualized. Building Integrated Technical Systems (BITS) are characterized in LCC to include maintenance. More information in (Brito, 2015)

To facilitate comparison, the analysis will focus on similar useful area scenarios: **Opt.0_hp,** that portrays the "Anyway Scenario" accounting for the costs to render it functional (see Morck et al., 2015) and heat-pump based acclimatization and domestic hot water, **Opt.1_hp** portrays "Business as Usual" regulation-inspired practices and **Opt.3_st-erh** that insulates only the horizontal portions of the envelope and integrates solar thermal heating to achieve "nearly Zero Energy Buildings" levels, mandatory for new European buildings in 2020 (European Parliament, 2012), where the low electricity needs do not justify investment in heat pumps.

Comparing both graphs demonstrates that higher IIC in efficient equipment reduces energy consumption (electricity and/or gas, as solar thermal and biomass are accounted as neutral in emissions in Portugal) and is, most of the times, favourable on the long term LCC. Nevertheless, comparing Opt.0_hp with Opt.1_hp casts doubts on masonry wall insulation and double glazing practices, and conclusions emerge when tackling the LCIA analysis.

The Life Cycle Impact Assessment (LCIA) evaluation of environmental impacts, expressed in parameters like Global Warming Potential (GWP), and "Total Primary Energy" (TPE),[16] demonstrates that in this climate **deep renovation interventions**, **recommended and/or imposed by regulations**[17] as interior insulation with windows replacement, Opt.1_erh, (black square**)**, have **worst long term impact on environment,** and owners pocket, than Opt.0_hp (grey circle), a lower price option.

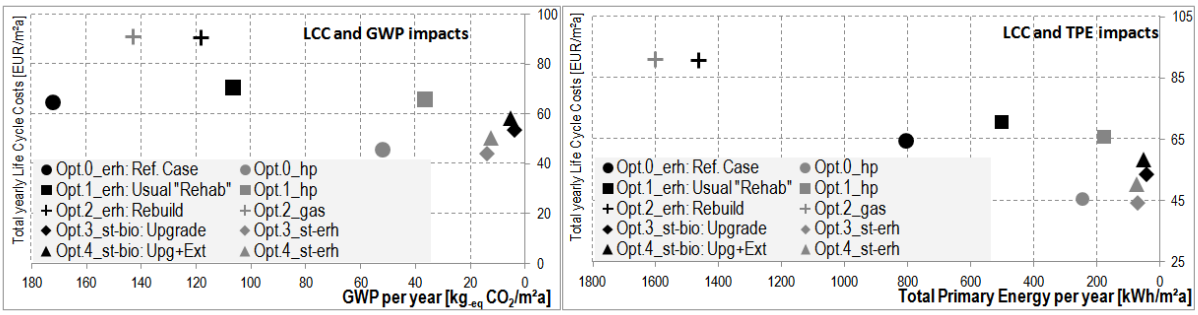

Figure 5: Life Cycle Impact Assessment using (EcoBat, 2014), recognized for the Swiss calculation methodology

[16] 30 years primary energy calculation including material collection, product fabrication, all transports, installation, maintenance, energy use, substitution and final disposal, annualized dividing by 30.

[17] (European Parliament, 2012) and national building/renovation codes with possible exceptions only in historic centres.

For ancient buildings in Mediterranean climate, installing heat pumps for acclimatization (air-air) and DHW (air-water)[18] is cost-effective, even considering their replacement each 15 years, but what would be the consequences of placing exterior units in each façade?

Anyway, **75% emission reductions (nZEB?)** and increased energy security are achievable in Opt.3 and Opt.4: **Opt.3_st-erh (grey diamond)** uses insulation only in the horizontal cavities (ceiling and floor over the basement, easy to install), and solar based DHW and heating with electric resistance heater backup.

Surprisingly, an undesirable cost equivalence occurs when accounting operational costs (OC) and maintenance costs (MC) of shallow and deep renovations: bigger investments in energy efficiency are often accompanied by higher maintenance costs, and savings can often disappear.

"COMMON EFFICACY": BECOMING GREENER WITHOUT SPENDING MORE

"Common Efficacy" identifies in ancient buildings' inherent characteristics and in the natural urban stakeholders –local communities, policy actors, universities & energy service companies– a set of "win-win" opportunities: collective responses reduce operating / maintenance costs, optimize efficiency, promote inclusive neighbourhoods and better Quality of Life.

Community level enrolment also overcomes the fact that only informed, technically able and financially capable inhabitants –a very small number– can act consciously towards emissions reduction, and from those only a few can access the funding available. By engaging local stakeholders in neighbourhood scale interventions, the costs of all the needed rehabilitation phases (awareness raising, assessment, depiction, design proposal, implementation and optimization) are reduced with scale.

In "Common Efficacy" a collective renewable energy system generation is proposed alongside with rehabilitation and energy conservation measures offered as an incentive to join in, with very low costs to the investors thanks to **cost-optimal choices**, **public access to funding** and the effect of **scaled interventions**. **Investments are paid back by savings through a monthly flat rate fee**: as operating and maintenance costs are reduced, "nZEB" neighbourhoods levels are achieved with **lower monthly costs for owners & users**.

By providing better Quality of Life with reduced costs, **renewed pride** and sense of belonging, the attractiveness of city centres is increased, bringing new customers to the system and further reduced overall impact to the environment, as density enhances the efficacy of the existing infrastructures and amenities. In short, more than a technical challenge, upgrading existing city centres is (only) **a societal challenge**.

The stakeholders, how they perceive each other: "win-win" approaches to change expectations

The natural urban stakeholders, here simplified as users, local communities, local policies, science and arts and ESCOs, have specific roles that are very relevant to reduce costs. For instance, local communities can **reduce contracting costs** when assuming the interface with individual users, while Local policies are essential to define the timeframe for the investments, **reducing infrastructure** costs by joining them with regular infrastructural replacement processes. Science and art are able to investigate the environmental impact of the existing situation and of potential alternatives (Brito, 2015) and to **lower initial investment costs** like in (Baker, 2010), demonstrating that single glass sash windows can be upgraded to meet double glazing comfort levels for a fraction of the cost; and here "art" in the form of design is necessary to facilitate a new comprehension. Finally, Energy Service Companies (ESCOs) capacity to **negotiate scaled solutions** and to procure and implement the most adequate solutions for each location, again reducing costs.

But how do these stakeholders perceive each other now, and what could be expected from them in a participatory cooperation? The next table illustrates in the horizontal text simplified perceptions of how each stakeholder perceives the other, the "have and know" status, and in rotated text what of the stakeholders "need and expect" of each other.

[18] "All in one" large systems are available, but prices double that of the two equipments approch chosen.

Table 2: From what we "have and know" to what we "need and expect": rotating facilitates cross-reading

X axis: "Have and know"

Y axis: "need and expect"

	Users / owners	Local communities	Local policies	Science and art	ESCOs
Users / owners	X: Long-lasting issues, low investment capacity	X: limited action and resources, close proximity;	X: Too many requirements	X: Far away entities, unintelligible contents	X: "Es what"?, "capitalists"?
Local communities	X: needed participants to strengthen their role	X: Competition for funds	X: Access to money and results;	X: punctual support through other stakeholders	X: Distant players
Local policies	X: moral and civic defaulters	X: Instrumental action	X: Disconnected realities, burocracy	X: Resource to complement information needs	X: Potential partners for financing
Science / art	X: needed spectators	X: Potential contact points	X: Clients for investigation	X: Disconnected production	X: a proven stakeholder in Industry
ESCOs	X: Disperse ownership, higher contracting costs	X: potential partners	X: funding partners, reduced context costs	X: knowledge and equipment	X: Evolving contexts

Acknowledging that what we "have and know" includes issues like (energy) poverty, fire and collapse risk in seismic events, the "needs" are simple and the expectations currently very low: it can only get better.

FINANCING

Financial institutions have well know (and proven) capabilities to anticipate business opportunities. One example is the expanding growth of our cities and the new centralities that an individual automotive mobility made available: access and parking limitations in the city centres created opportunities for an outward expansion, a momentum that "vacuum-cleaned" Quality of Life from many of central locations.
In this process many other business opportunities were created by the need to expand infrastructures and transport networks, to build new residential areas and shopping centres, to publicize and sell them and, to feed-back the circle, more cars to go each time further away to get things that were before just by our door.

Other than passing the blame –which we all share–, this small description identifies the financial institutions ability to identify opportunities and to scale them up to reduce costs and risks: even in the recent crises we can argue that the "context" is more to blame than the institutions.

On the other hand, we are now (finally) becoming aware that the Member States and the European Union are no longer capable of supporting all the needed investments, and that the Public Private Partnerships (PPP) can have a role in making change happen: it is our obligation to help prepare a context if we desire them to join in.

An emerging context allows for new trends and opportunities in city centers:

4. Oil prices escalated as a reflex of the "peak oil" issue, and are now low again, mimicking similar behavior as in the 70's oil crisis, one of the most inventive times in terms of renewable and alternative energy sources. Luckily the European Energy Security issue is present in the policy

makers opinion, meaning that support will continue, and maybe oil-dependent users paid enough to remember;

5. Resource intensity issues and sustainability metrics demonstrate that “The Greenest Building (..)” (PGL, 2012) is the one already built, while a recent investigation within the IEA EBC Annex 56 group on “Cost-Effective Energy and Carbon Emissions Optimization in Building Renovation” on the Montarroio case study, a XIV-XVIth century residential building located within the UNESCO protection area of Coimbra, demonstrates that the regulatory EPC proposed measures are not the cheapest, cost effective neither the sustainable option. (Brito, 2015), in line with JRC (2015).
6. Shrinking (and aging demography) create a problem of surplus housing, normally translated into lower prices, and a movement back to city centers is visible in younger populations;
7. Funding opportunities like “Jessica” are available for large investments, making the case for bundling or pooling of buildings for energy efficiency opportunities;
8. Europe still remains one of the most stable areas in the world to invest, and some clarification and definition for PPP in “energy efficacy” would attract investors.

Awareness is necessary to anticipate, there and elsewhere, the underlying factors and actors that may help to re-read what we “need and expect” in the perspective of what we already “have and know”: by adapting known ways (techniques, technologies, strategies and existing scenarios), the learning curve is compressed, partners are more comfortable to join in and risks reduced along the road.

By using Historic Centres as a small scale representation of European cities and their issues, the author brings into attention that the Energy Efficiency and Climate Change Mitigation goals, the context and the financing opportunities are a new chance for inclusive win-win interventions; and that, in the financial perspective, it would be too costly to ensure investments in Energy Efficiency, building upgrade, culture, enhanced mobility (...) and people without guaranteeing their (clients and investment) safety (structural, fire risk, indoor air quality), well being and resilience.

CONCLUSION

The objective of a roadmap is to "sell" a path, not a destination.

This statement is intended to remember readers that, individually or collectively, European citizens "consume" buildings and cities and, as final users, are unable to defend their own rights (Brito & Gameiro da Silva, 2012), enforcing the already consecrated need to "protect the health, safety and economic interests of consumers and to provide adequate information" (EEC, 1957).

The Directive on Consumer Rights (2011/83/EC) acknowledges that "service contracts in particular those related to the construction of annexes to buildings (for example a garage or a veranda) and those related to repair and renovation of buildings other than substantial conversion, should be included in the scope of this Directive", consolidating the idea of consumption and, on this sense, a fundamental right to be informed.

In fact the Energy Performance of Buildings Directive "recast" (European Union 2010) states Energy Performance Certificates as an information right, an essential milestone to boost the investments on energy efficiency, but such certificate makes no mention to the structural stability of the ensemble, neither to the minimum Indoor Environmental Quality requirements fulfilment, or not, inside the residential buildings.

This contribution proposes that the right to information can be a powerful tool to inform, and empower, building users about the safety levels the buildings they inhabit –in energy, fire, seismic and IEQ risks– , and leading them towards informed choices. It states that by aggregating the available funding with the natural urban stakeholders, **efficacy in the use of the available resources** can be achieved

In this process, financing institutions have the means, knowledge and will to promote neighborhood scale interventions in partnership with the other stakeholders, and are only waiting for reinforced stability for their investment.

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Contributes to the Roadmap

A Roadmap for existing buildings and cities must include the other needs (Quality of Life, Indoor Environmental Quality, fire risk reduction, accessibilities and many others), and evolving risks prevention like Climate Change mitigation and Energy Security;

Failure to include and anticipate the other needs leads to competition; success in gathering them and finding a compromise results in coopetition.

Open Issues (Required)

Public Private Partnerships (PPP) are recognized solutions to speed new solutions into practice, but in the residential sector issues still remain:

Information/training needs

- ✓ Energy Service Companies (ESCOs) still struggle for recognition in the Industry and Service buildings area, yet their potential is hardly recognized in the residential sector, where they could have a “phase-change” effect;
- ✓ Local communities have no idea about their own potential to make a difference, and current legislation and public services billing does not even favors cost and environmental impact reduction actions;
- ✓ Local policy actors rarely have the basic skills to properly assess ESCOs proposals, or to properly propose minimum requirements

Regulation

- **Building consumer rights must be clarified**: do they exist? Do they resume to Energy Performance Certificates? Can consumers demand for an “**EPC, IEQ, fire and structural stability” certificate** to make an informed decision on where they want to live (or die in case of a seismic event?)
- The lack of regulatory baselines for residential sector PPP makes them risky, and risk increases costs;
- To open the way to ESCOs in residential sector, basic guaranteed service responses and characteristics must be clarified so that “foul” play will not damage the reputation of a potential solution for the existing residential sector.

Dissemination

- ✓ First implementations, “lighthouse neighbourhoods”, are essential to evaluate the validity of the proposal in diverse contexts.
- ✓ Can we show that neighbourhood scale interventions are viable? How? Who´s joining in?

Financing

- ✓ ESCOs’ business is strongly dependent on the evaluation of the existing situation and definition of the target threshold: without a clear and global baseline scenario, risks are higher, costs too, and **decision is postponed**.

European existing buildings heritage: financial aspect and e valuation of cost-benefit related to lifecycle and performance

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ABSTRACT

The economic value of a real estate asset is closely connected to the constructional features and their performance over time (lifecycle). Fastness characteristics and static resistance to earthquakes, eco-efficiency and other constructive qualities of the building will provide benefits in the long time, but they are directly related to specific costs of the construction and/or for the maintenance. Moreover these characteristics have an impact on the value in use and on the potential significant loss of the value over time.

According to the definitions established by Regulation (EU) 575/2013 on prudential requirements for credit institutions and investment firms (CRD IV), even access to financing and mortgages (both for new construction and the upgrading and refurbishment of existing assets), depends on the «market value» of the property and the «mortgage lending value». The risk assessment, the risk management and the capital requirements for EU banking groups' exposures is directly linked to the value of properties, and then the characteristics of the collateral of the mortgage (or the financing) over time. The management of these aspects involves, among other things, the need to adopt a real estate risk assessment (real estate rating).

Building constructions and improvement of the characteristics of the existing buildings require a holistic approach that allows an overall valuation of the investment, also with regards to its town-planning/technical/economic aspects. The valuation can be done ex ante through feasibility studies (which are expressly provided in some national legislation, for example in the cases referred in the Italian Regulation for Implementation and Enforcement of the Italian code of Public Contracts (D.P.R. 207/2010); to this end it is necessary to reconcile the "project constraints" that take shape in four macro-areas: Resources (and Economic sustainability), Cost engineering, Time frames, Performance/Quality.

Demonstrating the economic sustainability of a building project by combining principles and definite rules consistent with international best practices – even more so in the current international economic-financial situation – constitutes the essential prerequisite for raising resources, sometimes even among international institutional investors, that make possible to develop all stages of the building process with continuity. An intelligent promotion and development of the immense national public real estate heritage will also promote a country's economic-social development.

Promoting and rethinking cities as inclusive, integrated and livable, however the implementation of programs and projects, in particular the urban regeneration and enhancement of the fastness characteristics and eco-efficiency of the building stock of the cities, requires the implementation of appropriate programs and sustainable projects.

Keywords

Lifecycle and performance of buildings, Resistance to earthquakes, Eco-efficiency, Valuation of projects; Real Estate risk assessment, Sustainability, Smart Cities.

Architecture and City Planning Session

Session Rapporteur: **Heiko Trumpf**

A Large Scale Approach for Sustainable Interventions on Built Heritage

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ABSTRACT

The paper provides an overview of recent Swiss experience in the domain of reusing and adapting existing buildings and points out the advantages of large-scale approaches. The first example concerns an inventoried Zurich residential settlement of the Fifties. Considering intervention at the scale of the whole settlement, as opposed to that of the single building, made it possible to devise an intervention strategy which obtained the support of all the parties involved: the city, the owners and the heritage department. The second example concerns the school buildings owned by the municipality of Zurich. By considering the city's entire school portfolio, changes and updates could be concentrated on a limited number of buildings, while minimising the impact of transformations on protected buildings. Additionally, a similar and equally successful large-scale approach was adopted for other building types, namely residential settlements and centres for the elderly.

Keywords

Reuse, conservation, sustainability, 2000-Watt Society, heritage, large-scale approach.

INTRODUCTION

Sustainability, in its several declensions, has currently become a prominent part of the building agenda. Consequently, profit-based approaches leading to the complete replacement of existing building stock are slowly but gradually being overtaken by new pragmatic approaches, which include **adapting, reusing and completing existing building stock.** The paper offers **an overview of recent Swiss experience in this domain**.

UPDATING A RESIDENTIAL SETTLEMENT WITH A LARGE-SCALE APPROACH: REUSE AND NEW CONSTRUCTION AS COMPLEMENTARY STRATEGIES

Today **densification** is one of the goals of the Zurich department of urbanism, as explained in the booklet "Dichter" (Zürich Hochbaudepartement, Amt für Stadtebau, 2012), which collects many examples of densification projects completed between 2009 and 2011. One of the published examples – the densification strategy adopted in the Else Züblin-Strasse residential settlement, in Zurich Albiesrieden – appears to be particularly interesting, because it implies a **change of scale** and shows that problems can be viewed in their entirety by taking a step back, and holistic solutions can be reached. Additionally, such solutions are often less expensive in global terms.

The *Else Züblin-Strasse Siedlung* was originally built for the Sunnige Hof cooperative in 1950-52. The settlement, a typical *Siedlung* of the Forties, was inscribed in the heritage inventory, but wasn't protected. In time, the municipality approved raising the building index by approximately 1/3, so in the year 2000 the cooperative announced a design competition to fully exploit the increased building volume of the site, calling for a two-pronged strategy: one third of the estate was to be demolished and replaced by new buildings, the rest – the buildings on the main street – was to undergo radical upgrading. Burkhalter Sumi Architekten won the competition, but they partially amended the initial strategy. On the basis of a careful evaluation of the *Siedlung*'s specific qualities, they decided to **maintain the buildings that were to be kept in a condition as close as possible to the original one**. They used the support of the Heritage Department to devise a minimal intervention, which they achieved by **concentrating all major changes in the new buildings**.

Figure 1. Else Züblin-Strasse Siedlung in Zurich Albiesrieden. New blocks and existing blocks after the intervention by Burkhalter Sumi Architekten. (Photo: Roberta Grignolo)

The six new compact blocks, designed to replace the ones which were to be demolished, incorporate all the answers to the new needs: the increased surface requirements, an expanded range of apartment types to put on the market, compliance to current standards (accessibility), and excellent energy performance, thanks to a thick layer of external insulation and a low shape factor. Consequently, interventions on the existing buildings were reduced to the bare minimum: no changes were implemented in the original apartment layout, no lifts or loggias were incorporated, no exterior insulation was added. Conversely, the original staircase windows were preserved, the exterior stone elements were cleaned and the metal entrance canopies were restored. The only major intervention was the replacement of the apartment windows with new high performance thermal-break profiles.

If the issue of improving the functional and energy performance had been faced at the scale of the single building, each building would have been deeply transformed and made unrecognisable, whereas by **moving to the larger scale** all changes could be concentrated in the new buildings while maintaining the appearance of the original ones, thus **minimizing any waste of resources.**

A LARGE-SCALE APPROACH FOR THE ZURICH SCHOOL PORTFOLIO

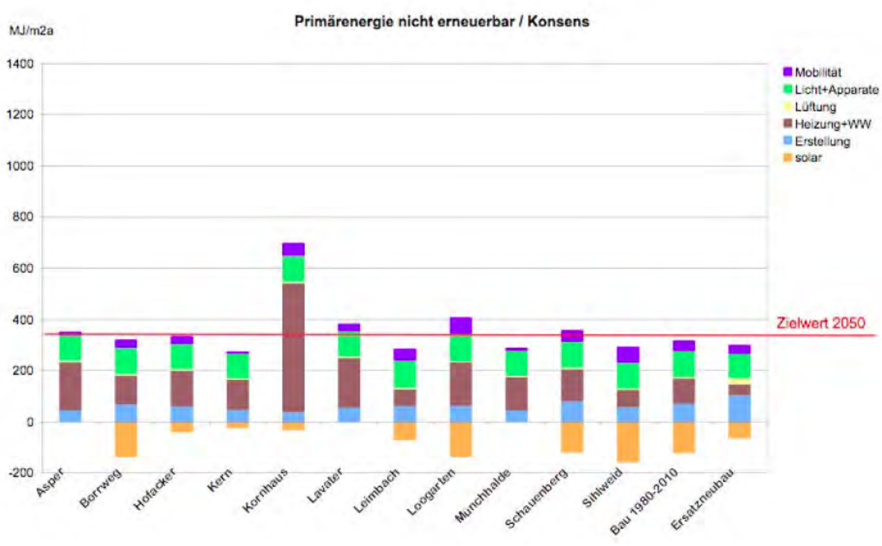
A few years later, the City of Zurich adopted a similar strategy on an even larger scale, that of **the whole portfolio of its school buildings.** This time grey energy was considered too. In 2008 the Zurich population voted the 2000-Watt Society vision, which aims at limiting individual energy consumption to a maximum of 2000 Watts. This vision was enshrined in the city's Constitution and thus stands on a par with other goals, such as the conservation of heritage. This forces all the parties involved in the evolution of the city and its built elements to factor in sustainability, including grey energy, when implementing an architectural design for the City.

The City of Zurich owns an extensive building portfolio, which comprises residential settlements, social centres, educational buildings, etc. The City is responsible for the maintenance of this portfolio, its compliance to new regulations and its upgrading to meet new needs. Almost half of the city portfolio consists of schools, 2/3 of which are listed in the *Inventar der kunst- und kulthistorischen Schutzobjecte* (Heritage inventory). Each time an intervention was planned and discussed with the relevant parties (Planning Department, Building Department, School Department, Heritage Department) there used to be **heated discussions** because each party pursed different objectives. It was these discussions, where sustainability, standards compliance and heritage issues were directly confronted with one another that led to thinking at the scale of the whole school portfolio: if one school doesn't comply with energy standards and another is instead well within limits, there can be an overall balance. Furthermore, if the issue is dealt with by considering the entire school heritage of the municipality, **direct conflicts between energy performance issues and conservation considerations can be reduced**.

This approach was adopted for the **Zurich-Schwamendingen neighbourhood**, which comprises 12 schools. Here the increased student population, the urgent need for more kinder-gardens and preschool spaces, as well as new pedagogical indications, led to the need for more floor surface. Instead of implementing just a few changes in each school building, a global strategy was developed in order to concentrate interventions on a limited number of them. Three schools were identified, within less than 800 meters from one another. Each of these was extended with one or two buildings containing either classrooms or gyms or multipurpose facilities, which are now used by several other neighborhood schools and sport clubs. **Concentrating interventions on three school complexes** allowed for the other nine buildings to remain practically unchanged.

Such a global and holistic approach was also **adopted for issues related to the reduction of energy consumption.** The study *Schulen auf dem Weg zur 2000-Watt-Gesellschaft* was launched in 2008 (Stadt Zürich, Amt für Hochbauten, 2012). It stemmed from the question of whether the school building portfolio – comprising 120 complexes – could meet the 2000-Watt Society vision by 2050, at the same time simultaneously meeting conservation, architecture, economy and utility goals. The coordinators decided to analyze a sample of 13 school buildings, which was considered representative of the whole portfolio.

Figure 2. Consumption of primary energy from non renewable sources: comparison of the performance of the 13 selected schools in the Consensus Variant (Stadt Zürich, Amt für Hochbauten, 2012).



Three variants were drafted: Variant 1 was considered a minimal intervention strategy, mainly used for listed buildings; Variant 2 suggested a thorough intervention focused on the reduction of energy consumption; the **"Konsenz" Variant** sought a compromise between energy, economic and conservation issues. In this "Consensus variant", the overall results of which are similar to those of Variant 2, **high standard energy**

retrofit interventions on some schools offset other interventions which are less efficient from the energy standpoint but more focused on conservation, thus allowing the most fragile and valuable buildings to be excluded from heavy retrofit transformations. Thus the Kornhausbrücke school, built by arch. Steiner in 1941-42, the envelope and window fittings of which are protected, stands well above the 2050 limit goal, but its “poor” energy performance is offset by the performance of the other buildings considered.

The *Schulen* study is now used to guide and programme interventions on the city school stock: the first buildings to undergo renovation were the ones in the study, but the representativeness of the sample provides **useful precedents** from the study that are also applicable to other buildings. On the basis of the success of this study, **the same approach was also extended to other building typologies** which are part of city’s building stock: the residential settlements (*Wohnsiedlung*) and the centres for elderly (*Alterszentren*).

CONCLUSION

The above examples and studies, all based on **large-scale approach**, provide **cunning strategies** which can usefully be adapted to other built portfolios when a constructive compromise is sought between frequently competing issues, such as sustainability, economy and heritage. Furthermore they highlight the importance of **establishing a culture of constructive dialogue between all relevant parties**, when interventions on building stock are required. Gradually this will allow not only protected buildings to be taken into consideration, but also high quality buildings, as yet unprotected.

In interventions on existing buildings there are no ready-made recipes. Each building requires choices based on its specific features, and these are closely related to its social value, to its context or its specific technical solutions. Nevertheless, the case of Zurich clearly shows that **a broader view of built heritage can help in drafting efficient transformation strategies, based on facts and figures, on performance criteria, as well as on an ethical approach to architecture and its professional practice.**

Contributes to the Roadmap

The Swiss experience shows that by adopting a large-scale approach, shared solutions can be found: solutions that bring together different standpoints such as those of sustainability, architectural quality, economy and conservation. The *Roadmap* should thus **encourage a large-scale approach** to the issues at hand.

Open Issues

Sustainability and conservation are too often considered as opposing and irreconcilable issues. Large-scale approaches can provide solutions for these contrasting stances. What other means can be devised?

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Seismic risk, Restoration, Sustainability: between prevention and compatible materials

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ABSTRACT
The contribution deals with issues related to seismic risk and sustainability in terms of prevention and compatible materials. To intervene in terms of improvement necessarily requires to design on the basis of an appropriate level of knowledge of the building, realizing only the project which, while giving the necessary guarantees of safety, is respectful of the environment. The improvement keyword also suggests the issue of compatibility, which means giving substance to what can only be made in respect of the nature of the asset excluding the rest. The relationship between emergency and seismic safety is another aspect of the vulnerability problem in historical architecture: despite the many existing recommendations, still occurs to systematize those practices that should ensure that the work conducted in the emergency will provide the most possible useful indications to the studies and preventive intervention, so that the latter can contribute effectively to limit the damage caused by earthquake.

Keywords

Cultural heritage, seismic risk, prevention, compatible materials, conservation

RESTORATION AND SUSTAINABILITY: A CRITICAL APPROACH

The importance of cultural heritage and its role in the economy of a country appears to be a widespread view, almost a prerequisite to ensure the sustainability of any restoration. Restoration that will be aimed at the conservation, protection and enhancement of the heritage, so that this becomes an accessible good, that can be enjoyed even in its social and singularity values and transmitted, as intact as possible, to future generations. It is not only a cultural legacy but also a great economic opportunity and through appropriate integrated management the cultural and environmental heritage can be a real asset, that must be preserved because it can provide a significant contribution to economic development of the territory, involving the activities connected to the tourism sector.

Cultural heritage is therefore intended as a resource for development, but it is necessary to highlight the awareness that it is a non-renewable resource, like some energy sources. Recently the issues related to the conflict between cultural value and economic value of architecture showed the prevalence of uncontrolled exploitation of cultural heritage based on single use and tourism: the second aspect has come to emerge, bringing some of the intellectuals more involved in the political debate, as Salvatore Settis, to speak out and criticize the overly economistic approaches to monuments that facilitate the promotion of superficial and consumerist ways of using of historical buildings and that exalt, consequently, the commercialization of the same architectural artifacts[19].

These observations related to the uncontrolled exploitation of the cultural heritage link the discipline of restoration and conservation to broader issues related to the consumption in the world: both attitudes are factors of erosion and impoverishment of the heritage and cultural material available today. "On the other hand, if sustainability means to know the reasons of nature preserving means to know the reasons of the monument and in both cases the starting point is to know the existing, in understanding it without bending it to rules imposed by criteria unrelated to it[20]".

[19] Settis S., (2002), *Italia S.p.A.. L'assalto al patrimonio culturale,* Torino

If the recent success of sustainability issues can be also for historic architecture a vehicle to reiterate the reasons and the need for conservation, we must pay attention to the risk of confusing the issues of cultural heritage with those, which are different in content and specificity, relative to the use and exploitation.

SEISMIC RISK AND PREVENTION

The opportunities presented by the historical buildings have now become even more topical in the territories that bring evident scars of seismic events, more or less recent, which have dealt a blow the manufacturing base but which preserve the cultural heritage as a resource to revitalize its economy.

The theme of the preservation of historic buildings from seismic risk has, in Italy and in some Mediterranean countries, a long history and several scientific contributions that have enriched an already significant literature, in which the common goal of understanding and prevention of damage is branched in disjoint paths for different methods, contents and languages.

In early operating manuals were substantially re-proposed technological solutions borrowed, for the most part, from the building techniques of reinforced concrete or steel, usually accompanied by schematizations of calculation usual in building science. Since the eighties of the last century were added handbooks more interested in traditional technologies, or, at least, with solutions specifically designed to both masonry and wood structures and, especially, appear the first essays that take census of historical architectures, as well as of the damages caused by the earthquakes, accompanied by the first critical considerations on the mechanisms of damage[21].

The analysis of the structural consolidations carried out in the historic factory, mainly deductive, has gradually joined an inductive approach, challenging the approximations required by the use of suitable formulas to describe the behavior of materials and structures other than the traditional ones, promoting a comparison with the multiplicity and specificity of the historical buildings. In case of historical architectures there are in fact objective difficulties in defining procedures for verifying the safety requirements, similar to those applied to ordinary buildings, because the variety of types and specific singularity of the monuments (also due to the specific history of each building) does not allow to specify a unique strategy and reliable modeling and analysis.

These considerations find now a systematization within the Guidelines[22] (which provide instructions for the evaluation and reduction of seismic risk of the cultural protected heritage, with reference to the Technical Regulations for Construction[23] in DM January 14, 2008 and -NTC2008- Relative Circular 2009 containing instructions for the application of the technical standards for the construction of the Ministerial Decree 14 January 2008[24]), where it is proposed a path of knowledge and analysis in which the judgment on the risk level of the building or the suitability of an intervention emerges from a comparison between the capacity of the structure, evaluated following a qualitative and quantitative knowledge of the construction, and the demand, assessed according to the seismic action calculated for the site where is the building itself. This comparison is not meant as a binding verification, in which the capacity must be greater than the demand,

[20] Fiorani D., (2006),*Fruire e trasmettere: convergenze e antitesi nel restauro,* in *La fruizione sostenibile del bene culturale. Atti del Convegno,* Palazzo Strozzi, Sala Ferri, Firenze, 17 giugno 2005, Nardini Editore, Firenze, p.17

[21] *Cfr.*:A. Aveta(a cura di), (2005), *Restauro e consolidamento*, Mancosu, Roma, R. Ballardini, F. Doglioni, (1986), *Indirizzi riguardanti le iniziative e i comportamenti atti a limitare i danni al patrimonio culturale in caso di sisma*, documento approvato dal Comitato Nazionale per la Prevenzione Culturale dal Rischio Sismico del 12/12/1986; S. Di Pasquale, *Architettura e terremoti*, in "Restauro", 59-61, 1982; F. Doglioni, A. Moretti, V. Petrini,(1994), *Le chiese e il terremoto : dalla vulnerabilità constatata nel terremoto del Friuli al miglioramento antisismico nel restauro, verso una politica di prevenzione,* Lint, Trieste; F. Doglioni, (1997), *Stratigrafia e restauro : tra conoscenza e conservazione dell'architettura,* Lint, Trieste; D. Fiorani, D. Esposito (a cura di), (2005), *Tecniche costruttive dell'edilizia storica. Conoscere per conservare*, Viella, Roma; A. Giuffrè, (1988), *Monumenti e terremoti*, Multigrafica, Roma; A. Giuffrè, (1993), *Sicurezza e conservazione dei centri storici. Il caso Ortigia*, Laterza, Roma-Bari; A. Marino (a cura di), (2000) *Presidi antisismici nell'architettura storica e monumentale*, Gangemi, Roma; *Monumenti e terremoti. Nuove esperienze di analisi di vulnerabilità-pericolosità sismica*, (2003), Ministero per i beni e le attività culturali, Istituto centrale per il restauro, Roma

[22] "Linee guida per la valutazione e la riduzione del rischio sismico del patrimonio culturale con riferimento alle Norme tecniche per le costruzioni di cui al decreto del Ministero delle Infrastrutture e dei trasporti del 14 gennaio 2008" (*Guidelines for evaluation and mitigatiom of seismik to cultural heritage*)

[23] Supplemento Ordinario n. 30 della G.U. n. 29 del 4.2.2008

[24] Supplemento Ordinario n. 27 della G.U. n. 47 del 26.2.2009

but as a quantitative element to be used, together with others, to make a qualitative judgment that takes into account the overall conservation needs, the desire to preserve the artifact from the earthquake damage and safety requirements, in relation to the use and the function performed.
To intervene in terms of improvement necessarily requires to design on the basis of an appropriate level of knowledge of the building, realizing only the project which, while giving the necessary guarantees of safety, is respectful of the environment on which goes to place. The improvement keyword also suggests the issue of compatibility, which means giving substance to what can only be made in respect of the nature of the asset excluding the rest.
In this sense the use of materials and practices are object of reflection: we have to prefer materials and working practices that ensure the reduction of the incidence of transport vehicles and operating machines with strong environmental impact and, as far as possible, the reuse of materials or the choice of materials with low production of waste and residues to be disposed of and, however, that can be found near the area of intervention.
Recent approaches testify an interest in the concepts of sustainability not only in terms of intentions, but of working practices starting from the physical properties of buildings materials such as: limited interventions determined with reference to a path of knowledge that shows characters of uniqueness of the historical artifact; the use of technologies compatible with the masonry and wooden structures; the rediscovery of traditional materials (such as the use of *cocciopesto* to increase permeability in masonry structures) conjugated to recent innovations in terms of eco-compatibility; the upgrading of fiber-reinforced composites which proposes fabrics made of natural fibers or organic materials - such as fabrics made with basalt fibers which can be impregnated with hydraulic-lime matrices.

CASE STUDIES OF INTERVENTION

Seismic events of May 2012 have significantly affected the territory of Emilia and neighboring. The following cases illustrate the themes previously developed related to the evaluation of the damage and seismic improvement and also the problems of intervention on a monument such as the Ducal Palace in Mantua, historically stratified, transformed and full of decorations and on buildings related to the reconstruction of a local heritage, but significant in terms of strong symbolic value for the land and its inhabitants.

Ducal Palace in Mantua, North-East tower of St. George Castle[25]

All the damage to the Ducal Palace complex, valued with expeditious files and deepened after the earthquake, showed old damage that led to the reactivation of some collapse mechanisms and often reported as the long absence of maintenance operations constituted a general lowering of the safety of the building, the consequent need to perform operations not just in repair but to improve safety through a coordinated system of works. The evident damage caused by the earthquake to the north east tower of St. George castle, containing the Bridal Chamber and its access path to the vision of frescoes by Mantegna, have highlighted the need for urgent safety measures associated with the concept of structural improvement with a series of operations aimed to influence the collapse mechanisms that have been highlighted in relation to the analysis of the articulation of the building and specified in function of the state of damage of the complex, in particular of the distribution of the crack and the presence of constructive discontinuities.
The interventions in the complex are considered passive protections needed to improve the box-like behavior of the tower, with a particular thought about the presence of the Bridal Chamber which obliges to provide higher levels of protection. The overall aim was to ensure, in addition to the necessary improvement, control procedures and the maintenance of works of consolidation. The actions do not affect the material but work on the functioning, maintaining the determined structural behavior, qualifying it where necessary.
On the wooden roof of the tower a double layer of plywood planks that solidarizes to primary and secondary framework is introduced, implemented by the construction of two fibre reinforced laminated wood

[25] The expeditious and subsequently digitalized files of the building state of damage and collapse with all the preliminary analysis to the intervention were carried out by the Working Group relating to LARS Seismic Risk Center Studies, scientific responsible prof. eng. arch. Paolo Faccio and prof. eng. Anna Saetta, IUAV University of Venice in front of an agreement between the University and the Regional Directorate for Cultural Heritage and Landscape of Lombardy; Surveys were made by CIRCE Laboratory of Surveys and GIS, IUAV University of Venice. The project of consolidation and structural improvement is signed by prof. Paolo Faccio.

stringcourses set and fixed at the wall. Moreover a metallic element calendered holds the top of the battlements at which rests the wooden structure of coverage

At different levels, with the exception of the Bridal Chamber, have been made stringcourses using metal T-profiles designed case by case: interior stringcourses in order to inhibit the possible overturning collapse mechanisms and a chain extrados system to counter the thrust of the existing vaults. Systems that are also able to define a plane rigidity of the extrados vault of the *Camera Picta*.

The damage to the Bridal Chamber was manifested mainly with the reopening of a lesion in the main figurative wall. The lesion was compensated, but the sensitivity to the damage of the room deserves further consideration. Noted the lack of options for safeguarding the integrity of the pictorial cycle, extremely vulnerable, has prepared a campaign of studies on the consistency of the walls of the compartment. Currently it has been provided for the arrangement of a series of chains in unidirectional carbon steel wire tissue housed in the cable duct in a narrow band of the existing floor.

Figure 1. Ducal Palace in Mantua.

Ducal Palace in Mantua, North-East tower of St. George Castle

Intervention on the second level of the tower

St. Catherine's Church in Rovereto sulla Secchia City, Novi, Modena[26]

Even this intervention aims to secure the building after damages occurred during the earthquake in May 2012, which caused extensive collapse of the hedge, of the internal vault, as well as a series of cracks in the apse zone. The project is intended to constitute not only a response to emergency but to define a series of works that, in addition to a temporary use in security, may constitute with the permanence a first phase of the next restoration.

The interesting aspect of the project consists in the fact that the principles used provide for the use of materials and technologies able to respond to an efficient and rapid assembly sequence and pose in work of the elements, as far as possible the use of standardized parts for cost reduction, lightness and handling of the elements for the reduction of the incidence of movement means and a adaptability of the elements used at last to minimize the operations in the assembly phase necessary for coherence with the characteristics of the historic architecture.

The materials used are wood and steel for the roof structures and support coverage and high strength hydraulic lime mortar and high strength carbon steel fibre fabric. The execution of the works provided for a first phase of safety with the elimination of unsafe parts irrecoverable, ridges of the walls, portions of the vault and wooden carpentry partially collapsed; a second stage of pre-consolidation, reconstruction and improvement of the walls, reconstruction of parts of the top of the walls and the realization of a stringcourse made of high strength hydraulic lime mortar and a stainless steel bar. A third phase has seen the realization of plinths in reinforced concrete for the construction of foundations of composed pillars. Subsequently the creation of vertical structures in wooden planks and metal sheets pre-processed and assembled, and the

[26] The architectural design is signed by arch. Barbara Pazi while the project of consolidation and structural improvement is signed by prof. Paolo Faccio.

connection to the wall by metal connections. A final phase involved the construction of the roof of the nave with the construction of trusses made by the same wooden planks and metal sheets pre-processed and assembled.

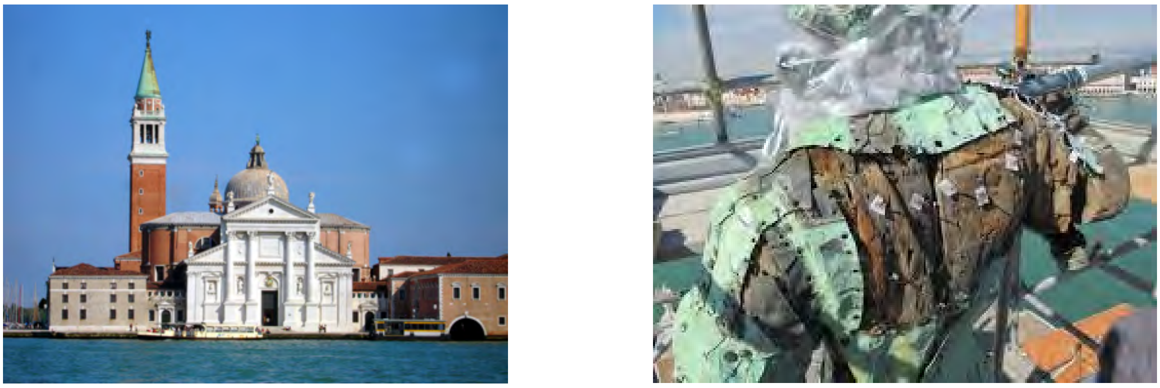
Figure 2. St. Catherine's Church

Damages after the earthquake | Reconstruction of the roof with standardized elements

The statue of St. George at the top of the dome of the Basilica of Palladio in Venice[27]

The last project concerns the statue of the saint, who stands on the dome of the church of San Giorgio, this, damaged by a lightning had stayed with the damaged arm for years, until it has been deposited in the church. The wooden structure once visible is made up of wooden planks put together, shaped and covered with copper plates fixed to the structure with metal nails. The need for consolidation action has highlighted a number of issues related to exposure (weather, wind, high temperature range) that did not allow to use adhesives or organic protective, therefore, traditional systems have been used for consolidation as shaped steel but also innovative systems such as basalt tissues.

Figure 3. Basilica of St. George in Venice



External view | The statue of St. George at the top of the dome, state of conservation

Such fabrics molded to bind and consolidate the wooden skeleton have characteristics of low thermal conductivity and they not need resins or hydraulic mortars allowing transpiration and therefore the preservation of the original wood material.

The intervention is part of a framework of research aimed at reducing the seismic risk of the movable cultural heritage[28], also allows to close the loop on the issues of vulnerability of cultural heritage by

[27] Intervention with the direction of the architect. Massimo Rigo, consulting professor Paolo Faccio, restorer Giuseppe Tonini, artisan blacksmith Alessandro Ervas, under the supervision of the Supeintendence; sponsorship Swarovski Foundation.

[28] Working Group relating to LARS- Seismic Risk Center Studies, scientific responsible prof. ing. arch. Paolo Faccio and prof. ing. Anna Saetta, IUAV University of Venice in front of more agreement between the University, ISCR, Secretary General of MIBACT,

considering both the storage of containers - architectures - that content, allowing reflections related to issues of security and conservation.

RESEARCH PERSPECTIVES

The working group relating to LARS- Seismic Risk Center Studies, principal investigators prof. ing. arch. Paolo Faccio and prof. ing. Anna Saetta, IUAV University of Venice, dealing from 2010, in terms of research, study issues related to the vulnerability of cultural heritage and seismic risk reduction. In these years, through agreements with the Ministry for Cultural Heritage, Environment and Tourism, lead institutions (ISCR and ICCD), Regional and local Superintendents, were held activities of consulting, indexing ,cataloging, monitoring about reduction seismic risk for the movable and immovable cultural heritage.

Through some PhD thesis the group is now developing insights regarding topics that address critical issues related to security in structural terms together with conservative and formal instances in architecture, considering the two problems, too often separated and assigned to different specialized figures, as two sides of the same coin, which constitute a unique architectural organism.

The use of historical documentation and cadastral data is the basis of the work concerning the historical urban centers, in order to deduce the transformations (morphological, structural, textural) suffered by the built in time, data required for a first assessment of vulnerability[29].

Figure 4. Civita di Bagnoregio, Viterbo

Historical settlement in aggregate

Gregorian Land Registry Plan, 1816

Two research then deal of employment of the reinforced concrete in structural consolidation of historical building[30] and in reconstructions of archaeological sites[31], that encourage reflection on "hybrid structures", and on a range of consequences inherent durability and interaction new materials with the original ones, the absence of methods of calculation and verification recognized for these types, the attempts to achieve, through these interventions, behavior patterns modeled with the new construction. Today in fact significant problems are related to the recognition of the role of these interventions, on the possibility of preserve them and about alternative technical and practical to substitute them.

Supeintendences and Direction of Museums

[29] Giulia Campanini, *Civita Di Bagnoregio. Studi finalizzati all'analisi di vulnerabilità degli insediamenti storici in aggregato*, Politecnico di Milano, Dipartimento di Architettura e Studi Urbani, Dottorato in Conservazione dei Beni Architettonici (in progress)

[30] Greta Bruschi, *L'impiego del calcestruzzo armato nel restauro architettonico: una rilettura critica degli interventi di Ferdinando Forlati,* Dottorato in Storia e Conservazione dell'Architettura - Curriculum Restauro, Università IUAV di Venezia (in progress)

[31] Elisa Fain, *Comportamento e durabilità delle "strutture miste" in area archeologica. Il tempio di Apollo Pizio all'acropoli di Rodi*, Politecnico di Milano, Dipartimento di Architettura e Studi Urbani, Dottorato in Conservazione dei Beni Architettonici

Figure 5. Acropolis of Rhodes, Temple of Apollo

Main view

Detail on reinforced concrete damages

Figure 6. Palace of three hundred Treviso

After the II World War

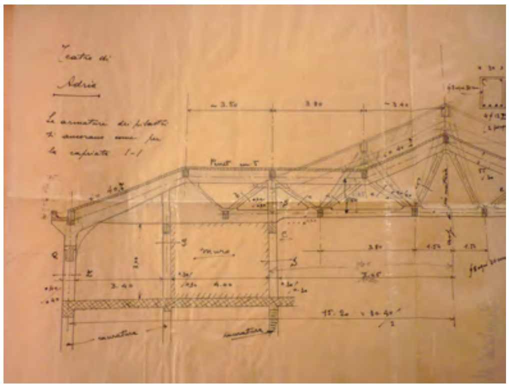
Intervention of reconstruction by Ferdinando Forlati

Finally, the examination and assessment of vulnerability of the architecture of the '900, made by historical reinforced concrete, designed with outdated regulations. A large part of the cultural heritage belongs to this group and it is a field of study where structure and architecture often coincide: topics that raise insights and reflections on the role of diagnostic tests and invasiveness of interventions in structural and formal terms[32].

[32] Paola Scaramuzza, *Il Teatro Comunale di Adria: conoscenza propedeutica alla conservazione del calcestruzzo armato storico,* Politecnico di Milano, Dipartimento di Architettura e Studi Urbani, Dottorato in Conservazione dei Beni Architettonici (in progress)

Figure 7. City Theatre of Adria, Rovigo

External view



Detail of the the concrete structures project, 1932

CONCLUSIONS

To achieve the goal of protecting the cultural heritage system, the way to go is neither that of the great projects (given the lack of resources) or the use of significant financial resources. Rather, it is a complex and widespread operation that involves the whole territory and that can have an impact not only on the level of protection, but also on the employment of high-level professional figures (engineers and architects) and can create attractive prospects for business world, even in the international scene.

Professional updates and authorities responsible for safeguarding (cultural heritage, but also regional and local) in close collaboration with the University would find a common perspective in combining development and security, in order to move from the logic of emergency to that of prevention and protection: the protection of cultural heritage from seismic risk is in fact, first and foremost, a matter of prevention.

The relationship between emergency and seismic safety is another aspect (and not the last) of the problem of vulnerability in historical architecture: despite the many existing recommendations, still occurs to systematize those practices that should ensure that the work conducted in the emergency will provide the most possible useful indications to the studies and preventive intervention, so that the latter can contribute effectively to limit the damage caused by earthquake.

For this to happen is not enough to pay attention to the state of the buildings after the disaster, nor work after the earthquake with adequate structural improvements, but we must above all ensure a constant work of monitoring and reducing vulnerability, at least in the historical buildings of the areas most at risk .

In a time when there are significant difficulties in the post-emergency intervention, such reference to prevention and this attention to buildings, that seem not so important, may appear unwarranted. On the contrary, whether you look at the mere economic aspect that to the more 'high' aspects that is to guarantee the survival of our culture and the same of human lives, is today more than ever necessary to look at what, if left untreated, could turn into the tomorrow emergency.

Contributes to the Roadmap

The relationship between emergency and seismic safety is another aspect of the problem of vulnerability in historical architecture: despite the many existing recommendations, still occurs to systematize those practices that should ensure that the work conducted in the emergency will provide the most possible useful indications to the studies and preventive intervention, so that the latter can contribute effectively to limit the damage caused by earthquake.

For this to happen is not enough to pay attention to the state of the buildings after the disaster, nor work after the earthquake with adequate structural improvements, but we must above all ensure a constant work of monitoring and reducing vulnerability, at least in the historical buildings of the most at risk areas.

Open Issues

It should be interesting developing topics related to security, in structural terms, together with conservative and formal instances linked to architecture, considering the two problems, too often separated and assigned to different specialized figures, as two sides of the same coin, which constitute a unique architectural organism. (cfr. "Research perspectives")

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Sensible Architecture
Sustainability as a part of the Architectural Design Process

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ABSTRACT

New technologies and advances in Research and Development have transformed the world, as we knew it 15 years ago. Sustainability and Eco-efficiency issues are now an integral part of Architecture, but how has this evolution and these issues have transformed our approach to Architectural Design? The architect's response to this transformation goes beyond the mere shape of the buildings or the constructive solutions. We understand that the answer lays in the beginning of the design process. Today architects have a key role integrating and coordinating the advances made in Research, Development and Innovation made by the different actors involved in the architectural design and construction process. To display this hypothesis, we present two case studies of different scales but with a similar approach, where sustainability and economic balance are an integral part of the design process and, as a result, of the final proposal. An architecture that is *sensible* to the changing of times and that is reasonable and conscious. An architecture that *'makes sense'*.

Keywords

Architectural Design Process, Amadora BD, Vírgula i, sustainability, innovation.

INTRODUCTION

The world we knew, 15 years ago, has been completely transformed by new technologies and advances in Research and Development. Europeans have become increasingly aware on sustainability issues. The policies developed in recent years and the investments made by companies to improve products and reduce their carbon footprint are proofs of this trend. The world of construction is also part of this process. But, in what sense has this evolution transformed the architectural design? Or, otherwise, how does it follow obsoletes criteria and processes? How are architects aware of these changes and how can they respond to them?

From our point of view, the architect can have a key role in this evolution in order to integrate and coordinate the advances made in Research, Development and Innovation made by the different actors involved in the architectural design and construction process. Architect's response to this transformation goes beyond the shape of the buildings and their constructive solutions. We understand that the answer starts at the beginning of the design process. To display this hypothesis, we present two case studies, of different scales but with a similar approach. Both share a similar tactic, aiming at a high Architectural Design quality in combination with a sustainable and economically based approach.

CASE STUDY 1. TOP INTERNATIONAL ARCHITECTURAL COMPETITIONS

Top International Architectural Competitions provide opportunities for the interaction between the high quality architectural design and the sustainable and financial planning progress. In our opinion, the architect and the client play key roles in allowing this combination. It is necessary to define the part of both of them nowadays; the architect presents itself as a manager and coordinator of teams - that are formed by several engineers and specialists; the client, appears as a figure whose tasks need to be redefined, especially in the regard of public contests.

The architect

The architect is no longer a person working alone in its own studio. Our experience on top international competitions at *Nieto Sobejano Arquitectos*, during the last ten years, enabled us to test and develop design workflows. The research and innovation potential of several of the engineering and construction companies involved has been completely integrated in the architectural design process. New technologies allow efficient and sustainable ways of communication, that were unaffordable just 15 years ago. As an example, to develop one of the last architectural competitions that took part in Switzerland, the team was managed by a team of architects located in Madrid, a structural engineer based in Berlin, three façade engineers and cost consultant from Frankfurt, a team of technical engineers working from London, and a sustainability and Minergie specialist from Switzerland. The work was carried out for a period of 15 weeks in which the different specialist joined the project gradually, throughout the process. Our task as architects has been to harness the potential of all the different specialists in order to integrate and coordinate their proposals in the architectural design, under clear sustainability criteria, clearly defined by the client and the local regulations.

The same way the architect incorporates into his design the conditions of structural systems and materials, making Architecture progress, sustainability and eco-efficiency criteria must also be integrated into the design process.

The client

High quality Architecture is not possible without a “good client”. The first step for a successful development of an architectural project is to find the right approach for the client necessities. Our experience in Architectural competitions has enabled us to identify that a clear definition of the brief allows for a conscious and sensible design development. Clear goals, a defined and studied programme, a correct estimation of the investment, precise information regarding the site, energy sources and regulations are key elements for the success of the project. It is the client’s responsibility to provide an adequate brief. But, who are the clients today?

Nowadays, new technologies and communication tools provide unprecedented access to information and participation worldwide. Even more, they are redefining the figure of the public client. Mechanisms for citizen participation allow people to take part on the definition of the public space from the initial moments of public projects. Well-known cases like Tempelhof in Berlin, or small-scale interventions in abandoned public plots in Madrid, are examples of participative processes that are becoming a commonly way to understand the European public space. New technologies provide tools that make these developments easier. Architects must be conscious of this change in order to understand the needs of ‘the new client’.

CASE STUDY 2. SMALL SCALE PROJECTS

Vírgula i is a young international architectural collective, based in Porto and Madrid, which develops strategies of multiple collaborations. Our experience in projects of different scales and programmes has led us to invest in a close dialogue with clients, as well as to address each project as a challenge, in order to achieve an appropriate response to the needs and existing conditions.

We bring to this presentation two different projects that share a common approach in terms of sustainability and economic viability; the *Amadora BD - International Cartoon Festival*, two exhibition projects made with the reuse of materials; and Hotel Minho, a renewal and re-branding of a hotel that has redefined its whole image and the business itself.

Figure 1. Amadora BD Festival 2014, Lisboa. Photo: Eva Sousa

Amadora Comic Festival

The Amadora International Comic Festival has been taking place in Lisbon for over 25 years. In 2013, the festival adopted a low-cost regime, as did many other public institutions in Southern Europe. Virgula i was first placed on a shortlist and then selected to develop a project for the Festival with these economic restrictions. We understood that the severe cut in the budget represented a complete break with the previous cycle, and that encouraged us to make it a radical turning point in the festival's logic and overall idea. We looked for new strategies to find an appropriate response for this challenge, by highlighting the re-use that was made of different materials.

Our approach was sensible to the succession of changes that this kind of festivals goes through and the many materials that the Comic festival had built up over the years. We understood the project as a metamorphosis of the existing materials mixed together with the movable equipment of the Forum Luís de Camões: goal nets for indoor football, wooden cable reels, cubes and pallets, halogen lighting, potted plants from the municipal plant nursery, crates, cladding panels painted by children, retractable seating systems that existed already in the sports hall (where the Festival is installed), modular metal structures, porticos made from timber beams, etc. The project was, basically, a reorganization of the flows and rhythms of these materials. An architecture based on the transformation, which hibernates and wakes up completely metamorphosed each season as a new project.

These strategy means a high degree of rigor in the analysis of the components available, their different cycles of use in the project's interior, the protection and packaging that they can produce and the overall logics that they generate: of permanence, permutation and standardization.

The management strategies for the festival's financial investment were also transformed by the proposal. For example, instead of renting a protective material to preserve the floor of the sports pavilion, that had required to set aside an important part of the budget, it was decided to buy a cheap material, OSB boards, that could be used as floor, but also for other purposes: walls, furniture, etc. The investment on purchasing these boards was recovered just by using the same material in the second project in 2014 in a different way.

The Festival takes place in two different spaces of the Fórum Luís de Camões - the sports pavilion and one of the car parking floors – which means two opposite architectural scenarios: the hall architecture involving the pavilion's 14 metres high ceilings and the garage architecture almost 3 metres high without even taking into account the service ducts and equipment hanging from the ceiling. One of the issues of the projects was to create a connection between both scenarios by using the material and the areas of circulation, providing singular moments that suggest that the creation of the "place" may be the basis for the scenario of a story. Then a silkscreen printed canvas, used as a curtain on the upper floor is placed horizontally to shelter and cover a structure that recycles metal tubes of the garage floor. Along the perimeter path, the visitor is taken to course places that either presents them as "front of scenario" of porticoes structures either exhibit the structural elements that support these scenarios. The centres of the spaces are an auditorium generated by tier of benches on the pavilion, and a central garden made by potted plants from the municipal nursery and metal tube structures.

After a hibernation of almost a year, the festival came back metamorphosed in 2014, with new forms but the same materials. The central core of the exhibition consisted of a topographical arrangement of pallets with a coloured top, enabling several uses: exhibiting books, reading areas, sittings or just plain walking surface. This new ingredient catalysed the metamorphosing. The porched structures were aligned in strips of different densities, with a crossed-path for circulating between them. In the garage, a goal net represented a cheap, quick to assemble and the easy to store material that became the catalyst of the intervention.

The cost of the construction was of €38,50 per square metre in 2013 and €30,50 per square metre in 2014.[1]

Figure 2. Hotel Minho, Portugal. Photo: Eva Sousa

Hotel Minho

Minho renewal and extension is part of a wider process of hotel redesign where architecture is the central part of the new hotel visual identity. Based on the architecture project, a new hotel was created, not only through the building, but also on how it communicates its various physical and digital media: in site, in the interior and product design, in the web, in its graphic identity or in its corporate image.

In all these fields of design the new hotel claims its contemporaneity, the quality of its materials, services and spaces. The architecture emerges as the anchor element of the Hotel Minho re-branding, making its middle name fall - Hotel Turismo do Minho - introducing new common areas, a new spa, a new business centre, new and renewed social areas, stating clearly in its architecture, interior and communication design, as well as the spaces created for the new hotel program. The architectural project was not limited to the coordination of various traditional fields of expertise - the engineering or the interior design - but it was also the coordinator of the teams who have handled with the new identity, linking all the parts of the strategy, in a strong proximity with the client.

The spatial solution created by the architecture project intended a strong integration between the existing building and the new extension, by reducing the visual impact of the new constructions. The project is strongly introverted turning itself to private inner-courtyards, where natural light is abundant, creating strong visual relationship with specific parts of its surroundings.

CONCLUSION

We opt for Sensible Architecture, architecture of the dialogue and the understanding of new limits posed by changing times. As architects, we understand that we have the responsibility to integrate sustainability criteria in the design process, both in terms of energy and economic issues. Economic constraints and regulations cannot be understood as inhibitors of high quality architecture, but rather as challenges to which the architect must respond. To do this, first we claim for an adequate preparation of the architect, which calls for investment in training at European Universities. Second, the architect can perform an integrative function of different lines of research and innovation carried out by engineering companies, universities and companies in the construction sector. We believe that high quality architectures carried out in international competitions, are themselves R&D+i projects. As such, they should be treated, encouraged and supported by European Institutions and policies.

Contributes to the Roadmap

- Understand the High Quality Architectural Design as a Research, Development and Innovation field where sustainability and eco-efficiency issues should be integrated. Architectural Competitions constitute outstanding opportunities to make progresses in these fields. As such, they must be supported an encouraged by European institutions and policies.
- Architects must be prepared for a world in constant change. This requires a continuous investment in training at European Universities, for professors, researchers and students, to educate Architects as integrators of advances in Research, Development and Innovation carried out by all of the actors involved in the construction industry.

Open Issues

How have new technologies and advances in sustainability and eco-efficiency issues transformed architectural design processes? How are architects aware of these changes and how can they respond to them? Is it possible to combine the highest quality architecture with financial and sustainable demands?

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The Urban Ruins of San Berillo, Catania (I)

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ABSTRACT

The current neighborhood of San Berillo is what remains from the demolition of the '60s, when it underwent a real estate transaction called Piano ISTICA, which consisted in a real gutting of the ¾ of the neighborhood and the deportation of its historical inhabitants in the new suburb of San Leone. San Berillo is a dense network of narrow streets that flows into small squares surrounded by ruins. Although over the years there have been various proposals for upgrading the district, San Berillo is in a state of advanced urban necrosis and it needs a regeneration process that enhances those potentials within it, giving voice to whom lives there every day and knows its complexities. Objective during the workshop will be to develop those issues related to the structural safety and resilience of these as well as their strategic re-use in terms of eco efficiency.

Keywords

Urban Ruins; Urban Regeneration; Opportunities of Regeneration; Neighborhood Identity; Conversion of Public Space; Experience

INTRODUCTION

"San Berillo is an imaginary place; a non-place in an irrepresentable reality; a cemetery of history and culture; the womb that has engendered the lost signs of the ancient world, that echo down to us through the centuries, mingling with the sound of the odd moped.

And its ghosts dream of us, we the shut-eyed spectator-actors of a one-act play: the void, the oblivion, the incessant recurrence of a whole that has never acquired a definitive form, but that lives in these painful and ironic stories that trace a continuity between an idealized past and a present in full need of restructuring."

from the movie: *"The Ghost of San Berillo"* by Edoardo Morabito

FEATURES OF THE NEIGHBOR AND OPPORTUNITIES OF REGENERATION

The ruins of San Berillo express architectural styles and historical-cultural aspects that are no longer reproducible. They give to the neighbor an identity that should be preserved. The neighborhood is surrounded by several kinds of boundaries and by physical assets such as the road axes that delimit it

Figure 1. Images of the actual condition of the neighbor San Berillo

The personality of the neighborhood is determined by people who live and work in these streets, as well as lava, courtyards, fountains (to be restored), windows and doors present in this district and that become both urban objects and focal points of the narrative district.

STUDY SCHEMES:

Figure 2. Change in Scale; **Figure 3**. Typical Courtyard; **Figure 4.** Neighboorhood Identity

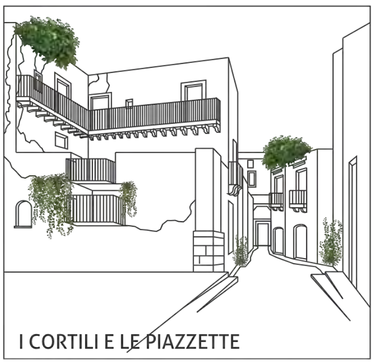


Figure 5.Lava Stratification

Figure 7.Garden Neighborhood

Deeper inside the neighborhood, you can earn a substantial change in scale compared to the surrounding environment, aided by the secular stratification of lava that works as basement of the historical buildings. **San Berillo remains a neighborhood garden on a human scale and based on the poly.centrism of its backyards.**

LACK OF PUBLIC SPACES

The road continues to be the only public space for social interaction and is used by the whole community of San Berillo. Unfortunately there are no elements of urban furniture suitable for meetings and dialogue.

Figure 8. Sense of Loss

Figure 9. Inadequate Illumination

The roads inside the neighborhood have preserved a rich mesh of inputs that would guarantee a lively mobility of people and a particular street life. Unfortunately, many of these inputs were forbidden since many of these entrances has been walled up by the police and the walk in some streets, as in Via Zara, is therefore not convenient and attractive.

CONVERSION OF THE URBAN RUINS IN PUBLIC SPACE

Figure 9. Regeneration Input: Implement the quality of the urban space

RECUPERO URBANO

ILLUMINAZIONE ADATTA

ARTE PUBBLICA

The concept design for San Berillo proposes the regeneration of these abandoned places that become the connective tissue of new public spaces for the neighborhood. **The public space is understood as a three-dimensional mesh, a mesh of routes and places that tell the neighborhood via its courtyards.** The study of the stratification of new public and private functions both in plan and in section, inside the ruins themselves, provides an extra degree of complexity to the intervention. The layering of public spaces inside the ruins will generate room for public gathering and economic growth of the neighbor, which will vary also according to its future needs.

Figure 10. Regeneration Input: Implement the livability of the urban space

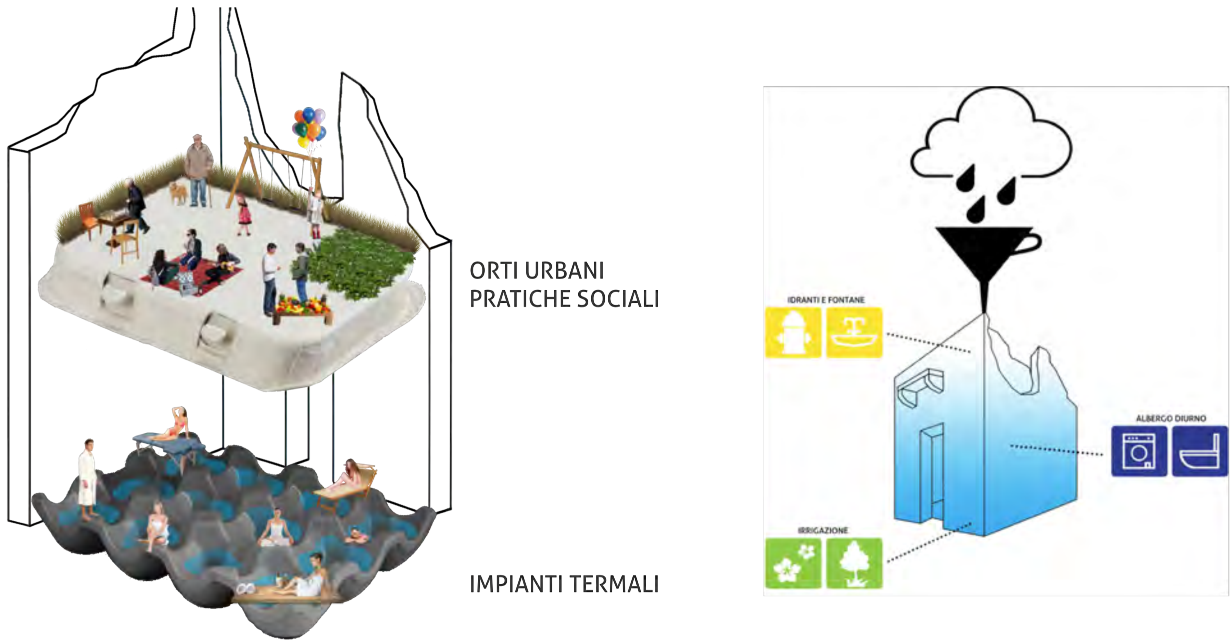
AREE ATTRATTIVE

POSSIBILITÀ DI SOSTA

ARREDO ESPERIENZIALE

All horizontal surfaces will be used for the collection and management of rainwater. Taking into account the low and irregular rainfall of Catania, it is essential to manage these resources in favor of the microclimate of the area. The rainwater is then collected in other underground rooms and can be used to irrigate the roof gardens or urban gardens that are born on the upper floors, always within the ruins.

Figure 11. Regeneration Input: Sustainable re-use of the ruins as roof garden, thermal bad and rainwater collector



Public spaces can also be formed using water as key element. Thermal bath complexes or a daytime hotel will become places for social cohesion in urban scale and will ensure that level of public hygiene currently absent in the neighbor. Body care becomes a reason to gather and will improve the social life of the inhabitants. **These thermal bath complexes include the use of lava stone for lining of the tanks**; its waterproof properties make it suitable for a use of this type. In addition it preserves the history of the underground river of Catania, the Amenano, whose path is still unknown, but often returns in the imagination of Catania in public and private locations (restaurants, hostel ...).

The ruins seen as containment structures with their empty facade will offer unique views of the private or semi-private gardens. Nature will find room to grow through the empty façade and will become vertical. The design will give an idea of regeneration that enhance the experiential dimension for those who want to take an ideal journey into the past, offered also by the effervescence of sensory stimulation: from the tactile to the visual, the olfactory component.

An environmental masterplan will provide the inclusion of plant species compatible with the lava landscapes and scenes that represent the green, to be equipped for resting and socializing. The project also includes a financial action: the creation of new commercial buildings on the upper floors of the ruins, which will act as an economic engine of the district. A plan of investment will be offered to the owners of the ruins. They will donate the lower floors of their ruins - to be allocated to public activities - in return for the profits of the commercial activities located on the upper floors, whose area of coverage will still be returned to the neighbor in form of public space.

The neighborhood will be revalued with the rest of the city and will be considered a unique and fascinating place, a real window to and from the city.

CONCLUSION

The neighbor should gain social articulation, able to change in according to the demand of mobility of the territorial population. This demand is related to work activities, leisure or social practices distinguishable on the basis of generations. The integration of the existing social fabric and new residents will be promoted through social and economic activities within the same district.

The architectural design should give an idea of interventions that enhances the experience to them who might want to find a portion of the city that offers an ideal journey into the past.

San Berillo is a neighborhood to be allocated to intergenerational users, which appreciates the dimension of slowness crossing it and the pleasure to linger in spaces that encourage the experience.

The size of slowness is to be intended as a strategic element. It's a long look on the soul of the humanity that rarely the city has to offer.

Contributes to the Roadmap

This study attempts to trigger a discussion about the lack of a model and the implementation thereof, aiming to recover large disused areas within very dense territories: land consumption Vs. requalification of the existing; demographic issues; urban eco efficiency and sustainability

Open Issues

The public dimension of our argument is not only the orientation towards a goal that is stated as a general, but it is mostly transparent, shared and explicit. The conditions of neglect that characterize much of the neighbor require a public path on private properties, in fact often abandoned.

What administrative, financial and economic opportunities can we offer to these individuals to share this journey? This path still affects the economic and social realities existing in the neighbourhood and definitely increases the need of "control" of the territory. What effects on the few activities (including prostitution) that now insist in the neighbourhood?

CREDITS

The project was presented in May 2015 at the **Biennale Public Space** in Rome as winning proposal of urban regeneration and led to the opening of a technical committee shared by the Public Administrations in Catania.

In August 2015 the project was awarded with the **Jury Price** during the
XXV International Seminar and Award for Architecture and Urban Culture
Camerino (Italy) July, 29th - August, 2nd 2015

Urban Eutopia Strategies for the combined redevelopment of social housing

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ABSTRACT

The architectural and urban regeneration should focus on a methodological and interdisciplinary approach, entrenched in the territories. Therefore, this paper promotes specific design actions, based on the use of reversible, low tech and low impact building systems. The combined procedures focus on an adaptive maintenance (with character: preventive and corrective) able to update the architectural objects in order to restore high typological and performance standard, qualitatively increased.

Keywords
Urban Eutopia, Synergies, Interdisciplinary, Combined redevelopment, Quality of life.

INTRODUCTION

The architectural and urban regeneration of the established city is today crucial not only for the disciplines involved (architecture, engineering, economics, sociology, etc.), but also for the economic growth of the Countries. As for us it appears fundamental to begin with the definition of an interdisciplinary methodological approach to face the problem. It is therefore necessary to promote a dialogue between different actors and an interaction of different skills, able to produce new virtuous forms of hybridization addressed jointly to the practice of combined redevelopment (structural-morphological type and performance) of the built environment.

The Europe, in times of economic circumstance, shows in certain territories different and dramatic forms of incongruity affecting in the urban environment. The lack of jobs, the disposal and neglect of the productive areas, the degradation of the peripheries, could be exorcized with the redevelopment and reactivation of all those buildings that are not adequate anymore to satisfy the living requirements of the users and the regulations, with an energetic, seismic and typological retrofit. The architectural and urban regeneration would represent for the local community a sort of reimbursement (both in terms of mending than of refund) of the spaces unapproachable for the accessibility, the fruition, the life.

The research carried out as part of PRIN[33] *New design practices for sustainable redevelopment of social housing complexes in Italy* referred to a regional sustainable development concept and to a theoretical consideration of the integrated regeneration of housing stock, without resorting to demolition. It continued with an investigation of the costs and benefits of urban maintenance operations carried out in Europe, analysing in particular those that experimented with the use of indigenous materials that root the architecture in its original context.

Urban Eutopia

Urban and architectural regeneration is not a utopia, a *non-place* ('ou-topos').

We should focus on structural, performance and space issues of the building and, through the design act aimed at improving the existing, turn them into positive for the environment, society and the economy.

It is understood that for many reasons is a way not easily practicable and fraught with obstacles. The aim is therefore to change the utopia in "eutopia" transforming the *non-place* - that actually has its irrepressible physicality - in a multitude of "good places" to re-establish and to care through interdisciplinary design tools congruent with legislation and reckless enough to be effective and valid over time.

Many different may be the ways ahead in a coherent strategy, which uses flexible tools to develop the architectural project.

According to some reports, the total value of real estate in Europe would amount to approximately two-thirds of the total social fixed capital of a Country (Lee, 1993). In particular, according to studies of the COST Action C-5 (*European Cooperation in the Field of Scientific and Technical Research*), the estimated value of the European real estate, considering only housing assets, is of worth over 40 trillion euros. The costs for maintenance, recovery and renewal of these assets is estimated at 1 trillion for year (Verhoef, 2002).

This holding is not only accumulated asset, but also an active factor for the production of new wealth not only economic but also environmental and, above all, social.

Only in Italy, the housing stock consists of a large number of buildings built before the Second World War (30.1% of the real estate) to a share less noticeable housing units (22% of households). Since the Second World War until the Nineties of the last century the Italian built housing has expanded greatly (70% of the buildings and 78% of housing refers to that period) (Cresme, 2015).

Of this huge quantity of artifacts built, almost 800.000 housing units are now in a state of severe obsolescence in terms of energy performance (30% of energy costs are generated by residential buildings, responsible for approximately 27% of national greenhouse gas emissions) (Micelli, 2011), earthquake resistance, etc.

It is here that regeneration is needed, requiring a defragmentation of a series of different situations in order to grasp the full extent. This is not only seen in intensive peripheral agglomerations as an *exceptional case* (for example the complex Bijlmermeer in Amsterdam, the Corviale in Italy, Park Hill in the United Kingdom, etc.) but also comprises the tiny particles of buildings found across a large part of Europe's urban landscape.

This *place,* profoundly marked by construction characteristics and recurring performance deficits[34], cannot be eliminated: it would not be appropriate and we would not know where to put the rubbish this would generate. Utopia can become *eutopia* ('eu-topos') however, transforming buildings that have deteriorated in

[33] The Research Project of National Interest held by the Ministry for Education, Universities and Research (PRIN 2009) emphasised the need to define new architectural practices to be adopted for the redevelopment of large and medium-sized low-cost and social housing construction complexes built in Italy in the last fifty years; those that were seen to be suffering from a structural and/or construction, functional (or plant engineering) and/or social perspective. The members of research group are: Marina Montuori (national coordination), Arch. PhD. Barbara Angi, Arch. PhD. Massimiliano Botti, Arch. PhD. Genny Celeghini, Arch. PhD. Filippo Orsini, Arch. PhD Olivia Longo, Ing. Giuliana Scuderi and the professor Giulio Lupo e Alessandro Muraca. The three local consortium members are: the Second University of Naples (coordinator: Prof. Pasquale Belfiore); the University of Salerno (coordinator: Prof. Roberto Vanacore); and the Department of Architecture in Cesena of the University of Bologna (Prof. Valter Balducci – coordinator – and Prof. Valentina Orioli).

[34] The activity of energy requalification seems the forced direction for the next years for different reasons: first, the European Directive on Energy Efficiency (2012/27/EU) seeks for a long-term strategy for mobilising investment in the renovation of the national stock of residential and commercial buildings, both public and private.

many *good places* so as to experience new ways of urban development who can trace unpublished design practices to change, the way we think and to enjoy the contemporary city.
To design virtuous tools of urban and architectural redevelopment appears necessary a formulation of targeted programs and the use of combined and sustainable techniques of urban *remodelage* (Castro, 2005), able to develop new forms of scheduling can conceive an organic and interdisciplinary strategies of manipulation on built.
The goal, now unavoidable, is to revive the housing stock, the parts of the city subject to obsolescence. Not accepting them passively, but managing and programming the 'combined' redevelopment of the built environment.
We must learn from the urban contexts, "listen" to the places and measure the fragility trying to use the same care and wisdom that, in the past, allowed “mending” the clothes all kinds of signs of wear or tearing.
In this regard Italian architect Renzo Piano refers to the practice of «mending [it will be] the physical structural, hydrological, but also functional, relational and aesthetic» through «small interventions in stitching that can trigger regeneration through new crafts, micro-enterprises, start-up, lightweight construction and widespread, thus creating new jobs. It is a modern vision (lightweight and diffuse like any effective network), much more dynamic and realistic heavy of the urban gigantism that led to endless rows of tenements anonymous [...] » (Piano, 2014)[35].
Renzo Piano, through the laboratory G124, puts the focus of discussions for the sustainable development of society the regeneration of suburbs that, in his view, represent the city of the future and, at the same time, the very future of the city.

Figure 1. The Italian architect and Senator Renzo Piano with the staff of lab G124. Alongside the review of the experimental laboratory.

The laboratory G124 is an experimental workshop to plan the redevelopment of urban hinterland. The suburbs have become the most populated, but also more 'brittle', part of urban structure (where it is estimated a population, in Italy alone, 28 million people). This territory will be left, presumably, as a legacy to future generations. The group operates on heterogeneous design themes to trigger a process of experimentation using a multidisciplinary nature availing, periodically, of highly qualified consultants.
The Investigations analyze practices for energy upgrading, consolidation and restoration of the existing buildings, the functional and spatial issues of contemporary public space, focusing also on the peculiarities of parks and transportation in order to activate a process 'combined' regeneration supported in the first instance, by participatory activities of citizens to implement shared and supportive strategies.

[35] Report from the G124 - 2013/2014. The magazine reflects the experience of the first year's work of G124 and careful multidisciplinary reflection on the potential of “mending” the Italian suburban and priorities to achieve it, including the need for a new generation of legal instruments capable of adapting to contemporary contexts building .

At the base of the interventions proposed by the workshop G124 for the re-activation of the suburbs, there is an programmatic agenda consisting of a methodology for a structural strategy aimed at systematic regeneration and economic relaunch of brittle urban territories[36]. (Figure 1)
The method identified by Renzo Piano focuses on general regenerative issues from which, probably, may well unpublished project synergies and suburban development. The Italian architect identifies some slogans for the combined redevelopment: growing cities of implosive type; protection of agricultural area and landscape around the urban agglomerations (*Greenbelt*); transformation of brownfields; build on existing buildings, public transport optimized; consolidation of the buildings; energy upgrading, self-construction as a tool for mending buildings, participatory processes "from bottom", identity of the suburbs, microenterprise as an accelerator of the regeneration processes, European public funding widespread, construction of public places.
The formulas identified by Renzo Piano presupposes an interdisciplinary projectuality that can transform, from environmental, social and economic point of view, the suburbs. The outskirts is real places, far from theoretical abstraction, in which it seems possible to test, experiment and define concrete strategies for a futuristic city.

Strategies for the combined redevelopment of social housing

A good part the contemporary residential construction has exceeded the fifty year life cycle and is in a severe state of disrepair, but that more recent construction is also in need of urgent regeneration capable of triggering a process to bring housing in line with regulations governing earthquake vulnerability and energy saving.
From this stems the need to provide a maintenance strategy that is both preventative and corrective in nature; one that can restore an updated typological and performance standard and provide for higher quality housing.
From this stems the need to provide a maintenance strategy that is both preventative and corrective in nature; one that can restore an updated typological and performance standard and provide for higher quality housing.
In our opinion, in the scale of the architectural redevelopment of residential, are necessary levels of intervention attributable a maintenance operations that can limit the seismic vulnerability of the existing building, to improve functional performance and the energy behavior of the facades and, simultaneously, able to prepare the update of the building type so as to reduce the mono functional configuration of the building (functional mix) with the introduction of differentiated housing types and, where necessary, with the insertion of commercial activities[37].
From a construction point of view, moreover, it appears necessary provide technological solutions that can ensure the reversibility of the process so that, in future, the people have the opportunity to use their homes adapting them in the time to emerging needs and to changing requirement of space.
It is therefore necessary to act with dry and disassembly constructive systems who affording, in addition to the possibility of quick assembly, even which of a possible removal in view of the recycling of the materials employed, using relatively reasonable times. This technical concept can providing the guarantee the low environmental impact of constructions without producing hazardous waste, and to lengthen the life of the building without interrupting its regenerative capabilities, such as biology teaches.
This would enable, de facto, to improve the quality of life through the reuse and recycling of urban fabrics thank to a technical, type-morphological and entrepreneurial point of view. The contemporary city has a

[36] In this regard it is useful to point out the studies and research carried out by AUDIS (Association dismissed urban areas) that are designed to help improve the definition of objectives widely shared between public and private institutions in urban regeneration projects. Audis has also developed a system for evaluating the quality of urban area, so-called 'matrix', as an instrument of work shared between the public and private sectors to be applied to urban transformation projects complex.

[37] Cf. Montuori M. (2014), *Eutopia Urbana. Strategie per la riqualificazione integrata dell'edilizia sociale* in Cappochin, G., Botti, M., Furlan, G., Lironi, S., a cura di, *Ecoquartieri / EcoDistricts, strategie e tecniche di rigenerazione urbana in Europa / Strategies and Techniques for Urban Regeneration in Europe*. Venezia: Marsilio.

transformative potential that just waiting to be revealed and interpreted by means of technologies available with a view to saving resources and of 'acceleration' of the conversion processes.
A design approach such as this, which focuses on the adaptability of existing housing with a view to saving resources and providing rational and reasoned maintenance to what has already been built, is assumed furthermore by studies carried out on the development of the metropolitan area of Paris since 2010 by the Office of the President of the Republic of France, in partnership with the Ministry for Culture and Communication, promoters of the *Atelier International du Grand Paris*. Thanks to the *Grand Ensemble* project, the scientific committee of architects and urban planners prominent in the international debate within the field prepared fresh design methodologies focusing on the redevelopment of existing buildings. In particular MVRDV, the Dutch practice run by Winy Maas, laid the foundation in the programmatic document, *Pari(s) Plus Petit* for a wide-ranging discussion of the modification of existing housing. From an analysis of the lifestyles of Parisian families, MVRDV deduced the impossibility of continuing to view housing as something that can meet the needs of a standard nuclear family, of predicting its evolution and the consequent need for space. They instead argued that existing housing must be developed through the provision of adaptable housing, with typological devices capable of varying space (a free plan, sliding walls, mobile structures, etc.). The *Grand Paris Adaptable* proposal also promoted the possibility of implementing *planned obsolescence* maintenance schemes capable of modifying housing over its period of use. Architectural work should therefore be capable of "extending" its life without limiting its regenerative potential, or that of the urban fabric. (Figure 2)

Figure 2. MVRDV, ACS, AAF, *Pari(s) Plus Petit*: Strategies for combined redevelopment.

Research Themes. From the recovery of settings to the recovery of the building: the adaptive exoskeleton

Taking the premises mentioned above gathered from considerable analysis of European projects as our starting point, our working group experimented with design practices through simulations of real cases in Italy and abroad. This was aimed at the integrated recovery of architectural (typological and morphological), performance (energy efficiency) and structural (earthquake resistance) components of buildings, actions that may also include a re-examination of housing typologies and a redefinition of open spaces.
Our research was widened to university teaching and the relationship with the institutions in charge of governing the region (ALER and the Township of Brescia) through the development of degree theses and the

holding of courses and workshops focused on the theme of regenerating several districts of Brescia: San Polo, Casazza, San Bartolomeo, Villaggio Violino and Case Marcolini Facella. Some members of the group also took part in design competitions. The Regeneration of the production area of the Villaggio Prealpino – Vantini Stocchetta – in Brescia, the winning project in partnership with faculty from the University of Pavia, is particularly worthy of mention.

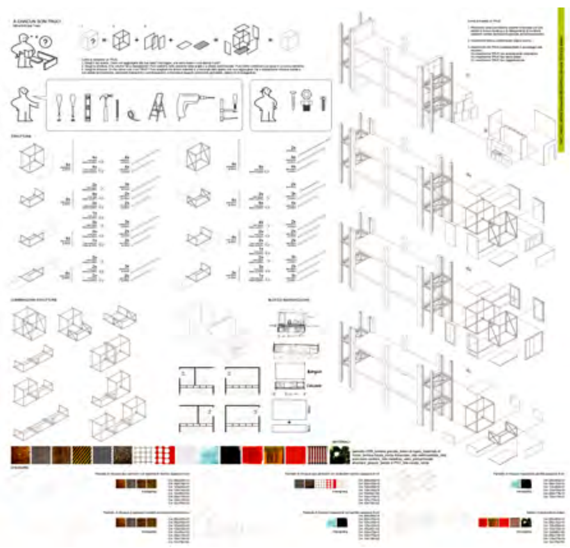
Among the project's many threads, particular attention was paid to *rural-urban* issues, a type of morphological category for the construction of new landscapes introduced by Vicente Guallart based on the *Sociopolis* project (2004), which came about in order to «explore the possibility of creating a "shared habitat" capable of encouraging greater social interaction among its inhabitants, by proposing new housing types in keeping with the changing family situations of our time, and against a backdrop of high environmental quality» (Guallart, 2004). This strategy allowed for a distancing of the city-countryside dichotomy, generating transition areas — defined in Italy as "semi-rural" areas — aimed at promoting integration between the agricultural world and the city. (Figure 3)

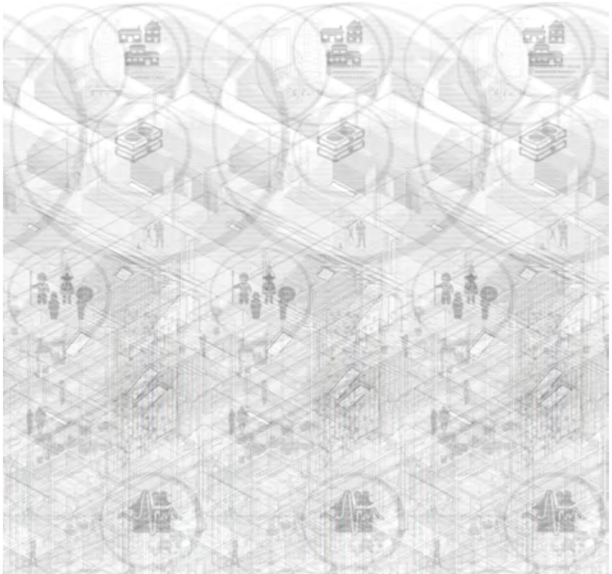
Figure 3. Vicente Guallart, *Sociopolis project* and the studies for *rural-urban* approach.

The research group also developed a technological device described as an adaptive exoskeleton, a type of metal scaffolding (that can also be made from materials such as wood or FRP profiles) to support and become integral to the building being redeveloped. The adaptive exoskeleton favours dry and reversible

technological solutions, with a view also to saving resources and recycling construction materials in order to offer a valid alternative to so-called building replacement, which takes a significant toll on the environment.
The adaptive exoskeleton was also considered within a general urban redevelopment plan; it could be morphologically defined as a type of scaffolding used to make the exterior of an existing building rigid, working with it not only to optimise structural resistance and energy performance, but also to improve the quality of the internal spaces.
This technological superstructure in fact includes new plant engineering equipment and incorporates earthquake resistant elements through the insertion of horizontal partitions to transfer the stress on the frames to the vertical elements, targeting solutions that allow for the preservation of existing ceilings and floors. The exoskeleton may also include new *objects* that are independent of each other (rooms to expand the housing, solar greenhouses, winter gardens, terraces) built—depending on the different needs of the residents—without costly changes to their housing. These could also accommodate new distributive elements (e.g. galleries) in the case of a typological reworking of the whole building, to allow for the construction of superelevations (other residential units or shared structures to serve a wider catchment area), the sale or rental of which could partially cover redevelopment costs, in the light of the experience of *Dutch Housing Associations*. (Figure 4)

Figure 4. University of Brescia. Combined Bachelor and Master Degree Courses Architectural Engineering.
Left: Course + Laboratory of Architecture and Composition 2, *Installation instructions of volumetric expansion in the exoskeleton*, students: Mensi A., Mussinelli G., Tedoldi M.
Right: Thesis, *Exercises of combined urban renewal in the San Bartolomeo district in Brescia*, student: Peroni A., supervisor: Montuori M., co-supervisor: Angi B., Minelli F.





CONCLUSION

In summary, this solution, which may be thought to be paradigmatic, may also be modified easily over the course of time with regard to different geographic, climatic and urban settings, in addition to being adoptable for the recovery of deteriorating buildings. It is not a type of *camouflage* that crystallises the image of the building, preparing it for future obsolescence, but an "open" system that helps the building to respond to the changes it will encounter, such as social, economic or those that relate to housing needs.
The adaptive exoskeleton aims to prolong the life cycle of the architecture (now set at fifty years for residential buildings) through gradual adaptation that leads to a reduction in the environmental impact of the architecture itself, distributing this over a longer period. In this sense, our research can be seen as a continuation of that already developed by certain European projects, such as Image, SESAC and SureFit, focused on energy saving, sustainable building and the regeneration of existing buildings, in harmony with the objectives of the *European Union Horizon 2020 framework programme*. (Figure 5)

Figure 5. University of Brescia. Combined Bachelor and Master Degree Courses Architectural Engineering. Thesis, *Exercises of combined urban renewal in the San Bartolomeo district in Brescia*, student: Damioli V., Dò M., supervisor: Montuori M., co-supervisor: Angi B., Preti M.

Contributes to the Roadmap

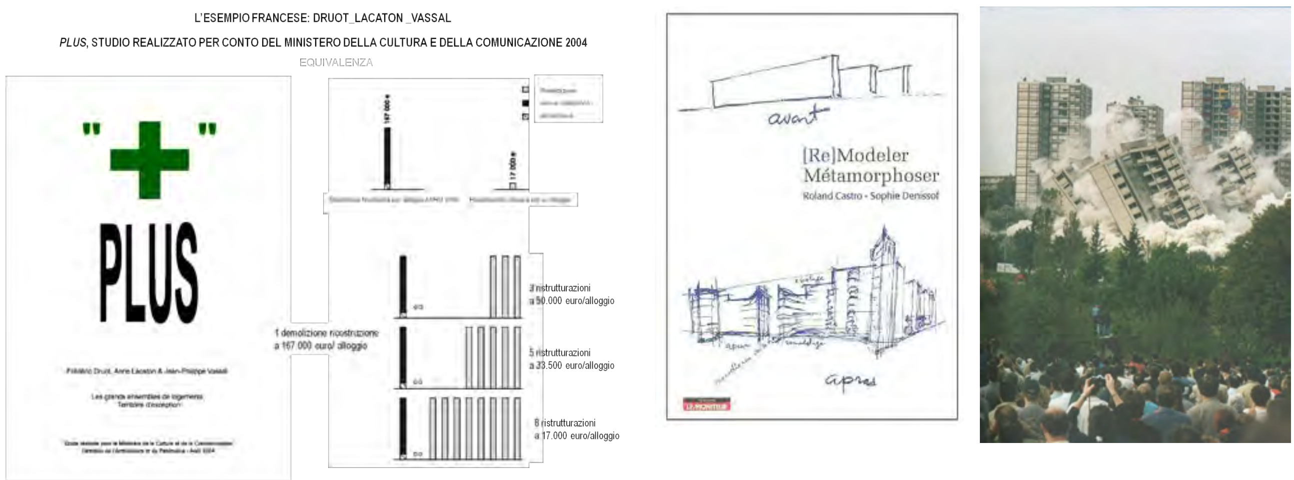
Many applied research programs funded by the European Commission have tried, over the last decade, to contain the messy and 'undifferentiated' growth of the residential neighborhoods by predisposing plans for saving of energy resources and the use of renewable sources. Chief among them is to remember CONCERTO, *Energy solutions for Smart Cities & Communities*[38], an initiative under the Sixth and Seventh Framework Program, which showed as the energy optimization of the neighborhoods is more advantageous compared with the reconquered efficiency of a single building, provided that all stakeholders work together by integrating different technologies in an intelligent way. Established in 2005, CONCERTO was created to encourage local communities to engage in the development of concrete initiatives towards sustainability and high efficiency performance of the built. The small towns or communities to which it is directed can be newly created or existing, the important thing is that they are interested in improving their performance, if not to revolutionize towards energy self-sufficiency, clean and renewable.

The community supported by CONCERTO strive therefore to pursue the direction of Carbon Free politics, able to harmonize the indispensable use of renewable resources with innovative technologies and systems to minimize energy consumption; the goal, of course, is to improve the quality of life of citizens. Or yet the sub-project SESAC, *Sustainable Energy Systems in Advanced Cities,* which focused attention on the possibility of predispose efficient local economic systems and, at the same time, to reduce CO^2 emissions, making clear how these objectives can be achieved through the combination of several factors: good governance of the territory, the innovative cooperation between the parties involved, the preparation of guidelines appropriate to the specific nature of the places and easy searchable by users.

The above examples show that it is possible to establish and/or redevelop neighborhoods and residential buildings by obtaining new artifacts from the high performance energy and technology through involvement at multiple levels of the different actors involved, but at the same time, showed how the approach to issues often prefers the technical construction. The proposed solutions appear so often a sort of single thought result, which puts on the first place the performance of building elements and infrastructural networks.

It should be noted as, increasingly in Europe, are ongoing some architectural research aimed at developing regenerating design strategies for the consolidated residential environment able to increase the quality of housing, and the resulting market value of existing buildings in order to accommodate applications for flexible and adaptable space for the contemporary domestic living.

Figure 5. French studies of combined redevelopment: *Plus* by Frédéric Druot, Lacaton Anne and Jean Philippe Vassal and *[Re]modeler, Métamorphoser* by Roland Castro and Sophie Denissof.



[38] The results so far obtained have led the way to the creation of a new European legislation in the form of recommendations of energy policy for the energy to be implemented by 2020 and in order to achieve their goals of climate change by 2050 (Energy roadmap).

Thanks to the contribution of authors such as Roland Castro and Sophie Denissof, Frédéric Druot, Lacaton Anne and Jean Philippe Vassal, the UK agency Urban Splash and the Dutch Studio MVRDV[39] the architectural aspects related to housing quality of residential buildings have been addressed very effectively, although not yet appear introjected in best practices developed within the continental research financed by the European Commission. (Figure 5)
These experiments clearly demonstrate the need to place in the roadmap *for improvement of earthquake resistance and eco-efficiency of existing buildings and cities* the aspects linked to quality of architecture. This discipline is the unique that can achieve the aesthetic ransom of built environment so to realize urban structures capable of increasing the market value of the artefacts, through qualified professionals supported by an appropriate culture of the project.

Open Issues

In our view, the variety of expertise that is required by the workshop SAFESUST *improvement of earthquake resistance and eco-efficiency of existing buildings and cities*, must depend necessarily on a disciplinary system able to a multi-directional and never self-referential approach. The starting assumption, now commonly accepted not only by the scientific community, is to reduce the environmental impact of each operation of urban transformation.
The architecture is a discipline that allows it to interact with each other different professional expertise (technology, economics, sociology, etc.), and can play the role of coordination and control of combined redevelopment of existing buildings, or if you prefer, that of "orchestra leader" capable of harmonizing the various skills for the construction of spaces for the welfare and human health.
In conclusion, the practices of transformation and maintenance of the built environment have the opportunity to detect the multiple scales of intervention in the urban organism and to discover the potential through the harmonization, in empathetic mode, with the polyphony of needs which come by its inside. It should focus attention on the spatial criticality of the residential construction and, through the act of design aimed at improving the existing, transform them into positive aspects for the environment, society and economy.

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Ancient constructive devices and new techniques: the structural improvement of existing buildings between memory and project

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ABSTRACT

This paper tries to compare the results of some different researches and experiences of intervention for the preservation and structural improvement of ancient buildings. The study involved both an urban and a rural constructive context, whose peculiarities determined the different features and peculiarities of the single buildings that were examined, both from a geometrical and constructive point o view.

But also some common problems were pointed at, first of all the physical decay of metal connections and the loss of structural reliability as a consequence leading to the intervention. The most interesting aspect was the fact that traditional interventions reveal an attitude toward the reinforcement of existing structures rather than their complete replacement.

This fact introduces the topic of structural strengthening by adding modern devices, as a support of the existing ones, rather than by simply replacing them, nor even altering their way of working. A preservative principle that perhaps let restoration meet sustainability.

Keywords

Existing buildings, old structures, preservation, seismic improvement

INTRODUCTION

The importance of the architectural Heritage is undeniable in any town, especially in Italy, where the consolidated urban pattern is often a strong presence, as much in the big cities as in the smallest villages.

Sometimes old buildings build up a wide, well preserved and still living monumental site, as in Venice, which is made of a thick connective tissue of small historical houses linking huge palaces one to another in a continuous flow, like the one of water along the Grand Canal.

More often, the remains of the past are condensed in a part of the town, usually the centre, acting as a counterbalance of more recent urban settlements. And where the old is fragmentary, or even a ruin, it plays a considerable role anyway, both from a cultural-historical and an economical point of view, as a memento or even just a turist target. But, above all, we can think of an ancient artefact through a social perspective, as a landmark and a catalyst of the collective memory, often a meeting point as well, facilitating public consciousness and mutual relationships.

Whatever the age or meaning, ancient buildings are subjected to a continuous transformation, due both to the natural dacay and human changes. Involving them into a project of urban redevelopment means finding a balance between maintenance and renewal, a very difficult goal to reach without a deep knowlwdge, not only of the formal features, but of their materials and structural peculiarities, as well as the environmental context they have been growing in, that deeply influences the constructive aspects.

THE IMPROVEMENT OF EXISITNG BUILDINGS AT THE CROSSROADS OF RESTORATION AND SUSTAINABILITY

Sustainability is one of the more advanced pattern of life and cultural perspective of contemporary society, providing a framework both of economical and social principles and of technical systems to reach the goal of a sustainable development. A widespread research is constantly in progress to find new devices and techniques, in any filed of present life. Can restoration be involved in such an apparently distant field of interest? And, if so, how?

In my opinion there can be some meeting points between sustainability and restoration, both from a cultural and operational point of view.

First af all from a conceptual perspective, both fields rest upon the second law of thermodynamics; entropy brings the awareness of the non-reversibility of phenomena, hence giving rise both the need of preserving the things of past as a cultural and ethical concern, just as the necessity of sparing natural resources.

Existing buildings- which are made of natural and artificial materials and have a functional, economical and social role, as human products and resources - can be compared to the natural resources we can rely on.

Thus the attention for the material culture of a place, as well as the concern for an aware use of local resources are either sustainable principles and concepts leading to a preservative approach to existing buildings, which pays attention to the past contructive wisdom, not just as a nostalgic icon but as an operative resource.

Such criteria as the preservation of the existing matter instead of replacing old parts with bright new ones meets the sustainable principle of saving natural resource, just as the principle of reversibility[40] and minimun intervention; or, compatibility, which leads to prefer local materials, or even the reuse, as recycling.

But the most impressive point is the basic concept of preservation, that is the acceptance of the physical and functional limits of the old buildings.

This approach conceives the intervention as a means to improve their remaining resources in order to reuse them properly but without expecting them to fit higher standards of performance than they actually are able to. This is also the idea of *improvement* rather than *compliance* to external standards of performance, giving rise to a kind of strengthening by adding new supports to the old structures, rather than replacing them. Here are some examples.

Venice: condition of the site and constructive peculiarities

The first example comes from a research about Venice constructive systems and their behavior over time, lead within an agreement between the Iuav University of Venice and the Venice Heritage Superintendence, with the support of a local defence institute (Corila)[41]. Many buildings and bell-towers[42] were studied, focusing on the so-called "legamenti" (links) which are an essential part of the constructive culture in Venice, where the building system is based on diffused joints between thin structures (the so-called *fiube*), rather than on massive walls and rigid connections, because of the site peculiarities, first of all the unreliability of the ground[43].

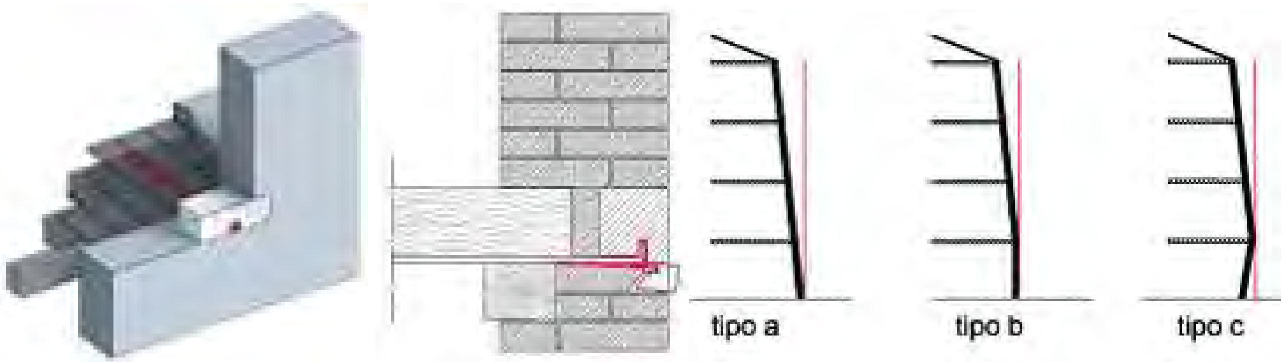
[40] Doglioni, F., Squassina, A., 2003.

[41] Doglioni, F., Mirabella Roberti, G., 2011.

[42] Lionello, A., 2011.

[43] Lupo, G., 1998; Squassina A., 2007, 2009a; Doglioni, F., Squassina, A., Trovò, F., 2007.

Figures 1-2 – Venice, Ca' Dario, whose irregular geometry is partially intentional and partially due to structural damages. On the right: lines of *fiube*, along the façade of Fondaco del Megio



Figures 3-5 – Scheme of a fiuba and of its way of damaging by oxidation;

on the right: a-b intentional slopes inward of facades in Venice; c – structural problems due to the loss of efficiency of connections (taken from Doglioni, F., Mirabella, G., 2011)

Allthough Venice is a monumental site, the nature of the place and the difficulty both in finding and shipping materials, developed a general economic view where cheapness was a principle explaining the widespread reuse of materials and architectural elements, as well as the presence of stratified buildings.

Figures 6-8 – Stratified connections of different periods in a medieval building and (on the right) in a "barbacane" (stone-and wooden shelves)

Moreover, the constructive culture is grounded on praxis, that is on a continuous process of revisoin and amendment of previous systems, following the behavior of the ground, with a full awareness of the nature of the site, of its needs and of the available resources.

Perhaps this is the reason of the diffusion of punctual and elastic - most times stratified - supports and connections, that act as improved solutions over time but within the permanence of patterns and an overall structural framework.

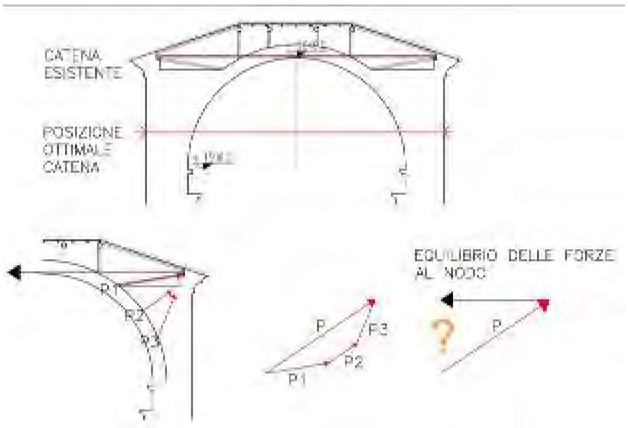


Figures 9-11 – Modern repairs using new materials and traditional systems

One can find, on the facades of Venice, many layers of tie rods and such links as “forks”, connecting single parts or broken elements, at the same time letting them mutually move, adapting to the adjustments of the ground. And where a concrete structure was experimented, it proved to be inadequate because of its rigidity. That’s why tradition is not a dogma but a kind of constructive necessity in Venice.

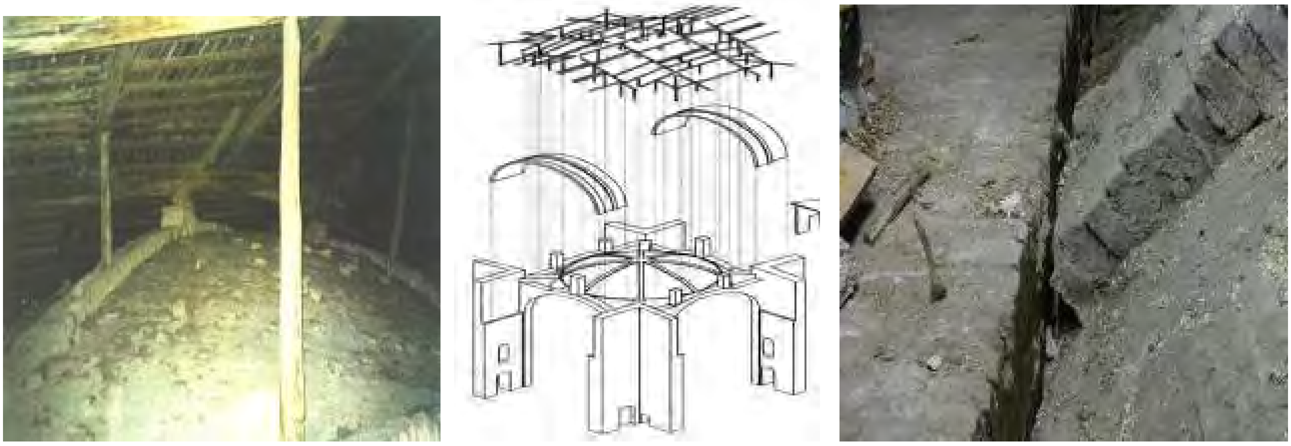
Rural contexts: rough materials and refined techniques

Within rural contexts, any architectural aspect (building orientation and exposure, as well as the structural arrangement or the inner distribution and functional layout) reveals a constructive wisdom though formal features are often essential; shapes usually simply follow the function, facilitating the everyday life and work of inhabitants. Where existing, decoration is simple. Good sense seems prevailing over any formal aspect.

Figures 12-13 – Botticino (Bs): a peculiar connection between dome and walls in a church; (on the right) cross section with the scheme of working of the device

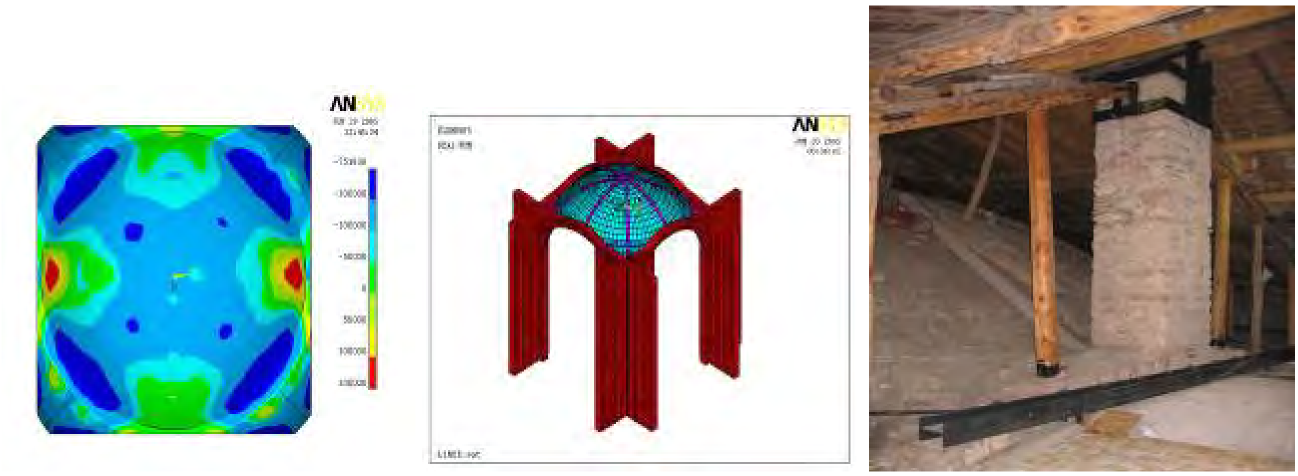
Though we can find some extremely peculiar, yet refined structural systems, deserving an attentive intervention, taking care of ancient devices, rather than renovating the whole structure, in a word respecting both the matter and the constructive logic.



Figures 14-16 – Immages and scheme of working of the roof and (on the right) the damage due to the earthquake

Thus some wood-to-metal or wood-to-masonry ties sometimes carry out some interesting and refined connections, such as the ones which were observed in a rural roof of an old Lombard church[44].

In this case, the wrong perception of unsteadiness, given by the irregularity of the rough wooden structures, almost lead to the idea of a hasty replacement, after the church was damaged by an earthquake, in 2004. Thanks to such modern analysis as the FEM (Finite Element method) the rural roof turned out to be safe, just in need to be reinforced through modern links improving its earthquake resistance[45].



Figures 17-19 – Result of the FEM (Finite Element method, by Prof.Ing.S.Lagomrsino, ing.S.Podestà, University of Genua); (on the right) the intervention of improvement of the earthquake resistance of the dome (from Squassina A., Tonoli, S., 2008)

This is the logic of seismic improvement, providing the old building against earthquakes but avoiding any alteration of structual logic and way of working, that keeps on relying on the original structures.

The Lombard case shows how the most refined techniques can help preservation but different means of analysis can contribute to a deeper knowledge of the building and of its vulnerabilities, as well.

[44] Squassina, A., 2014.

[45] Squassina, A., Tonoli, S., 2008; Squassina, A., 2009.

For example, the direct observation of material marks of transformation by a stratigraphical reading[46], can help in understanding past behaviors and events, such as raising, enlarging or unification interventions, as well as new openings or the closing of previous ones, but also structural alterations and problems, cracking and seismic damages and repairs[47].

The goal is the comprehension of old buildings and of the level of their residual efficiency, in order to enhance their performances, without making them loose their character nor altering the way of working, both from the material-and-structural or functional point of view.

Following a perspective where preservation and sustainability maybe can meet, old buildings could be lead toward future through a conscious development of their constructive memory, that is not just as untouchable relics or as single pieces of art, but as an active presence within the everyday life of the community.

CONCLUSION

Contributes to the Roadmap

The results of the study cannot lead to a conclusion; on the contrary they raise a reflection and several questions. The main one: law requirements aim at defining standardised answers, both form the conceptual and technical point of view. How can we reach an improvement, following the law in such peculiar contexts requiring a very individual approach, without altering the nature and way of working of the existing structures?

A second aspect is the fact that a deeper analysis is needed to understand peculiarities. This paper aims at underlying the importance of preliminary knowledge, both about the material and structural aspects of existing buildings. These ones deserve to be seen as individuals, not simply as geometrical objects. Such an approach opens the issue of method, pointing at the meaning of some different kinds of surveys, so as to understand not only the formal features of old buildings but also to record those signs and traces both of transformations and previous structural damages, because they can reveal the vulnerabilities with regard to earthquakes[48].

On the other hand, a second important issue is the importance of relying on the remaining capabilities of old structures, improving, strengthening them but not altering their way of working, nor the material and structural nature of the existing buildings.

This aim often requires a change in the order of precedence, first of all as what concern function, that should not be indifferently superimposed to the building, disregarding its actual strength and structural resources.

The fact is that, though it is not easy, we should try to figure out improvement as a balance among different goals: safety and comfort from the one hand and respect for the material and structural features, even if this means a not perfect adaptation to standards.

[46] Doglioni, F., Squassina, A., 2011.

[47] Doglioni, F., Mirabella Roberti, G., Bondanelli, M., Squassina, A., Trovò, F., 2008.

[48] Doglioni, F., Petrini, V., Moretti, A., 1994 and Doglioni, F., 2000.

Open Issues

1 – Law: singularity versus standard / improvement vs compliance

Have we to make the old buildings perfectly comply the requirements of law? Or may we expect the law to adjust in respect of the peculiarities of old buildings? I.e.: when we are planning the improvement of an old building in accordance to the law (for example the seismic law, or the eco-save law), if requirements are too strict we could change the building irreversibly.

May we rely on notwithstanding the current regulations in order to preserve the peculiarities or the way of working of the buildings we are going to reinforce? May we expect a lapse, a limit which we can move up to?

Or have we to accept the law to drive the destiny both of old and new buildings indifferently?

2 – Technique to maintain or to renovate?

On the one hand, a continuous technical progress makes new materials and objects available, and allows more and more analysis, providing both knowledge and operative instruments.

On the other hand modern life standards are very different in respect of old ones. Thus ancient buildings are lacking in services and modern comfort devices. Though a new use is a way to preserve, often upgrading and refurbishment are simply conceived as a radical way to make old things accomplish new requirements which sometimes depend on our needs as consumers. In this case, doesn't technique look like a bare instrument of exploitation?

Are we able to conceive an idea of intervention in which technology is at the service of a proper and sustainable employment of the existing buildings, making use and preservation meet, that is improving but, at the same time preserving them?

Can we afford a branch of technique to develop proper means of analysis and intervention for old materials and structures, without reducing them to the analytical model of new and different materials as, for instance, reinforced concrete? A challenge for research.

An idea of restoration in terms of sustainability maybe can give an answer to such questions.

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Occupants and Users into THE Servitized Built Assets

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ABSTRACT

The paper sketches the evolutionary processes undertaken by the construction sector. The building is described by the data in this new paradigm, starting from a concept of space as basic framework including requirements and needs generated by behavioral patterns and configured as data sheet. The bi-dimensional definition of space (based on two coordinates size and a function) is replaced by a multidimensional matrixes populated by data, options, dynamic attributes, communicated by different stakeholders of the design/construction/operating phases of the building. The human factor becomes a shaping element supported by the digital technologies, evolving in a multi-option scenario driven by a probabilistic approach. The behavioral workflow goes from the first step of the evaluation, by means of gamification and augmented reality, to the conceptual sketching into a BIM environment for digital optioneering with the last user validation that can be monitored as a time lapse portrait of the in-use building.

Keywords

Pre Occupancy Evaluation; Simulation of the Users' Behaviors, Multidisciplinary integration

INTRODUCTION

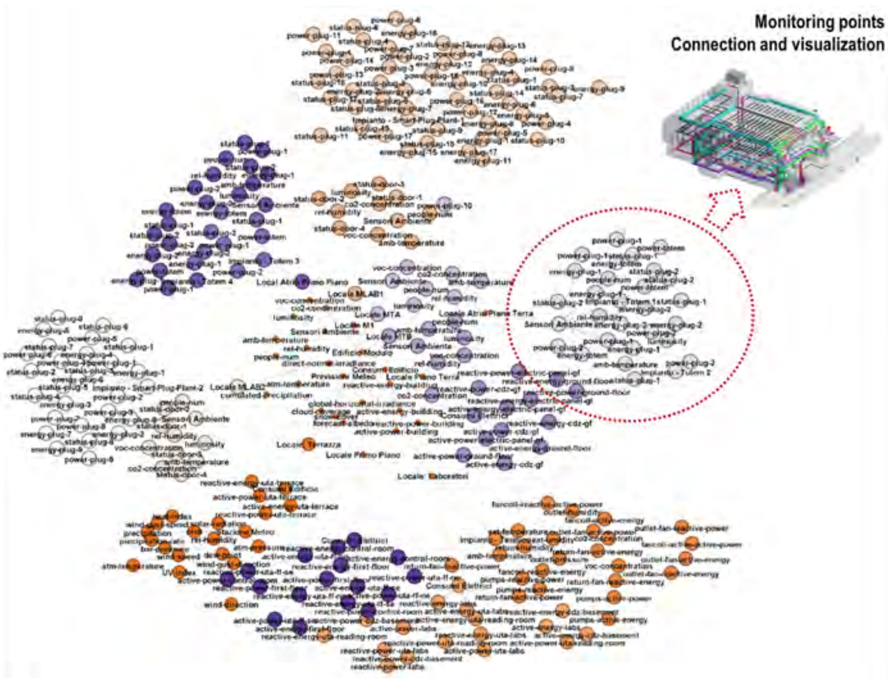
Sustainable behaviors are a key factor in the cultural shifting driving our future in term of energy and management. The building sector has a crucial role in energy saving and environmental impact reduction is a *dictat* on which the design and construction market have to face every day. The digital era hands out multiple tools to manage the optioneering (Angi, 2015) in the project phase when the decision process can make the difference in the impact of the building for decades.

MANAGING OCCUPANCY IN THE DIGITAL AGE

The Data-Driven Processes are more and more affecting the Industry of the Built Environment, causing a dramatic re-shaping of the Construction Markets.
It means that a lot of traditional Identities and Roles might be suddenly disrupted and con-fused.
Occupancy, the way of exploiting and living Spaces, seems to act as the focused turning point.
Simulation and Connection allow the User's Behaviors to be imagined and perhaps customized, indeed.
However, the traditional storytelling stems from the Occupant's wellbeing and health, but, from the very early beginnings (e.g. within the Energy Performance Contracting-Based Frameworks) the User becomes a proactive (counter) part.

On the same time, Individuals might be simulated as well as tracked, as pedestrians, when flowing into indoor environments. A shift is occurring amongst the Internet of Things (Buildings, Infrastructures, and Grids) and the Internet of Fellows. Pedestrian Tracking and Traffic Management engender and cause the surge of the Industries of Behaviors, to be conceived as the whole range of the Location-Based Services.
Moreover, the Servitization of the Built Asset itself implies the primacy of the Life Cycle as the main target and priorities to be taken into account.
Until this point, a sort of trivial approach could be adopted, because the rationale highlights how Operations & Maintenance appear as the main goal to be achieved.
Nevertheless, the change of imaging and simulating any patterns of Services sounds challenging and transformational, moving the paradigm from Performances of the Assets to Behaviors of the Occupants.
Client & Owner Organizations begin to self-portrait themselves as Commissioners, of course, but also as Designers of Needs, Services and Emotions. Otherwise, the usual attitude of a Repeat Client echoes the capability of establishing and devising Briefs over the early stages of the Projects by means of Data Sheets and Dialogues, but the contents of the expectations did remain a little bit far away from the Conceptual Primacy. It was always the Design Teams (the Architects and their Technical Consultants) to own and hold the Authorial Leadership throughout the tools of the Representation, whilst the Digital Era makes the Simulation directly affordable to the Clients themselves. Such a challenge causes the Client to deal with the Design Options, in order to manage a Proactive Interaction when faced to the Professionals.
Unprecedented Practices in Intelligent Client-ship are arising, in order to enable the Clients to create Behavioral Spaces: the configured Services, throughout the Simulation devices could be thought within Spaces, within Immersive and Multi-Sensorial Environments.
Spaces, instead of Forms and Geometries, are the ultimate Field and Topic of the Architects: whenever a Client tries to be concerned with the Spatial Dimensions, the Primacy of the Designer is menaced obviously.
Furthermore, when the Spaces could be originated and derived from Motions and Flows, the nature of the Asset, its Architectural Meaning, moves from a static to a dynamic thread (Simeone, 2015).
Likewise, how might a Tangible and Immovable Asset become Ineffable and Dynamic?
It depends on the Data Flows, because the Connected Built Assets must be nurtured and fostered by Data Sets coming from the Sensors (Miller et al. 2015; Agarwal, 2010).

Figure 1. Sensors become nodes with dynamic attributes of a network likewise spaces of the building.



Apart from the non-mechanistic essence of the Connected Built Assets, the Anticipation Paradigm lies with the so called Pre Occupancy Evaluation: once again, the terms are reversed because the Operational Client is compelled to attained some findings from the assessment sourcing from any simulated Occupancy.

WORKFLOWING THE CONCEPTUAL ASSEMBLIES

The Data-Driveness explains the reason why any conventional approach to Building Information Modelling seems too rigid and fragile in starting from a mechanistic assumption tied to the BIM Libraries, linked to an Object-Based criterion.

The Digital Sketches somehow bridge the transition from the Space Programming to the Outline Design Stage, supporting the Client's Intents aimed at being made ascertained about the compliance of the submitted design options against the original Behavioral Patterns and Data Sheets.

In other words, a Computable and Creative Design Process can nor be constrained on a deterministic environment neither be left to the wishful thinking of the Designers.

A main concern proper to the Client Organization should stay in avoiding Information Losses, i.e. a breach in the overhauling efforts to be aware of the outcomes of the Designers' Choices.

It entails that a competition could grow between Clients and Designers in order to own and exploit the available skills in Big Data Analytics. Both Clients and Designers become enabled and accustomed as Intelligent Players, capable of operating the key levers and cleavages.

An innovative workflow can be, consequently, shadowed, according to the scheme in the following figure.

Figure 2. Behavioral Workflow.

SUSTAINABILITY AND BEHAVIOUR

Building performance and environmental impact are strongly related to energy requirement and occupants' behavior (Tagliabue et al., 2015; Hong and Lin, 2013) toward sustainable way of life. A 30% of energy saving can be achieved by building automation and control using sensors to provide energy (thermal energy, lighting) tailored on variable occupancy. A gap between predicted thermal behavior of the building and actual value (De Wilde, 2014) can vary between 60% and 90% (Hamilton, 2011). The variation on actual performance is ascribable built quality, occupancy behavior, management & control meanwhile predicted performance variation is given by design assumption and modelling tools (Menezes, 2012, Demanuele et al., 2010). A previous analysis on behavioral patterns and data sheets provided by the use of the building spaces (originated from databases used for benchmarking could allow the designers to manage the variability through a modular and parametric approach to renewable energy systems that could be designed as arrangement to feed the building.

CONCLUSION

A responsive building, designed as a service for the user, is the new dimension of product the built environment has to deal with. The Data flows provide the information to the building and a dataset of information could provide clouds of point of the building situation derived by monitored behaviors transposed into values, as a scanned reality inside the built environment that can be visualized as a dynamic network of changing value nodes or levels' maps. A workflow of the conceptual assembly shown and the connection to energy efficiency highlighted as the centrality of the responsible behavior and the role of the monitoring values collected during the operating phase is unavoidable to bridge the gap between the prediction of the building behavior and the actual behavior in a reliable management scenario of the building energy lifespan. In fact, during the life of the structure, it should be also considered the possibility of the earthquake as squanderer of energy with resulting increased environmental impact of the building product.

Contributes to the Roadmap

The development of digital models through BIM optioneering and Behavior Design for the improvement of earthquake resistance and eco-efficiency of existing buildings and cities, may lead a significant paradigm shift in the building process. The change is tied to a more efficient use of resources, tangible and intangible, available through a shared process of all those involved in the process of upgrading of the buildings.
On the other hand, the simulation of the behavior of the people through the *gamification* could ensure, already in the design phase, a more efficient management of space in the event of earthquake by determining innovative emergency plans to ensure the safety in extremes cases of building's fruition.

Open Issues

In the multidisciplinary nature of topic *the improvement of earthquake resistance and eco-efficiency of existing buildings and cities*, the use of BIM optioneering allows to manage the necessary flow of information for the design of combined redevelopment project. The digital approach can supporting the entire decision-making process but, above all, the design the construction site and operational sequences of the different processes from the earliest stages of defining the intervention itself.
In terms of redevelopment project, the use of BIM optioneering is a crucial need for planning and management of construction activities since is necessary, de facto, to do coexist the requirement for speed and precision operating with those related to safety worker, users and, in general, of the structure.
From the digital model all the necessary information to the definition of project and of the construction site can be extracted. This information is needed in the definition phase of the intervention, before the work of redevelopment and during the same in the case of variations in the process.
We believe that the preparation of the digital model must be the essential prerogative, and not optional, in the process of urban and architectural renewal, since it ensures the proper and effective management of all disciplines involved (i.e. the economy, social aspects, architecture, urban planning, structural engineering, energy efficiency, environmental engineering, etc.).
The BIM methodology ensures operational effectiveness also in support of innovative topics and research and aims to be an 'active' tool for monitoring and verification of high complex activities, especially if combined with current decision methods such as MCDM (*Multiple Criteria Decision making).*

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The eco-efficiency design pattern of the existing buildings, with their earthquake resistance, and cities, in Türkİye and in the World

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ABSTRACT

The eco-efficiency design pattern of the existing buildings, with earthquake resistance, and cities in Türkiye and in the world, may be a helpful guide for the rest of the world. Due to the local conditions, nearly all old buildings in Türkiye and in the world, were built in an eco-efficiency manner, to get the most economic outcome for a healthy sustainable environment. And the result of these buildings is the cities which are having the most suitable layout, to live forever, as they are in Mardin, Aksehir, Tire, Didim, Alacati, Cesme, Venice, Valencia, San Sebastian, Bilbao, etc. and as they are in past in Efes, Bergama, etc. In old times, all buildings should have the eco-efficiency feature to last long years in safety and healthy situation. The long time experience helps the people to buid the most correct buildings, they live in or they use. Through these built examples, we may easily get the hint of building correctly eco-efficient buildings of future and also cities of future. **In the paper, the built examples, which compose the eco-efficient cities will be defined with their most highlighted points, to have a design pattern how to get the most eco-efficient buildings and cities.**

Keywords

Eco-efficient, earthquake resistance, Türkiye,

INTRODUCTION

Yes, in Türkiye, for %95 of its lands is being affected by seismic waves, through the centuries, and all old traditional buildings, still alive, are being built due to the earthquake resistance rules and also due to the climatic conditions of the area. We have lots of cases, to be researched. Surely, this is not only a unique case, esp. for Türkiye, it is the same occasion, taking place in the whole world.

If there is an old built example, existing in a place in the world, researches should be done about this case to learn about the reasons why it still stands up as an alive space, still in service in today's conditions.

To have a design of a building under the rules of earthquake region is one of the first laws of having an eco-efficient environment. When we talk about a region under the effects of earthquakes, we have to underline also the features of its buildings, built in an earthquake region.

THE CHARACTERISTICS OF OLD TURKISH TRADITIONAL MASONRY BUILDINGS

If we continue talking about the features of the old Turkish traditional masonry buildings, with their earthquake resistance and also with their local building conditions and rules, we may say that there are one-story and two-story buildings, may be built in masonry. Coming from the old times and still with the Turkish traditional construction methods, they may build only one-story or two-story buildings. Mostly ground floor is constructed in stone, where first floor is constructed in brick or in wooden frame. If it is earthen-adobe, structure, one-story buildings and two-story buildings still exist. From area to area, while first floor is barely in brick or in adobe structure (earthen structure), there is no other type to build. The first floor may be wooden framing and in between wooden columns, there may be brick infill or earthen infill. The framing structure is always wooden structure for the first floor walls in masonry buildings. If the outer side of the perimeter walls is made of plaster while the inner side of the walls is plaster also or if the outside of the perimeter walls is covered barely with wooden material, inside of the walls, may be covered with wooden sticks under the plaster, which makes the structural system be more stable.

Mainly the floors in Turkish traditional buildings are constructed with wooden framing system with main wooden beam and secondary beams on it, and finally with wooden cover at the top.

In some buildings, there may be basement to make air flow between the wooden flooring system. This basement has a semi-floor height, from the ground level, to make the entrance level of the building raise to prevent the building from the high level of water tide, also. Always, the basement, if there is, and ground floor are constructed in stone.

The stability of the stone walls is being managed with the other stone walls, perpendicular to the perimeter walls in certain intervals, as the walls outside of the churches, to support the mid hall's outer walls with raised rooftop.

In Turkish traditional buildings eg. in Mardin, Aksehir, Tire, Didim, Alacati, Cesme, etc., to support the first floor, there are small covered spaces in a cantilever position, called "cikma". Also these spaces may create more daylight and visibility of the street from the inside of the building. Such kind of architectural elements are present in some cities of the world, eg. in Venice, Bilbao, San Sebastian, Valencia, etc.

"Cikma" is in a form of a rectangular plan to arrange a suitable plan layout, even though the ground floor is following the street pattern downstairs, in Turkish traditional buildings.

There are inner courtyards, behind the buildings. Buildings are standing up just nearby the street as a protective wall to create a sacred inner life in an open manner.

There are wooden closing doors for windows, And the eaves of roof structure, covered with the ceramic tiles are continuing up to a distance from 50cm to 100cm or more away from the perimeter wall of the building, to protect the building from sun and also from rain.

In some places, as in Birgi/Izmir, the outer walls may be double to create a thermal insulation.

…AND CITIES

Of course, the list of the characteristics of old Turkish traditional buildings may continue longer. Through these buildings, the list of the characteristics of old settlements, which are the main knowledge sources, about building and construction and social life, for today, such as Efes, Bergama, etc. may be written by pointing that there are lots of open-air meeting places, such as amphitheaters, agoras, temples, etc. in a city.

IN BERGAMA/IZMIR, TÜRKİYE

In Bergama, if the ruins are coming from 3rd and 2nd century before Christ, and still if we may visit them, then Bergama may be a good venue to be explored to understand the past better, why it is standing up, even though there has been lots of earthquakes and hazards along the 24 centuries, since 3rd century BC (figure 1, figure 2, figure 3, figure 4).

Figure 1. The tunnels under the area for Trajaneum- North Hall, Hellenistic Chambers, in Bergama/Izmir, Türkiye

(photo taken by Yesim Kamile Aktuglu, on 7th of November, 2015)

Figure 2. The amphitheater in Bergama/Izmir, Türkiye

(photo taken by Yesim Kamile Aktuglu, on 7th of November, 2015)

Figure 3. The amphitheater, from the top, in Bergama/Izmir, Türkiye

(photo taken by Yesim Kamile Aktuglu, on 7th of November, 2015)

Figure 4. The view of the amphitheater at the top far away, from the Asklepion, in Bergama/Izmir,

(photo taken by Yesim Kamile Aktuglu, on 7th of November, 2015)

CONCLUSION

What i want to underline through my paper is that there is no need to explore new things in the meaning of development. What is needed is to understand about the former lives better as in which conditions they lived.

By this way, by learning more and more from past, we will have a real resource to light new ideas for a better life in 21st century through planning, building and construction.

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Urban Regeneration

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ABSTRACT

Urban regeneration is thinking in a sustainable way whether the physical space or the social one of the city over the ability of the people to respond to the present needs without compromising or limiting the choices of the future generations to respond their needs.

In the progress of the contemporary city, the balance between urban growth and sustainability has to be the main theme.

Indispensable resource for a new urban sustainability, allowing you to rediscover the social benefits due to the proximity as the establishment of relations of solidarity between the people and the ecological benefits such as increase the energy efficiency and reduce resource consumption.

Urban regeneration should now tend to conjure ways to inhabit the city, of sustainability, of transformations in search of a higher level of intervention, technological and humanistic social circles powering up all the stairs of the city.

The project of urban renewal will be the instrument to build a different society.

Keywords

Urban regeneration, social, Europe 2020, sustainability, empty spaces, civic elements, sustainable mobility, society.

INTRODUCTION

The condition of the crisis of the Western system forced us to reconsider our way to act, to communicate and to make architecture.

The urban theme become, today, the main problem for the government and for and the next years too. A renewed attention to the ecological dictates, a reinterpretation of capitalism with its failures, and its waste, are calling into question the design of the society and, accordingly, the relationship that it has with the architectural design of the city.

The object of architecture - a symbol of the last century and unsuited to today's society moved to the need for an integrated and economically sustainable transformation for the entire urban system.

Today we need to develop new strategies and instruments to address urban issues exacerbated by the economic and financial crisis and we have to do it quickly because time acceleration of the contemporary causes phenomena develop in a very fast manner.

The fundamental issues that make the complexity of the urban matter in our territory are: the poor condition of the buildings built after the war; the failure of quality public spaces; the use of the land; the issue of waste and non-recyclable materials; the cost and the consumption of energy.

The new urban policies should be implemented with “few and clear” rules and with many public projects, away from an approach of legal codification of urban life, but able to adapt them to the speed of the phenomena while preserving elements of defence and regeneration of urban habitat.

The concept of *urban regeneration* is part of an European Union document entitled Europe 2020,which aims to a growth and a development of the city which is: intelligent due to more effective investments in education, research and innovation; sustainable due to the decisive choice in favour of a low CO2 emissions; inclusive, that is supportive and focused on creating jobs and reducing poverty.

Urban regeneration is thinking in a sustainable way whether the physical space or the social one of the city over the ability of the people to respond to the present needs without compromising or limiting the choices of the future generations to respond their needs. In the progress of the contemporary city, the balance between urban growth and sustainability has to be the main theme.

Space and territory are poor resources and therefore very valuable. To continue to consume new land is no longer a sustainable condition and it is a structural problem of the contemporary territory.

The solution to this emergency lies in the growth of the city into the city through densification, replacement and regeneration of existing buildings, through the search for a new balance between full and empty city.

The population density creates the ability to protect and safeguard the city empty spaces; indispensable resource for a new urban sustainability, allowing you to rediscover the social benefits due to the proximity as the establishment of relations of solidarity between the people and the ecological benefits such as increase the energy efficiency and reduce resource consumption.

Regenerating a city means using architecture as an indication of a more deep and radical transformation can bring the human being at the centre of all considerations.

Between the civic elements, the public space is the incentive behind every regenerative process quality of the city and the sole foundation on which to lay the certainty of the urban quality of the future; and where the size of the people is that one allows us to tap the city and the buildings; that one which actually measure its quality.

The regeneration project has to work in the spaces between things, conveying a sense of belonging to a community with the principle of collective space: the system of urban voids, with its value aggregation, collective and socialization among people, guarantees an interest public in the determination of the urban future and wealth of citizens. Improvements for people in urban areas are connected to the healthy desire of city life, safe and sustainable, and it takes the company f construction of a space of existence.

Urban regeneration for a polycentric city and with a development project is reticular services spread throughout the territory and able to respond to citizens' needs, expressed in terms of quality based on listening to the city, being subsidiary to open a model participatory contemporary composing a continuous urban cycle.

Urban regeneration is also a project of sustainable mobility. The objective of a sustainable mobility project is to perfect the connection between the city and its surrounding territory with the services and the network of urban spaces, the system of infrastructure that is key component of the public city.

Urban regeneration should now tend to conjure ways to inhabit the city, of sustainability, of transformations in search of a higher level of intervention, technological and humanistic social circles powering up all the stairs of the city.

The project of urban renewal will be the instrument to build a different society, engaging in the fabric worn parts of the city started to lose a new meaning and a new force in the form of new citizens, new forms of employment opportunities, new links between people and the spaces that surround them.

CONCLUSION

The concept of *urban regeneration* is part of an European Union document entitled Europe 2020,which aims to a growth and a development of the city which is: intelligent due to more effective investments in education, research and innovation; sustainable due to the decisive choice in favour of a low CO2 emissions; inclusive, that is supportive and focused on creating jobs and reducing poverty.

Urban regeneration should now tend to conjure ways to inhabit the city, of sustainability, of transformations in search of a higher level of intervention, technological and humanistic social circles powering up all the stairs of the city.

Contributes to the Roadmap

Urban regeneration should now tend to conjure ways to inhabit the city, of sustainability, of transformations in search of a higher level of intervention, technological and humanistic social circles powering up all the stairs of the city.

Open Issues

The project of urban renewal will be the instrument to build a different society, engaging in the fabric worn parts of the city started to lose a new meaning and a new force in the form of new citizens, new forms of employment opportunities, new links between people and the spaces that surround them.

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Learning from the interaction between earthquakes and vernacular architecture

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ABSTRACT

Learning from vernacular building cultures is not a "new idea": their evolution during centuries attests of it. Today, this learning process still represents a great potential to further strengthen the resilience of societies dealing with seismic hazard (Hofmann, 2015).

This paper briefly introduces a basic attitude for the investigation of the interaction between earthquakes and vernacular architecture. It focuses - as a case example - on the vernacular building type whose specific feature is to have wooden horizontal element integrated into load bearing masonry.

The global purpose is to underline the importance of collecting and assembling relevant data in relation to each particular vernacular building type. This is crucial not only for increasing the effectiveness of disaster risk reduction programs, but also in order to support ordinary architectural activities, in a convenient and apt way.

Keywords

Earthquakes, vernacular architecture, building type and sub-type, seismic damages, local resilient practices.

INTRODUCTION

A large part of ancient built environments in earthquake prone areas have been accomplished exclusively thanks to the experience that their builders developed over centuries of practice. Several of the resulting techniques - empirically developed using mainly natural materials - have showed a satisfactory performance during earthquakes (Langenbach, 2009; Schacher, Ali and Stephenson, 2010), attesting sometimes of risk cultures (Ferrigni, Helly, Mauro, Mendes Victor, Pierotti, Rideaud and Teves Costa, 2005; Caimi, 2014).

Nowadays, the seismic phenomenon is not systematically considered as a factor that might have been taken into account by ancient builders. A lack of knowledge about vernacular building cultures and their correlation with these phenomena increases the probability that interventions on ancient built stock and prevention activities do not take advantage of site potentialities, even enhancing its vulnerability.

BUILDING VARIABLES

Globally, vernacular architectures present a great heterogeneity in terms of techniques, materials and details; so, to understand their effective behaviour, it is essential to consider their seismic vulnerability using data related to the corresponding building type and sub-type.

Through the analysis of architectures of a specific type that are located in areas with different levels of seismicity (in terms of Severity and Recurrence), several building variables can be identified.

Referring to buildings with wooden horizontal elements integrated into load bearing masonry existing in diverse seismic regions along the North Anatolian Fault, the most evident variables are the building materials

(Figures 1a,b), the type of masonry bonding and the masonry units size at the corners; the form of the horizontal elements - ladder-like (Figures 1c) or planks (Figures 1d) - and their vertical position in the wall; as well as the type of joints binding them together longitudinally - nailed plain or half-lap scarf joints - and at the intersection of perpendicular walls - simple halved corner joint or with double dovetail.

Figure 1. a) Adobe masonry; b) Stone masonry; c) Ladder-shaped wooden elements; d) Planks. Credits: M. Hofmann

Starting from identified building variables, a building type can then be subdivided into various sub-types. For example, a particular sub-type of the building type considered here can be defined as follows: double-wall masonry bonds type made of rubble stone combined with ladder-shaped horizontal timber elements.

BUILDING VARIABLES & SEISMIC VULNERABILITY

Such an advanced categorization is particularly helpful for carrying out further detailed analysis, as well as for investigating a built environment after an earthquake. This latter activity plays a key role in understanding the influence that building variables have on the seismic performance of structures. During post-earthquake assessment, the features that are likely to increase or to reduce their vulnerability can be identified and then, critical factors related to each building variable can be examined.

Following this approach, a post earthquake investigation was performed in a Macedonian village in the North area of Ohrid Lake, situated 9 km away from the epicentre of a moderate 4.5 Magnitude earthquake that occurred the June 07, 2012 (hypocentre at 1 km depth).

In that occasion, the post seismic reconnaissance has led to some remarks about the influence of the vertical position of horizontal elements and the timber joint types. In some buildings, stones in the masonry walls have been overthrown due to out-of-plane movements (Figure 2a). This generally occurred in the higher parts of the constructions. This failure mechanism appears to be reduced when the height of masonry between the two upper horizontal timber elements is minor and if the roof rafters are imbedded between two horizontal timber elements situated at the top of the wall (Figure 2b). In some cases, a disconnection also occurred between horizontal timber elements. This happened mainly in the lower part of the building and in conjunction with weakened nailed plain or half-lap scarf joints. These connections lost their binding efficacy over time and were unable to support these new seismic forces: previous earthquakes, wood rotting, nails rusting can be considered as the major causes of this new state of vulnerability. Related to this specific seismic effect, it is interesting to record that in a particular case a masonry wall cracked vertically exactly where this type of disconnection occurred (Figure 2c).

Figure 2. a) & c) Seismic damages on two different buildings; b) Undamaged building. Credits: M. Hofmann

CONCLUSION

In general, highlighting the aspects influencing the vulnerability of vernacular architectures through the investigation of building types and their respective sub-types, and by combining data collected before and after earthquakes, has a dual interest. Firstly, it facilitates a structured identification of technical choices taken by the vernacular builders likely to be related to seismic risk. Secondly, it fosters a better understanding of the performance of each particular structure, allowing for more accurate hypotheses about their dynamic behaviour.

The resulting data are essential references for developing guidelines on critical points of each vernacular building type, taking also into account the differences that can exist between sub-types. Such guidelines can be particularly helpful either for ordinary architectural activities or for disaster risk reduction programs: a deeper knowledge of vernacular practices helps stakeholders to prevent natural (e.g. materials deterioration) and human (e.g. architectural modifications) phenomena that are the most susceptible to have a disruptive impact on the structural performance of existing built environment.

Thus, learning from the interaction between earthquakes and vernacular architectures represents a great potential for strengthening the resilience of contemporary societies, who have to deal with an important ancient building stock that has been shaped on the basis of a set of knowledge and know-how no more common nowadays.

Contributes to the Roadmap

- Documentation of <u>local building cultures</u> … for a meticulous understanding of the diffusion and evolution of vernacular practices;
- Investigation by <u>type and sub-type</u> … for a structured analysis of vernacular building generalities and particularities;
- Damages assessment after <u>moderate and frequent earthquakes</u> … for an accelerated comprehension of vernacular buildings seismic behaviour;

Open Issues

- In which way actual knowledge about <u>seismic behaviour</u> of vernacular architecture is shared between European concerned institutes? How this diffusion could be enhanced and expanded?
- In which way existing data on <u>seismic damages</u> occurred to vernacular architecture is shared between European concerned institutes? How the “learning from earthquakes” process could be more efficient and effective?

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Rapporteurs' Minutes

SAFESUST Workshop

A roadmap for the improvement of earthquake resistance and eco-efficiency of existing buildings and cities

Structures Session November 26th, 9:15

Keynote lecture: **HelenaGervásio** , University of Coimbra
Eco-structural efficiency in natural hazard events

Roberta Apostolska, Ss. Cyril and Methodius University, Skopje
The need of integrated renovation of the existing building stock in Macedonia

Alessandra Marini, Università degli Studi di Bergamo
Coupling energy refurbishment with structural strengthening in retrofit interventions

Elvira Romano, Università degli Studi di Napoli Federico II
Improving sustainability performances of existing buildings: a case study

Antonio Salzano, Università degli Studi di Salerno
Seismic retrofitting and new way of living in existing social housing settlements

Session Rapporteur **Paolo Riva**
Summary of selected presentations

REPORT edited by Paolo Riva

During the session the need of reconsidering structural and energy retrofitting under a sustainability point of view has been clearly affirmed. The main issues emerged in the structures sections may be summarized in the following points:

- quantify sustainability in both environmental and economic terms;
- life cycle thinking should be adopted to compare demolition and refurbishment;
- include robustness, resilience and sustainability in cost analysis;
- unsafe buildings should not be energy retrofitted: safety is a cost;
- design cost is a negligible part of the building cost, hence we need to invest in better design processes.

The overall Roadmap Contributions and Open Questions which emerged from the session are summarized in the following.

Contributions to Roadmap

- *Life Cycle Thinking*: for new constructions (buildings or portions of buildings), conduct a life-cycle assessment of the project's structure and enclosure that demonstrates a minimum of 10% reduction, compared with a baseline building. (…) No impact category assessed as part of the life-cycle assessment may increase by more than 5% compared with the baseline building.
- Appropriate institutional support (in the whole phase of renovation: preparation of technical documentation, obtaining the construction permits, construction etc.) is required.
- Networking of projects (finished/on-going) involving topics as eco-efficiency, smart renovation, low-carbon construction, sustainability etc. in order to profit from their gathered knowledge.
- *Environmental Sustainability* is only achieved if *Safety* is guaranteed.

- Interventions carried out from the outside should be pursued: improve feasibility, limit the impairment and cost.
- co-benefits of *Structural and Energetic Retrofit* may be: lengthening of the building service life, seismic resilience, long term protection of the investment, construction of upper storeys, reduced life cycle costs and minimization of the environmental impact over the building life cycle.
- Environmental impact associated to seismic risk can be high. The relevance of such a remark is emphasized when considering the district and city level, where the vulnerability of entire districts may jeopardize the effectiveness of extensive energy saving measures.
- The structural vulnerability of existing buildings, resulting in major damage or even collapse during a seismic event, affects the energy savings obtained with energy retrofit interventions, beside being a safety hazard.
- Depending on the site seismicity, the target of nearly-zero-energy buildings can only be achieved if the appropriate energy efficiency interventions are carried out on structurally safe constructions.
- Remarks on single buildings are even more critical when expanded at district and city level, where the vulnerability of entire districts may jeopardize the effectiveness of extensive energy saving measures.
- Earthquake performance of the buildings should be determined based on economic losses and casualties. For this purpose, loss functions should be identified. After seismic events, it is needed to establish recovery time, recovery functions, and desired level of functionality depending on type of structure.
- The legal frame for quality control and responsibilities systems in the field of construction must be improved. Investments in dynamic soil investigations (field and laboratory testing) are needed. Dedicated programs for earthquake disaster mitigation in Europe are needed.

Open Issues

- Investments in research in the field of integrated renovation of existing buildings are required (experimental verification of the proposed innovative methodologies/techniques/materials).
- Increase public awareness concerning both safety and energy issues, convincing of the necessity to live in safe and eco-efficient buildings.
- Financial, institutional and regulatory barriers are still present.
- Disregarding building structural vulnerability may result in erroneous expectations on the actual effect of extensive energy saving measures. The current way to assign national subsides for energy refurbishment should be changed.
- The influence of seismic risk is not actually included in the evaluation of environmental impact of existing buildings. Ways of including the seismic risk in life cycle assessment (LCA) and life cycle cost (LCC) procedures should be defined.
- Main parts of the resilience concept should be established clearly for quantification. Connections between community, building and cities should be discussed.
- The social cultural advantages or disadvantages of upgrading existing buildings over demolition need careful consideration, including discussion amongst involved parties on how aspects should be weighted. The comparison of upgrading versus demolition of the buildings (and creating new urban of rural housing) is an area in which stakeholders may have different opinions depending on their interests and point of view.

An overall summary of all presentations is given in the following.

KEYNOTE LECTURE

HELENA GERVASIO

Environmental criteria should be included into the design process of buildings in order to make a more efficient use of resources and to reduce the environmental burdens. About ¾ of all fatalities in earthquakes are due to building collapse;

Increased urban densification, rapidly expanding informal settlements leads to poorly designed and constructed buildings;

Earthquakes have major damage on the poorest populations;

Current technology and skills are able to dramatically reduce the number of fatalities and reduce the damage on the built environment;

The attitude towards the prevention of natural hazards should be proactive rather then reactive;

A stronger and more resilient built environment will enable to avoid the repetition of the catastrophic impacts of cyclic events leading to a more sustainable built environment.

Structural and Sustainability Design: Eco-Structural design

Ability of the structure to sustain functionality after disastrous impacts and timely return to normalcy

Rapid recovery of the building functionality after a catastrophic event (e.g. critical facilities and utility lifelines) is crucial for the minimization of damages.

LIFE CYCLE THINKING: For new construction (buildings or portions of buildings), conduct a life-cycle assessment of the project's structure and enclosure that demonstrates a minimum of 10% reduction, compared with a baseline building. (…) No impact category assessed as part of the life-cycle assessment may increase by more than 5% compared with the baseline building.

Seismic events often result in many fatalities and major damage on the economy and on the environment.

The robustness and resilience of structures is fundamental to enable a quicker recovering of society activities and thus minimizing the corresponding impacts.

Further research is needed so that innovative materials and structures will be developed, enabling to save more lives but simultaneously leading to lower environmental impacts.

Moreover, in order to ensure that future generations will be able to satisfy their own needs, the improved design of building should take due account of the environmental impacts caused by its construction, use and demolition

INVITED LECTURES

ROBERTA APOSTOLSKA

The National Status Quo Analysis (February, 2013) showed that around 70% of existing buildings in Macedonia are more than 25 years old with the high average specific energy consumption. The lack of National Regulations on energy performance of buildings in Macedonia has been an obstacle for the improvement of energy & eco-efficiency of buildings for many years, together with education for certification of energy controllers.

The "First Energy Efficiency Action Plan of the Republic of Macedonia by 2018" was developed pursuant to the Directive 2006/32/EC. These energy savings in residential sector by 2020 is expected to be achieved through enforcement of building energy codes (for new) and energy efficient retrofit of the existing buildings.

It can be concluded that in the Republic of Macedonia there is a long tradition and positive experience in the field of seismic design of new and strengthening of the existing buildings up to defined by code levels of seismic protection. However, this practice generally targets only one of the basic work requirements defined in CPD/CPR i.e. mechanical resistance and stability.

Starting from 2013, when the first national regulation for energy performance of the building was issued, there are some positive initiatives/examples at national and local scale. One of the unique case study who offers innovative technology for providing both, earthquake resistance and energy efficiency of the existing buildings, is System RÖFIX. However, it should be pointed out that this is not national brand and IZIIS served only as an experimental logistic for verification of this integrated method.

Contributions to Roadmap

Appropriate institutional support (in the whole phase of renovation: preparation of technical documentation, obtaining the construction permits, construction etc.)

Transfer of knowledge and best practices from the economies/regions who already set the roadmap

Networking of projects (finished/on-going) involving topics as eco-efficiency, smart renovation, low-carbon construction, sustainability etc. in order to profit from their gathered knowledge

Open Issues

Facilitation of research in the field of integrated renovation of existing buildings (experimental verification of the proposed innovative methodologies/techniques/materials)

Multidisciplinary education of the engineers who should deal with this integrated approaches – updating of high schools curricula and training

Increasing public awareness concerning energy issues and necessity to live in eco-efficient buildings

Financial, institutional and regulatory barriers

ALESSANDRA MARINI

Almost half of European Building stock; degraded suburbs; anonymous architectural features; low energy efficiency; living discomfort; poor structural performance; material decay and seismic vulnerability.

Is sustainability ensured? Energy Upgrade Only (*Not Sustainable*); Structural Strengthening Only (*Not Sustainable*); need for investing on integrated retrofit. Proposed Integrated approach: structural double skin.

Design should guarantee: easy maintenance, reparability after an earthquake; maximum flexibility and adaptability over time; fully demountable structures; easy integration of other components. Dry solutions, standardized connections, eco-compatible materials and recyclable devices should be preferably adopted.

Multi Criteria Performance Based Design: relevant performance design targets for the given building and the specific Seismic Hazard Level should be adopted.

Co-benefits of a Holistic Approach (structural double-skin, from outside): possible construction of upper storeys; protection of human life; resilience; long term protection of the investment; reduced life cycle costs; reduced impact on the environment associated to seismic risk; elongating service life; adaptive structure; maintenance.

Contributions to Roadmap

Environmental sustainability is only achieved if safety is guaranteed.

Intervention carried out from the outside: improve feasibility, limit the impairment and cost.

Design abaci could be developed under the Multi Criteria Performance-Based-Design.

Co-benefits such as the lengthening of the building service life, seismic resilience, long term protection of the investment, construction of upper storeys, reduced life cycle costs and minimization of the environmental impact over the building life cycle may be attained.

Environmental impact associated to seismic risk can be high. The relevance of such a remark is emphasized when considering the district and city level, where the vulnerability of entire districts may jeopardize the effectiveness of extensive energy saving measures.

Open Issues

The role of floor diaphragm action during seismic excitation is critical. Are the existing floors able to perform like in-plane diaphragms?

Disregarding building structural vulnerability may result in erroneous expectations on the actual effect of extensive energy saving measures. Should the current way to assign national subsides for energy refurbishment be changed?

ELVIRA ROMANO

Durability assessment considering quantitative approaches based on service life concept.

The challenge of sustainability of structures is to maximize the mechanical, durability, economic and environmental performance of a structure, during the whole life-cycle, reducing, at the same time, the adverse impacts played on planet, people and economy.

Integrated Approach:

- Multi Performance: Enhanced safety and reliability; Reduced environmental impacts; Optimized life-cycle costs
- Life-Cycle Oriented: The basic requirements shall be achieved during the whole life-cycle of the construction
- Quantitative Methodologies: Performance requirements shall be verified according to quantitative methodologies

Deep renovation of existing buildings is a European high-priority issue to achieve in order to make cities safer and sustainable

Focusing on the Italian context, pre-1970 reinforced concrete residential building show an inadequate structural response particularly in relation to seismic loads, thus retrofit interventions are urgently needed.

An integrated approach is recommended, so a potential integrated life-cycle multi-performance based design and/or assessment methodology has been briefly discussed.

A case study which refers to a non-seismic resistant structure in Naples has been analyzed and two seismic retrofit interventions have been considered: a reinforced concrete jacketing and a base isolation solution.

ANTONIO SALZANO

An example of intervention using Steel Shear Panels and new sandwich thermically efficient curtain walls is shown.

PAOLO RIVA REVIEW AND SELECTED PAPERS

Research Objectives at Community Level: Lower impact on the environment; Reduced energy consumptions, raw material extraction, and waste production; Safe environment.

Safety: 40% of the existing buildings exhausted their *Structural Service Life*

Vision: Energy retrofit, high energy efficiency, reduced CO2 emissions, (European targets), + structural safety.

Challenge: to achieve some results, building owners must share this vision and must be convinced that an immediate and widespread intervention is needed.

Research Objectives at Individual Level: living comfort (architectural and urban retrofit); safety feeling (structural and seismic retrofit); money saving (energy and structural retrofit).

Demolition and Reconstruction as well as Energy Retrofit alone: not compatible with community and individual objectives.

Integrated structural and energetic double-skin solutions: compatible with both community and individual objectives.

BARRIERS: To achieve some results, building owners and public investors must be convinced that an immediate and widespread intervention is needed.

BELLERI AND MARINI

It is possible to follow a probabilistic framework to assess the environmental impact associated to seismic damage. The evaluation has been carried out in terms of expected losses (carbon footprint, energy savings…). The embodied carbon associated to repair measures required after an earthquake could be as high as the operational carbon.

Contributions to Roadmap

The structural vulnerability of existing buildings, resulting in major damage or even collapse during a seismic event, affects the energy savings obtained with energy retrofit interventions, beside being a safety hazard.

Depending on the site seismicity, the target of nearly-zero-energy buildings can only be achieved if the appropriate energy efficiency interventions are carried out on structurally safe constructions.

Remarks on single buildings are even more critical when expanded at district and city level, where the vulnerability of entire districts may jeopardise the effectiveness of extensive energy saving measures.

Open Issues

The influence of seismic risk is not actually included in the evaluation of environmental impact of existing buildings. How could the seismic risk be included in life cycle assessment (LCA) and life cycle cost (LCC) procedures?

Disregarding seismic risk may result in erroneous expectations on the actual effect of extensive energy saving measures. Should the current way to assign national subsides for energy refurbishment be changed?

BOZDAĞ AND SEÇER

Seismic Resilience and the main issues concerning its evaluation should be considered in the design process, earthquake performance of the buildings should be defined based on economic losses and casualties. For this purpose, loss functions should be identified.

Structural designs that provide minimizing the disruption and cost of repairs following major earthquakes are required. Hence, damage control in the design rather than life loss prevention should be considered. This way, economic impacts due to earthquake damages can be reduced to an acceptable level.

Limit state cost functions is affirmed as an important part of the life cycle cost. The term limit state cost functions consists of potential damage cost from earthquakes which may occur during the lifespan of the building. The limit state dependent cost functions mainly consists of damage cost, loss of contents, relocation cost, economic loss, which is the sum of rental and income loss, cost of injury, and cost of human fatality, and other direct or indirect economic losses.

Contributions to Roadmap

Earthquake performance of the buildings should be determined based on economic losses and casualties. For this purpose, loss functions should be identified. After seismic events, it is needed to establish recovery time, recovery functions, and desired level of functionality depending on type of structure.

A methodology is outlined for determining earthquake damage cost of a steel building during the planning phase accounting for performance based design procedures. The outcomes of the analyses are easy to be understood, when the reliability and performance of a building is indicated in economic terms.

Open Issues

Main parts of the resilience concept should be established clearly for quantification. Connections between community, building and cities should be discussed.

The value and effectiveness of the methodology should be judged in the context of how efficiently it manages direct losses and improve seismic resilience. Likewise, cost components other than the earthquake damage cost should be evaluated and their effects on total life cycle cost should be reported

BLOK AND TEUFFEL

Rehabilitation of Masonry Buildings in the Netherland (Groningen), where fracking is becoming a concern, is nowadays required.

As a result, seismic upgrading of buildings through isolation using triple sliding friction pendulum bearing system and improvement in term of energy upgrading by means of thermal isolation of the ground floor is proposed.

Contributions to Roadmap

Further development of the proposed seismic isolation method for the existing masonry houses in Groningen/NL clearly contributes to the main goals and the proposed roadmap for the resilient transformation of the existing building stock. It involves and considers occupants safety in this area with increased seismic hazard, it provides solutions honoring architectural/heritage value. Further development is needed, but by combining the seismic retrofit with thermal insulation, the retrofit approach clearly has an economic rationale. It thus contributes to improving overall energy and functional (comfort) performance.

Open Issues

The economic feasibility of the proposed methodology would involve test designs on existing buildings including construction detailing, and solving the logistics of the construction process, and thus optimizing the involved cost aspects. Estimation of the changed thermal energy behavior by the insulated ground floor can provide more insight in the advantages of this approach in terms of financial and sustainability energy gains.

The social cultural advantages or disadvantages of upgrading the existing buildings over demolition need careful consideration, including discussion amongst involved parties on how aspects should be weighted. The comparison of upgrading versus demolition of the buildings (and creating new urban of rural housing) is an area in which stakeholders may have dfferent opinions depending on their interests and point of view.

ZAO AND MU

A new type of energy efficient structural system applying multi-layer sandwich wall panel having both structural and insulating function is described.

The panel is composed of five layers, while both outer layers serve as formwork during the construction and as support for the external finishing. The center core is made of a precast foam concrete slab which significantly reduces energy loss. The remaining part of the wall panel is cast in place using fine aggregate concrete, wire mesh and restrained at the panel ends by small reinforced columns.

According to the experimental results and theoretical analyses, the multi-layer sandwich wall panel has quite good ductility and may be used in earthquake prone areas.

CRISTIAN

Is Europe prepared to solve the seismic risk problem? How far are we from reaching Japan or Chile's resilience? These are two questions with possible solutions not only from Brussels politicians, but also from scientific communities.

The developer, the structural engineer, the construction company and the official from the city hall, who make the verifications, have to be life responsible for the quality of their product.

Difference between GSHAP and SHARE (2014) map are shown. It is observed that SHARE map is referenced to rock soil, whereas actual hazard may be sensibly different. This might be misleading. The proposal to use the results from SHARE research project in the future hazard maps of EUROCODE 8 without any verification, discussion at national level is maybe the easy way to show to the European Commission the use of the output.

Contributions to Roadmap

The legal frame for quality control and responsibilities systems in the field of construction must be improved. Investments in dynamic soil investigations (field and laboratory testing) are needed. Dedicated programs for earthquake disaster mitigation in Europe are needed.

Open Issues

If no actions will be taken by all partners (policy makers, European Council, scientist) the proposed alternative might be found in rural huts. The construction is resilient to earthquakes and eco efficient. It is not used anymore in Romania but it can be alternative...

SAFESUST Workshop

A roadmap for the improvement of earthquake resistance

and eco-efficiency of existing buildings and cities

Energy Session November 26th, 11:30

Keynote lecture: **Alexandra Troi**

Transforming of existing buildings balancing energy, comfort and heritage value

Jesús García Domínguez – ACCIONA Infraestructuras S.A.

BREakthrough Solutions for Adaptable Envelopes in building Refurbishments+

Stefano Prosseda – TIS innovation park

Lime plastering systems for energy-efficient and seismic retrofitting

Francesca Guidolin – Università Iuav di Venezia

Taxonomy of the redevelopment methods for non-listed architecture:

from façade refurbishment to the "exoskeleton system"

Valentina Puglisi – Politecnico di Milano

A new model to evaluate the performance of the building envelope

Session Rapporteur **Roberto Lollini***: Conclusions and final remarks*

REPORT edited by Roberto Lollini

Thanks to the contributions by Energy session participants

9.12.2015

Context about energy and buildings

The high housing demand, low cost of energy and insufficient attention to sustainability and resilience, brought to poor architecture and engineering solutions for building. Energy consumption in building sector became important after the energy crisis in the 70s. The running passive house standard includes among the several requirements that Primary Energy Demand, the total energy to be used for all domestic applications (heating, hot water and domestic electricity), must not exceed 120 kWh per square meter of treated floor area per year. In the meanwhile EU issued a directive on energy performance in buildings: 2002/91, re-casted as 2010/31, and currently under another revision process. The re-cast version 2010/31 introduced the concept of nearly zero energy, moving building from energy consumer to energy producer thanks to RES exploitation on the building itself or in the nearby.

Lately scientific world have just started to face energy flexibility of building (e.g. http://www.iea-ebc.org/projects/ongoing-projects/ebc-annex-67/), that is the capacity of a building to react to dynamic loads interacting at best with the energy grids to keep comfort and low energy consumption when in a changing context.

Nevertheless, it is still missing a strong top-down support on building resilience, evaluating possible synergies among different physics and requalification technologies, as well as exploiting potential co-benefits to optimize the building stock renovation costs.

Starting from such a context for contributing to enforce a strategy for the improvement of earthquake resistance and eco-efficiency, in the energy session arose three main topics:

1. Development of multi-functional technology approach
2. Definition of integrated process
3. Identification of a specific economic rationale

In the following the main outcomes of the session, also considering the final round table and energy related discussion in other sessions, organized in the three above mentioned topics.

<u>Multi-functional technologies</u>

- Use already available technologies for energy efficiency and seismic adjustment, solving issues related to the physics coupling with a comprehensive renovation approach.
- New features to be considered in envelope energy retrofitting solutions: adjustable, adaptable, active easy to install, easy to maintain, standard anchoring. Standard but also <u>customizable</u>: each innovation product may consider also the process innovation, in order to allow the maximum of the spread.
- New skills needed for stakeholders (designers, manufacturers, general contractors, installers): system integration.
- Novel “SafeSust” solutions need (i) taxonomy/semantic/metrics, (ii) assessment framework, considering effects at building and urban scale
- “SafeSust” solutions need Inclusive technology development driven by integrated performances
- It would be necessary an extensive evaluation of status of existing infrastructures: building and district, as well as a parametric analysis of urban features, to understand if energy efficiency is safely sustainable.
- “SafeSust” solutions need smart Building Energy Management System to monitor/handle/hide complexity

e.g.: “exo-skeleton system” allows to improve: (i) safety (ii) energy efficiency (iii) architecture (in general it can imply a global perspective of different technology elements, energy systems, structural improvement, inclusive design tools.)

Processes/methods

- It is needed auditing/monitoring protocol to be applied before and after renovation.
- “SafeSust” solutions effectiveness depends on the boundary conditions. General approach and parametric model of building and “SafeSust” solution would be used for driven innovation, while dedicated auditing would provide the base to fix design and implementation issues of specific renovation action.
- Renovation design and implementation time must be reduced. The main answer to that challenge seems to be the standardization and industrialization of the renovation process.
- Social/human factor it very important: stakeholders must be motivated towards the renovation challenge. The study of an appropriate communicative strategies and processes (a communication tool?) can facilitate the transmission of the benefits of this issues.
- “SafeSust” solutions need inclusive and participative renovation process to solve “conflict” at the early design stages (solution concept development)
- “SafeSust” solutions need two sides approach:
    - ✓ Top-down: regulation to ensure safety
    - ✓ Bottom-up: convince investors and users

Economic rationale

- Energy saving can “finance” structural improvement.
- Business model in life cycle prospective:
    - ✓ need of reliable quantitative numbers for decision makers
(single owner or policy maker)
    - ✓ need of system integrator as advisory in the “SafeSust” renovation process? (that is an usual approach in façade development)
    - ✓ “SafeSust” approach means long term protection of investment
    - ✓ “SafeSust” solutions LCC must include embodied costs (costs of possible recovery after an earthquake)
- A comprehensive LCC must be able to consider the economic value of renovation "side effects” in the whole building time frame.
- “SafeSust” solutions need to make explicit the risks of innovative approach/solutions in the value chain and new sharing/distribution of responsibilities
- “SafeSust” solutions need specific market analysis: stakeholders (clients, skilled advisors, …), data and information flows

For a practical and quantitative analysis, as well as support of the renovation design, implementation and maintenance it is important to fix a set of Key Performance Indicators and performance benchmarks.

Key Performance Indicators

Comprehensive approach need specific KPIs. For building facade, the main building component connected to both energy efficiency and safety, the standard reference is EN 13380.

Requirements categories under EU Regulation 305/2011	**Requirements implementation for curtain wall CE marking under EN13830**		
Mechanical resistance and stability	Resistance to wind load, Resistance against impact, Thermal shock resistance, Resistance to live horizontal loads	Safety	Sustainability
Safety in case of fire	Reaction to fire, Fire resistance and Fire propagation		
Safety and accessibility in use	Seismic resistance: performance before and after the event		
Hygiene, health and the environment	Water tightness, Water vapour permeability, Air permeability	Healthy	
Protection against noise	Airborne sound insulation		
Energy economy and heat retention	Thermal transmittance, Air permeability	Efficiency	
Sustainable use of natural resources	Durability		

Resilience, social impact (accessibility and inclusive design) and heritage value are example of thematic which would need indicators to be added to the ones already in EN 13380 (e.g. the housing program "Piano Casa" in Veneto region allows to increment the building volume of 20% for renovation action aimed at the building accessibility improvement, which is more than what allowed with energy efficiency retrofitting).

Finally in the following specific inputs for the roadmap and open points that could be the basis for a possible research strategic agenda.

Contribution to the roadmap

- Turn the building envelope into an active element rather than a passive, meeting more functions than just the separation of the outer space from the interior with insulation. On the other hand, it is conceived to accommodate further modifications enabling also to adapt to a dynamic environment and to building occupant's requirements during its lifetime.
- Construction materials for combined structural and thermal performances to promote a growth in seismic and energy-efficient renovation, due to simplified and potentially more cost-effective renovation works.
- Method based on small and rapid R&D optimization steps can activate motivated SMEs to invest in quick adaptation and optimization of their actual products. This will reduce time-to-market cycles and involve SMEs (and not just large enterprises) in more effective market-driven research activities. Methods for activation and increase of SMEs research activities, such as "Under

construction" which supported this work, are an effective mean of driving a realistic market and technical change.

- A new strategy for EU building stock renovation could be called "integrated requalification", allowing to perform comprehensive action on existing building. The introduction of "integrated requalification" would allow the development of solution-sets including energy and structural adjustments, as well as functional and architectonic upgrades, to allow a better accessibility and usability of the building. The comprehensive action can also improve the costs-benefits ratio increasing the building value on the market.
- It is important to provide strategies for requalification not only in terms of technical solutions but also facing urban and social issues.
- Technological systems such as the "exo-skeleton" that allows energy requalification avoiding the interruption of fruition and activities and so avoiding construction site extra cost should be further promote.
- Communication strategies for participatory energy efficiency projects management.
- *"Exo-skeleton system"*[1] is a declination of socio-technical device for envelopes, since it is not only a technical artefact for the physical regeneration, but also a social device, capable of triggering integrated and sustainable mechanisms, also in terms of user management.
- Building cluster (large scale) approach to achieve energy balance targets (need information, social and personal motivation), but ensuring "good building physics" and IEQ

Open points

- Sizing of the structural elements that must support the external claddings to the existing envelope and resist the different loads, and must provide an alignment of the different claddings ensuring a good aesthetics from the architectural point of view.
- Design, implementation and maintenance of envelope with added functions, such as energy production, with the Integration of the PV modules or solar collector, or air exchange with distributed ventilation machines.
- Simultaneous improvement of mechanical and thermal properties is known to be difficult, because both properties are affected by the same material characteristics. The question need coupled physics modelling approach.
- Need of communication strategies for participatory site management.
- Need of reliable business models (performances, costs, stakeholders) with clear risks assessment and responsibilities.
- Rating and labelling systems: do we need them?
- Strategy for development of benchmark coming from actual measurement.
- Role of facility management and continuous commissioning approach to promote "SafeSust" renovation

1 For the definition "exoskeleton system" F.Guidolin, "*Taxonomy of the redevelopment methods for non-listed architecture: from façade refurbishment to the "exoskeleton system"*".

- LCA must be increasingly used to take decisions related to seismic and energy retrofitting operations: how to make it more accessible to SMEs and with reduced analysis time effort?
- Cost-effectiveness of energy/structural renovation (e.g. can energy saving pay for seismic adjustment?)
- How to manage multi-disciplinary approach?
- How to improve also comfort and indoor environmental quality, while performing seismic and energy renovation, in order to get more customer acceptance for the related investments?
- A combined seismic and energy retrofitting requires complex construction processes: how to improve the robustness, performance and delivery time of construction works? How to improve the basic process knowledge to properly install renovation systems?
- Is there room to convince private investors to perform “SafeSust” renovation or is it possible only with public subsidies?
- Have all possible communication tools already explored in order to facilitate the requalification decisions and management?

EU policy promotes sustainable, secure and affordable energy for Europeans buildings and cities. “SafeSust” can be the right approach to face such multidisciplinary challenges.

EC ISPRA WORKSHP SUMMARY AND SUSTAINABILITY DESIGN OF STRUCTURES

Koji Sakai

The Japan Sustainability Institute, JAPAN

INTRODUCTION

The global population now exceeds seven billion. This means that during the past 250 years or so, it has increased tenfold that of the Industrial Revolution in the mid-18th century, which is believed to have been 700 million. Eighty percent of the global population live in developing regions, which means that the consumption of resources and energy will increase enormously in the future. Resources and energy are one of the most fundamental elements for the daily life of humankind. In recent years, it has been recognized that increasing fossil energy consumption could even change the global climate. It is anticipated that global warming will cause extremely serious problems in the future, in fact, climate change driven by global warming has already increased the intensity and frequency of weather action such as typhoons/hurricanes and torrential rainfall, causing enormous damage (IPCC: The frequency or intensity of heavy precipitation events has likely increased in North America and Europe).

On the other hand, developed countries, such as EU states and Japan, have accumulated a huge amount of infrastructure and building over a long time. It means that these structures have to be properly maintained by taking cost, natural resources consumption, and more severe loading and environment into consideration. In other words, it is very important how to incorporate "sustainability" concept into construction industry.

Under such a circumstance, the EC Joint Research Centre organized SAFESUS Workshop to discuss "a roadmap for improvement of earthquake resistance and eco-efficiency of existing buildings and cities" In Ispra during November 26-27, 2015. This report summarizes in particular the material session of the workshop. The author proposed a sustainability design of a structure from the cross-disciplinary viewpoint as the materials session rapporteur. It is also described in this summary for the future of construction industry.

SUMMARY ON MATERIALS SESSION PRESENTATIONS IN SAFESUST

The main materials for the construction of a structure include concrete, steel, and wood. Each material has its advantage and disadvantage in use circumstances. Concrete is the most used material in the Earth. This comes from the fact that its constituents are abundant. The weakest part of concrete is cracking due to various reasons. Therefore, one of the most important aspects is the control of cracking. In addition, recycling of concrete is also a significant issue to be solved. Recently, sustainability assessment is becoming more and more important. Especially, the assessment for structural retrofit is hardly conducted. We need to established a comprehensive criteria on whether or not a structure has to be used further. Steel structures have been constructed depending on the cost and construction term. There is still a competition between concrete and steel for a structure. Wood structure is very popular especially in one- or two-story houses. Recently, however, much effort is being made to use wood for multi-story buildings with laminated lumber.

Nemkumar Banthia gave a keynote lecture entitled “Smart city dream through engineered high performance materials. His topics were the effect of global climate change on concrete, ultra-high performance fibre-reinforced concrete (UHPFRC) and its applications, and structural health monitoring. The increase of CO_2 concentration and temperature will accelerate the carbonation of concrete. UHPFRC is effective against CO_2, but normally its production emits a lot of CO_2. It seems that without considering sustainability aspects comprehensively, its application will not make generalization. In addition, we may have to consider the reason why the fibre-reinforced concrete has not become widely used. The structural health monitoring is important from the difficulty in the renewal of deteriorated concrete structures due to the financial problem of owners. The sustainability assessment may help to take a proper judgement on how to deal with such structures.

Takafumi Noguchi discussed the sustainable recycling of concrete with environmental impact minimization. Firstly, he outlined the history of quality requirements for recycled concrete aggregate in Japan and introduced the framework of “guideline for mix design, production and construction practice of concrete with recycled concrete aggregate” by the Architectural Institute of Japan in 2014. Secondly, he showed some concrete recycling technologies developed by his research group, including cement recovery-type CRC (Completely recyclable concrete) and aggregate recovery-type CRC. The former is concrete in which materials are entirely usable after hardening as materials of cement. The latter is concrete in which the aggregate surfaces are modified without excessively reducing the mechanical properties of the concrete. The combination of heating by microwave radiation and crushing produces more good recycled aggregates than usual technologies. CO_2 emission is also smaller. The application of recycled aggregates has not been generalized due to the quality of aggregates and also its cost. A proper system for using recycled aggregates is also needed.

Petr Hajek discussed sustainable concrete structures which contribute to the development of a sustainable built environment. Especially, he focussed on the advantages of concrete structures on the advantages of concrete structures from the viewpoints of sustainability like 1) thermal mass, 2) acoustic properties, 3) fire resistance, 4) long-term durability, 5) use of by-products, and 6) structural safety. The thermal mass can contribute to energy savings for cooling and heating. Other advantages are well-known. These advantages are classified into economic, environmental and social aspects, which are the three pillars of sustainability. He emphasized two principle sustainability goals, including the reduction of non-renewable raw material consumption and the increase of performance quality. In addition, LCA to assess the sustainable performance of concrete and concrete structures is needed. ISO and CEN are developing usable standards for that. It seems that the importance of LCA is recognized gradually. However, to accelerate such movements, the owners and users of structures need to require sustainability at the beginning of the projects.

Constantino Menna described the LCA-based sustainability assessment approach applied to structural retrofit of building, in which the environmental impacts of different roof replacement options and structural strengthening on masonry walls were assessed. The roof replacement options are RC, steel, and PC flat roof. The minimum CO_2 and primary resources are RC flat roof. The environmental impacts by the shear strengthening of brick wall with local replacement of damaged masonry, mortar injection, steel chain installation, and glass reinforced mortar were also assessed. The impact categories considered are global warming, ozone depletion, eutrophication, acidification, photochemical oxidation, and nonrenewal energy. It seemed that glass reinforced mortar was a good selection as the whole. This work is very valuable in showing the best option of environmental impacts. However, the cost and other aspects should also be investigated. Thus, the sustainability assessment of existing buildings is complicated.

Liberato Ferrara introduced the five-year research results on self-healing cement based construction materials to add a new value for sustainable concrete. The project focuses on both experimental characterization and numerical predictive modelling of the self-healing capacity of a broad category of cementitious composites, ranging from normal strength concrete to high performance cementitious composites reinforced with different kinds of steel and natural fibres. The self-healing has two mechanisms: "autogenic" and "engineered." The self-healing engineered techniques include tailored admixtures, embedded functional elements, and other. It seems that all have some self-healing capacity. The numerical modelling of self-healing may be possible. However, more work will be necessary to ensure whether or not we can incorporate it into concrete in actuality.

It can be concluded that the keynote and selected presentations provide significant aspects in which there is a common recognition that we need to change the existing concrete technologies and systems.

A NEW PRINCIPLE FOR GLOBAL SUSTAINABILITY

Considering the difference of the socioeconomic situation in each country, adopting the new idea of a double standard is unavoidable in order to achieve global sustainability. For developed countries, a drastic reduction of energy/resource consumption should be made obligatory, and for developing countries, the introduction of cutting-edge technologies/systems should be established as a principle, while allowing them to increase their energy/resource consumption. Ideally, the reduced amount of energy/resource consumption by developed countries should exceed the increased amount of energy/resource consumption by developing countries.

Despite some fluctuation resulting from the economic situation or price of crude oil, their overall energy/resource consumption in developed countries has more or less reached a ceiling and there is no way that it will show a rise like that of developing countries in the future. Developed countries will therefore need to focus on steering towards policies which dramatically enhance energy and resource efficiency. Further, they should promote technology transfer to developing countries, provided however that such transfer is based on the obligation to pay an appropriate remuneration on the part of developing countries. In fact, it is only natural that developing countries should also bear a reasonable cost as it is for their own survival. A Sustainable Earth will not be realized unless we make these principles clear, thereby promoting the renovation of individual industries.

SUSTAINABLE CONCRETE CONSTRUCTION

In contemporary society, elements that create convenience and amenity can be broadly divided into three categories. These are electrical appliances, automobiles and infrastructure and buildings. For electrical appliances, there is a dizzying pace of advance in energy-saving technology such as LED lighting and LCD televisions. In the automotive sector too, the use of hybrid cars is spreading rapidly, and it is highly likely that hydrogen vehicles will also come into general use in the future.

Infrastructure and buildings, meanwhile, play a very important role as elements of the socioeconomic foundation. However, development of infrastructure and buildings has a positive side in terms of promoting socioeconomic activity, but also a negative side in terms of the associated increase in environmental load. As part of economic activity, there is a natural limit to material consumption once demand has reached a mature level. In contrast, the increase in human movement is causing an increase in the resources and energy used for transport. In recent times, there has been a marked improvement in the fuel efficiency of aircraft.

Against this background, what progress has been made regarding resource and energy consumption in the construction and utilization of infrastructure and buildings? In the construction of infrastructure and buildings, concrete, steel and wood are used as the main materials. Wood is used primarily for the structural members of low-rise residential buildings and for the non-structural members of steel-reinforced concrete and steel structures, and will therefore not concern us any further in this discussion. We often hear calls for the use of wood to be increased, but in terms of its performance, resource reproducibility, and its role as a CO_2 sink, it can in no way substitute for concrete and steel. The proportion of urban dwellers in the populations of Europe, North America and other developed regions is around 75%. The corresponding figure for Asia is currently below 50%, but is expected to reach the level of developed countries in the future. This is another viewpoint suggesting that the use of wood as an architectural material will decrease.

Worldwide production of raw steel rose from 1.06 billion tons in 2004 to 1.65 billion tons in 2013, an increase of more than 50% in ten years. The proportion of raw steel production used by the construction industry in Japan is thought to be around 30 to 40%. If the same applies worldwide, then raw steel production volume for construction purposes would be around 500 to 660 million tons in 2013. Meanwhile, worldwide cement production doubled from 2.11 billion tons in 2004 to 4.0 billion tons in 2013. Of these 4.0 billion tons, China accounts for 58.6%, India 7%, Japan 1.5%, and other Asian countries 12.2%. This means that Asia actually produces 80% of the world’s cement and accounts for approximately 60% of the world’s population, while Africa accounts for only 15%.

Based on these basic data, the issue of sustainability in the concrete and construction sector is discussed below. Given the state of infrastructural and architectural development in Asia, a direct reduction in cement production would be difficult to achieve in the near future. Therefore, it is necessary to reduce environmental load by using current technology as efficiently as possible. Below are listed some potential methods for achieving this.

(1) Lower CO_2 emissions levels in cement production to the level of Japan and other developed countries.
(2) Optimize the use of fly ash and blast furnace slag as replacements for cement.
(3) Use a high-performance water-reducing agent to reduce the amount of cement used.
(4) Reduce the energy consumption required through improvement of construction efficiency.
(5) Introduce high-performance concrete with high strength and durability to boost the strength of structural members, thereby reducing their size.

(6) Introduce technology to minimize energy consumption during the use of a building.
(7) Introduce ultra-high strength concrete to promote more advanced structural styles.
(8) Use CO_2-absorbing concrete.
(9) Implement optimal maintenance.

For quantitative evaluation of the effect of these measures, objective rules are needed, for which the ISO13315 series of standards are useful. The comprehensive evaluation systems LEED and CASBEE are also effective, but they have disadvantages in that their evaluation items vary widely, so that individual effects are not readily apparent, and the priority of environmental load reduction is not made clear.

Much of the environmental burden reduction in the items above relates to reduction of resource and energy consumption, but sustainability seeks the optimal balance between environmental, social and economic needs. In terms of the social aspect, it should include the impact generated in the case that safety and use of structures are jeopardized. So, where safety is concerned, the extent of assured safety margin is important, while as for use, limitations on the use of structures due to their deterioration could lead to major social loss. In this way, taking account of sustainability in ~~the~~ construction involves the actual design system itself. This has to be considered separately from the sustainability of the construction sector. In other words, sustainability ~~in~~ of the construction sector is essential to the sustainability of society. These interdependent relationships are crucially important, and if they do not function appropriately, society will collapse.

In the construction of a structure, the relationships between safety, the environment and cost are complex. If the safety margin is minimized, environmental burden and cost can generally be reduced. However, when we consider the uncertain nature of external actions and the materials and structures selected which determine safety, it is desirable to allow the greatest margin possible. Whether the additional environmental burden and cost associated with such increased safety margin is acceptable, depends on the judgment of the stakeholders involved. But ideally, it would be best if we could increase the safety margin while reducing the environmental burden and cost. This is not an easy path to follow, but through technological innovation, it should be the ultimate goal of the construction sector. A major task going forward will be to establish sustainability design that allows us to holistically deal with these issues.

In order to take account of sustainability in the design of concrete structures, it should be possible to set sustainability as a performance requirement in design standards. The first such standards to be introduced were embodied in the fib Model Code 2010 issued in 2013. This code includes safety, serviceability and sustainability as performance requirements. Under sustainability, CO_2 and a wide range of other environmental impact items are considered alongside social impacts such as landscape.

In 2014, the American Concrete Institute (ACI) allowed the setting of sustainability as a performance requirement in its Building Code Requirements for Structural Concrete, provided however, it was limited to technology professionals qualified in the field of sustainability who could set such performance requirements. In this way, sustainability has become integrated in the standards of world-leading academic societies. From now on, these are likely to become the norm in the design of concrete structures.

SUSTAINABILITY DESIGN OF CONCRETE STRUCTURE

The sustainability design of a structure is a system that considers the social aspects of safety and serviceability, the economic aspect of cost, and the environmental aspects of resources and energy, in a comprehensive fashion. To this end, it is necessary to place the sustainability of all humanity, regions and the globe as of the utmost importance, and to make the evaluation index appropriately selectable in order to judge the balance between society, the economy and the environment.

The construction costs and environmental burden of a structure can only be determined once the structural style, the materials, and the construction methods have been decided. The design procedure should therefore start by identifying the external forces and making a provisional selection regarding the materials and structural style to be used.

Outlined below is the procedure for sustainability design. For the sake of simplicity, the parameters have been restricted to the social aspect of safety, the economic aspect of cost, and the environmental aspect of energy and resource consumption and CO_2 pollution. Other items are basically the same, or can be regarded as additional study items. A composite aspect can also be set by combining all these aspects.

(1) Collect and organize basic information for construction project implementation
- Social aspect
- Economic aspect
- Environmental aspect
- Composite aspect (increase in energy/resource consumption and cost relative to safety enhancement; CO_2 emissions relative to concrete strength)

(2) Set performance requirements concerning society, economy and environment from the above information (1) based on comprehensive assessment. Example settings are shown as follows;
- Social aspect: Set assumed load regarding safety and serviceability performance. (Durability performance is a precondition for safety and serviceability performance)
- Economic aspect: Set standard cost regarding economic performance, but the final decision should be made with reference to safety and environmental benefit.
- Environmental aspect: Set reduction targets for energy/resource consumption and CO_2 emissions regarding environmental performance, but the final decision should be made with reference to safety and cost and based on lifecycle performance. In terms of environmental impact, not only the burden, but also the improving effect should be considered appropriately.
- Composite evaluation: Set the numerical targets for the adopted evaluation index.

(3) Select structural style, cross-sectional dimensions of members and reinforcement, materials, concrete mix, and construction methods, based on the above performances requirements (2).

(4) Implement verification of safety and serviceability, and examine effect of safety margin γ_i, based on the above (3). As γ_i is involved in comprehensive evaluation of sustainability, it is called the ‘sustainability coefficient’.

(5) Calculate economic performance and environmental performances within the range of γ_i to be considered, and verify with reference to performance requirements. Regarding economic and environmental performances, include those of the construction stage. If necessary, consider also the utilization stage and the final stage.

(6) Make comprehensive assessment of the verification results concerning the safety, serviceability, and economic and environmental aspects. Re-examine, returning to (3) above as necessary, and in some cases to (2) above.
(7) Report the following items concerning the above assessment;
  ・Sustainability coefficient as margin
  ・Standard cost and final cost (amount of reduction or increase, reasons for permitting cost increase, etc.)
  ・Environmental impact (amount of energy and resources used, extent of environmental burden reduction (CO_2, etc.), and reasons for permitting environmental burden increase, etc.)

CONCLUDING REMARKS

Global problems, in essence, come down to rapid population growth leading to resource and energy consumption, and the resulting environmental contamination. Global warming occurs because humankind has re-released into the atmosphere CO_2, which had been immobilized in the Earth at the time of its formation. As the development of science and engineering brings improvements in the human residential and nutritional environment, the population grows. Humankind is now entering uncharted territory. The global system that operates on the premise of economic expansion based on growth in resource and energy consumption will sooner or later collapse.

The construction sector is the industry that builds the residential environment and the socioeconomic foundation, and consumes large amounts of resources and energy as a result. At the same time, it is the industry that creates the physical environment in which humans can live in safety and amenity and engage in societal activity. That does not however mean that the construction sector should be exempted from responsibility for its environmental burden, and needless to say, it must make utmost efforts to reduce it, like all other industries.

However, the construction industry as a whole has little interest in these realities. The major reason is that the conventional construction industry is based on low technology and the equipment used for construction is made by other industries. In other words, we are the users of things developed through the efforts of other industries. However, we still have plenty of things to think about; how efficiently we can use such equipment, what we need specifically, and what is required for ingenuity and innovation concerning materials and structural design. In order to achieve innovation for the reduction of environmental burden, it is also necessary to ascertain current hindrances. We also have to draw up basic rules to comprehend these tasks. Thus, the concrete and construction sector has a vast amount of work to do. It should not simply be an industry that enjoys the fruit grown by others.

It is the time for concrete and construction industries have to change by altering the existing technologies and systems. It is hoped that the EC Joint Research Centre can play an important role for that.

SAFESUST Workshop

A roadmap for the improvement of earthquake resistance

and eco-efficiency of existing buildings and cities

Financial Session November 26th, 16:45

Keynote lecture: **Oliver Rapf**

Investing in buildings efficiency - challenges and opportunities

David Christmann – PATRIZIA Immobilien AG

The tension between competition and regulation on European real estate markets

Alessio Rimoldi – BIBM, European Federation for Precast Concrete / The Concrete Initiative

An extended financial dimension of sustainability

Nelson Silva Brito – University of Coimbra / modular / ICOMOS ISCES

Common Efficacy: from what we "have and know" to what we "need and expect"

Giampiero Bambagioni – European Real Estate Institute

European existing buildings heritage: financial aspect and evaluation of cost-benefit related to lifecycle and performance

Stefano Bellintani – Politecnico di Milano

Decision support tools for efficiency in energy field

Session Rapporteur **Marco Castagna**: Conclusions and final remarks

REPORT edited by Marco Castagna

Thanks to the contributions by financial session participants

8.01.2016

During the session regarding the financial aspects, came out that several tools and financial incentives are available, with regard to energy efficiency and structural measures in buildings. Moreover, some of the concepts that have been discussed can be summarized in four points:

Resilience of buildings

The improvement of existing buildings and cities proposes that it is necessary to evaluate what is already existent and why is done in that way, identify the expectations and, with these results, perform the necessary adjustments to make it attractive and useful. In this way and according to the durability of the materials, it is possible to take benefits of long service life structures and infrastructures and, as consequence, we have the lowest return of investment and the lowest life cycle cost of EU building stock transformation.

Role of public authorities

Legislation introduced requirements mainly in terms of energy consumption and rents' regulation. In Germany, from 2000 to 2014, the constructions' cost rose by 36%, due mainly to energy efficiency regulations, but the building's price index rose only by 27%. This is due to regulations concerning the increasing in rent and sale prices, as well as the supervision on affordable housing.

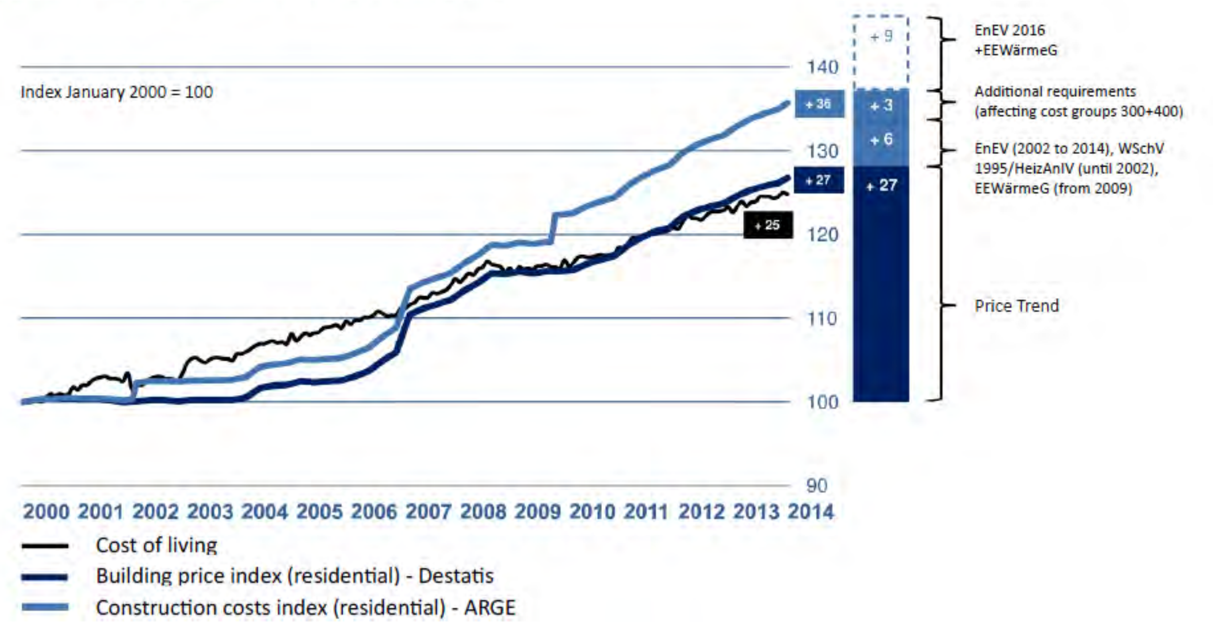

Figure 1: Competition on real estate markets

These circumstances impede the development of high quality architecture, by utilizing even more sustainable materials and procedures.

Legislation and local policies have to operate in a smart way to achieve a "win-win" approach, every actor (investors, tenants, customers) have to take advantage of energy efficiency and improvement of earthquake resistance measures. A possible solution could be, rather than just regulate the costs of rent, to regulate rent together with the standard expenses. This approach allows regulating the increasing of the global cost of living for the renters, allowing investors to increase the rents because of bills reduction that have an effect on the return of investment.

The role of the stakeholders

Every stakeholder plays a role in reducing the costs:

- Contracting cost
- Common infrastructures
- Negotiate scaled solutions
- Promoting local materials that can have a strong "indirect impact" in the economy
- Finding interesting synergies between energy aspects, structural aspects and functional aspects

This last point is particularly interesting since, during the sessions of the workshop, many presentations showed that structural and energy interventions could significantly improve the architecture of the buildings. Moreover, interventions may allow the creation of additional spaces, like balconies. Synergic interventions, therefore, allow a double benefit: reducing the costs of the single interventions, and increasing the value of the property.

Awareness of the people

The awareness of the people in terms of

- overall energy buildings consumption (heating, cooling, electricity, transportation etc…)
- earthquake resistance
- fire resistance
- air quality

of the buildings is too low. Almost anyone is aware of the situation in their own home regarding these issues. The lack of awareness is a serious problem, because it prevents the investments in building retrofitting by the owners (both private and public). It is impossible to sell a solution if the customers don't know that there is a problem.

A proposal could be to develop a mandatory building evaluation, which contains some simple key-indicators for every aspect mentioned before, just as happens today for the energy certification.

SAFESUST – workshop

Session no 4
Architecture and City Planning

Session Summary

JRC, Ispra

November, 26-27 2015

Summary of selected presentations – Roadmap

I. Conversation of Existing Buildings

- ‚Sensible Architecture‘ starts on the first day – low tech, low impact
- Keeping heritage buildings as much as possible origin
- Define potential investors
- Solve conflict ‚conversation vs. energy performance/structural improvements‘ first under consideration of the user needs
- Offset of functional spaces wrt performance criteria
- Close combination of existing and new buildings
- Reuse extracted original building materials
- Innovations in new buildings to balance overall performance
- Use of wood, steel, high-strength hydraulic mortar, HPC => hybrid structures

II. Design Process – Cradle to Cradle

‚Listen to places‘

- Prevent
- Reduce
- Reuse
- Recylce
- Downcycle& Waste management

Summary of selected presentations - Roadmap

III. Densification – Change of Scale

transform - top elevation - sub elevation - colonisation - extension - inclusion – combination

=> Encourage large-scale approach, build a different society

IV. Building Design Process

- The architect in the role of the coordinator ‚lead of orchestra‘
- ‚Learn from the past – local building cultures‘
- Occupancy, exploiting and living – simulation of user behaviour (model simulation)
- Process tools and workflows (BIM etc.)
- Design Brief
- Design Process Scheme
- Compile sum up of existing of local building components
- Close Cooperation of whole design team and network
- Build ‚BIG‘ – redundancy for building transformation (volumes and redundancy)
- Gradual adaption
- Incorporate population for approval and acceptance (IDP)

Summary of selected presentations - Roadmap

IV. Criteria Catalogue for building and urban scale

-Define Conversation approach for Building and People – local building culture
-Change of Scale to improve quality
-Neighbourhood identitiy
-Courtyards
-Public Spaces
-Semi-rural (urban agriculture)
-Live balance: Residential-Work-Leisure
-Environmental Master Plan, e.g. water management, electricity etc.

V. Systemization supported by realized examples as well as databank

-Define Requirement Premisses with the client and authorities (Needs and Expactations)
-Constant Structural Survey (moderate and frequent earthquakes) and Energy Monitoring
-Process catalogue of ways and means for Prevention

Summary of selected presentations - Roadmap

Main challenges

-Adminstration/Authorities obstacles – action required
-Compliance with codes and laws - exception
-Financial limits – funding
-Maintain by high-tech&full renovation or low/tech – open decision by client
-Sustainable Regulations – exceptions, creative solutions
-Improve specialized education at Universities
-Provide excellent profession career perspectives
-Building design in urban context
-Land consumption vs requaltification of existing buildings
-Encourage district level design strategies, which co
district (or portfolio) performance rather the perform
building".

Visions

Think and behave different!

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