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The evolution of Eurocodes for bridge design

Background documents in support to the implementation, harmonization and further development of the Eurocodes

Steve Denton, Georgios Tsionis

Editors: Artur Pinto, Admantia Athanasopoulou, Bora Acun

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Institute for the Protection and Security of the Citizen

Contact information
Artur Pinto
Address: Joint Research Centre, Via Enrico Fermi 2749, TP 480, 21027 Ispra (VA), Italy
E-mail: artur.pinto@jrc.ec.europa.eu
Tel.: +39 0332 78 9294
Fax: +39 0332 78 9049

http://ipsc.jrc.ec.europa.eu/
http://www.jrc.ec.europa.eu/

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Foreword

The **construction sector** is of strategic importance to the EU as it delivers the buildings and infrastructure needed by the rest of the economy and society. It represents more than **10% of EU GDP and more than 50% of fixed capital formation**. It is the largest single economic activity and the biggest industrial employer in Europe. The sector employs directly almost 20 million people. In addition, construction is a key element for the implementation of the **Single Market** and other construction relevant EU Policies, e.g.: **Environment and Energy**.

In line with the EU's strategy for smart, sustainable and inclusive growth (EU2020), **Standardization** will play an important part in supporting the strategy. The **EN Eurocodes** are a set of **European standards** which provide common rules for the design of construction works, to check their strength and stability against live and extreme loads such as earthquakes and fire.

With the publication of all the 58 Eurocodes parts in 2007, the implementation of the Eurocodes is extending to all European countries and there are firm steps towards their adoption internationally. The Commission Recommendation of 11 December 2003 stresses the importance of **training in the use of the Eurocodes**, especially in engineering schools and as part of continuous professional development courses for engineers and technicians, noting that they should be promoted both at national and international level.

In light of the Recommendation, DG JRC is collaborating with DG ENTR and CEN/TC250 "Structural Eurocodes" and is publishing the Report Series '**Support to the implementation, harmonization and further development of the Eurocodes**' as JRC Scientific and Technical Reports. This Report Series include, at present, the following types of reports:

1. Policy support documents – Resulting from the work of the JRC and cooperation with partners and stakeholders on 'Support to the implementation, promotion and further development of the Eurocodes and other standards for the building sector.

2. Technical documents – Facilitating the implementation and use of the Eurocodes and containing information and practical examples (Worked Examples) on the use of the Eurocodes and covering the design of structures or their parts (e.g. the technical reports containing the practical examples presented in the workshops on the Eurocodes with worked examples organized by the JRC).

3. Pre-normative documents – Resulting from the works of the CEN/TC250 Working Groups and containing background information and/or first draft of proposed normative parts. These documents can be then converted to CEN technical specifications.

4. Background documents – Providing approved background information on current Eurocode part. The publication of the document is at the request of the relevant CEN/TC250 Sub-Committee.

5. Scientific/Technical information documents – Containing additional, non-contradictory information on current Eurocodes parts which may facilitate implementation and use, preliminary results from pre-normative work and other studies, which may be used in future revisions and further development of the standards. The authors are various stakeholders involved in Eurocodes process and the publication of these documents is authorized by the relevant CEN/TC250 Sub-Committee or Working Group.

Editorial work for this Report Series is **assured by the JRC** together with partners and stakeholders, when appropriate. The publication of the reports type 3, 4 and 5 is made after approval for publication from the CEN/TC250 Co-ordination Group.

The publication of these reports by the JRC serves the purpose of implementation, further harmonization and development of the Eurocodes, However, it is noted that neither the Commission nor CEN are obliged to follow or endorse any recommendation or result included in these reports in the European legislation or standardization processes.

The report "The evolution of Eurocodes for bridge design" is part of the so-called Technical information document (Type 5 above). The report presents the national experience in the implementation of the Eurocodes for the design of bridges together with a structured work plan, including prioritized topics and related research need, for their evolution. The report results from the work of CEN/TC 250 Horizontal Group 'Bridges' and the feedback provided by its National Contacts through a questionnaire and discussed at a special workshop. This special workshop took place on the occasion of the training workshop "Bridge Design to the Eurocodes" with emphasis on worked examples of bridge design. The workshop was held on 4-6 October 2010 in Vienna, Austria and was organized by the Joint Research Centre in collaboration with CEN/TC250/Horizontal Group Bridges, the Austrian Federal Ministry for Transport, Innovation and Technology and the Austrian Standards Institute, with the support of CEN and the Member States.

The editors and authors have sought to present useful and consistent information in this report. However, **users of information contained in this report must satisfy themselves of its suitability for the purpose for which they intend to use it**.

The report is available to download from the "Eurocodes: Building the future" website (http://eurocodes.jrc.ec.europa.eu).

Ispra, June 2012

Artur Pinto, Adamantia Athanasopoulou and Bora Acun

European Laboratory for Structural Assessment (ELSA)

Institute for the Protection and Security of the Citizen (IPSC)

Joint Research Centre (JRC) – European Commission

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Executive summary

This report presents the national experience in the implementation of the Eurocodes for the design of bridges along with a structured work plan, including prioritised topics and related research needs, for their evolution.

Based on feedback collected from National Contacts, it appears that despite difficulties encountered in the process of national calibration, the implementation of the Eurocodes for bridge design is advanced as regards the publication of national standards and national annexes, the legal framework and training of students and the profession. There is high potential for further harmonisation, as shown by the uniform responses to technical questions and by the high percentage of acceptance of recommended values for the nationally determined parameters. It is noteworthy that most countries considered as priority the reduction of divergence from the recommended values.

In response to the programming mandate in the field of Eurocodes, CEN/TC250 Horizontal Group “Bridges” (HG-B) proposed a five-year project to support the evolution of the Eurocodes for the design of bridges. It is foreseen first to prepare a technical report detailing proposals for improvement and development, to consult national standardization bodies, CEN-CENELEC technical committees and other scientific and technical bodies and ultimately to develop contributions in those areas where significant improvement can realistically be achieved within the available timescales. Based on experience and on the feedback collected from National Contacts, a priority list of items to consider for future development has been compiled, whereas specific topics and research needs to underpin the proposed work have been identified.

The development of the proposed work areas will have positive impact on the safety of citizens in the built environment, on the functioning of the Internal Market for construction products and services and on the harmonisation of the European family of standards in the construction sector. The project will integrate research results and guidelines that are already available and will harmonise national initiatives. It will consider the effects of climate change, building on the experience of countries that have incorporated climate impacts in the selection of nationally determined parameters (e.g. wind maps). Finally, the project will fill gaps in the design of bridges carrying light rail and/or road traffic that are expected to expand in the context of sustainable transportation systems.

Acknowledgements

This reports draws from the valuable contribution of the National Contacts to the Horizontal Group “Bridges”, namely J. Horvatits, Austria; P. Van Bogaert, Belgium; L. Georgiev, Bulgaria; I. Ivanchev, Bulgaria; M. Sýkora, Czech Republic; H. Lilja, Finland; W. Eilzer, Germany; G. Braouzi, Greece; G. Farkas, Hungary; T. Kovács, Hungary; A. Romeijn, Netherlands; B. Isaksen, Norway; L. Oliveira Santos, Portugal; C. Cristescu, Romania; J. Bujnak, Slovakia; A. Pérez Caldentey, Spain and E. Rosell, Sweden. Their feedback through the questionnaires and during the workshop is highly appreciated.

The workshop with National Contacts was organised with the support of the Joint Research Centre of the European Commission and the Directorate General for Enterprise and Industry of the European Commission.

The Austrian Federal Ministry of Transport, Innovation and Technology, and in particular E. M. Eichinger-Vill, are gratefully acknowledged for hosting the workshop.

The project for the evolution of Eurocodes for bridge design and the research needs result from the input and discussion of the members of the Horizontal Group “Bridges”: E. Bouchon, P. Crespo, P. Croce, L. Davaine, R. Frank, H. Friedrich, B. Kolias, J. Lane and M. Tschumi.

1 Introduction

The scope of this report is to present the national experience in the implementation of the Eurocodes for the design of bridges together with a structured work plan, including prioritised topics and research needs, for their evolution. The report results from the work of the CEN/TC 250 Horizontal Group "Bridges" and the feedback provided by its National Contacts through a questionnaire and discussed at a special workshop.

As agreed by CEN/TC 250, the purpose of the Horizontal Group "Bridges" (HG-B) is to facilitate technical liaison on matters related to bridges with subcommittees and to support the wider strategy of CEN/TC 250. In this context, the strategy for HG-B will embrace the following workstreams: maintenance and evolution, development of national annexes and harmonization, promotion, future developments and promotion of research needs.

HG-B is supported by National Contacts, who are nominated by the national standards bodies and are expected to provide a network to support the activities of the HG-B and facilitate international liaison. The views of National Contacts are sought in shaping the activities and priorities of the HG-B. National Contacts are also expected to act as a conduit for disseminating the work of the group.

In the framework of the strategy and general programme for promotion and training on the Eurocodes[1], the workshop "Bridge Design to Eurocodes"[2] took place in October 2010. On the occasion of this event, HG-B and the National Contacts came together with the objectives to:

- understand national experience in the implementation of Eurocodes for bridges;
- contribute to the programme for maintenance and evolution;
- prioritise items to develop in the future;
- identify partners interested to collaborate.

The work presented in this report was developed to support the response of CEN/TC 250 to the programming mandate in the field of Eurocodes[3]. It is hoped that the publication of the report will motivate further contributions to the project for future development of Eurocodes for bridge design and will contribute to better communication of stakeholders and coordination of actions.

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[1] Training and promotion of the Eurocodes, JRC Scientific and Technical Report EUR 22857 EN, 2007, http://eurocodes.jrc.ec.europa.eu/doc/EUR22857EN

[2] http://eurocodes.jrc.ec.europa.eu/showpage.php?id=334_1

[3] M466/EN - Programming mandated addressed to CEN in the field of the structural Eurocodes

2 Feedback from National Contacts

2.1 GENERAL

This chapter presents the feedback collected from National Contacts by means of the questionnaire given in the Annex. The purpose of the questionnaire was to gather information regarding technical issues, the national implementation of the Eurocodes in Member States and proposals for further development.

The information was collected during the last quarter of 2010 and refers to twelve countries: Austria, Belgium, Cyprus, Czech Republic, Finland, Germany, Greece, Norway, Slovakia, Spain, Sweden and Switzerland. It is understood that not all countries implementing the Eurocodes are covered, however the data may be considered indicative of the overall situation.

A session of the workshop was dedicated to the discussion of items for future development, as proposed by HG-B and the National Contacts. The prioritised topics are presented at the end of the chapter.

2.2 NATIONAL IMPLEMENTATION

Information on the national implementation of the Eurocode bridge parts is collected in Figure 1, where it is shown that the use of Eurocodes for the design of bridges is imposed by the law in most countries. However, other existing standards and codes are also in use. These include existing national standards, codes and guidelines that provide non-contradictory complementary information and in particular:

- BS 5400: Steel, concrete and composite bridges, British Standards Institute;
- EAK 2000: Greek Aseismic Code, Earthquake Planning and Protection Organisation[4];
- DIN-Fachbericht 101: Actions on bridges; DIN-Fachbericht 102: Concrete bridges; DIN-Fachbericht 103: Steel bridges; DIN-Fachbericht 104: Composite steel and concrete bridges, German Institute for Standardization;
- Guidelines for the application of DIN-Fachberichte in Greece, Greek Ministry of Public Works;

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[4] http://www.oasp.gr/userfiles/EAK2000.pdf

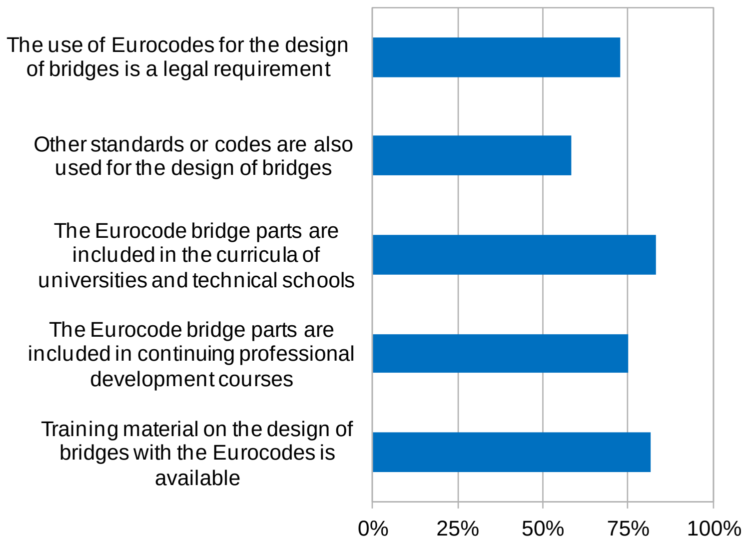

Figure 1. National Implementation of the Eurocode bridge parts

- Circular E23: Guidelines for the design of bridges against earthquake in conjunction with DIN-Fachberichte & Guidelines for the design of seismically isolated bridges, Greek Ministry of Public Works;
- Provisory guidelines for the design of bridges in conjunction with the relevant Eurocodes, Greek Ministry of Public Works;
- Handbook 185: Design rules for bridges, Norwegian public roads administration;
- EHE-08: Code on structural concrete, Spanish Ministry of Public Works[5];
- Structural steel code (EAE), Spanish Ministry of Public Works[6];
- IAP-96: Loads to be considered in the design of road bridges, Spanish Ministry of Public Works;
- SIA 260 – 276: Swisscodes, Swiss Society of Engineers and Architects.

The Eurocodes are included in the curricula of universities and technical schools and in continuing professional development courses in almost all countries, where teaching material is also available.

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[5] http://www.fomento.es/NR/rdonlyres/92D5ACD8-7DCF-4EA0-BF01-E6C35E17E24C/96815/EHE08CODE0K.pdf
[6]http://www.fomento.gob.es/MFOM/LANG_CASTELLANO/ORGANOS_COLEGIADOS/CPA/INSTRUCCIONES/VERSION_INGLES/

2.3 NATIONAL ANNEX AND NATIONALLY DETERMINED PARAMETERS

Almost 70% of National Annexes of Eurocode bridge parts were available at the beginning of 2012, as seen in Figure 2. The progress was uniform among different Eurocodes, with Eurocodes 5, 7 and 8 remaining slightly behind. It is noted however that timber bridges are not very common and that seismic design does not apply in all countries.

More than half of the recommended values for Nationally Determined Parameters (NDPs) have been adopted, as illustrated in Figure 3. Lower percentage of acceptance is noted for Eurocodes 5, 7 and 8. The last two though, contain several NDPs that depend on specific geographical or geological conditions. Overall, there seems to be potential for further harmonisation of NDPs in the next generation of Eurocodes.

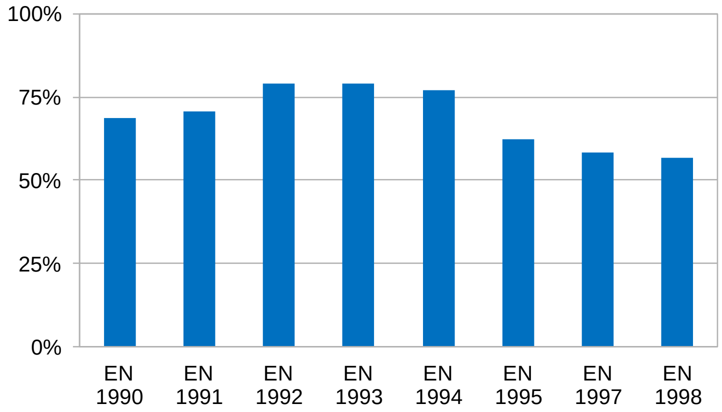

Figure 2. Progress in the preparation of National Annexes relevant to bridge design

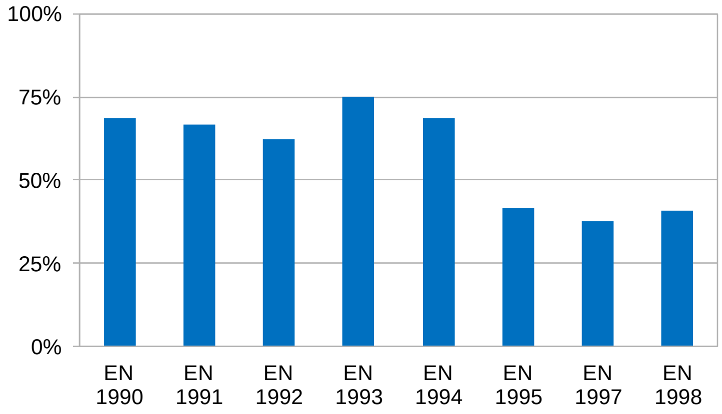

Figure 3. Proportion of accepted recommended values of NDPs in bridge parts

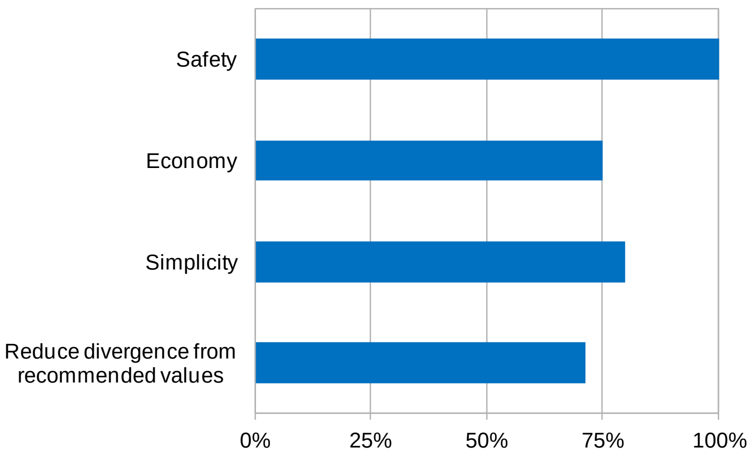

Figure 4. Objectives of the selection of NDPs

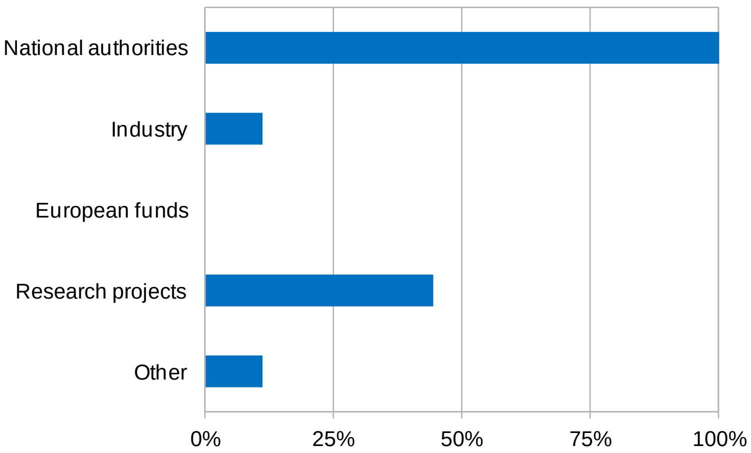

Figure 5. Source of funding of calibration studies for the selection of NDPs

The selection of NDPs was based on comparative analyses of alternative solutions, numerical parametric studies, engineering judgment and existing experience. As discussed in the following, compatibility with previous standards was sought in most countries. On the other hand, background information on the selection of NDPs is available only in few countries (30%).

Figure 4 presents information on the objectives of the selection of NDPs. It was a major concern to obtain similar levels of safety as with the existing codes in all countries. Achieving similar levels of economy and simplicity was also important in most countries. It is noteworthy that in most countries it was intended to reduce the divergence from the recommended values, leading to the high level of acceptance mentioned above.

Calibration studies for the selection of NDPs were funded in all countries by national authorities, as see in Figure 5. Funding in some countries was also raised from national or European research projects, industry, as well as directly from universities.

National Contacts reported on several difficulties encountered during the calibration period. These include:

- lack of background information, calibration studies and information on NDPs adopted by other countries;
- lack of data on traffic loads;
- complex rules (e.g. design load combinations);
- inconsistencies between standards (e.g. design of bearings and expansion joints);
- incompatibility with national regulations on durability;
- fatigue issues.

These topics, together with proposals for further harmonisation, were considered in the definition of the items for further development in 2.5.

2.4 SPECIFIC TECHNICAL QUESTIONS

In this section is presented the information on national practice regarding specific technical issues that are covered in informative annexes or are not yet covered by the Eurocodes or where the Eurocodes allow for a selection among several options.

The informative Annex B of EN 1990 “Management of structural reliability for construction works” is used in practice in some countries (40%). Annex B of EN 1990 suggests three Consequences Classes for buildings and civil engineering works, based on the consequences of failure of the structure or structural member concerned. This classification system is not formally applied in many countries. Bridges are normally classified in the Medium Consequences Class (CC2), while in Cyprus and Germany all bridges belong to the High Consequences Class (CC3). Existing national classification systems, similar to the Eurocodes, are also in use.

Most countries did not take into account the climate change effects on environmental actions in the selection of NDPs. In Slovakia climate change was taken to affect the wind map. In Sweden a higher water level is considered, though this issue is not directly related to the Eurocodes.

Integral bridges exist in most countries (70%) and their popularity is increasing, but design guidelines exist in few countries. Examples are listed below:

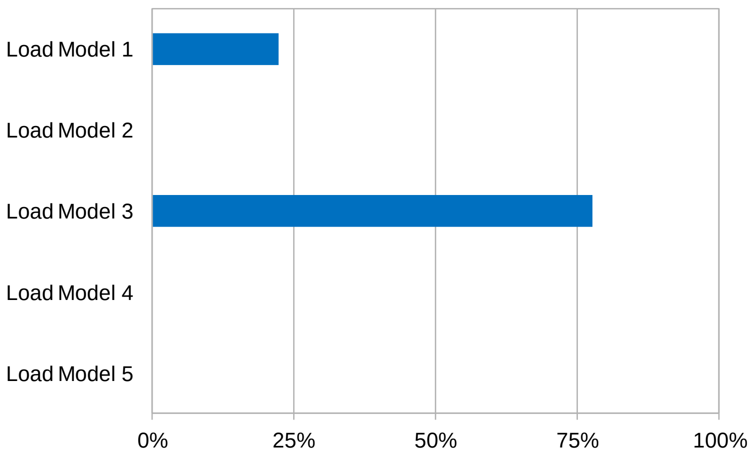

Figure 6. Use of fatigue load models

- guidelines scheduled for publication by the Austrian Association for Research on Road, Rail and Transport (FSV);
- several guidelines in Finland, scheduled to be updated in the near future;
- ESTEYCO - Guía para la concepción de puentes integrales en carreteras y autopistas, published in 1997 by the Spanish Ministry of Public Works.

As illustrated in Figure 6, for fatigue load modelling, Load Model 3 is used in most countries, whereas Load Model 1 is also used in few countries.

Finally, it is noted that the infrequent combination of actions is used in practice in few countries (30%).

2.5 FUTURE DEVELOPMENT

The last session of the special workshop with the National Contacts was dedicated to the prioritisation of items for future development. The participants were asked to grade more than 70 topics that had been previously suggested through the questionnaire or by HG-B, or identified during the workshop. Similar items were subsequently grouped, leading to the classification given in Table 1.

The organisations to involve in the further development of the Eurocodes for bridges include:

- national technical associations;
- national standards bodies;
- ministries of infrastructures;

Table 1. Prioritisation of items for further development

Item	Votes
Design of bearings & expansion joints	13
Partial prestressing + difficulties with crack control rules applied to post-tensioned structures / relationship between durability and crack width / skew cracking due to combined shear and bending	13
Robustness requirements for bridge design	11
Fatigue: load model, complex/conservative rules	10
Integral bridges & earth pressure on moving walls	9
Load combinations (incl. rail/highway)	8
Effect of load distribution on shear resistance of slabs	6
Simplification for normal structures at an European level	6
Footbridge vibrations, vertical deflections and vibrations	6
New materials: FRP, recycled & self-compacting concrete, concrete-timber composites	5
Patch loading on steel elements	4
Selection of geotechnical approach	3
Lateral & lateral-torsional buckling resistance	3
Temperature effects & thermal actions	3
Traffic loads for bridges over 200 m	2
Climate change impacts on thermal actions	2
Earth pressure on moving walls	1
Effect of control during construction on partial factors	1
Design rules for piles	1
Seismic design: soil-structure interaction	1
Light rail and tram loading	1
Safety format for extradosed and cable-stay bridges	1
Durability: effect of cement type, crack width at surface and at reinforcement	0
Safety concepts in design of tension elements	0
Vertical wind loads through wind tunnel tests	0
Design rules for bridge with open deck	0
Loading of noise barriers from aerodynamic effects of passing vehicles	0
Design of integral bridge piers	0

- national railways authorities;
- universities;
- international associations, e.g. fib, IABSE, UIC, JCSS.

Background material related to the items listed in Table 1 is available in the form of existing standards and guidelines as well as scientific publications and PhD theses. References given by National Contacts are listed in the following:

- Design manual for roads and bridges, Highways structures: Approval procedures and general design, General Design, Design rules for aerodynamic effects on bridges[7];
- DIN 4014 and DIN 1054 (for the design of piles);

[7] http://www.dft.gov.uk/ha/standards/dmrb/vol1/section3/bd4901.pdf

- fib Task Group TG4.1 (for cracking of concrete structures);
- SIA 261:2003 - Narrow gauge railways, Swiss Society of Engineers and Architects;
- Influencia de la distribución de la carga en la capacidad resistente a cortante en elementos sin armadura transversal (UPM), PhD thesis by Patricio Padilla for the effect of load distribution on shear resistance.

Although assessment of existing bridges is a topic of interest in most countries, it is not included in the work plan of the Horizontal Group Bridges, in view of the establishment by CEN/TC 250 of the Working Group 2 "Existing Structures". Related background documents that were suggested by the National Contacts are:

- ONR 24008:2006 - Evaluation of load capacity of existing railway and highway bridges, Austrian Standards Institute;
- SIA 269: 2010 - Assessment of existing structures, Swiss Society of Engineers and Architects;
- ČSN 73 6222:2009 - Assessment of load-carrying capacity of bridges, Czech Office for Standards, Metrology and Testing;
- Probabilistic Assessment of Existing Structures, JCSS report, 2001[8];
- Procedures required for the assessment of highway structures, COST 345 reports[9];
- Reliability-based classification of the load carrying capacity of existing bridges, Danish Road Directorate, 2004[10];
- TP 224 - Verification of existing concrete road bridges, Czech technical rules.

2.6 OTHER ISSUES

Comments were received from National Contacts also on issues not covered by the questionnaire. These issues comprise simplification and ease of use as well as informatics tools to facilitate communication.

It was suggested that commentaries attached on the main text would facilitate users of the Eurocodes. For the same reason, it was also proposed to expand EN 1991-2 to include all actions involved in bridge design and to attach EN 1990-A2 (EN 1990/A1) to either EN 1991-2 or EN 1992-2.

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[8] http://rilem.net/gene/main.php?base=500219&id_publication=96
[9] http://cost345.zag.si/final_reports.htm
[10] http://www.vejdirektoratet.dk/publikationer/VDrap291/index.htm

Simplification of the Eurocodes was proposed to address the length and complexity of some parts that are considered difficult to manage by some engineers, and the complexity of certain application rules (e.g. joints and connecting elements of steel structures, combination rules, calculation of envelopes, etc). It was also noted that the checking of software output becomes hard and as a result, the risk of errors is increased.

Finally, the establishment of an internet forum was put forward so that users may be notified on forthcoming corrigenda and amendments and they may ask questions or request clarification on issues related to the practical application of the Eurocodes. Additionally, the Centralised Eurocodes Helpdesk[11] platform that will be officially launched in 2012 will give the opportunity to national standards bodies to submit to HGB questions they receive on national level.

[11] https://ndphelpdesk.jrc.ec.europa.eu/login.php (the platform has controlled and restricted access)

3 Project for the evolution of Eurocodes for bridge design

3.1 DESCRIPTION OF THE PROJECT

The project seeks to support the evolution of the Eurocodes for the design of bridges. In particular, it focuses on those aspects of bridge design that draw upon several Eurocode parts and other European Standards where there is value in achieving alignment of approach. It is noted that other aspects of the evolution of the Eurocodes relating to bridge design have been proposed in other project proposals regarding specific Eurocode parts.

The five-year project comprises three main activities:

1. preparation of a technical report detailing proposals for improvement and developments in aspects of bridge design to Eurocodes (18 months);
2. consultation of national standardization bodies and CEN-CENELEC technical committees and other scientific and technical bodies (12 months);
3. development of contributions to the revision of ENs based on results of Activities 1 & 2 (30 months).

It is proposed that work be initiated in all of the following areas. Initial explorations will be undertaken during Activity 1. On the basis of the findings of Activity 1 and subsequent consultation in Activity 2, those areas where significant improvement can realistically be achieved within the available timescales will be determined and progressed in Activity 3. The planned milestones and deliverables are listed in Table 2.

Table 2. Project deliverables and milestones

Deliverables		Milestones	
D1	Technical report (possibly a JRC Scientific and Technical Report)	M1	Acceptance for publication of technical report by TC 250
D2	Report on consultation and conclusions for revision	M2	Completion of consultation
D3	Contribution to EN revision stage 34	M3	Contribution to EN revisions stage 34 (first draft)
D4	Contribution to EN revision stage 40	M4	Contribution to EN revision stage 40 (enquiry)
D5	Contribution to EN revision stage 49	M5	Contribution to EN revision stage 49 (formal vote)

1. Design of integral bridges

   Integral bridges have become a popular form of construction in many European countries because of their improved durability and the avoidance of expansion joints and some bearings. However, cyclical thermal movements of integral bridge decks lead to enhanced earth pressures behind abutments. Key aspects of the design of integral bridges are not currently addressed in the Eurocodes. National Contacts identified the need to develop rules for integral bridges as a priority.

2. Footbridge vibrations

   Following issues encountered with several lightweight bridges, notably including the Millennium Bridge in London, a significant amount of new scientific research has been undertaken to develop design approaches to account for pedestrian-induced vibrations. Such issues are currently not well covered in the Eurocodes.

3. Fatigue verification in road bridge design

   EN1991-2 currently includes five fatigue load models, but in practice only one can readily be used in bridge design. In fact and as reported by the National Contacts, designers use almost exclusively fatigue load model 3. There is the possibility for some simplification. Furthermore, based on recent measurements of traffic data, re-calibration of the λ factors used in conjunction with fatigue load model 3 is merited.

4. Impact of climate change on environmental actions

   Bridges are long-life assets and their design can be particularly sensitive to environmental actions. It is appropriate to design bridges accounting for the predicted magnitude of environmental actions at the end of their lives. Adapting the design of bridges to climate change is likely to offer significant cost sustainability benefits compared with the need for subsequent structural modifications.

5. Design of bridge bearings

   Aspects of the design of bridge bearings, in particular the appropriate combinations of actions to be used, are not currently well covered in Eurocodes. Liaison has been established with TC 167 to address alignment issues with EN 1337. National Contacts to the HG-B have asked for the refinement of design rules for bearings and for the removal of inconsistencies between standards.

6. Light rail and tram loading models

   Traffic loading models for light rail and tram loading are not currently included in Eurocodes.

7. Combination rules for rail/light rail and highway traffic loading

   Combinations rules for bridges carrying rail/light rail and highway traffic are not currently included in Eurocodes.

8. Robustness requirements in bridge design

   The definition of robustness, relevant actions and requirements given in EN 1990 are not readily usable by users of the Eurocodes. Based on the review of documented failures, also collapses during execution, the project will investigate additional requirements and rules applicable to the design of bridges.

9. Loadings of noise barriers due to passing trains and related fatigue effects

   Queries have been raised by CEN/TC256/SC1/WG40 concerning the actions from passing trains on noise barriers and the existing provisions of Eurocodes.

10. Simplification and improving ease of use at a European level

    There is a need to examine opportunities to enhance the ease of use of the Eurocodes for bridge design, through improved clarity and simpler navigation between parts. Several countries are developing sets of simplified rules for particular bridge types. There is enthusiasm from National Contacts to explore whether such guidance could be shared internationally, albeit that it is recognised that it may well not be appropriate to include it within the main Eurocode parts.

11. New materials

    The Eurocodes for the design of bridges do not cover at present the use of new materials, e.g. FRP, recycled and self-compacting concrete and concrete-timber composites, although their use is increasing and is not anymore limited to demonstration projects. Rules need to be defined, in collaboration with relevant TC 250 subcommittees and working groups and based on existing guidelines.

3.2 JUSTIFICATION AND IMPACT

The areas listed above were identified by the members of HG-B and its National Contacts, based on their experience and on the feedback collected on the implementation and use of the Eurocodes around Europe.

The development of the proposed work areas will enhance the safety of citizens in the built environment.

Harmonised rules will facilitate the functioning of the Internal Market for construction products and related services.

Research work has been performed on several areas and guidelines are available or under development. The project will integrate such results and will harmonise national initiatives.

The removal of inconsistencies between the Eurocodes and product standards, and also between Eurocode parts, will contribute to the harmonisation of the European family of standards in the construction sector.

The project will consider the effects of climate change on the design of bridges, building on the experience of countries that have incorporated climate impacts in the selection of NDPs (e.g. wind maps).

In the context of sustainable transportation systems, light rail and tram networks are expected to expand. The project will fill the gap in the area of loading models and combination rules for bridges carrying rail and road traffic.

There is evidence of a high percentage of acceptance of the recommended values for NDPs in the Eurocodes for the design of bridges. Although the reduction of NDPs will be possibly the object of a specific mandate, there is potential for the project to contribute in this direction.

3.3 STAKEHOLDERS

The following parties and stakeholders will be involved in the consultation and the standardization works:

- all related CEN/TC 250 subcommittees and working groups;
- national standards bodies, national technical associations and national authorities (through HG-B national contacts);
- CEN/TC 167;
- CEN/TC 256;
- international associations: fib, IABSE, UIC, JCSS;
- universities and research institutions where appropriate;
- the Joint Research Centre of the European Commission.

4 Research needs in support of the evolution of Eurocodes for bridge design

The HG-B identified the following specific topics and research needs to underpin proposed work in support of the evolution of the Eurocodes:

1. Design of medium and long integral bridges

   Integral bridges have become a popular form of construction in many European countries because of their improved durability and the avoidance of expansion joints and some bearings. Key aspects of the design of integral bridges are not currently addressed in the Eurocodes. There may be issues relevant in bridges subject to seismic actions.

   Research should aim at enhanced understanding of the behaviour of soils behind bridge abutments subject to repeated thermally induced cycles of movement, leading to the provision of models that can be used in the design of integral bridges with rigid and flexible abutments.

2. Fatigue verification in bridge design

   EN1991-2 currently includes five fatigue load models for road bridges, but in practice only one can readily be used in bridge design. There is the possibility for some simplification. Furthermore, based on recent measurements of traffic data, re-calibration of the λ factors used in conjunction with fatigue load model 3 is required to ensure the durable design of bridges.

   Research needs include:

   (i) review of fatigue load models for highway bridges with the objective of refinement and simplification;

   (ii) confirmation of λ factors for road and rail bridges;

   (iii) extension of λ factors to cases not considered currently, or guidance on how to treat these without extensive calculation effort and

   (iv) examination of fatigue verification of shear links to consider whether the possibility that Eurocode designs of shear links is governed by fatigue considerations is realistic.

In identifying research needs it is considered helpful to distinguish between load effects and resistance and the different coverage in the Eurocodes for different materials. S-N curves for steel are based on extensive measurement and there is no current need to revisit them, while there might be some merit in examining S-N curves for embedded bars. It is noted that no S-N curves for concrete are included in EN 1992-2.

Regarding rail bridges, it is sensible to retain the load spectra currently given in the Eurocode, albeit that there may be some variation across Europe. It is also noted that the λ factors for reinforcement in concrete rail bridges received less emphasis during initial Eurocode development than factors for steel structures.

3. Bridge bearings and expansion joints

Aspects of the design of bridge bearings, in particular the appropriate combinations of actions to be used, are not currently covered in Eurocodes. This is a major omission and, together with consistency issues with EN 1337, will be addressed in liaison with CEN/TC 167.

The following research needs are identified:

(i) examination of realistic extreme thermal ranges and realistic combinations of actions to be used in bearing design and in accounting for the effects of bearings on the overall structural system and

(ii) consideration of the effects of vertical variable actions on load transferred through sliding bearings into piers.

It is noted that the basic action combination expressions and recommended ψ factors were calibrated predominantly for deck design.

4. Robustness requirements in bridge design in service and during execution

The definition of robustness, relevant actions and requirements given in EN 1990 are not readily usable in bridge design. This work item will establish additional requirements and rules applicable to the design of bridges to enhance their safety.

Relevant research needs comprise:

(i) identification, review and analysis of documented bridge failures and collapses in service and during construction to identify measures to enhance robustness that could eliminate such failures in future and

(ii) synthesis of approaches to the treatment of scour and flood effects in bridge foundation design and consideration of their realistic treatment in Eurocode context.

5. <u>Lateral torsional buckling in bridge design</u>

   Issues have been identified with the treatment of lateral torsional buckling for bridge design that can significantly affect the economy of designs, including the suitability of the buckling curves for plated steel members. This work item will seek to address conservatism in current approaches and address omissions relevant to bridge design, particularly in transient design situations.

6. <u>Partial prestressing and crack control requirements in bridge design</u>

   The suitability of the current provisions for crack control for bridges, particularly prestressed and partially-prestressed structures have been challenged by several National Contacts to HG-B. This work item will examine the need for additional and/or simplified guidance to improve the economy and durability of concrete bridges. Research will aim to study the implications of current Eurocode rules for crack control for realistic bridge design cases and to identify specific concerns.

7. <u>Footbridge vibrations</u>

   Following issues encountered with several lightweight bridges, notably including the Millennium Bridge in London, a significant amount of new scientific research has been undertaken to develop design approaches to account for pedestrian-induced vibrations. This work item will address current omissions in the Eurocodes through the examination and comparison of alternative models proposed for treatment of vertical and lateral pedestrian induced vibrations, looking to a synthesis to develop recommendations for future Eurocode coverage.

8. <u>Impact of climate change on environmental actions</u>

   Bridges are long-life assets and their design can be particularly sensitive to environmental actions. Adapting the design of bridges to climate change is likely to offer significant cost benefits compared to the need for subsequent structural modifications.

   Research will focus on the identification of critical events for bridge structures that are potentially impacted by climate change, and on the examination of the potential significance of projected changes. Development of recommendations enabling Member States to account for climate change in design of bridges will be developed.

9. Light rail and tram loading models

   Traffic loading models for light rail and tram loading are not currently included in Eurocodes. International review of design practice and common vehicle types and characteristics will lead to recommendations for loading models.

10. Combination rules for rail/light rail and highway traffic loading

   Combinations rules for bridges carrying rail/light rail and highway traffic are not currently included in Eurocodes. This lack will be addressed through a preliminary study to examine issues and potential options for treatment. It is not considered that extensive statistical study would be merited at this stage.

11. Aerodynamic actions on noise barriers due to passing trains and related fatigue effects

   Queries have been raised by CEN/TC256/SC1/WG40 concerning the actions from passing trains on noise barriers and the existing provisions of Eurocodes. This work item will address current omissions in the Eurocodes by means of review of international experience and available data concerning aerodynamic actions applied to structures, including bridges and noise barriers. CEN/TC256 has developed a relevant European Standard, whose consistency with the Eurocodes requires examination.

12. Simplification and improving ease of use at a European level

   There is a need to examine opportunities to enhance the ease of use of the Eurocodes for bridge design, through improved clarity and simpler navigation between parts. While no specific research needs are identified at this stage, specific recommendations for simplifications for bridge design should be developed.

13. New materials

   The Eurocodes for the design of bridges do not cover the use of new materials, e.g. FRP, recycled and self-compacting concrete and concrete-timber composites, although their use is increasing and is no longer limited to demonstration projects. Rules need to be defined, in collaboration with relevant CEN/TC250 subcommittees and working groups, and based on existing guidelines. This work item will contribute to this effort in the field of bridge design. At this stage, no specific research needs are identified.

Annex: Questionnaire for National Contacts

1 Personal details of National Contact[12]

Country
Name, surname
Organisation

Position
Email

I am interested in collaborating on the following topics:

2 National implementation

		Yes	No
2.1	The use of Eurocodes for the design of bridges is a legal requirement in your country.	☐	☐
2.2	Other standards or codes are also used for the design of bridges. If yes, please give reference.	☐	☐
2.3	The Eurocode bridge parts are included in the curricula of universities and technical schools.	☐	☐
2.4	The Eurocode bridge parts are included in continuing professional development courses.	☐	☐
2.5	Training material on the design of bridges with the Eurocodes is available. If yes, please give reference.	☐	☐

[12] Personal details will be used only for communication between the Horizontal Group "Bridges" and the National Contacts and will not be made available to third parties.

3 National Annex and Nationally Determined Parameters (NDPs)

3.1 Give an estimate of the progress in the preparation of National Annexes relevant to bridge design.

	0%	25%	50%	75%	100%
EN 1990	☐	☐	☐	☐	☐
EN 1991	☐	☐	☐	☐	☐
EN 1992	☐	☐	☐	☐	☐
EN 1993	☐	☐	☐	☐	☐
EN 1994	☐	☐	☐	☐	☐
EN 1995	☐	☐	☐	☐	☐
EN 1997	☐	☐	☐	☐	☐
EN 1998	☐	☐	☐	☐	☐

3.2 Give a rough estimate of the proportion of the recommended values of NDPs relevant to bridge design that have been accepted.

	0%	25%	50%	75%	100%
EN 1990	☐	☐	☐	☐	☐
EN 1991	☐	☐	☐	☐	☐
EN 1992	☐	☐	☐	☐	☐
EN 1993	☐	☐	☐	☐	☐
EN 1994	☐	☐	☐	☐	☐
EN 1995	☐	☐	☐	☐	☐
EN 1997	☐	☐	☐	☐	☐
EN 1998	☐	☐	☐	☐	☐

3.3 Briefly describe the methodologies that have been employed for the selection of the NDPs.

3.4 The objectives of the selection of the NDPs were:

to obtain same design as with the previous code regarding	Yes	No
safety	☐	☐
economy	☐	☐
simplicity	☐	☐
to reduce divergence from the recommended values	☐	☐
other (please specify)	☐	☐

3.5 The calibration studies for the selection of the NDPs were funded by

	Yes	No
national authorities	☐	☐
industry	☐	☐
European funds	☐	☐
national/European research projects	☐	☐
other (please specify)	☐	☐

3.6 Background material on the national selection of NDPs is available. ☐ ☐
If yes, please give reference.

3.7 Refer to any particular difficulties faced during the preparation of the National Annexes and the selection of the NDPs.

3.8 List issues that should be considered for the further harmonisation of NDPs.

4 Further development

4.1 List existing rules of the Eurocode bridge parts that need refinement and/or updating.

4.2 List new topics that should be developed and included in future Eurocodes.

4.3 Give reference to background information (e.g. technical reports, codes, guidelines, etc) on the topics under 4.1 and 4.2.

4.4 Suggest national and international organisations that might be interested to collaborate on the development of the topics under 4.1 and 4.2.

5. Specific technical questions

	Yes	No
5.1 The infrequent combination of actions is used in your country.	☐	☐
5.2 Annex B of EN 1990 is explicitly used in practice.	☐	☐
5.3 The following models are used in practice:		
fatigue load model 1	☐	☐
fatigue load model 2	☐	☐
fatigue load model 3	☐	☐
fatigue load model 4	☐	☐
fatigue load model 5	☐	☐

5.4 Explain how bridges are classified in the consequences classes of EN 1990 – Annex B.

5.5 List any effects of climate change that have been taken into account in NDPs for environmental actions on structures (snow, wind, thermal).

5.6 Do you have national guidelines or recommendations for the analysis and design of integral (monolithic) bridges (if so, please provide a reference)? Is this form of construction common in your country?

6 Other issues

Please use the space below to elaborate on issues that you consider important and are not covered in the questionnaire.

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Abstract

This report presents the national experience in the implementation of the Eurocodes for the design of bridges along with a structured work plan for their evolution. Based on feedback collected from National Contacts, it appears that despite difficulties encountered in the process of national calibration, the implementation of the Eurocodes for bridge design is advanced and that there is high potential for further harmonization. The report also presents a five-year project to support the evolution of the Eurocodes for the design of bridges that was prepared by CEN/TC250 Horizontal Group "Bridges". Based on experience and on the feedback collected from National Contacts, a priority list of items to consider for future development has been compiled, whereas specific topics and research needs to underpin the proposed work have been identified. The project will integrate research results and guidelines that are already available and will harmonise national initiatives.

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