European Commission

JRC TECHNICAL REPORTS

D.I.F. Adobe - The Dynamic Performance of Adobe masonry components

Open Access to JRC Research Infrastructures

Call 2017-1-RD-ELSA-HopLab: User Access Report

***HopLab**, Hopkinson Bar facility*

Peroni, M; Tsionis, G; Solomos, G; Li Piani, T; Weerheijm, J; Koene, L; Krabbenborg, D; Sluys, LJ

2020

OPEN ACCESS

to JRC Research Infrastructures

Joint Research Centre

EUR 30308 EN

Contact information
Name: Marco Peroni
Address: Via E. Fermi, 2749, 21027 Ispra (VA), Italy
Email: marco.peroni@ec.europa.eu
Tel.: 00390332789775

EU Science Hub
https://ec.europa.eu/jrc

JRC121428

EUR 30308 EN

PDF ISBN 978-92-76-20870-9 ISSN 1831-9424 doi:10.2760/17519

Luxembourg: Publications Office of the European Union, 2020

How to cite this report: Peroni, M; Tsionis, G; Solomos, G; Li Piani, T; Weerheijm, J; Koene, L; Krabbenborg, D; Sluys, LJ, *D.I.F. Adobe - The Dynamic Performance of Adobe masonry components; Call 2017-1-RD- ELSA-HopLab: User Access Report*, EUR 30308 EN, Publications Office of the European Union, Luxembourg, 2020, ISBN 978-92-76-20870-9, doi:10.2760/17519, JRC121428

Contents

Foreword

The European Commission's Joint Research Centre (JRC) opens its scientific laboratories and facilities to people working in academia and research organisations, industry, small and medium enterprises (SMEs), and more in general to the public and private sector.

Offering access to visiting researchers is part of JRC's strategy to:

- enhance dissemination of scientific knowledge;
- boost competiveness;
- bridge the gap between research and industry;
- provide training and capacity building.

Scientists have the opportunity to work in the following fields:

- nuclear safety and security (Euratom Laboratories);
- chemistry;
- biosciences/life sciences;
- physical sciences;
- ICT;
- Foresight.

The present document constitutes the "User Access Report", which summaries the results from the access given to the Hopkinson Bar facility (HopLab).

Authors

JRC Research Infrastructure (HopLab, Hopkinson Bar)

- Peroni, M
- Tsionis, G
- Solomos, G

User Access Project (D.I.F. Adobe, The Dynamic Performance of Adobe masonry components)

- Li Piani, T (Lead User, Delft University of Technology)
- Weerheijm, J (TNO Defence Safety and Security, Delft University of Technology)
- Koene, L (Netherlands Defence Academy)
- Krabbenborg, D (Netherlands Defence Academy)
- Sluys, LJ (Delft University of Technology)

Abstract

This report presents the technical aspects of the experimental test campaign relevant to the project "DIF Adobe", whose proposal was successfully reviewed and selected in the framework of the JRC OPEN ACCESS programme. The research conducted concerns the investigation of the compressive strength of two different mixtures of adobe (in oven-dried and air-dried conditions) at three different strain-rates ranging from static to fast dynamic. Specimens were provided by the User.

Sample preparation and test programme was proposed by User Access Team according to proposal and agreed with ELSA-HopLab laboratory staff. Preliminary static tests, granulometry and density characterization tests on the adopted mixtures were performed by User Access Team at the Laboratory of Geomechanics of Delft University of Technology and at the Royal Military Laboratory in Breda (the Netherlands).

The subsequent preparation of the specimens and the execution of the tests have been done completely by the ELSA-HopLab laboratory staff. The static and low velocity tests have been carried out on a servo-hydraulic testing machine while the high strain-rate tests have been performed on a particular setup of Hopkinson bar specifically designed to perform tests of brittle and geo-materials.

The report also presents the elaboration of the raw experimental data in order to obtain the forces and displacements directly applied to the specimens during the tests. However, no considerations about the material mechanical behaviour have been drawn. Finally, a description of the storage structure of the elaborated data has been included, which will help future users to effectively manage and use this data for their purposes.

1 Introduction

Adobe is a building material made of earth (clay, silt, sand) mixed with water and an organic material (usually straw), predominantly used in the form of bricks. Adobe construction is a traditional form of masonry whose adobe bricks are arranged together using mud mortar. It is one of the most ancient building technologies on Earth; spread in almost all continents of the world, many adobe buildings are characterized by architectural value. Nevertheless, even the basic mechanical properties of Adobe are still unknown to a large extent.

Unfortunately, Adobe buildings, situated in areas prone to earthquakes or involved in military operations, often suffer from catastrophic failures, which result in dramatic losses of human lives and cultural heritage. In order to increase safety it is of paramount importance to understand the static and dynamic mechanical performance of Adobe through appropriate testing and generation of reliable data. In this direction the DIF Adobe project has as main objective to investigate the fibre and water content influences on the static and dynamic compressive strength of adobe.

In particular, concerning the material dynamic behaviour, it is possible to observe a lack of experimental data available in the literature due to the fact that adobe has specific characteristics that are not compatible with the Hopkinson bar technique normally employed to perform dynamic tests on materials (the Hopkinson bar technique has been developed to test ductile materials with a strength comparable to that of metals). For this reason, a proper design adopted in the JRC Hopkinson bar facility has been essential to fully characterize the compressive behaviour of this kind of materials (see 3.2).

Concerning the logistics of the project, the activity took place in the period May to July 2018. The actual tests were carried out exclusively by the ELSA-HopLab staff under the scientific supervision of Marco Peroni. The User team visited the laboratory for a few days, where several arising technical issues and the work planning were discussed and jointly resolved. In particular, Tiziano Li Piani was hosted at the JRC-Ispra for longer periods of time, following the progress of the work, familiarising with the technique of Hopkinson bar testing and conducting a preliminary assessment of the test results.

2 Specimen manufacturing

The original set of specimens was constructed by the users. These included 62 specimens with a diameter of about 113 mm and height 55 mm. Of these, 31 specimens had low content of fibres and 31 specimens had higher fibre content. For each specimen type, 16 specimens were air-dried and 15 specimens were oven-dried.

Due to some unexpected problems related to the test setup with respect to the particular behaviour of adobe,, it was decided to use a different geometry for the specimens. The finally used specimens of this test campaign have been manufactured at the ELSA-HopLab laboratory following the instructions agreed upon with the users. Specifically, smaller cylindrical specimens have been core drilled, using a diamond drilling machine, from the specimens originally supplied by the users (110x55mm cylinders). Typically, three small specimens of 35 mm diameter have been cut from each specimen, as shown in Figure 1 (some small specimens have been rejected due to the presence of large disuniformity).

Figure 1. Specimen manufacturing with diamond drilling machine (left) and overview of 35 mm specimens machined from 110 mm specimens (right)

To achieve suitable dimensions for the dynamic tests all specimens have been ground in order to obtain a specimen with a diameter-to-length ratio of about 1. To ensure the planarity of the two specimen faces a proper guiding tool has been designed, as shown in Figure 2a, to reach dimensional tolerances of less than 1 mm.

Figure 2. Grinding operation (left) and overview of all machined specimens (right)

Figure 2a presents the grinding operation, while Figure 2b shows all specimens machined with the described procedure and properly marked. At this point the specimens were separated and the air-dried specimens have been maintained at the laboratory conditions for three days. The oven-dried specimens were cured at 100° C for 60 hours and then air cooled at laboratory conditions for two days. Figure 3 shows the oven drying operation and a detail of the specimens during the oven drying.

At the end of the specimen curing procedure all specimens were stored in sealed plastic bags, as shown in Figure 4. As prescribed by the users, the oven-dried specimens have been vacuum-packed to avoid any change in the specimen moisture content before the test phase.

Figure 3. Oven dried operation (left) and specimen details (right)

All specimens have been accurately measured just before the packaging phase to ensure the requested manufacturing tolerances. Specifically, two orthogonal measurements of the cylinder diameter and height have been registered with a precision of 0.1 mm. In addition, the specimens have been weighed with a precision scale during the specimen measuring phase and for the oven-dried ones also before the drying procedure.

Figure 4. Sealed specimens at the end of the preparation phases

All data concerning the specimen dimension and weight measurements (and those of the original specimens) are reported in the tables in the annexes 1 and 2. The marking code for the specimens is as follows:

- the first letter specifies the adobe mixture type; *A*: low fibre content and *B*: high fibre content,

- the second letter specifies the curing method; *A*: air drying curing and *O*: oven drying curing,

- the number specifies the original large specimen sent by the users and

- the last letter identifies the three smaller specimens machined from the original one (*a*, *b*, or *c*).

Finally, all specimens have been accurately examined (visual inspection) to identify possible observable defects (inclusions or holes) that could affect the material behaviour and characterization. Such “defective” specimens (highlighted in orange in the tables) have been used only to assess the testing machines and not to evaluate the mechanical properties of the adobe.

3 Test equipment and execution

As requested by the users, the specimens of the two mixtures of adobe have been tested at three different velocities of deformation in order to assess the effect of the strain-rate parameter on the material behaviour. Due to the large range of strain-rates investigated, the tests have been performed with two different experimental apparatuses.

Static tests and low strain-rate tests have been performed on a MTS universal testing machine with a cross-head velocity of 0.01 mm/s and 90 mm/s, respectively.

High strain-rate tests have been performed using the Hopkinson Bar techniques and in particular using an ad-hoc designed bar for brittle and geo-materials.

In the next sections a short description of the equipment is given, including the detailed list of instruments and sensors employed.

3.1 MTS Servo-hydraulic testing machine

As mentioned before, the static and low strain-rate tests have been performed with an MTS universal testing machine (810 Material Testing System – 50kN) controlled with the FlexTest 40 Digital controller unit. Figure 5 shows the testing setup and a closer view of the specimen and the loading equipment e. For both static and low strain-rate tests a camera has been adopted to acquire a photo sequence synchronized with the sensors data recorded by the testing machine (the force derived by the load cell and the piston displacement recorded with an LVDT). Two special compression plates (MTS 643 Compression Platen) have been used to correctly load the specimens in compression.

Figure 5. Testing setup for static and low strain-rate tests (left) and closer view of the specimen and loading equipment (right)

3.1.1 Static tests

For the static tests forces and displacements have been directly recorded by the FlexTest 40 unit synchronized with an IDT Y4-S2 camera; illumination was provided by two cold lights Veritas Constellation 120.

Before starting the testing phase the stiffness of the machine has been identified with a void test (a test without the specimen). Using this parameter, in fact, it is possible to improve the evaluation of the Young modulus of the tested material without a proper extensometer applied to the specimen. Table 1 summarizes the static tests performed and the label of each experiment.

Table 1. Static tests.

Test Label	Test Type	Maximum Displacement	Date	Specimen
f2	Monotonic MTS	5 mm	16/07/2018	AA2c
f3	Monotonic MTS	5 mm	16/07/2018	AA4a
f4	Monotonic MTS	5 mm	16/07/2018	AA13a
f5	Monotonic MTS	5 mm	16/07/2018	AA7a
f6	Monotonic MTS	5 mm	16/07/2018	AO13b
f7	Monotonic MTS	5 mm	16/07/2018	AO5b
f8	Monotonic MTS	5 mm	16/07/2018	AO3b
f9	Monotonic MTS	5 mm	16/07/2018	AO11a
f10	Monotonic MTS	5 mm	16/07/2018	BA10a
f11	Monotonic MTS	5 mm	16/07/2018	BA6a
f12	Monotonic MTS	5 mm	16/07/2018	BA4c
f13	Monotonic MTS	5 mm	16/07/2018	BA9c
f14	Monotonic MTS	5 mm	16/07/2018	BO13a
f15	Monotonic MTS	5 mm	16/07/2018	BO6b
f16	Monotonic MTS	5 mm	16/07/2018	BO10b
f17	Monotonic MTS	5 mm	16/07/2018	BO12b

3.1.2 Intermediate strain-rate tests

Low strain-rates tests have been performed with the same mechanical instrumentation as the static tests. The only difference concerns the acquisition system that has been changed to face the needed performance in terms of velocity required by this particular test type. Specifically, the MTS displacement and force signals have been recorded with a National Instruments acquisition board (NI USB-6366) controlled with the Labview software.

To ensure greater measurement performance at these velocities an additional piezo-electric load cell has been installed (Kistler 9361B), connected to a Charge Amplifier (Kistler 5015). Due to the greater resonance frequency of the piezoelectric load cells the force measurements acquired with this device are not influenced by the applied load (in this range of velocity), thus ensuring the absence of ringing phenomena (resonance of the measuring load cell).

In this tests series a faster camera has been used to record a suitable number of frames during the test (see 5.2). This is a Photron SA1.1 high speed camera synchronized with the NI acquisition board and the Veritas lights.

Table 2 summarizes the low strain-rate tests performed and the label of each experiment.

Table 2. Low strain-rate tests.

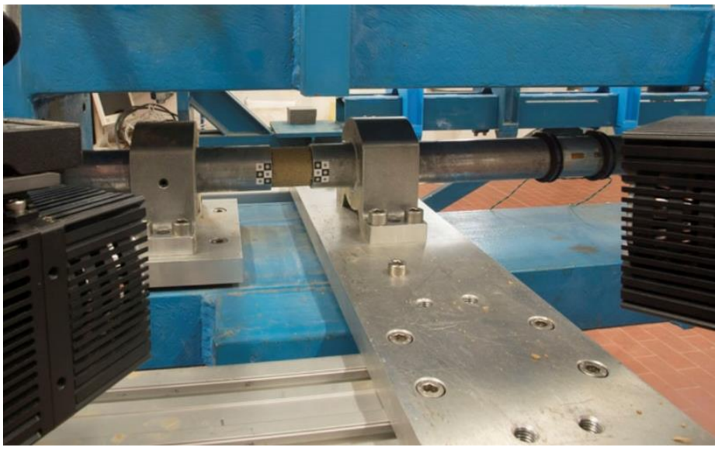
Test Label	Test Type	Maximum Displacement	Date	Specimen
g2	Monotonic MTS	10 mm	17/07/2018	AA6b
g3	Monotonic MTS	10 mm	17/07/2018	AA6c
g4	Monotonic MTS	10 mm	17/07/2018	AA13a
g5	Monotonic MTS	10 mm	17/07/2018	AA7c
g6	Monotonic MTS	10 mm	17/07/2018	AO13c
g7	Monotonic MTS	10 mm	17/07/2018	AO14a
g8	Monotonic MTS	10 mm	17/07/2018	AO11c
g9	Monotonic MTS	10 mm	17/07/2018	AO10c
g10	Monotonic MTS	10 mm	17/07/2018	BA13a
g11	Monotonic MTS	10 mm	17/07/2018	BA4a
g12	Monotonic MTS	10 mm	17/07/2018	BA9b
g13	Monotonic MTS	10 mm	17/07/2018	BA5c
g14	Monotonic MTS	10 mm	17/07/2018	BO3c
g15	Monotonic MTS	10 mm	17/07/2018	BO6a
g16	Monotonic MTS	10 mm	17/07/2018	BO12a
g17	Monotonic MTS	10 mm	17/07/2018	BO11a

To ensure that the test velocity was reached by the testing machine piston a small gap was maintained between the compression plate and the initial position of the specimen upper face. For this reason, the maximum displacement of the test has been increased to 10 mm (compared with the 5 mm stroke of the static tests) to attain the proper level of maximum strain.

3.2 Split Hopkinson Pressure Bar

As mentioned above, high strain-rate tests have been performed on a particular setup of Hopkinson bar specifically designed for brittle and geo-materials. In particular, the bars present a large diameter to clamp specimens of a greater cross-section (compared with standard Hopkinson bars) and are made of aluminium to maintain an adequate sensitivity in terms of deformation (to reduce the signal to noise ratio of acquired signals). In addition, the equipment is designed to generate a long input pulse (of about 0.7 ms) to achieve the maximum specimen strain requested by the user. Figure 6 shows the whole apparatus and a detail of the equipment close to the specimen. The machine is an example of the so called "modified Hopkinson bar" because the input pulse is generated through the pre-stressing of a portion of the input bar and quickly released, and not by the impact of the striker bar accelerated with a gas gun apparatus. In this case the pre-stressed bar is made of Maraging steel (diameter 25 mm), connected with an aluminium input bar of 40 mm diameter. The output bar has the same characteristics of the aluminium input bar.

Figure 6. SHPB setup for brittle and geo-materials at ELSA laboratory (left) and details of the specimen zone (right)



Both input and output bars are equipped with semiconductor strain-gages (Kyowa KSP-6-350-E4) connected with a half-bridge configuration. The Wheatstone bridge signal is amplified using a strain-gage amplifier with a cut-off frequency of 500 kHz (EFS SGA02 high-speed) and then recorded at a sample-rate of 5 MHz with a fast transient recorder (GAGE CSE8482-H2).

Using a reference load cell (HBM U15) the whole measurement chain (three strain-gage measurement points on each bar) has been statically calibrated by pre-stressing in compression the equipment bars and comparing the signal of the reference load cell and those of the strain-gage measurement points, according to a procedure derived by standard EN ISO 376_2011.

In addition to the classical Hopkinson bar instrumentation a high speed camera (Photron SA1.1) has been used to capture a photo sequence of each test (frame-rate of 50000 fps) synchronized with the transient recorder. A series of reflector targets have also been placed on the input and output bar close to the specimen in order to apply a target follower algorithm for the computation of additional bar-end displacement measurements. The same cold lights Veritas Constellation 120 have been used to ensure the optimal illumination during the test.

All tests have been performed with an average pre-stressing of about 90 kN that generates, on the specimen, a displacement with an average speed of about 4.2 m/s. Table 3 summarizes the high strain-rate tests performed on the Hopkinson bar and the label of each experiment.

Table 3. High strain-rate tests.

Test Label	Test Type	Date	Specimen
i3	SHPB	18/07/2018	AA2b
i4	SHPB	18/07/2018	AA4c
i5	SHPB	18/07/2018	AO10a
i6	SHPB	18/07/2018	AO3a
i7	SHPB	18/07/2018	BA5b
i8	SHPB	18/07/2018	BA9a
i9	SHPB	18/07/2018	BO3b
i10	SHPB	18/07/2018	BO13c
i11	SHPB	19/07/2018	AA7b
i12	SHPB	19/07/2018	AA11b
i13	SHPB	19/07/2018	AO11b
i14	SHPB	19/07/2018	AO13a
i15	SHPB	19/07/2018	BA4b
i16	SHPB	19/07/2018	BA6b
i17	SHPB	19/07/2018	BO11b
i18	SHPB	19/07/2018	BO10a

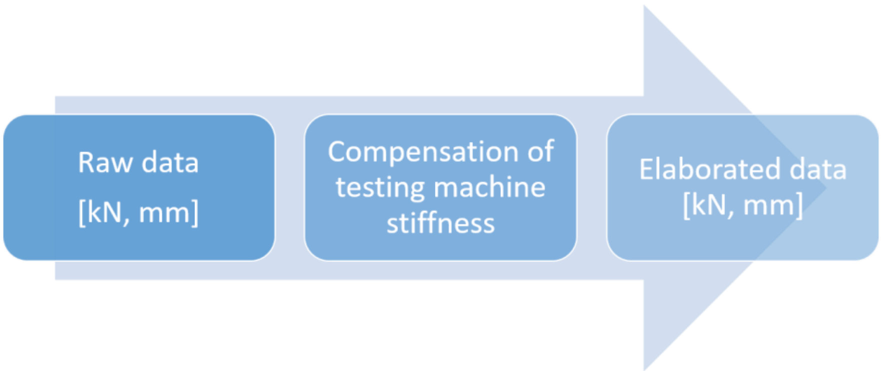
4 Data elaboration

All recorded data in the above described tests are not directly useful to derive the force-displacement curve of the tested specimen. Some signals have to be simply scaled (because they are recorded by an AD converter in Volt) but there are some additional elaboration techniques that improve substantially the accuracy of the results derived from the acquired data. In addition, especially for the Hopkinson bar apparatus, the signal elaboration is not trivial and requires particular procedures due to the wave propagation phenomena that are exploited in this experimental technique. The next paragraphs explain the principles of the data elaboration adopted to derive the force-displacement curves of each specimen.

4.1 MTS Servo-hydraulic testing machine

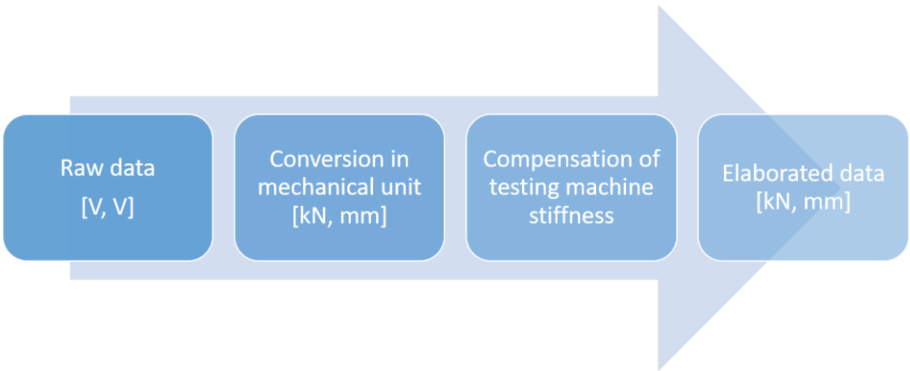
For what concerns the experimental data obtained in a test performed with a standard testing machine the raw data are already converted in mechanical units (Forces [kN] and displacement [mm]). In any case, if it is not possible to apply an extensometer, it is better to compensate the elastic deformation of the frame structure of the testing machine (knowing the machine stiffness) to achieve a greater accuracy in the evaluation of the Young modulus of the specimen. The elaboration block diagram for this kind of test can be summarized as in Figure 7.

Figure 7. Elaboration block diagram for static tests



Regarding the elaboration of low strain-rate tests, since the machine was the same as for static tests, the adoption of the external acquisition board requires an additional step in the elaboration process. In fact, the sensor signals recorded have first to be converted in mechanical units and then elaborated, as reported in the block diagram of Figure 8. In addition, in this case, it is possible to compare the converted raw data with those recorded by the digital control unit of the testing machine (which are recorded at a lower sample rate) to control and ensure data consistency.

Figure 8. Elaboration block diagram for low strain-rate tests



4.2 Split Hopkinson Pressure Bar

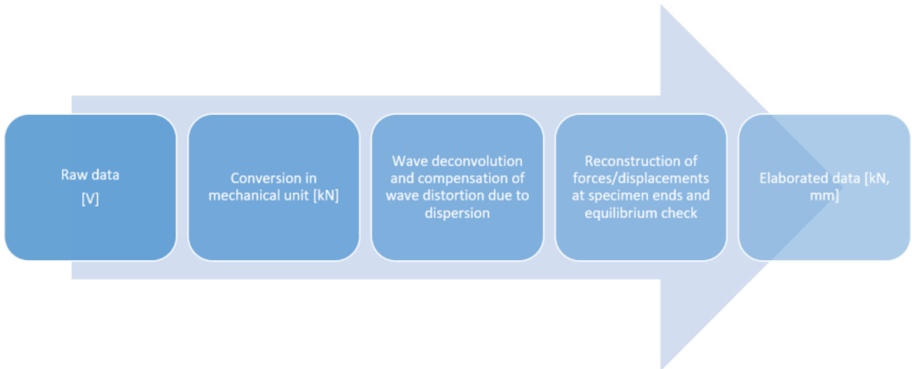
The elaboration of data recorded in a Hopkinson bar test is totally different from the techniques adopted in standard mechanical testing methods. Since this machine exploits the propagation of elastic waves in elastic rods the elaboration procedure requires some typical algorithms of signal processing like Fast Fourier transforming, deconvolution, phase shifting, etc.

Figure 9 presents the elaboration block diagram of the recorded signals in a Hopkinson bar test.

Specifically, the signals, which are proportional to the input/output bar strains (recorded in three locations for each bar), are converted into forces and then with a deconvolution algorithm the two travelling waves (*ascending* and *descending*) in each bar are distinguished and the needed incident, reflected and transmitted waves are determined. This algorithm has to compensate for distortions due to dispersion phenomena because a wave pulse when it propagates through an elastic confined medium changes its shape (the different frequency wave components propagate with slightly different velocities).

Knowing the *ascending* and *descending* waves in each bar the forces and displacements at the specimen ends can be accurately reconstructed and then the equilibrium of the specimen checked. If the specimen is in equilibrium, as checked to be the case in these tests, the forces and displacements reconstructed are appropriate for the evaluation of the stress-strain curve of the tested material.

Figure 9. Elaboration block diagram for Hopkinson bar tests



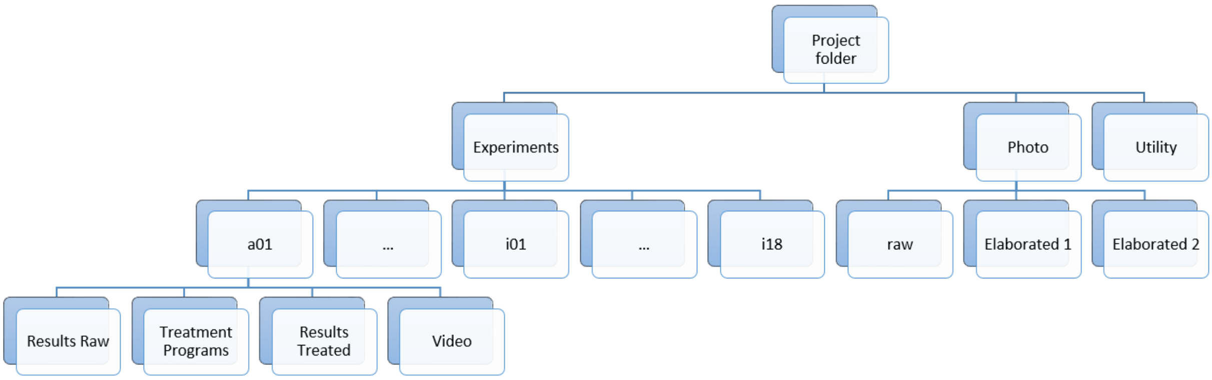
Due to the complexity of Hopkinson bar elaboration (the accuracy is related also to the precise positioning of the strain-gage sensors on the bars) it is important to have additional independent measures which could serve for comparisons with the reconstructed quantities with the algorithms just mentioned above.

One possibility is to elaborate the high speed photo sequence of each test to compute the displacements of the bar-ends, using a tracking algorithm. The data extracted in this way have a sample rate lower than the standard Hopkinson bar data but they have a precision that can reach the order of 0.01 mm. A good correlation of these two independent-source data ensures the accuracy of the results obtained with a Hopkinson bar test especially in tests performed on non-conventional materials (for the Hopkinson bar methodology) such as brittle and geo-materials.

5 Database structure and data results

For the large number of tests of the DIF Adobe campaign a considerable amount of data has been stored and managed. This section provides a basic description of the database structure of the user data (raw and elaborated),which is similar to the database adopted since 2000 in the ELSA laboratory. Diagrammatically the database is organized as depicted in Figure 10.

Figure 10. Database structure



The main project folder contains two excel files (*DIFadobe_experiments.xlsx* and *SamplesGeometryJRC.xlsx*), which contain, respectively, the table with all experiments performed (test label, test type, etc.) and the specimen tables (with the relevant data). The main folder contains in addition:

- The *Experiments* folder. This folder contains several subfolders named with the test labels described in the *DIFadobe_experiments.xlsx* file. In each experiment folder there are four subfolders that contain: the raw data acquired during the experiments (*Results Raw*), the matlab routines used to elaborate the data and save them in the format required by the users (*Treatment Programs*), the treated results (*Results Treated*) and a subfolder that contains the photo sequence acquired during the tests (*Video*).
- The *Photo* folder contains all the photos shot during the tests campaign. The original photos are stored in the *raw* folder while the elaborated ones (in general subsampled for paper purposes) are saved in the other *elaborated* folders (with a label that identifies the test campaign phase).
- The *Utility* folder contains some applications useful for the elaboration of the data results. In this case this folder contains two software useful to open the test photo sequences.

In the next paragraphs a small description of the data in the experiments folders will be given to help the users in the elaboration phases of all experimental data.

5.1 Static tests data

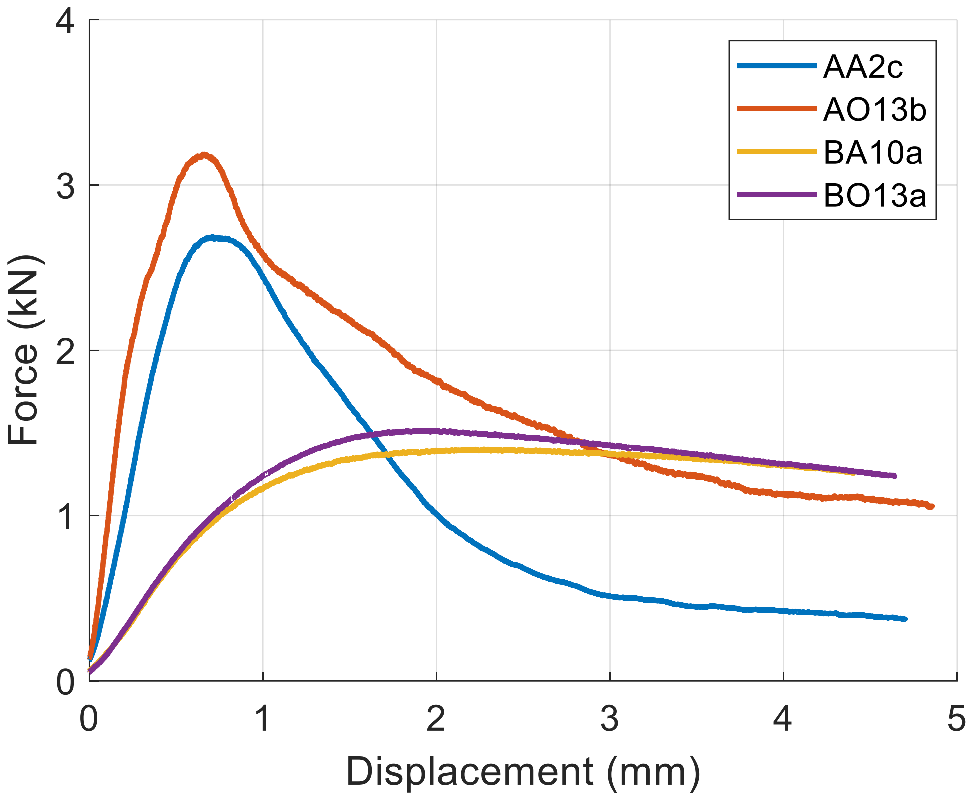
Raw results consist of text files with three columns and without headers: time (s) with a frequency of about 10 Hz (500 seconds of acquisition), displacement (mm) and force (kN).

The image photo-sequence is composed of 500 images acquired at sample rate of 1 Hz synchronized with the other signals.

The elaborated data are reported in text files with four columns and headers: time (s), corrected displacement (mm), Force (kN) and test velocity (mm/s)

Figure 11 presents an example of force-displacement curves (*Results Treated*) for the specimens tested under static test.

Figure 11. Force-displacement curves for the static tests



5.2 Intermediate strain-rate tests data

Raw results consist of two files in the form *test_label.txt* and *test_label.csv* that contain, respectively, the raw file generated by the MTS testing machine and the NI acquisition board. The text files have three columns without headers: time (s) with a frequency of about 1 kHz (about 150 ms of acquisition), displacement (mm) and force (kN). This file is used in the data elaboration only to have additional sub-sampled measures.

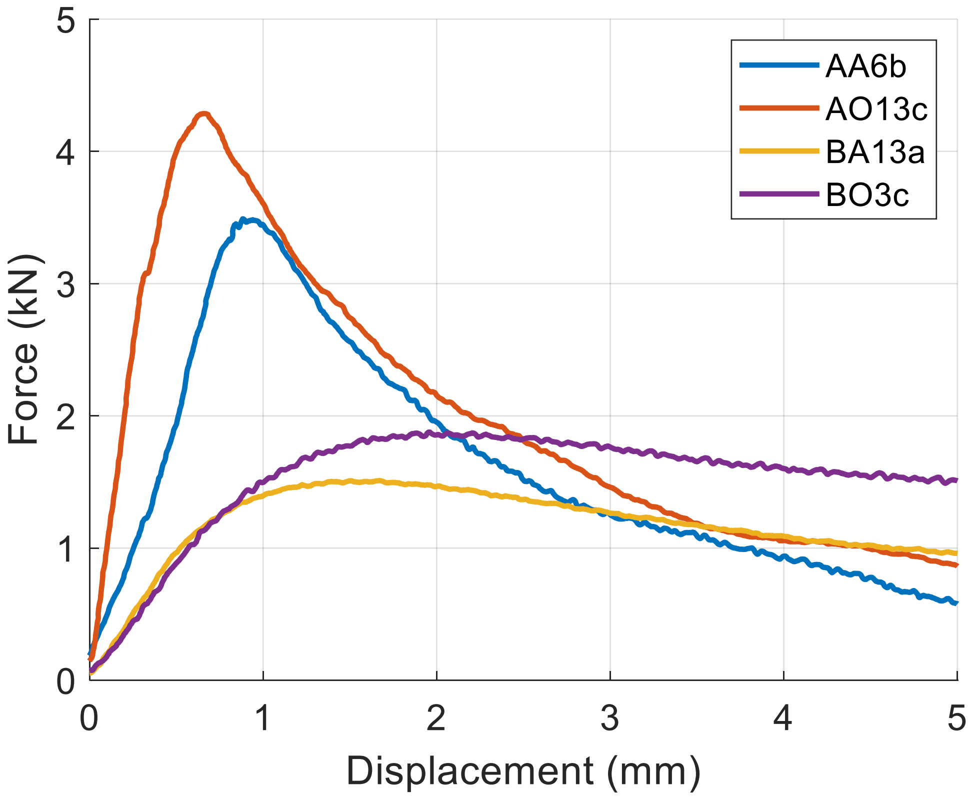
The csv files have three columns without headers: displacement (V), force derived by the MTS load cell (V) and the force derived by the Kistler load cell. The files contain 5000 points sampled at 20 kHz (250 ms). The conversion factors of these quantities can be found in the matlab elaboration files of each test.

The image photo-sequence is composed of 601 images acquired at sample rate of 5 kHz synchronized with the other signals (from time 80 ms to 200 ms where time = 0 is the start of the NI board acquisition).

As in the case of the static tests, the elaborated data are reported in text files with four columns and headers: time (s), corrected displacement (mm), Force (kN) and test velocity (mm/s). The Force signal is deduced by the piezoelectric load cell.

Figure 12 presents an example of the force-displacement curves (*Results Treated*) for the specimens tested under low strain-rate.

Figure 12. Force-displacement curves for the low strain-rate tests



5.3 High strain-rate tests data

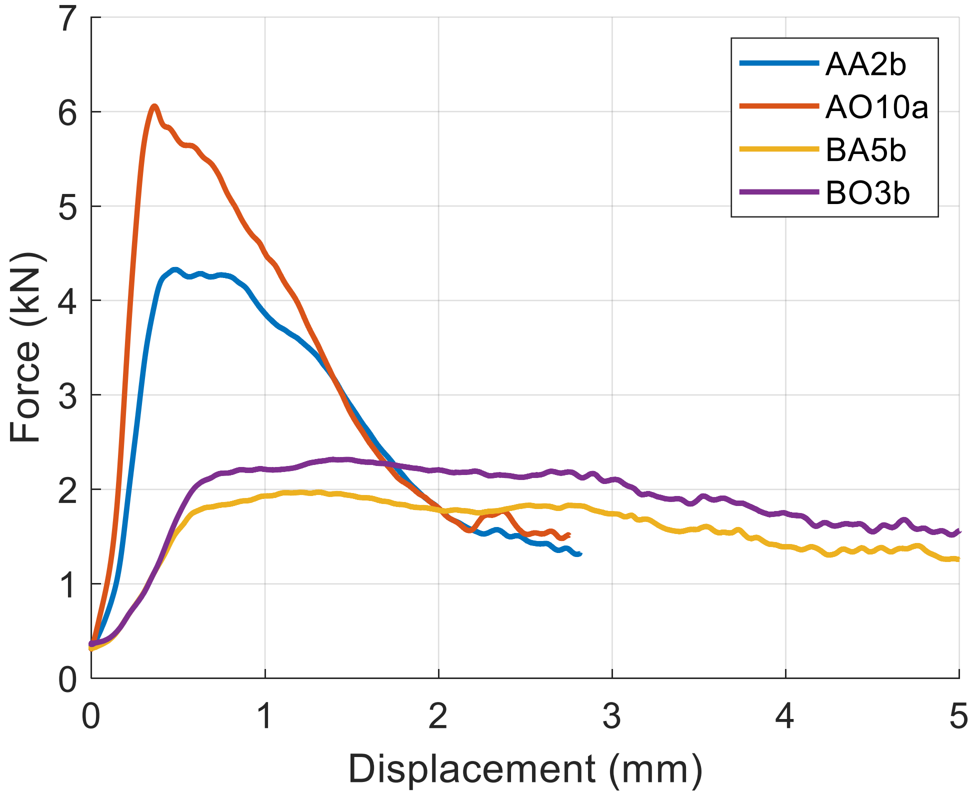
Raw results consist of several ASCII files with the time histories of the strain-gage measurements from the points along the bars. Each file has two columns: time (s) and strain-gage signal (V). The conversion factors of each strain sensor can be found in the matlab elaboration files of each test. The acquisition lasts from -0.4 ms to 5 ms.

The image photo-sequence is composed of 271 frames captured at 50000 fps. The photo sequence time acquisition coincides with the time of the sensors acquisition.

The elaborated data are reported in text files with four columns and headers: time (ms), input bar-end displacement (mm), output bar-end displacement (mm) and output bar-end Force (kN). The elaborated data do not have a constant duration but depend on the specimen failure time. However, the time is always synchronized with the image acquisition.

Figure 13 presents an example of the force-displacement curves (*Results Treated*) for the specimens tested under high strain-rate.

Figure 13. Force-displacement curves for the high strain-rate tests



6 Conclusions

This report has presented the main technical aspects of the DIF Adobe test campaign carried out in the context of the JRC OPEN ACCESS activity at the HopLab laboratory. A description of the test machines and elaboration procedures has been reported to help the user to effectively use the data results. The large amount of data, in terms of sensor signal histories and image acquisitions, has been organized following the established structure of the ELSA laboratory database, and stored on the JRC BOX for a fast data exchange with the potential users.

It must be underlined that, due to the particular properties of the tested adobe materials, during this test campaign several unexpected problems have been encountered, which, however, have been efficiently resolved through an effective cooperation between User and access providers. The project has reached its objectives and the activity is deemed to be a success by both parties. The experimental data obtained are considered to be of high quality and of significant scientific interest and they could constitute a solid starting point for future collaborative investigations.

List of figures

List of tables

Annexes

Annex 1. Properties of oven-dried specimens

Specimen Name	Weight (g) (before curing)	Weight (g) (after curing)	h1 (mm)	h2 (mm)	D1 (mm)	D2 (mm)	Notes
AO10a	63.51	63.35	35.6	35.7	35.5	35.5	
AO10b	62.8	62.61	35.8	35.8	35.4	35.4	Small inclusion
AO10c	62.8	62.65	35.8	35.9	35.5	35.5	
AO13a	63.23	63.59	35.9	35.9	35.5	35.5	
AO13b	63.16	63.56	35.8	35.9	35.5	35.4	
AO13c	63.32	63.66	35.9	35.9	35.5	35.5	
AO3a	63.15	63.45	36.0	36.0	35.5	35.5	
AO3b	63.02	63.33	35.7	35.8	35.4	35.5	
AO3c	62.77	63.04	35.8	35.8	35.5	35.4	
AO11a	62.87	62.76	35.7	35.7	35.5	35.4	
AO11b	62.8	62.61	35.7	35.7	35.4	35.5	
AO11c	62.83	62.68	35.7	35.7	35.4	35.5	
AO14a	62.69	63.2	35.9	35.9	35.4	35.5	
AO14b	62.42	62.91	35.9	35.92	35.44	35.46	External hole
AO14c	62.34	62.63	35.6	35.6	35.4	35.4	
AO5a	61.98	61.71	35.3	35.3	35.4	35.4	
AO5b	62.01	61.74	35.6	35.7	35.3	35.3	
AO5c	62.71	62.44	35.6	35.7	35.3	35.3	
BO3a	37.17	37.44	35.5	35.6	35.6	35.6	Damaged end
BO3b	38.02	38.28	35.7	35.7	35.5	35.6	
BO3c	38.05	38.29	35.8	35.8	35.5	35.6	
BO6a	38.25	38.6	35.8	35.8	35.5	35.5	
BO6b	37.66	37.92	35.8	35.8	35.5	35.5	
BO10a	40.09	40.4	35.7	35.8	35.6	35.7	
BO10b	38.17	38.48	35.6	35.6	35.5	35.6	
BO10c	38.88	39.16	35.8	35.8	35.5	35.5	Damaged end
BO11a	38.25	38.8	35.7	35.7	35.7	35.7	
BO11b	39.61	40.07	35.7	35.7	35.6	35.7	
BO11c	38.32	38.76	35.7	35.7	35.6	35.6	Damaged end
BO12a	38.79	39.33	35.7	35.8	35.6	35.6	
BO12b	39.54	40.02	35.6	35.6	35.5	35.6	
BO12c	38.28	38.78	35.1	35.1	35.6	35.6	Damaged end
BO13a	38.87	39.42	35.7	35.8	35.5	35.5	
BO13b	38.23	38.8	35.8	35.7	35.5	35.6	Small inclusion
BO13c	39.47	40.05	35.8	35.8	35.6	35.6	

Annex 2. Properties of air-dried specimens

Specimen Name	Weight (g)	h1 (mm)	h2 (mm)	D1 (mm)	D2 (mm)	Notes
AA2a	61.69	35.6	35.7	35.3	35.5	External hole
AA2b	62.32	35.8	35.8	35.3	35.3	
AA2c	62.61	35.8	35.7	35.5	35.4	
AA4a	63.44	35.6	35.8	35.4	35.4	
AA4b	62.83	35.8	35.6	35.4	35.3	Small inclusion
AA4c	62.85	35.7	35.6	35.4	35.4	
AA6a	63.21	35.7	35.7	35.4	35.4	
AA6b	63.02	35.8	35.8	35.4	35.5	
AA6c	63.33	36	36	35.4	35.4	
AA7a	62.59	35.8	35.8	35.4	35.4	
AA7b	62.99	35.9	35.9	35.3	35.4	
AA7c	62.63	35.7	35.7	35.4	35.3	
AA11a	62.84	35.7	35.6	35.4	35.4	External hole
AA11b	63.63	35.9	35.8	35.4	35.4	
AA11c	62.62	35.6	35.7	35.4	35.3	External hole
AA13a	63.42	35.8	35.7	35.5	35.4	
AA13b	63.81	35.9	35.9	35.4	35.4	
AA13c	62.99	36	35.8	35.4	35.4	

BA4a	39.21	35.9	35.9	35.5	35.5	
BA4b	39.2	35.9	35.9	35.5	35.4	
BA4c	38.58	36	35.9	35.5	35.5	
BA5a	36.86	36	35.9	35.2	35.2	Damaged end
BA5b	37.6	35.9	35.9	35.3	35.3	
BA5c	37.8	35.8	35.8	35.5	35.6	
BA6a	37.97	35.9	35.9	35.2	35.1	
BA6b	37.82	36	36	35.3	35.3	
BA6c	38.44	35.8	36	35	35.2	Small inclusion
BA9a	37.94	36	36	35.4	35.4	
BA9b	38.63	36	36	35.6	35.4	
BA9c	37.58	36	36	35.2	35.4	
BA10a	38.35	36	36	35.3	35.3	
BA10b	38.15	36	36	35.2	35.1	
BA13a	36.97	36	36	35.3	35.3	

GETTING IN TOUCH WITH THE EU

In person

All over the European Union there are hundreds of Europe Direct information centres. You can find the address of the centre nearest you at: https://europa.eu/european-union/contact_en

On the phone or by email

Europe Direct is a service that answers your questions about the European Union. You can contact this service:

- by freephone: 00 800 6 7 8 9 10 11 (certain operators may charge for these calls),

- at the following standard number: +32 22999696, or

- by electronic mail via: https://europa.eu/european-union/contact_en

FINDING INFORMATION ABOUT THE EU

Online

Information about the European Union in all the official languages of the EU is available on the Europa website at: https://europa.eu/european-union/index_en

EU publications

You can download or order free and priced EU publications from EU Bookshop at: https://publications.europa.eu/en/publications. Multiple copies of free publications may be obtained by contacting Europe Direct or your local information centre (see https://europa.eu/european-union/contact_en).

KJ-NA-30308-EN-N

The European Commission's science and knowledge service
Joint Research Centre

JRC Mission
As the science and knowledge service of the European Commission, the Joint Research Centre's mission is to support EU policies with independent evidence throughout the whole policy cycle.

EU Science Hub
ec.europa.eu/jrc

@EU_ScienceHub

EU Science Hub - Joint Research Centre

EU Science, Research and Innovation

EU Science Hub

Publications Office of the European Union

doi:10.2760/17519

ISBN 978-92-76-20870-9