SERIES
SEISMIC ENGINEERING RESEARCH INFRASTRUCTURES FOR EUROPEAN SYNERGIES

Workpackage [WP3]

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ABSTRACT

The main focus of this report was on large testing facilities, which owing to their special character and relatively small number, their differences in technical solutions, the wide variety of testing procedures among their operators. The work performed within the concept of this report checked the compliance of the different approaches used with the requirements of the applicable standards or reference recommendations. The examined testing procedures mainly focused on seismic experimentation through real time (shake table), pseudo-dynamic (reaction wall) and quasi static testing. Repeatability and reproducibility are employed as the main criteria for technical competence and quality assurance in order to guarantee the reliability of testing in a laboratory. Throughout the study, information on testing procedures used in seismic testing was collected from laboratories in Europe with large testing facilities. This information was then critically assessed and various items were recommended for the Common Protocol that will be prepared for the Qualification of large testing facilities.

Keywords

Certification
The formal procedure by which an accredited or authorized person or agency assesses and verifies (and attests in writing by issuing a certificate) the attributes, characteristics, quality, qualification, or status of individuals or organizations, goods or services, procedures or processes, or events or situations, in accordance with established requirements or standards.

Accreditation
The certification of competence in a specified subject or areas of expertise, and of the integrity of an agency, firm, group, or person, awarded by a duly recognized and respected accrediting organization.

Qualification
The process to demonstrate the ability to fulfill specified requirements (ISO 9000).

Standard
A technical specification approved by a recognized standardization body for repeated or continuous application, with which compliance is not compulsory (Directive 98/34/CE).

Facility/Facilities
The laboratory/laboratories dealing with the large-scale seismic testing and/or monitoring of structures.
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1 Work Package 3 Overview

1.1 INTRODUCTION - RELATED AIMS OF THE SERIES PROJECT

SERIES project aims at bridging the two gaps of RTD in experimental earthquake engineering and structural dynamics:

(a) between Europe and the US or Japan, and

(b) between European countries with high seismicity but less advanced RTD infrastructures on one hand and some more technologically advanced but not so seismic Member States on the other.

It will do so by integrating the entire European RTD community in earthquake engineering via:

- A concerted program of Networking Activities, fostering a sustainable culture of cooperation among all research infrastructures and teams active in European earthquake engineering;
- A distributed database of test results, pooling data from the beneficiary research infrastructures and others, accessible and maintained by a virtual research community after the project’s end;
- Tele-presence and geographically distributed concurrent testing at the research infrastructures;
- Standards, protocols and criteria for qualification of RTD infrastructures in earthquake engineering;
- Enhancement of human resources by training new users and beneficiary technical/research personnel in courses on good practices in operation and use of research infrastructures;

The networking activities of the project will enhance the services provided by the research infrastructures, transcending their current extreme fragmentation, through the following:

- The creation of a very large virtual European research laboratory, through tele-presence and geographically distributed testing at the participating research infrastructures;
- Wide sharing of data and knowledge across the field of earthquake engineering and between academia, research and industry, through a web portal and distributed database, to be maintained and enhanced well beyond the end of the project;
• A better structure and integration at a European scale of the way similar research infrastructures operate, developing synergies and complementarities between them and fostering their joint development in terms of performance and access;
• Common European standards and protocols for similar research infrastructures and qualification criteria for European research infrastructures in earthquake engineering.

1.2 INTRODUCTION - DESCRIPTION OF WP3 NA2

WP3 NA2 is the Networking Activity of the SERIES Project whose aim is to create the conditions leading to the qualification (in the form of mutual accreditation) of Structural Testing Laboratories specializing in earthquake engineering and equipped for large scale testing.

For the qualification it was recognized that the combination of two main requirements on the laboratories is necessary: technical competence and quality assurance. The final objective of the mutual accreditation is to guarantee the reliability of testing in each laboratory. In reliability implicit is repeatability, i.e., the principle that experimental activities repeated on the same specimen in the same laboratory lead to the same result (within, of course, certain tolerances and fixed conditions).

The conclusions of the assessment of testing and instrumentation management procedures in Tasks NA2.2 and NA2.3, respectively, will most likely lead to a critical analysis of the requirements imposed by official standardization and accreditation organizations, National and European.

The activities in NA2 will address the assessment criteria for technical competence of the beneficiary laboratories – and of similar ones in future – and develop the basis for their mutual accreditation. This will focus on seismic experimentation through real-time (shake table), pseudo-dynamic (reaction wall) or even quasi-static testing and on-site testing and monitoring, which concerns all research infrastructures in this project.

The activity involved directly all Structural Research Infrastructures performing seismic experimentation and equipped for large scale testing; furthermore the networking involved the users of the research infrastructures (S/T community and Industry), which will ultimately draw the benefits from the qualification of laboratories for Products Certification.

The activity was broken down in four Tasks.

Task NA2.1: Evaluation and impact of qualification of experimental facilities in Europe

The task included:
• a critical analysis of the problems that limit the free circulation of the products of the European Industry, the solution of which will be promoted by the qualification of structural laboratories, and
• a study of the issues – of technical, quality or commercial relevance - which in fact constitute obstacles to the mutual accreditation.
Final Users (Industry) and Accreditation or Standardization Organizations were directly involved, through questionnaires and meetings. A detailed roadmap towards the common protocol for mutual accreditation among the laboratories will be drawn.

Task NA2.2: Assessment of testing procedures and standards requirements

The focus of this task was on Shaking Table and Reaction Wall facilities, which, owing to their special character and relatively small number, their differences in technical solutions, the wide variety of testing procedures among their operators and the almost non-existence of knowledge of the technology itself among the Users (Industry), do not lend themselves to fully harmonized approaches. The task checked the compliance of the different approaches used with the requirements of the applicable standards or reference recommendations (concerning, for instance, the selection of the seismic input and how it conforms to reference spectra, as well as the measurement, assessment and documentation of the technical aspects affecting the reliability of the tests). The work was based on a comparative analysis and critical assessment of present procedures and equipment in the different laboratories for the execution of tests. Quality Assurance approaches were investigated as well. There was exchange of information among the laboratories, round visits of test operators to the co-operating facilities, especially on the occasion of important or benchmark tests.

The task was carried out in three main phases:

- Collection of data and information on the testing procedures used for seismic experimentation.
- Critical assessment of the information.
- Production of the report of the task.

Task NA2.3: Criteria for instrumentation and equipment management

This task treated the issue of the management criteria of the instrumentation (testing equipment, measuring instrumentation, acquisition systems and processing tools), including the issues related to the calibration of instruments (periodicity and technical conditions), their maintenance, the estimation of measurement uncertainty, the practice used for applying measuring instrumentation on specimens, etc. As in Task NA2.2, a critical assessment of the presently adopted methods was made, after exchange of information among the laboratories regarding the procedures used, cross visits of the laboratory operators to the co-operating facilities on the occasion of important or benchmark tests, etc.

The task was carried out in three main phases:

- Collection of data and information on the laboratory use of instrumentation and its management for seismic experimentation.
- Critical assessment of the information.
- Production of the report of the task.
**Task NA2.4: Development and implementation of a common protocol for qualification**

The starting point of this task will be the International Workshop on “Role of research infrastructures in performance-based earthquake engineering”, organized by beneficiary IZIIS in Ohrid (Republic of Macedonia), in conjunction with the 14th European Conference in Earthquake Engineering in Sept. of 2010. A day of that workshop will be dedicated to NA2, with the participation of the beneficiaries in NA2 and of representatives from Industry and European Accreditation or Standardization Organizations, specially invited to this event. It will be an occasion for informing the audience about the goals and progress so far of NA2, disseminating the achieved results and receiving feedback from Industry and the representatives of Accreditation or Standardization Organizations.

Using as baseline the outcomes of Tasks NA2.1 to NA2.3 and the conclusions of the discussion at the Workshop, the most important part of this NA2 will follow, notably the development of a draft Common Protocol for the qualification of research infrastructures in earthquake engineering, in agreement among the beneficiary facilities. The draft protocol will give in detail the technical rules and the quality assurance approach to be adopted as a condition for mutual accreditation of an earthquake engineering laboratory. The protocol will be supplemented by the necessary technical guidance and recommendations, in the form of Technical Annexes. Beneficiary research infrastructures will then implement the protocol in their laboratories, on a voluntary and pilot basis. Potential difficulties in the application of the draft protocol will be highlighted by its pilot implementation and the protocol will be revised into a final Common Protocol for the qualification of research infrastructures in earthquake engineering.

1.3 **GENERAL CRITERIA AND REFERENCES**

1.3.1 **References**

The activities were conducted with reference to the documents listed at the end of the present report.

1.3.2 **General criteria**

The activities of WP3 are conducted making reference to docs. from |8| to |14|: the justification of this choice is following:

- As far as the two main requirements for the qualification of the laboratories, quality management system and technical competence, a sound experience is available in the application of international standards as docs. from |8| to |10|; this choice will allow to fulfill the requirements of the last task of NA2, when a contribution from European Accreditation or Standardization Organizations is expected to reach an agreement to issue a final Common Protocol for the qualification of research infrastructures in earthquake engineering;
From a technical point of view the mutual accreditation is a tool to guarantee the reliability of testing laboratories: reliability is translated in practice into
- Repeatability [15], the principle that experimental activities repeated on the same specimen in the same laboratory lead to the same results, and
- Reproducibility [15], the principle that experimental activities repeated on the same specimen in different laboratories lead to the same results.

Repeatability and reproducibility can be easily achieved if common standard test procedures are used. Moreover a common language can be established on the basis of international standards which could help avoiding mismatches and misunderstandings.

1.3.3 Task NA2.2:

The task includes the following activities:
- Identification of European Large Testing Facilities with Shaking Tables, Reaction Walls, On-site Testing and Large Structures Monitoring Capabilities;
- Preparation of a questionnaire to be circulated among the identified Large Testing Facilities in order to collect information about:
  - Procedures for testing management and performance;
  - Check of the compliance of the procedures with the requirements of the applicable standards or reference recommendations for the performance of experimental seismic testing
  - Check of the compliance of the procedures with the requirements of the applicable standards or reference recommendations for the performance of data acquisition and processing, including frequency analysis, statistics, modal analysis;
- Comparative analysis and critical assessment of present procedures;
- Comparative analysis and critical assessment of present equipment;
- Production of the report of the task
2 Collection of information

2.1 PREPARATION OF THE QUESTIONNAIRES

In order to save time and to optimize the compilation of the questionnaires by the contacted Institutions it was decided to prepare only four questionnaires covering all the issues of task 1, 2 and 3; then, after the collection of the filled questionnaires, they were processed by each task leader with reference to the specific parts dealing with the relevant task objectives.

For the seismic testing procedures, there is not any internationally recognized standard. Because of this reason, the questions related to the testing procedures mainly focused on identifying the type of test employed, equipment utilized, measured quantities, personnel in charge of test, and the way the test is being conducted. The questionnaire related to the testing procedures was only distributed to the European Large Testing Facilities.

2.2 EUROPEAN LARGE TESTING FACILITY QUESTIONNAIRE

The questionnaire to be circulated among European Large Testing Facilities Laboratories related to the testing procedures was as follows:

- **Identification of the test**
  - What types of items are typically tested?
  - What test method is typically employed (standard, internal)?
  - What type of test is typically performed (static test, pseudo-dynamic test, sinusoidal vibrations, multi-frequency vibrations, etc.)?
  - What is typically measured?
  - What is the typical measurement range?

- **Personnel in charge of the test**
  - What are the typical qualifications of personnel (study degree, years of experience)?

- **Test methods**
  - Is the test method a Standard?
  - Does the Facility have its own test procedures?
  - Does the Facility verify its own tests repeatability?
  - Does the Facility have a procedure for the evaluation of the measurements uncertainty according to ENV 13005?
- **Test performance**
  - Does the Facility verify that the testing equipment comply with the requirements of the test standard or method?
  - Are the raw data traceable starting from the test report?
- **Maintenance**
  - Does the Facility have procedures for the maintenance of the test equipment?
- **Calibration**
  - Does the Facility have calibration procedures stating responsibilities and calibration time intervals?
  - Does the Facility perform intermediate controls between two calibration dates?
- **Test report**
  - When opinions and interpretations are included, are they clearly marked as such in the test report?

2.3 IDENTIFICATION OF EUROPEAN LARGE TESTING FACILITIES

34 facilities responded the questionnaires. The list of the facilities was presented below:

- **International Institutions:**
  - EC-JRC - ELSA Laboratory
- **Belgium:**
  - University of Liège – Laboratory of Mechanics of Materials and Structures
- **France:**
  - CEA Saclay – Tamaris Laboratory
  - LCPC – Laboratoire Central des Ponts et Chaussées
- **Germany:**
  - UNIVERSITY OF KASSEL – Department of Civil Engineering
- **Greece:**
  - University of Patras - Dept. Of Civil Engineering - Structures Laboratory
  - National Technical University of Athens - Laboratory for Earthquake Engineering
  - Aristotle University – Laboratory of Geotechnical Earthquake Engineering and Soil Dynamic
- **Italy:**
  - EUCENTRE, Universita di Pavia
  - CESI – LPS Laboratory – Seriate
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- University of Trento - LABORATORY FOR MATERIAL AND STRUCTURAL TESTING
- University of Naples – Federico II University – Structural engineering Department
- Alga SpA
- FIP Industriale – Research and Development Department
- PeP LMC Srl
- GEWISS S.p.A

- Portugal:
  - FEUP - Faculdade de Engenharia da Universidade do Porto
  - IST - Instituto Superior Técnico
  - UA - Universidade de Aveiro
  - UM - Universidade do Minho
  - FCT - Faculdade de Ciências e Tecnologia da Universidade Nova de Lisboa

- Romania:
  - Technical University Gheorghe Asachi of Iasi – Faculty of Civil Engineering
  - INCERC branch of Iasi

- Turkey:
  - METU – Middle East Technical University, Structural and Earthquake Engineering Laboratory
  - Istanbul Technical University – Structural and Earthquake Engineering Laboratory
  - Bogazici University - Department of Civil Engineering - Structures Laboratory
  - Pamukkale University – Earthquake and Structural Technologies Laboratory
  - Karadeniz Technical University – Structural and Material Lab.
  - Kocaeli University – Department of Civil Engineering
  - Istanbul Kultur University - Department of Civil Engineering - Structural Mechanics Laboratory
  - Gazi University - Engineering Faculty – Department of Civil Engineering

- UK:
  - University of Bristol
  - University of Cambridge
  - Cardiff School of Engineering
3 Analysis of data

3.1 INTRODUCTION

The task included the following activities:

- Identification of European Large Testing Facilities with Shaking Tables, Reaction Walls, On-site Testing and Large Structures Monitoring Capabilities;
- Preparation of a questionnaire to be circulated among the identified Large Testing Facilities in order to collect information about:
  - Procedures for testing management and performance;
  - Check of the compliance of the procedures with the requirements of the applicable standards or reference recommendations for the performance of experimental seismic testing;
  - Check of the compliance of the procedures with the requirements of the applicable standards or reference recommendations for the performance of data acquisition and processing, including frequency analysis, statistics, modal analysis;

34 Large Testing Facility responded the questionnaire. There were 1 response from an international institution, 1 from Belgium and Germany, 2 from France and Romania, 3 from Greece and UK, 5 from Portugal, and 8 from Italy and Turkey.

3.2 EUROPEAN LARGE TESTING FACILITIES LABORATORY RESPONSES

The first part of the questionnaire about the testing procedures targeted to identify the items that are being tested for at European Large Testing Facilities. The summary of the tested items are presented below. The items are first classified according to the industry that they belong to and then according to their structural behavior.

- Civil Structures
  - System Level
    - Large/full scale structural systems
    - Shelter
    - RC Mock-up
    - Sub-assemblages
    - Frames with/without infill walls
  - Component Level
    - Non structural components
    - Beams
    - Columns
    - Slabs
Steel or composite steel
Concrete beam column connections
Steel bracing (bars, metal sheets)
Steel connections
RC walls
Masonry walls
Composite timber-fiber concrete walls
  • Special Devices
    • Bridge Bearings
    • Seismic Isolators
• Geotechnical Structures
  • Soil Specimens
  • Earthworks
  • Structures on Soils
• Electrical Structures
  • Electrical cabinets
  • Medium-high voltage electrical equipments
  • Electromechanical cubicles
  • Telecommunication equipment
• Mechanical Structures
  • Mechanical Components
  • Valves
• Automotive
• Nuclear
• Aeronautical
• Oil Industry
• Medical

The very wide range of items is being tested at the European Large Testing Facilities, from civil engineering industry to electrical, oil and nuclear industry. These items are not only single components such as columns, beams but also a combination of various components such as frames, sub-assemblies etc.

Another important issue for the identification of testing procedures is the test equipment and testing capabilities. The current test equipment existing at the European Large Testing Facilities can be grouped under five categories such as:

• Reaction Wall with static / quasi-static test equipment
• Reaction Wall with pseudo dynamic test equipment
• Shake Table with uni-axial or multi-axial excitation
• Centrifuge with sinusoidal or random dynamic excitation capabilities
• On-site testing related equipment
Numerous different types of tests are being conducted at the facilities for understanding the seismic behavior of an item. The type of test depends on the item that is tested and the experimental capabilities and equipment of the testing facility. According to the response to the questionnaires, several types of tests were identified. These tests are as follows:

- Pseudo-dynamic tests
- Static - Cyclic - Quasi static tests
- Low cycle fatigue (dynamic sinusoidal displacements)
- White noise
- Vibration
- Sinus sweep, multi frequency dynamic, impulsive and stepped sine tests, sinusoidal vibration
- Modal testing
- Ambient – shock hammer
- Shake table tests
- Tri-axial multi-frequency tests
- Environmental and impact vibration tests
- On-site testing
- Free-forced vibration tests

The last part of the questions related to the test methods focused on what is measured and the measurement range. The laboratories that perform static and pseudo dynamic tests mostly measure force, displacement, strain, crack opening, and rotations. The ones that have the real-time dynamic testing capability, such as shake table and on-site testing equipment, measure accelerations, velocities, and frequencies. The list of measured quantities and their minimum/maximum ranges are presented below.

- Force: +/- 3000 kN
- Displacement +/- 1m
- Strain 0-5000 με
- Crack Openings
- Acceleration 0 – 25g
- Mechanical Integrity
- Rotations
- Velocity
- Pressure
- Frequencies 0-200 Hz
- Micro-tremors
- Pore pressure

The personnel in charge of the test are another important aspect that affects the quality of tests. According to the response to the questionnaires, highly educated and experienced engineers and
academicians are conducting the tests. If the laboratory belongs to an academic institution, usually academicians with a PhD degree together with the graduate students and/or technicians are the responsible personnel. The summary of the responses regarding the personnel is presented below.

- Graduate Students
- Engineers – BS Degree
- Engineers – Msc Degree
- Engineers - PhD Degree: 5-20 years of experience
- Technicians 3-10 years of experience
- Academicians, PhD 10-30 years of experience

Repeatability is the principle that experimental activities repeated on the same specimen in the same laboratory lead to the same results and considered as one of the tools for accomplishing reliability of a test method. Repeatability can be achieved by utilizing common standard test procedures but only 19% of the laboratories are only performing tests according to a common, internationally accepted procedures or standards. The remaining 81% of the laboratories have their own testing procedures (Figure A.2). 77% of the laboratories, especially the ones that have their own testing procedures, verify their testing procedures’ repeatability (Figure A.3). The way they test repeatability is to compare the experimental results with the results of the analytical simulation or by testing the specimen with low amplitude motion a couple of times. 10% of the laboratories verify repeatability on a single test specimen, not on all specimens. The majority of laboratories do not have a procedure for the evaluation of the measurement uncertainty according to ENV 13005 (88%, Figure A.4).

31% of the laboratories are conducting standard tests only and 40% of the laboratories are conducting their own internal testing procedures (Figure A.1). 25% of the laboratories are performing both standard and internal procedures that depend on the item that is being tested. The list of the standards and guidelines for test procedures and seismic testing of various items is presented below:

- **Structural Components**
  - ECCS Recommended Testing Procedure for Assessing the Behavior of Structural Steel Elements under Cyclic Loads, N° 45, 1996
  - ATC-24, Guidelines for Cyclic Seismic Testing Components of Steel Structures for Buildings, Report No. ATC-24, Applied Technology Council, Redwood City, CA
- ANSI/AISC 341-05, Seismic Provisions for Structural Steel Buildings, AISC, 2005
- ICC-ES AC156, Seismic Qualification by Shake-Table Testing of Nonstructural Components and Systems, ICC Evaluation Service, Approved Criteria

- **Electrical Products**
  - EN 60255-21-3: Electrical relays-Part 21: Vibration, shock, bump and seismic tests on measuring relays and protection equipment-Section 3: Seismic tests.
  - IEEE/ANSI Std 344 - IEEE Recommended Practice for Seismic qualification of class 1E equipment for nuclear power generating stations.

- **Test Procedures**
  - IEC EN 60068-2-6 (2008-02) Environmental testing - Part 2: Tests - Test Fc: Vibration (sinusoidal)
  - IEC EN 60068-2-47 (2005-06) Environmental testing - Part 2: Test methods - Mounting of components, equipment and other articles for vibration, impact and similar dynamic tests
The current seismic testing standards and guidelines are mostly for a specific item like steel connections or elastomeric isolators and define procedures for a single test type. For example ECCS and ES 2126-02a define loading protocol for cyclic testing of steel elements and wall of buildings, respectively. The majority of the test standards are for structural components rather than systems. The system tests are defined only for electrical products and non-structural systems.

87% of the laboratories verify that the testing equipment complies with the requirements of the test standard or method (Figure A.5) and 84% includes the traceable raw data in the test report. 13% of the laboratories either put the raw data in the test report according to the request of the customer or put only the significant ones in the report. In other words, the majority of the laboratories give all necessary test results for tracing the performance of the test.

The maintenance and calibration of test equipment is another important factor that influences the quality of a test. 68% of the laboratories have procedures for the maintenance of the test equipment and 10% of them have maintenance procedures only for some of the equipment (Figure A.7). Moreover, 75% of the laboratories have calibration procedures stating responsibilities and calibration time intervals (Figure A.8). 6% does not have a specific time interval for calibration but they calibrate the testing equipment before every major series of tests. Only 51% of the laboratories perform intermediate controls between two calibration dates and 10% sometimes perform intermediate calibrations, where appropriate (Figure A.9).

It is very important to let the customer know that what part of the report are the opinions and interpretations of the laboratory personnel and what part is directly obtained from the test. According to the results of the questionnaires, the majority of the laboratories (87%) mark opinions and interpretations as such in the test report (Figure A.10). 13% of the laboratories do not include the opinions and interpretations in the test report, they just report the test results.
4 Roadmap for the qualification

4.1 INTRODUCTION

The main purpose of NA2 activities is to address the assessment criteria for the technical competence of the facilities and develop basis for their mutual accreditation. As a first step, European Large Testing Facilities were identified and information about the way they perform was collected. For this purpose, a questionnaire was prepared related to the testing procedures and distributed to the large testing facilities. 34 responses were received from 10 countries from Europe.

4.2 RESULTS FROM THE QUESTIONNAIRES ANALYSIS

Earthquake engineering laboratories carry out seismic testing with the following motivations, and related sources of funding:

a) Verification testing of a commercial product with industry funding,
b) Confirmation of code procedures for providing public safety, with public funding,
c) Pure research and development related testing, mostly with public funding.

Commercial products include factory produced or prefabricated structural components such as steel and timber members, nonstructural components such as exterior cladding, curtain walls and partitions, and several seismic devices such as seismic isolators, energy absorbers and bridge bearings. They also include electrical and mechanical products. Guidelines and specifications for the verification testing of these products are well established [4-21] where the producer stands as the client, and laboratory is the service provider. Laboratories are asked an accreditation certificate by the client for eligibility in verification testing. Accreditation does not guarantee the accuracy of the results, but it is related to the appropriateness of the testing procedures employed. The cost of accreditation changes from one country to another; it is, however, usually a significant amount which can only be provided by a laboratory which has income from commercial testing. Commercial motivation does not prevail for the other two categories of testing. Most of the laboratories which conduct seismic testing predominantly for research purposes do not apply to an accreditation agency for accreditation according to ISO/IEC 17025 or any other standard simply because nobody asks for such an accreditation, and probably they do not have available resources to meet the cost of accreditation.

There is not an internationally accepted standard for the qualification of research facilities that perform seismic testing. On the other hand, ISO/IEC 17025:2005, International Standard for General Requirements for the Competence on Testing and Calibration of Laboratories, covers
most of the issues that is required for the qualification of a facility. Thus, as a starting point, the questionnaires were analyzed according to their compliance to ISO/IEC 17025:2005. In this task, the technical competence of the testing laboratories was examined.

The technical competence of a facility will guarantee the reliability of tests conducted at such facilities. The reliability of testing laboratories can be achieved through repeatability and reproducibility of an experimental activity. Repeatability and reproducibility can be easily achieved if common standard test procedures are used. Moreover, a common language can be established on the basis of international standards which could help avoiding mismatches and misunderstandings. According to the results of the questionnaires, the existing test procedures in various standards and guidelines usually focused on a single component type (such as beam-column connection test) and a single type of experiment for a specific purpose. On the other hand, laboratories have a wide range of variety of test equipments for performing seismic tests. They perform numerous tests from simple static tests to more complex dynamic tests. The items that are tested are not only single components such as beams, columns, and walls but also the sub-assemblies and structures that involve combination of components. The things that are measured or investigated also change depending on the type of items that are being tested and the aim of the test. Thus, within the view of the responses of many large testing facilities in Europe, a single standard is not sufficient for understanding, defining, and predicting the seismic performance of components, devices or structural systems. Because of this reason, the majority of the laboratories have their own testing procedures that depends on their testing capabilities and items they are testing.

ISO/IEC 17025:2005, obligates the validation of a non-standard or laboratory designed/developed method. Among various validation techniques that exist in ISO/IEC 17025:2500, two of them have significant importance in terms of seismic testing: comparison of results achieved with other methods and inter-laboratory comparisons. These two validation technique are actually enforcing the reproducibility of an experimental activity which is another requirement for qualification besides repeatability. According to the results of the questionnaires, the majority of the laboratories that are conducting their own test methods confirm the repeatability of their testing procedures but reproducibility was not confirmed for most of the experimental activity.

ISO/IEC 17025:2005 also requires that laboratory developed methods shall be assigned to qualified personnel equipped with adequate resources. The questionnaires illustrated that the seismic tests are conducted by very well educated and highly experienced team of engineers and academicians. The person in charge of tests is usually an engineer with a minimum MSc degree at least 20 years of experience or an academician with a PhD of minimum 10 years of experience. The engineers and technicians that perform the test have also years of experience in the area. As a result, currently the seismic tests of any kind at European Large Testing Facilities are being conducted by highly competent personnel and experts in the area. Furthermore the majority of the laboratories had testing equipment that complies with the requirements of the test
standard or method. Thus, it can be concluded that the laboratories that utilize their own testing procedure comply with the requirements of ISO/IEC 17025:2005.

According to ISO/IEC 17025:2005, all equipment used for tests that have a significant effect on the accuracy or validity of the result of the test shall be calibrated before being put into service. Also, it requires that the laboratory shall have an established program and procedure for the calibration of its equipment. Most of the large testing facilities had calibration procedures that state the procedure and time intervals. Some of them also perform calibrations between scheduled time intervals. It is mandatory to have a maintenance plan for the testing equipment in order to ensure proper functioning according to ISO/IEC 17025:2005. It was observed that most of the laboratories had a maintenance procedure for the important testing equipment thus fulfill the requirements of ISO/IEC 17025:2005. Another requirement of ISO/IEC 17025:2005 is the estimation of uncertainty of measurements but only a few laboratories have a procedure for evaluating the measurement uncertainty according to ENV-13005.

The way the test reports should be prepared are explicitly defined in ISO/IEC 17025:25. It is required that the result of each test or series of tests shall be reported accurately, clearly, unambiguously and objectively. In addition to this, when opinions and interpretations are included in the report, the laboratory shall document the basis upon which the opinions and interpretations have been made. Opinions and interpretations shall be clearly marked as such in the test report. The way the laboratories prepare the test reports fulfill the requirements of ISO/IEC 17025:2500. Most of the laboratories include the raw data and mark any opinion and interpretation as such in the report.

4.3 RECOMMENDATIONS

ISO/IEC 17025 covers most of the issues that is required for the qualification of European Large Testing Facilities in terms of testing procedures. The questionnaires showed that ways the seismic tests are being conducted at the majority of laboratories are parallel with the requirements of ISO/IEC 17025. Thus, the first step of qualification may be suggested as the laboratory to satisfy all the requirements of ISO/IEC 17025 and be accredited by a third party. Such an approach may be suitable for laboratories that have industry funding. Handling the cost of accreditation by a third party and the maintenance of this accreditation, on the other hand, may be very difficult, sometimes not possible for research laboratories. Such laboratories’ funding is mainly coming from research projects and it may be hard to allocate funding from projects for periodic accreditation costs. Thus, research laboratories with limited flexible funding can satisfy the requirements of ISO/IEC 17025 by themselves.

One of the main problems of seismic testing is having numerous testing techniques, the variety and complexity of the tested items, and wide range of variety of equipments for seismic tests. For this reason, it is not possible to have a single standard for seismic testing. For each specific item and for each test technique, a different standard must be produced. Such an effort will require
significant amount of time and resources. Moreover, it is very common to see that research laboratories develop innovative testing procedures when they are involved in the assessment of specific structures, new components or materials. In this case, the test campaigns cannot be covered by any kind standard or certification. For such cases, it should be the scientific and technical competences of the laboratory that guarantee the reliability of the tests. As the new testing campaign reaches the necessary level of maturity, a standard for the new test procedure can be developed or the test procedure can be certified.

As a long term project, however, internationally accepted standards for each type of seismic test equipment are required for the qualification of laboratories. There are several international standards for quasi static testing of various components but standards for dynamic tests such as pseudo dynamic and shake table testing have not been produced yet. As a starting point, a common standard that focuses on the general aspects of dynamic testing for producing reliable test results can be produced.

An alternative approach is to have every laboratory validate their testing procedure through reproducibility. In other words, a single test structure whose seismic performance was known can be tested at every laboratory with the laboratories’ own testing procedure (benchmark testing). If the test results are within an acceptable limit, the laboratory can be considered as having satisfactory technical competence for seismic testing. The benchmark specimen should be easy to duplicate in dimensions and mechanical properties. A cantilever steel column is a good candidate for validating component level tests. Several of them can be produced in the same steel plant, and then qualified for benchmark testing through metallurgical inspections and very low level mechanical testing. The qualified specimens can then be transported to the laboratories for benchmark testing. Each test can be performed once for every different testing equipment and testing procedure. Funding of benchmark testing can easily be provided by the research laboratories’ own resources. It is important to note that, however, satisfying reproducibility for a single component may not guarantee the reproducibility of a test on a larger complex structure.

Another important aspect of reproducibility is the documentation. Every qualified laboratory must document the tests they performed for certification purposes in such a way that the same test can be reproduced at another laboratory with the same or different testing procedure, and the raw and treated data can be compared and verified so that similar conclusions are obtained. The distributed database that is being developed within the scope of SERIES project WP2/NA1 activity will be a very suitable choice for documentation and sharing the test results among European Large Testing Facilities. In this case, all partners of SERIES project should be able to upload and share their test data via distributed database.

SERIES project WP2/NA1 focuses on creation of a European platform (the Distributed DataBase) for wide sharing of data and knowledge across the field of earthquake engineering and between academia, research and industry. The main advantage of the distributed database is the possibility of an external user to connect to the SERIES Central Web and access an experimental data that exist at one of the European Large Testing Facility. Within the context of the
distributed database, a common language is being designed in order to reach all experimental data for different types of tests. This common language, named exchange data format, include all the necessary information for reproducing a test at another laboratory and allow comparison of test results and conclusions.

The qualification steps of laboratories for seismic testing procedures in terms of technical competence can be summarized as follows:

1. Any standard should resemble the frame of ISO/IEC 17025 and the confirmation of management criteria by an accreditation body, even if preferable, depends on financial resources. If they’re limited, then ISO/IEC 17025 requirements could be eventually checked and reported by the laboratory itself.

2. Verification of the test results by a third party established by the SERIES Consortium should be preferable, but it is open to discussion regarding the duration of the SERIES Consortium and on the acceptance of third party statements by USA, Japan, China or scientific Institution. One option is to have SERIES Consortium formed during the SERIES project but stay in charge even after the project is finalized. Benchmark testing can be utilized as a tool for test result verification.

3. An effort to produce international standards for dynamic testing procedures should be initiated. A common standard that covers the general aspects of dynamic testing can be a good starting point.

4. Test results should be documented through SERIES distributed database by filling all the related data fields in order to provide enough information for reproducibility of the test results.
5 References

2. ISO/IEC 17025 - General requirements for the competence of testing and calibration laboratories, 2005.
3. ENV 13005 – Guide to the expression of uncertainty in measurement, 1993
4. ECCS Recommended Testing Procedure for Assessing the Behavior of Structural Steel Elements under Cyclic Loads, N° 45, 1996
5. ATC-24, Guidelines for Cyclic Seismic Testing Components of Steel Structures for Buildings, Report No. ATC-24, Applied Technology Council, Redwood City, CA
10. ICC-ES AC156, Seismic Qualification by Shake-Table Testing of Nonstructural Components and Systems, ICC Evaluation Service, Approved Criteria
Appendix A: Responses to Questionnaires

Figure A.1: Response to the 1st Question about Test Methods
Figure A.2: Response to the 2nd Question about Test Methods

Has the Facility its own test procedures?

- **YES**: 81%
- **SOMETIMES**: 19%
- **NO**: 77%
- **N/A**: 10%

Figure A.3: Response to the 3rd Question about Test Methods

Does the Facility verify its own tests' repeatability?

- **YES**: 77%
- **SOMETIMES**: 13%
- **NO**: 10%
- **N/A**: 13%
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Figure A.4: Response to the 4th Question about Test Methods

Does the Facility have a procedure for the evaluation of the measurements uncertainty according to ENV 13005?

- **YES**: 88%
- **SOMETIMES**: 12%
- **NO**: 0%
- **N/A**: 0%

Figure A.5: Response to the 1st Question about Test Performance

Does the Facility verify that the testing equipment comply with the requirements of the test standard or method?

- **YES**: 87%
- **SOMETIMES**: 13%
- **NO**: 0%
- **N/A**: 0%
Are the raw data traceable starting from the test report?

- YES: 84%
- SOMETIMES: 13%
- NO: 3%
- N/A: 0%

Figure A.6: Response to the 2nd Question about Test Performance

Does the Facility have procedures for the maintenance of the test equipment?

- YES: 68%
- SOMETIMES: 22%
- NO: 10%
- N/A: 0%

Figure A.7: Response to the 1st Question about Maintenance
Does the Facility have calibration procedures stating responsibilities and calibration time intervals?

- **YES**: 75%
- **SOMETIMES**: 19%
- **NO**: 6%
- **N/A**: 0%

Figure A.8: Response to the 1st Question about Calibration

Does the Facility perform intermediate controls between two calibration dates?

- **YES**: 51%
- **SOMETIMES**: 39%
- **NO**: 10%
- **N/A**: 0%

Figure A.9: Response to the 2nd Question about Calibration
Figure A.10: Response to the 1st Question about Test Report

When opinions and interpretations are included, are they clearly marked as such in the test report?

- **YES**: 87%
- **SOMETIMES**: 13%
- **NO**: N/A
- **N/A**: N/A

The chart shows that 87% of respondents answered in the affirmative, indicating that opinions and interpretations are clearly marked as such in the test report.