Distributed data bases, data communication and access, distributed testing and PsD transnational access test campaigns within the SERIES Project

A. Bosi, F. Taucer & P. Pegon
Joint Research Centre, Ispra (VA) Italy

SUMMARY:
The present paper focuses on the research activities, namely networking activities and pseudo-dynamic test projects, being carried out at the European Laboratory for Structural Assessment (ELSA) of the Joint Research Centre of the European Commission (EC), as part of the Seismic Engineering Research Infrastructures for European Synergies (SERIES) project financed by the Seventh Framework Programme of the European Commission. The SERIES networking activities aim at providing both off-line access to data by means of a distributed database and on-line access by means of telepresence implementation that allows virtual access to test equipments. The experimental test campaigns are part of SERIES transnational access activities. Ongoing projects at the reaction wall facility of ELSA are: the seismic retrofit of a four-storey reinforced concrete wall with shear walls, the design of a new steel-concrete composite eccentric braced frame with easily replaceable dissipaters, and the seismic assessment and retrofit of a multi-span reinforced concrete bridge.

Keywords: databases, pseudodynamic testing, telepresence, transnational access

1. GENERAL INTRODUCTION

The SERIES Project is a 23 partner consortium of the key actors in Europe's seismic engineering research, covering all aspects of seismic engineering testing, from eight reaction wall pseudo-dynamic (PsD) facilities and ten shake table labs, to EU's unique tester of bearings or isolators, its two major centrifuges and an instrumented site for wave propagation studies. The SERIES Project aims to overcome the extreme fragmentation and lack of collaboration that currently characterizes the European RTD community in earthquake engineering and to create a culture of collaboration and integration. To do so, a concerted program of networking activities and a coordinated transnational in-person access of users activity are foreseen.

One part of the Networking Activities aim at facilitating the exchange of data and data communication among research infrastructures in Europe providing both off-line access to data by means of a distributed database and on-line access by means of telepresence implementation that allows collaborative decision making during experimental test campaigns. The paper outlines the harmonization and unification of databases and the set up of a unique centralized data access to the different databases distributed over the network of earthquake engineering infrastructures in Europe.

The SERIES project offers Transnational Access to a portfolio of world class research complementary infrastructures to selected talented European researchers "free of charge" along with full infrastructural, logistical, technological and scientific support. Users of access are attracted, selected and trained through the networking activities of SERIES. Users are given access to the infrastructures for the design of the test model and the instrumentation, for the execution of the tests and for the processing and interpretation of results. The paper presents the projects selected for access at the European Laboratory for Structural Assessment.

2. SERIES DISTRIBUTED DATABASE

The European scientific community is currently highly fragmented, with each laboratory holding experimental data, stored in some cases in a non-structured way. As a consequence, the dissemination and use of experimental results outside of the laboratory where they are produced can be problematic. This leads to wasteful duplication of tests and ultimately limits the impact of earthquake engineering research on practice, innovation and earthquake risk mitigation.

On its side, the ELSA laboratory has started to preserve data in a structured way since its inauguration in 1992. The “database” was originally conceived as ordered folders where only time series (signals) where preserved. These data were store automatically and retrieved/visualized by means of a simple interface. It became very soon clear that basic information on the performed tests and on the acquired signals was missing, making difficult to retrieve and re-use those data. In 2000, this system was substituted by a structured SQL Database, putting more context to the experimental activities (projects, key-words, experiments, signals, documents, etc.). This database is still in use, however, at the beginning of the SERIES project, ELSA decided to upgrade the current database because important information was still missing (e.g., loading, boundary conditions, etc.).

The SERIES database offered also a great opportunity, since its aim was not to build a central database where local databases would either migrate or merge, but instead to provide centralised access to database nodes that are distributed over a network that are able to dialog with a central portal in a uniform manner. To this end, database nodes use Web Services, to cast their data into a uniform standard format for uploading and downloading. This is quite feasible using available techniques and technology, in particular when access time and scalability are not primary concerns.

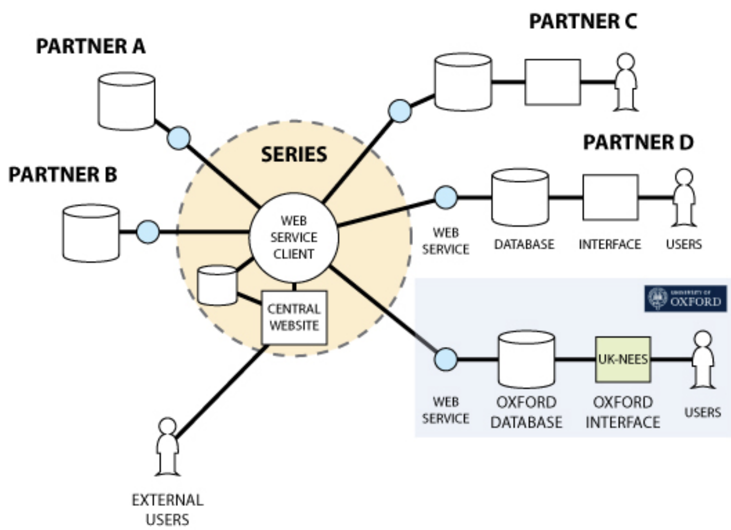

Figure 1. The distributed database (scheme elaborated by the University of Oxford).

Fig. 1 schematically represents the working principle of the Distributed Database (DDB). The external user connects to the SERIES Central Web site at the University of Patras, providing various functionalities (such as navigation or search) giving access to data. Some of these data (mostly regarding the content of the DDB) are stored locally at the central site (and automatically uploaded/updated from the partner sites to the central site according to an automatic mechanism), whereas the rest of the data (signals, documents, images, etc.) are kept locally at the partner’s repository and can be downloaded by the user by means of Web Services (WS). The Central Site gives thus access to a community of results which is accessed by the external user in a uniform way, without transferring the effective data values (and the ownership) to the Central Site.

Since the partners do not store their own data in the same way, a common "vocabulary" has been carefully designed to access the data, to allow uniformity of data for the external user, encapsulating values and context. These elements form the so called Exchange Data Format (EDF).

2.1. The Exchange Data Format

The definition of SERIES EDF was not a trivial task, because the requirements for uniformity had to accommodate very heterogeneous needs. It is sufficient to think that while a PsD test can last for several hours, a shaking table test lasts less than a minute and a centrifuge one just a few seconds; as a consequence the amount of tests performed in the same model in a PsD facility are much smaller compared to the number of tests performed in the other two facilities.

For this reason, the first draft version of the EDF was elaborated at ELSA (a reaction wall facility) on the base of a critical analysis of available data formats (NEESCentral data format, current ELSA data format). The support and revision of the shaking table facility belonging to the University of Bristol and of the centrifuge of the Institut Français des Sciences et Technologies des Transports, de l'Amégagement et des Réseaux (IFSTTAR) in Nantes, allowed to improved the EDF and define an updated version. The final database was enriched by the comments/suggestions of the SERIES partners. In order to evaluate the completeness of the EDF, a prototype database was created by the University of Oxford, Using MySQL.

The EDF assumes a twofold role: i) For the laboratories that already have a database, it is the format in which their data and information are made public; and ii) The prototype database could be implemented at all the SERIES nodes still missing a Database, profiting also of the Web Services associated with the updating and downloading mechanisms.

A four-tiered hierarchical structure consisting of project, specimen, experiment/computation & signal was chosen for the database, as shown in Fig. 2.

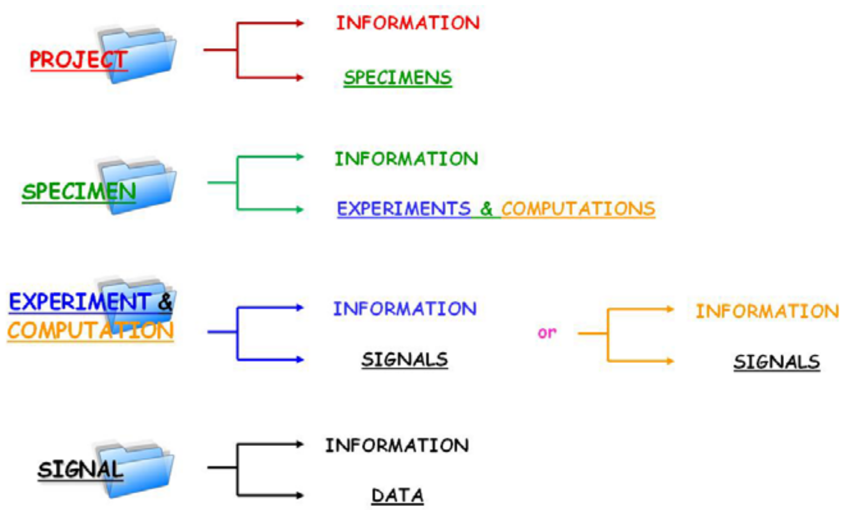

Figure 2. Data hierarchy overview.

At each level, the information considered fundamental for the accessibility of the data to external users is mandatory; other fields are strongly recommended. Ideally, with the information available in the SERIES Database (DB), any external user should be able to fully understand what has been done/what has been obtained and, and to reproduce (more or less exactly) the tests and the results. Some of the fields may contain data or information useful only for local users (i.e. those generating the data). Those fields may remain completely hidden to the external users.

The first level is the *Project* level, which collects general information of the project (name, starting and closing data, facility, reference persons) and detailed information such as project reports (preliminary, on-going and final). The Project level also contains a list of keywords for defining the main focus of the project and the key actions performed in the test campaign.

In the definition of the SERIES EDF, there was a precise intention of defining as much fields as possible by means of keywords. This improves uniformity, by reducing the possibility to have different names for the same data and to improve the accessibility of data and information by external users by allowing to implement the search tool at the central site. Examples of possible project main focus are: structural performance, retrofit techniques, code checking, etc. Examples of key actions are: experiment, computation, in situ, in lab, static, quasi-static, shaking table, bearing tester, monitoring, linear time history, multi-mode push-over, modal analysis, etc. This vocabulary has been defined with the collaboration of all SERIES partners.

Multiple models can be tested within a single project; their characteristics are defined at the *specimen* level. Two cases are possible: i) The project foresees to test more than one physical (or numerical) structure (a short bridge pier and a tall one, several masonry structures made by different kinds of clay, etc.); or ii) It is also possible to test the same structure but in different “states”: for example the structure in its original state and then with different types of retrofitting. While it may be argued that in this case, all the experiments are performed on the same specimen, the hierarchical structure of the database demands that retrofitted specimens are included as new specimens.

Geometrical, physical and mechanical parameters of each specimen are specified according to a special template. Each specimen is classified for typology and material. The list of typologies includes soil, structural systems and elements (soil layers, 2D frame, 3D frame, bridge, retaining walls, foundations, piping, joints, isolation devices, structural control devices, beams, columns, girders, tendons, etc.). Nevertheless, a specimen can be composed by more than one structural system: for example a 3D frame with seismic beam-column joints and elastomeric isolation devices, or a structural system with additional structural elements such as a 3D frame with shear walls. The concept is that if some structural elements assembled together are composed by one or more of the structural systems given above, they are not required to be listed separately but can be grouped together; other parts that constitute the specimen can be added separately.

Particular attention was placed on the definition of the material properties allowing to introduce not only the nominal property value but also, when available, the actual value. Since the definition of the mechanical parameter can be very heterogeneous (in particular for soil, it is usually expressed with curves rather than with coefficients), it is foreseen the field *additional documentation*, where all useful documentation can be uploaded.

Some special fields are also foreseen to store any kind of additional documentation (drawings, pictures, videos, reports) that might be useful for external users or, in particular, for the local user that after time needs to recall what has been done and how it has been done. These fields are non mandatory, but it is in the interest of users of the database to store as much relevant information as possible to allow easier access to data.

Testing campaigns are collected at the *Experiment and computation* level. The aim of this level is to allow reproducibility of the experiment (in another facility or in the same one after time). For this purpose, particular attention was placed in the definition of the loading condition and boundary conditions.

For the loading condition, the original source loading input (e.g. the name of the original earthquake signal and its characteristics, such as the peak acceleration) has to be indicated and in addition it is foreseen a special table for the definition of the effective input files (in case the signal has been reduced/amplified, direction of application, etc.).

With the aim of improving the fidelity and the reproducibility of the obtained results, it is also required to specify the characteristics of the loading devices and of the sensors. In particular, for the sensors it is required to specify their location, their accuracy and range of measurement. For both loading system and sensors it is also required to specify the date of the last calibration.

Treatment programs are private resources that collect files used internally for converting raw data into meaningful measurements (for example Volts converted in meters following a calibration curve). Other programs used for data processing of original signals may also be stored (e.g. identification of the modes and related equivalent damping). These files are accessible only for local users. For all media resources (videos, pictures, etc.) it is also required to store the time stamp in which they are produced to allow the synchronization of all resources.

The bottom level of the database consists of the *signals*. Each signal contains a simple array of data and the location where it has been measured, and the related device that generated or acquired it. For better preservation raw data (private resource) as well as treated data are also stored.

2.2. Implementation

Currently, the Data Access portal has been completed at the University of Patras, with some in-depth demonstration tests having been performed between the University of Oxford, ELSA, the University of Trento and the University of Patras. The work is mostly to be performed at partners level, feeding of the prototype data base for the partners starting from scratch, or development of the local site Web Services for the partners already having a data base. The situation at ELSA is hybrid. The laboratory will used the prototype data base and is involved in the migration of data from its current data base towards the new one.

3. TELEPRESENCE

The aim of a Distributed Laboratory is to use up-to-date IT tools to increase the value of testing. One of these tools is Telepresence. Telepresence tools not only allow a remote user to watch a test, which increases the visibility of the test, but also to participate to it, thus reaching more users. There are thus two complementary needs: show what occurs in the laboratory and to display synchronized laboratory results. What occurs in the laboratory can only be done using on-line, real-time tools. On the contrary, and depending of the nature of the test (site monitoring, PsD, shaking table, centrifuge) the display of synchronized laboratory results can be done using on-line or off-line (with short delay for broadcasting), in a slow or accelerated time.

At the beginning of the project, only two SERIES laboratories made full use of telepresence: ELSA and University of Bristol (as part of UK-NEES). They both used the well known NEES-tools RBNB ("data turbine" ring buffer for recording multimedia data and synchronized streaming) and associated Sources (for feeding RBNB from a camera or a Data Acquisition system), RDV (Real Time data Viewer) and FlexTPS (view and robotically control live video over internet with a web browser). However, due to test duration, RBNB, Source and RDV are used off-line, and sometimes in slow motion at the Shaking table of Bristol. The DAQ streams the data to the data turbine during the test, and these results are screened in play-back mode after test completion.

The situation at ELSA is quite different: the test data are sent real-time to the data turbine, being visualized in real-time by the remote user. One of the possibilities of RDV is to be able also to activate play-back mode and thus review the results already stored on the turbine in accelerated mode. As a deliverable of SERIES, ELSA, University of Bristol and University of Oxford (for FlexTPS) issued guidelines that allowed the laboratories in SERIES to set-up telepresence. One interesting case is the centrifuge at IFSTTAR that decided to store the DAQ results, upload them after test completion on the data turbine and then allow users to screen them before deciding the next step.

5. TRANSNATIONAL ACCESS PROJECTS AT ELSA

Three projects were accepted for Transnational Access at the ELSA infrastructure, as described in the following sub-sections. The experimental campaign of the first project has already been concluded, while the two other are on-going. The description of the projects presented in the present paper is taken from the proposals submitted by the user groups to the User Selection Panel of the SERIES Project as well as from the documentation produced during the development of these projects.

5.1. SERFIN Project

The Seismic Retrofitting of RC Frames with RC Infilling (SERFIN) Project is led by Prof. Christis Chrysostomou, from the Cyprus University of Technology in Cyprus, with partners from the University of Cyprus, DENCO Design & Engineering Consultants (Greece) and the Ecole Central de Nantes (France).

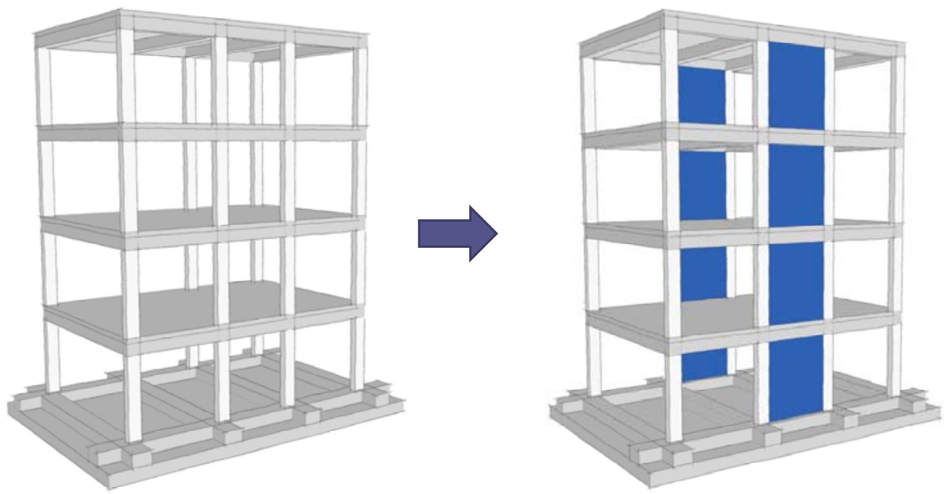

Figure3. Sketch of the full-scale SERFIN model retrofitted with RC infill walls

The SERFIN Project studies experimentally the effectiveness of seismic retrofitting of multi-storey multi-bay Reinforced Concrete (RC) frame buildings by converting selected bays into new walls through infilling with RC. The construction of new walls is the most effective and economic method for retrofitting multi-storey reinforced concrete buildings, especially those with Pilotis (soft-storey). Their structural and economic effectiveness increases when they result from infilling with RC a bay of an existing frame. Due to the practical difficulties of testing large specimens with high force resistance, only one- or two-storey specimens of such a system have been tested up-to-date. Because of this lack of knowledge, Eurocode 8 Part 3 does not cover this technique despite its cost-effectiveness and popularity.

In order to start filling this gap of knowledge, a full-scale test specimen was constructed for testing at the ELSA Laboratory. The specimen is a four storey structure consisting of two parallel frames in the direction of testing, each frame consisting of three bays. The scale of the specimen is 1:1, with a total length (axis to axis) in the direction of testing of 8.5 m (central bay of 2.5 m and two exterior bays of 3.0 m) and inter-storey height of 3.0 m, for a total height of the specimen (excluding the base of the specimen) of about 12.0 m (Fig. 3). The two parallel frames are spaced at 6.0 m and are linked through a RC slab and transverse beams. Each frame is retrofitted at the central bay with an infill RC wall following different strategies defined during the numerical modelling and design phases.

The RC frame of the mock-up was constructed outside the laboratory shed and then transported inside by pulling the structure sliding over flexible rubber rollers as shown in Fig. 4a. The model was moved in front of the reaction wall where it was connected to 1000 kN and 500 kN actuators (two per floor) at the two upper and two lower floors, respectively, through specially designed steel beams ensuring a uniform transfer of the lateral force to the floor slab (Figure 4b).

(a) (b)

Figure 4. (a) Transportation of the SERFIN model into the ELSA Laboratory; (b) Mock-up fixed to the strong floor and with actuators connected at all floors.

The specimen was subjected to a ground motion compatible with a target spectrum with a peak ground acceleration of 0.25g corresponding to a 475 year return period, and to a cyclic test of 100 mm amplitude for determining ultimate displacement capacity. The main parameters of the test structure were the connection between the RC infill and the surrounding RC frame and the percentage of the reinforcement in the RC infill. The effect of these parameters was studied during the experiment, by using different connection details and reinforcement percentages for the two infilled frames at each storey. Open issues such as the interaction between the infill wall and the frame, and the effect of higher modes on the shear forces in the various storeys after formation of a plastic hinge at the base of the wall, were studied. Numerical simulations are being developed to calibrate a methodology for the calculation of the force resistance, the stiffness and the deformation capacity of such assemblages, with the ultimate goal to develop design procedures for effective retrofitting of RC frames by converting selected bays into RC walls through RC-infilling. A proposal will come out for Part 3 of Eurocode 8, the current provisions of which do not cover this very common and effective type of retrofitting.

5.2. DUAREM Project

The Full-scale experimental validation of dual eccentrically braced frame with removable links (DUAREM) Project is led by Prof. Dan Dubina from the "Politehnica" University of Timisoara (Romania), with partners from the University of Liege (Belgium), University of Naples Federico II (Italy) and University of Ljubljana (Slovenia) and University of Coimbra (Portugal).

Current seismic design philosophy is based on dissipative structural response, which implicitly accepts damage to the main structure and significant economic losses. Repair of the structure is often impeded by the permanent (residual) drifts of the structure. The DUAREM Project aims at reducing the repair costs and downtime of a structure hit by an earthquake, and consequently more rational design approach in the context of sustainability (Dubina et al., 2008). These objectives are attained through removable dissipative members (links) and re-centring capability of the structure. The concepts of removable dissipative members and re-centring capability are implemented in a dual structure, obtained by combining steel eccentrically braced frames with removable bolted links with moment resisting frames (MRF). The bolted links are intended to provide the energy dissipation capacity and to be easily replaceable, while the more flexible moment resisting frames provide the necessary re-centring capability to the structure. The moment resisting frames and the columns of the eccentrically braced frames are constructed from high strength steel, in order to keep these members in the elastic range even under strong seismic input.

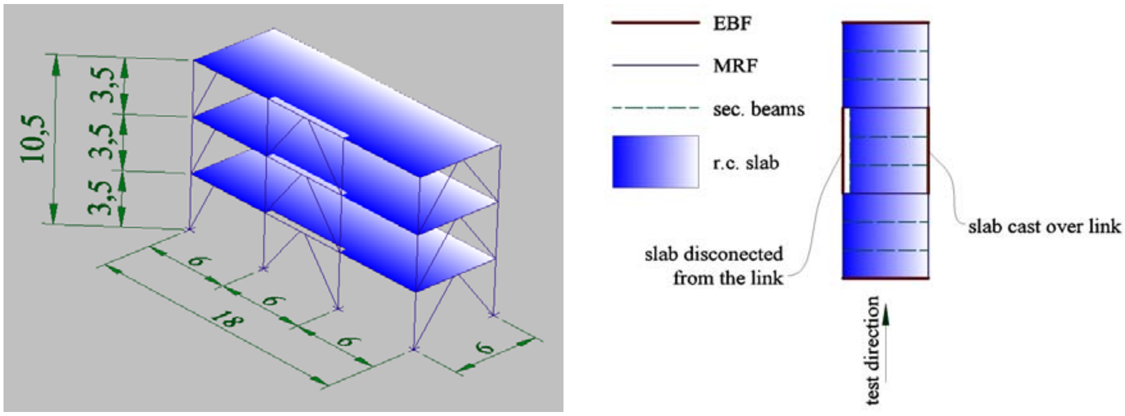

Figure 5. General view and plan layout of the test structure (measures in m) (Source: D. Dubina)

Current seismic design philosophy is based on dissipative structural response, which implicitly accepts damage to the main structure and significant economic losses. Repair of the structure is often impeded by the permanent (residual) drifts of the structure. The DUAREM Project aims at reducing the repair costs and downtime of a structure hit by an earthquake, and consequently more rational design approach in the context of sustainability (Dubina et al., 2008). These objectives are attained through removable dissipative members (links) and re-centring capability of the structure. The concepts of removable dissipative members and re-centring capability are implemented in a dual structure, obtained by combining steel eccentrically braced frames with removable bolted links with moment resisting frames (MRF). The bolted links are intended to provide the energy dissipation capacity and to be easily replaceable, while the more flexible moment resisting frames provide the necessary re-centring capability to the structure. The moment resisting frames and the columns of the eccentrically braced frames are constructed from high strength steel, in order to keep these members in the elastic range even under strong seismic input.

The validation of the proposed solution will be achieved through PsD testing of a full-scale model of a dual eccentrically steel-concrete composite braced frame (EBF). The model consists of a three-storey, three bay structure with a total height of 10.5 m, total length of 18 m and a width of 6 m, eccentrically braced at the central bay (Fig. 5). The dissipative members are located in line with the beam and bolted with end plates, as shown in Fig. 6. The slab is supported over secondary beams in order to allow deformation and replacement of the device. The lateral force will be applied by means of two actuators at every floor, of 1000 kN at the two upper storeys, and of 2x500 kN at the first storey.

The research will demonstrate the feasibility of the proposed concept (re-centring capability of dual structures with removable dissipative members), clearing the route toward implementation into design practice. Additionally, the overall seismic performance of dual eccentrically braced frames will be validated. The full-scale test will provide valuable information on the interaction between the steel frame and the reinforced concrete slab in the link region, for which virtually no experimental results exist.

The test campaign will consider several levels of the earthquake input: SLS (serviceability limit state), the model will experience inelastic deformations in the dissipative member while the non-dissipative members will remain in the elastic range, so that if large permanent drifts are recorded, the removable links will be replaced, re-centring the structure and providing the original strength and stiffness; ULS

(ultimate limit state), significant inelastic demands are accepted in the removable dissipative members, the MRF and non-dissipative members of the EBF respond in the elastic range, and the removable links are replaced, re-centring the structure to its original strength and stiffness; NCLS (non-collapse limit state), heavy damage to both the and MRF, the vertical elements are still capable of sustaining vertical loads, the structure has a low residual lateral strength and stiffness, and no re-centring capability is believed to be feasible at this performance objective.
The dissipative members will be replaced by flame cutting. The sequence and strategy for replacing the links will be a crucial aspect studied in the experimental campaign.

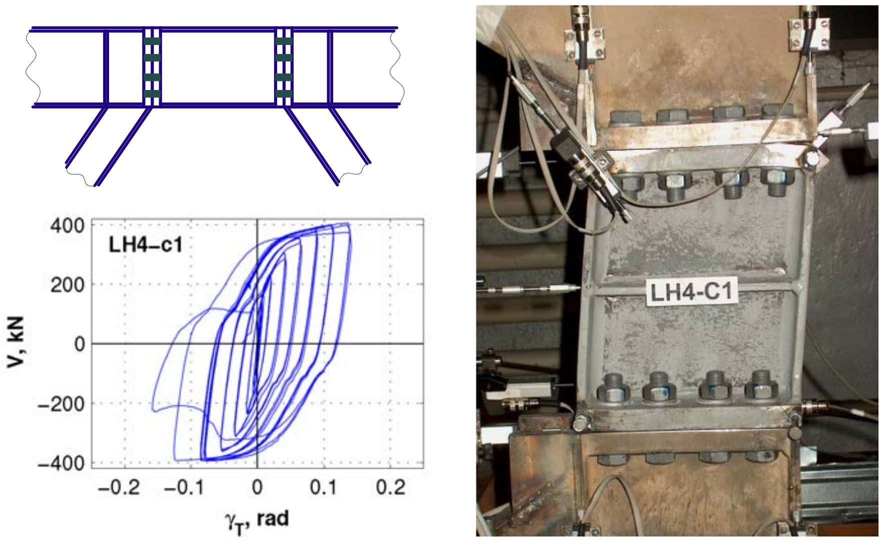

Figure 6. Dissipative member: force-displacement cycles and component testing (Source: D. Dubina)

5.2. RETRO Project

The assessment of the seismic vulnerability of an old RC viaduct with frame piers and study of the effectiveness of different isolation systems through PsD tests on a large scale model (RETRO) Project is led by Prof. Fabrizio Paolacci of the University of Roma III (Italy), with partners from the Politecnico di Torino (Italy), University of Sannio (Italy), Bogazici University (Turkey) and Alga SpA (Italy).

The project aims at studying the seismic behaviour of an existing RC bridge built in the 1950's in Italy and not properly designed for seismic action (Fig. 7), together with the analysis of the effectiveness of innovative and traditional retrofitting systems. Two specimens (initially planned at scale 1:2, but reduced to 1:2.5), a frame pier of two levels (height = 10.3 m) and a frame pier of 3 levels (height = 5.8 m) (Fig. 8), will be constructed and tested using the PsD technique with sub-structuring), whereby the parts of the bridge not physically tested (deck and remaining piers) are modelled numerically.

The full scale tests follow a preliminary experimental evaluation performed by the University of Roma III on a single pier at a reduced 1:4 scale (Giannini et al., 2008) that showed that the damage concentrated at the beam linking the columns of the pier, following shear failure and buckling and bond slip of the smooth steel reinforcement. Several tests will be carried out taking into account the effect of asynchronous ground motion in the following sequence: (i) Cyclic test inducing slight damage on the as built configuration of the viaduct (no isolation), (ii) PsD substructured earthquake tests on the bridge viaduct retrofitted with an elasto-plastic isolation system and with spherical sliding bearings tested with three identical earthquake records to simulate the effect of aftershocks, and (iii) PsD substructured earthquake test on the as built configuration of the viaduct (no isolation) at the life safety limit state, inducing large levels of damage with the aim of assessing the performance of the viaduct.

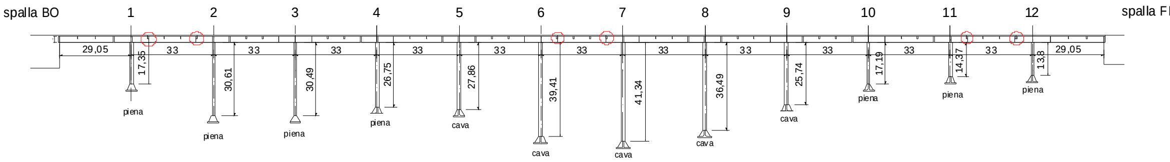

Figure 7. Geometry in elevation of the bridge, highlighting physically tested piers (Source: F. Paolacci)

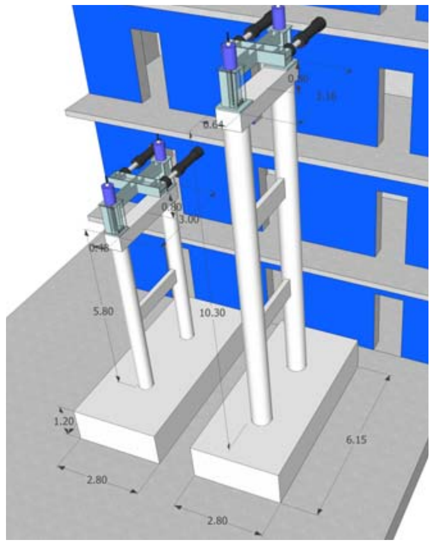

Figure 8. Geometry of the bridge piers and test set up (Source: F. Paolacci)

A dedicated testing rig will be constructed to test the isolation system separate from the piers via substructuring. The system will be used first to characterize the isolators at cycles of increasing displacement and then for the earthquake PsD tests. During testing a constant vertical load equal to the weight of the deck will be maintained on the isolators; the same vertical load will be applied and maintained on the bridge piers.

AKCNOWLEDGEMENT

The research leading to these results has received funding from the European Community's Seventh Framework Programme [FP7/2007-2013] for access to the EUROPEAN LABORATORY FOR STRUCTURAL ASSESSMENT of the EUROPEAN COMMISSION – JOINT RESEARCH CENTRE under grant agreement n° 227887.

REFERENCES

Bosi, A. and Pegon, P. (2009). The ELSA database and what can be done regarding SERIES networking activities. *JRC Scientific and Technical Reports EUR report 23931 EN*. European Commission.

Dubina, D., Stratan, A. and Dinu, F. (2008). Dual high-strength steel eccentrically braced frames with removable links. *Earthquake Engineering & Structural Dynamics*, **37:15**, 1703-1720.

Giannini, R., Paolacci, F. and Sibilio, E. (2008). Experimental study on the cyclic response of an existing R.C. bridge pier. *14th World Conference on Earthquake Engineering*, Beijing, China.

Lamata Martinez, I., Pegon, P., Bosi, A., Dietz, M., Bousias, S., Fidas, C. and Wenzel, H. (2010). D2.1 – Distributed DataBase: Review of beneficiary current data formats . Specifications for the common data format and Data Access Portal. *SERIES – Grant Agreement 22788*, 7thFP DG RTD European Commission.

Pegon, P., Dietz, M., Lamata Martinez, I., (2010). D2.2 – Guidelines for implementing a telepresence node. *SERIES – Grant Agreement 22788*, 7thFP DG RTD European Commission.

SERIES Description of Work (2009). Seismic engineering research infrastructures for european synergies. *SERIES – Grant Agreement 22788*, 7thFP DG RTD European Commission.