SERA
Seismology and Earthquake Engineering
Research Infrastructure Alliance for Europe

DELIVERABLE

D2.17 Final compilation of technical reports

Work package	WP2: Communication, Outreach, Dissemination
Lead	ETH Zürich
Authors	Nadja Hermann & Michèle Marti, ETHZ
Reviewers	Kauzar Saleh
Approval	Management Board
Status	Draft
Dissemination level	Public
Delivery deadline	12/04/2020
Submission date	12/04/2020
Intranet path	[DOCUMENTS/DELIVERABLES/SERA_D2.17_Technical-Reports]

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 730900.

Table of Contents

Contact

Project lead	ETH Zürich
Project coordinator	Prof. Dr. Domenico Giardini
Project manager	Dr. Kauzar Saleh
Project office	ETH Department of Earth Sciences
	Sonneggstrasse 5, NO H-floor, CH-8092 Zürich
	sera_office@erdw.ethz.ch
	+41 44 632 9690
Project website	www.sera-eu.org

WP 3-NA 1: Engaging citizen seismologists worldwide

J. P Stevenson, BGS; P. Denton (ex-BGS; now DentonSeismo)

Keywords

Citizen seismology, educational seismology

Figure

Figure 1. Delegates from all over the world at EduCitiSeis2018 share information and experience of using different types of low-cost sensors. Some of them are deployed by professional, educational and citizen seismologists. (Image: reproduced with the permission of the British Geological Survey © UKRI. All rights reserved).

Main Results

EduCitiSeis2018 was claimed to be the world's first international discussion workshop for educational and citizen seismology. The event, held in central London in February 2018, brought together 47 delegates from 18 countries supported by SERA and UNESCO. The meeting provided an opportunity to fulfil one of the objectives of SERA WP3; to develop integration between educational and citizen seismology projects. The workshop was designed to be an outward facing activity for the SERA group and a showcase to the world of the educational seismology activities taking place within Europe.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 730900.

The workshop offered a unique opportunity for seismologists across a wide spectrum of fields including academia, schools, research institutes, equipment manufacturers, software developers and hobbyists. The workshop was truly participatory and therefore seen as unique and rewarding. Everyone had the opportunity to speak in the sessions and discuss the programme topics with other participants. This participatory approach was facilitated by every delegate having a two-minute "nano presentation" to introduce themselves and their work. Key delegates were empowered to lead parallel discussion sessions while a live voting app was used to decide on what issues to discuss and to vote on key questions. The discussions continued also during dinner: delegates rotated seats between courses so that they had a chance to meet and talk to everyone. EduCitiSeis2018 also served as a launchpad for the ESC2018 General Assembly sessions, S40 Seismology and Society and the 2019 IUGG 27th General Assembly, Innovation in Geoscience Education, Outreach and Citizen Science.

List of Publications

Aftab Khan, Paul Denton, John Stevenson, Remy Bossu. Engaging citizen seismologists worldwide. *Astronomy & Geophysics*, Volume 59, Issue 4, August 2018, Pages 4.15–4.18, https://doi.org/10.1093/astrogeo/aty190

2018 EduCitiSeis18 | Discussion Workshop on Educational and Citizen seismology, London (2018) YouTube video playlist, added by BGSChannel [Online]. Available at https://www.youtube.com/playlist?list=PLxpzCdkdwTWATfRu9KpSRSK83-SJKaQVM [Accessed 17 November 2019].

WP 4-NA 2: Access to European seismological waveform data infrastructure

R. Sleeman, J. Quinteros, H. Pedersen, J. Clinton, C. Evangelidis, K. Ionescu

Keywords

Seismological waveforms, ORFEUS, EIDA, data access webservices

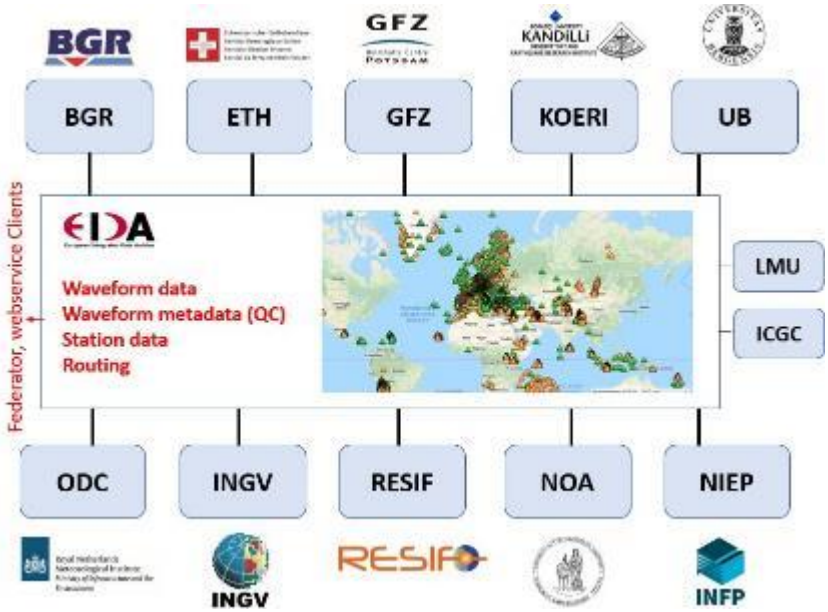


Figure 1. European Integrated Data Archive (EIDA) – the European Infrastructure for open access to seismological waveform data

Main Results

ORFEUS (Observatories & Research Facilities for European Seismology) is the European infrastructure for seismic waveform data, station metadata and products. Within ORFEUS, the European Integrated Data Archive (EIDA) is the federated infrastructure of seismological data archives that provides access to seismic waveform data from seismological networks. ORFEUS is the infrastructure for seismic waveform data in EPOS and provides access to high quality seismic waveforms and station metadata from EIDA and strong motion products.

SERA fostered the collaboration and cooperation between seismological observatories and ORFEUS in regions like the Balkans and South-West Europe. The number of seismic stations providing data to the European seismological data infrastructure impressively increased from about 7'000 to over 11'000 during the SERA project, with an increase of nearly 100 stations in the Balkans. Currently, EIDA holds beyond 450 TB of data of 107 permanent networks and 190 temporary networks, with a total of more than 10'500 velocity sensors, over 1'600 accelerometers and about 160 infrasound sensors. Also, two new archives, representing seismic networks deployed by Norway and Catalunya, were added to EIDA.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 730900.

Access to EIDA vastly improved during SERA through a) the implementation of standardized web services and formats across EIDA, b) the implementation of DOIs in metadata and c) the development and deployment of the Federator. Standardization of services and formats and the use of DOIs are in line with the FDSN (International Federation of Digital Seismograph Networks). Current standard web services are: fdsnws-dataselect, fdsnws-station, eidaws-wfcatalog and eidaws-routing.

The development and implementation of the EIDA Federator provide a single, unified access point to the waveform archives and the station and quality control information from the entire EIDA data holdings, i.e. from all the datacenters in EIDA. Access is through standard FDSN and EIDA web services. The Federator enables transparent and homogeneous access to EIDA by users and clients (e.g. ObsPy, EIDA StationBook, RRSM (Rapid Raw Strong Motion database - the European system to expose strong motion products close to realtime for earthquake scientists and earthquake engineers).

EIDA aims at sustainable high quality of services by a) the establishment of a User Advisory Group within ORFEUS, b) a ticketing system for reporting issues and providing feedback to EIDA and c) the implementation of a new authentication system for restricted data (e.g. AlpArray). Data quality is provided by the eidaws_wfcatalog web service; however new tools are being developed and tested.

Within SERA a comprehensive overview of metadata for other geophysical measurements was made to prepare EIDA, although tailored for seismological waveform data, potentially ready to serve other types of time series data (e.g. Distributed Acoustic Sensing, Near Fault Observatories). Finally, SERA facilitated long-term sustainability of EIDA by building up extensive documentation, best practice guidelines for data acquisition and distribution, as well as technical support.

List of Publications

Pedersen, H. A., Leroy, N., Zigone, D., Vallée, M., Ringler, A. T., and Wilson, D. C., 2020. Using Component Ratios to Detect Metadata and Instrument Problems of Seismic Stations: Examples from 18 Yr of GEOSCOPE Data, Seismological Research Letters 91 (1), 272-286

Access to Data and Services

http://www.orfeus-eu.org

http://www.orfeus-eu.org/eida

http://www.orfeus-eu.org/data/eida/webservices/

http://www.orfeus-eu.org/webdc3/

http://www.orfeus-eu.org/stationbook

http://www.orfeus-eu.org/data/eida/quality/ http://www.orfeus-eu.org/rrsm

WP 5-NA 3: Towards an open-access database in DSS data

I. DeFelipe, R. Carbonell, M. Ivandic, R. Roberts

Keywords

DSS data, ICTJA-CSIC database, EPOS, SERA

Figures

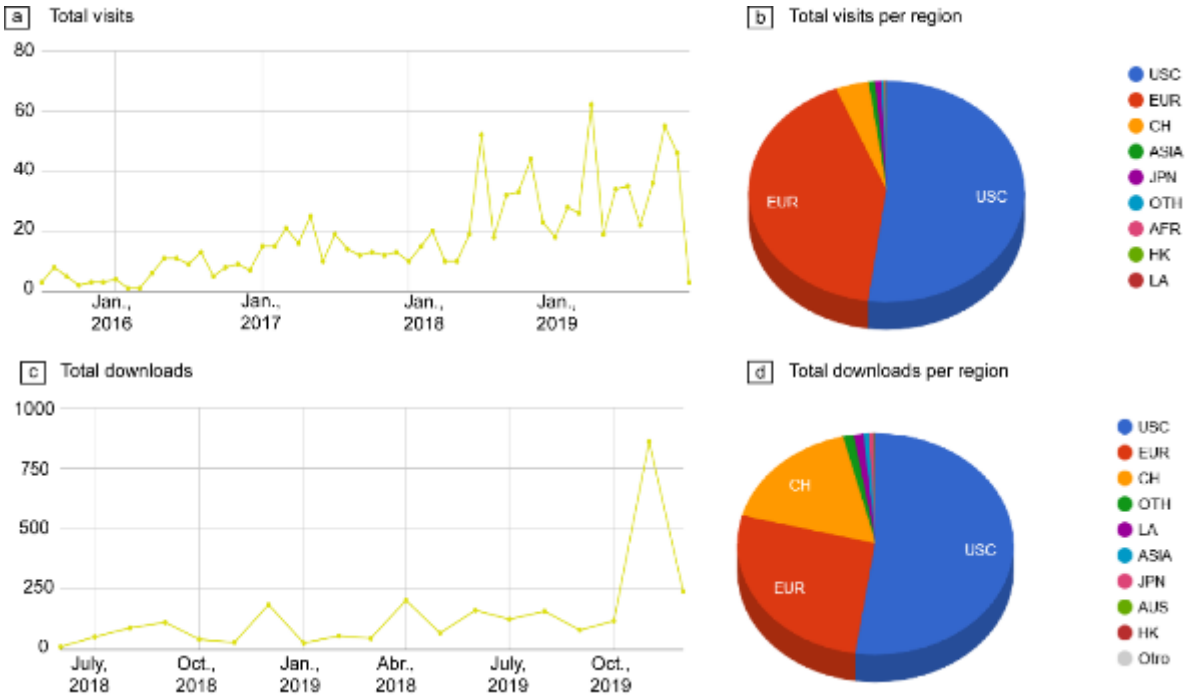


Figure 1. a and b). Total visits and total visits per region of data from the ICTJA-CSIC dataset; c and d) total downloads and total downloads per region of data from the same dataset, last access December 2019). USC: USA and Canada, EUR: Europe, CH: China, OTH: others or not defined, LA: Latin America, ASIA: Asia, JPN: Japan, South Korea and Taiwan, AUS: Australia and New Zeeland, HK: Hong Kong, AFR: Africa

Main Results

The increased volume of scientific data since the last decades is enhancing a new plan to facilitate integrated use of open access data and data products. Tackling viable solutions for Solid Earth challenges, the European Plate Observation System project (EPOS) is a long-term plan to facilitate distributed research infrastructures in Europe. In particular, within EPOS, a Thematic Core Service in seismology aims to provide open access data of seismological products services. Among the different e-infrastructures, stands out SERA, which final aim is to spread the scientific knowledge of earthquake engineering and seismology data trying to make research data more accessible (DeFelipe et al., 2019a, b). The availability and accessibility of these data, therefore, is of foremost importance for the society, including scientists, decision-makers and the general public.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 730900.

During its 50 years' history, the Institute of Earth Sciences Jaume Almera (ICTJA-CSIC) has generated numerous data in the fields of geophysics, mineral geochemistry and volcanology among others. This work provides a review of the most important seismic campaigns and a comprehensive dataset of geophysical data acquired in the Iberian Peninsula since the 90's, both onshore and offshore. The Iberian Peninsula has attracted the attention of international researchers in the fields of geology and geophysics for decades due to the exceptional outcrops of Alpine and Variscan mountain ranges, wide Cenozoic foreland basins, its offshore margins and its potential for natural resources. Our dataset was also acquired at very different scales, from continental/crustal scale to local/exploration scale in different geographical and geological settings. Therefore, we aim to make easily accessible old and recently acquired seismic data and, therefore, set the basis for the future campaigns of seismic data acquisition in order to create a FAIR dataset (Findable, Accessible, Interoperable and Reusable).

Our dataset is being increased since the last two years following the national and international mandates of open access data. In addition, the statistics based on total visits and downloads since its beginning show in general, an increased interest in the research carried out in the ICTJA-CSIC (Figure 1). According to these statistics, our dataset is being used more and more by users all around the world. Interestingly, our database is being visited mainly by users from USA and Canada, followed by European users and China being the third country in number of downloads of any of all the projects included in each dataset.

List of Publications

DeFelipe, I., Alcalde, J., Carbonell, R., Ivandic, M. and Roberts, R. (2019a). Towards an Open Access Data Policy for Deep Seismic Sounding data. SEISMIX2020.

DeFelipe, I., Alcalde, J., Fernandez-Turiel, J. L., Diaz, J., Geyer, A., Molina, C., Bernal, I., Fernandez, J., Carbonell, R. (2019b). Multi-disciplinary data contribution to EPOS e-infrastructure. SEISMIX 2020.

Access to Data and Services

The ICTJA-CSIC database presented in this work is freely available in:
https://digital.csic.es/handle/10261/101879

SERA
Seismology and Earthquake Engineering
Research Infrastructure Alliance for Europe

WP 6-NA 9: Roadmap for the integration of databanks and access services from earthquake engineering (SERIES) and seismology (EPOS) research infrastructure

A. Caverzan [(1)], G. Tsionis [(1)], P. Pegon [(1)], A. Athanasopoulou [(1)], J. F. Molina [(1)], Ch. Sintoris [(2)], S. Bousias [(2)], N. Avouris [(2)], A. Ntourmas [(2)], K. Atakan [(3)]

[(1)] Joint Research Centre (JRC)
[(2)] University of Patras, Greece (UPAT)
[(3)] Universitetet I Bergen, Norway (UiB)

Keywords

Data base, earthquake engineering, seismology, EPOS, SERIES

Main Results

Roadmap for the integration of data banks and access services from the earthquake engineering (SERIES) and seismology (EPOS) research infrastructures proposes the integration of the SERIES databases in the existing EPOS service as a new Thematic Core Service (TCS) and exploring possible interoperability with other TCSs (e.g. Seismology) and with international partners. The first step is to consider the SERIES database as the first service of a new Earthquake Engineering Thematic Core Service (E/ENG TCS) within the EPOS architecture. SERIES will initially provide, through EPOS, integrated access to key data and experimental measures produced in Europe at some of the best facilities for earthquake engineering worldwide. In its mature phase, the integration process will provide an advanced interoperability within the earthquake engineering community itself, with the sibling TCS seismology and other TCSs, and with international partners. This objective will be guaranteed by means of the implementation of new services and tools for improving user accessibility and experience.

The roadmap identifies the cross-discipline needs in earthquake engineering and seismology data assessed through a questionnaire directed to users and stakeholders operating in the two fields. The questionnaire collected information on requirements and use cases for earthquake engineering and seismological data serving as the basis for the developed roadmap. The metadata structures in EPOS and SERIES were compared, followed by a gap analysis and leading to the requirements for the metadata catalogues development for the proposed new E/ENG TCS.

The roadmap puts forward a strategy with different tasks envisaged to be performed in three steps (short-, mid- and long-term). In the short-term, by the end of the SERA project, a pre-operational access service will be provided to selected SERIES datasets in order to allow validation of identified access technologies and involvement of the user community, for further implementation in EPOS. The activities performed in the mid-term will include a review of how the newly developed services and products will be fully compatible with the requirements of EPOS, at the technical, legal, governance and financial levels. Full integration of the earthquake engineering TCS in EPOS will be achieved in the long-term perspective by providing also access to research infrastructures, laboratories and data centres established outside Europe, thus improving the international dimension of EPOS.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 730900.

List of Publications

Deliverable 6.5 Roadmap for the integration of data banks and access services from the earthquake engineering (SERIES) and seismology (EPOS) research infrastructures

WP 7-NA 5: Networking databases site and station characterization

C. Cornou, P.-Y. Bard, G. Cultrera, G. Di Giulio, D. Fäh, P. Bergamo, K.Pitilakis, E. Riga

Keywords

Site characterization, quality grading, standardization, performance of site condition proxies

Figure

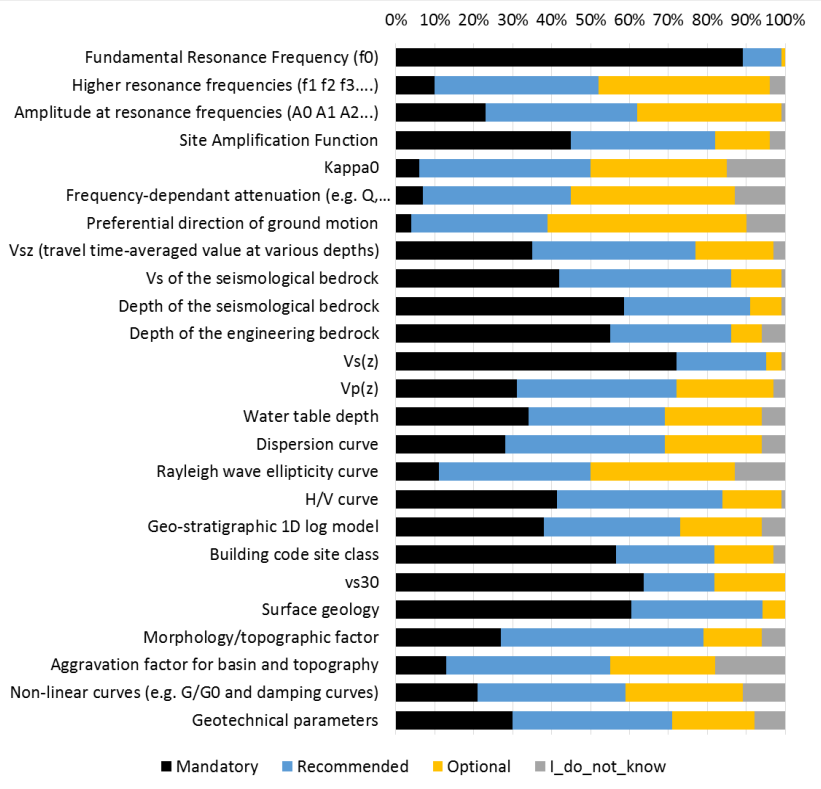


Figure 1. Results of an international questionnaire: importance ranking (mandatory, recommended, optional) of site condition indicators that should be indicated in site characterization databases

Main Results

Seismic site characterization of rock and soil properties has a large impact on earthquake ground motions and engineering seismology, especially for the evaluation of local site amplification, calibration of strong-motion records and realistic shaking estimates at seismic stations, site-specific hazard assessment, estimation of ground motion models, and soil classification for building code applications. However, there is not yet a common way to exchange site characterization information, whereas setting-up standard practices and quality assessment are becoming very important to reach high-level metadata. WP5 networking activity is leading to the definition of a European strategy and standards for site characterization of seismic stations in Europe. Based on the results of an international online

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 730900.

questionnaire, we defined a list of indicators considered as mandatory for a reliable site characterization: fundamental resonance frequency, shear-wave velocity profile (Vs), time-averaged Vs over the first 30 m, depth of seismological and engineering bedrocks, surface geology, EC8 soil class. We proposed a summary report for each indicator, containing the most significant background information of data acquisition and processing details, and a quality metrics scheme. This requires the evaluation of both (i) reliability of the site characterization indicators provided by different methods, and (ii) consistency among the indicators according to the current knowledge of the scientific community.

In addition, we have investigated the applicability, at a wide scale, of broad site condition indicators or proxies to correlate with measured local seismic amplification based on an extensive database comprising more than 1000 instrumented sites in Switzerland and Japan. Sensitivity of local amplification to the collected sets of site indicators highlight that proxies derived from in-situ geophysical measurements (f_0, Vs_{30}, etc.) perform better than parameters derived from local topography or geology. Furthermore, parameters derived from local geological models or databases generally show a stronger correlation with site amplification when compared to indicators from global models/databases. Prediction performance of various site condition parameter sets to predict frequency-dependent site amplification is assessed using neural networks. The most relevant direct proxy to predict local amplification over a wide frequency range is the quarter-wavelength parameter. Predictions based on V_{S30} only give satisfying results in intermediate frequency bands (1.67 – 6.66 Hz) while all direct site condition indicators except the quarter-wavelength parameters performs well in low and intermediate frequency bands (≤6.66 Hz). For indirect proxies (topography, geology, etc.), the prediction performance at all frequency bands shows best results when using all information that is available. This study also clearly outlines the importance of common geological classification from maps with different origins and scales.

List of Publications

Riga, E., Pitilakis, K., Argyroudis, S., Fäh, D., Cultrera, G. & Corbnou, C. 2019. Deliverable D7.1 Standard for site condition metadata, 27 pages

Di Giulio, G., G. Cultrera, C. Cornou, P.-Y. Bard, B. Al Tfaily, 2019. Deliverable D7.2 - Best practice and quality assessment guidelines for site characterization, 75 pages

Cornou, C., P.-Y. Bard, 2019. Deliverable D7.3 European strong ground motion characterization road map, 25 pages

Bergamo, P., Hammer, C. & Fäh, D. 2019. Deliverable 7.4: Towards improvement of site condition indicators, 104 pages.

Access to Data and Services

European Geotechnical Databases developed within EPOS (http://egd-epos.civil.auth.gr/)

WP 8-TA 1: Experimental study of a two-storey flat slab building under seismic and gravity loads

G. Tsionis, M. Lamperti, P. Pegon, J. Molina, M. Peroni

Keywords

Earthquake engineering, flat slab, large-scale tests, pseudodynamic testing, retrofit.

Figure

Figure 2. Test specimen: a two-storey flat slab structure

Main Results

Flat slab buildings for commercial, office, and residential use are built in many countries. Yet, their performance under seismic and gravity actions is still not very well understood. Many studies have been carried out in North America and Asia, but European research is lagging behind and Eurocode 8 does not fully cover the design of buildings with flat slab frames used as primary seismic elements.

The SlabSTRESS Transnational Access project at the ELSA Reaction Wall of the Joint Research Centre studied the response of flat slab reinforced concrete buildings under earthquake and gravity loads. The objective of the project was twofold: to study the ultimate capacity and failure modes of flat slab

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 730900.

structures with different layouts of reinforcement and to verify the effectiveness of steel studs for the repair of damaged slab-column connections.

The test specimen was a full-scale two-storey flat slab structure with plan dimensions 9×14 m. Punching shear reinforcement was placed only in the slab of the second storey. In addition, uniformly distributed horizontal reinforcement was placed in half of the slab at each floor, while, in the other half, the same amount of horizontal reinforcement was mostly concentrated close to the columns.

The testing programme included two pseudodynamic tests (hybrid simulation of the physical specimen and numerical shear walls) with input corresponding to the Serviceability and Ultimate Limit States and three quasi-static tests under imposed cyclic displacement with increasing amplitude (three slab-column joints were strengthened after the first cyclic test).

The project provided new knowledge on the response of flat-slab structures with different detailing rules that could not be captured in previous tests on column-slab sub-assemblies. The results will help calibrate models, verify the Eurocode and Model Code models for punching shear, and develop new rules for the deformation-based design and detailing of flat-slab structures subjected to earthquake and gravity loads, as well as to improve the design of flat-slab frames as primary seismic structures.

The results of the project are being exploited by the 14 Users of the SlabSTRESS project and by 19 research groups from 13 countries, who participate in an ongoing blind prediction competition.

More information: www.slabstress.org, www.researchgate.net/project/SlabSTRESS

List of Publications

Lamperti, M., Tornaghi, G., Tsionis, P., Pegon, P., Molina, J., Peroni, M., Coronelli, D., Pinho Ramos, A., Pascu, R. Experimental study of a two-storey flat slab building under seismic and gravity loads. 17th World Conference on Earthquake Engineering, 2020 (accepted abstract).

Access to Data and Services

All experimental and documentation data will be made available through the SERIES Data Access Portal after the completion of the blind prediction competition.

SERA
Seismology and Earthquake Engineering
Research Infrastructure Alliance for Europe

WP 9-TA 2: Shake table dynamic tests on a full-scale steel silo filled with wheat

I. Lanese [(1)], A. Pavese [(1, 2)]

[(1)] EUCENTRE, Pavia PV, Italy
[(2)] University of Pavia, Pavia, Italy

Keywords

Full-scale silo, seismic isolation, dynamic testing, shake table testing.

Figure

Figure 1. Full-scale silo structure tested in as-built and seismic isolated configurations

Main Results

The transnational access (TA) framework of the SERA project gave European and worldwide researchers the opportunity to target an extremely wide range of crucial aspects in earthquake engineering and seismology fields, trough the access to the largest collection of high-class European Research Infrastructures. The EUCENTRE experience, in addition to the coordination of the TA framework, resulted in relevant contributions to earthquake engineering fields in which experimental data on full-scale structures and non-structural components is very limited.

EUCENTRE TA activities encompass real time dynamic testing of innovative optimized variable-friction seismic isolation devices, silo structures and industrial facilities with respect to early warning and protection from dangerous leakage and both structural and non-structural damage.

In Figure 1, a real full-scale silo tested on the EUCENTRE shake table is pictured. The structural design of steel flat-bottom ground-supported silos containing granular material represents a challenging issue. They differ from many other civil structures since the weight of the silo structure is sensibly lower than the one of the ensiled particulate material and, in case of earthquake ground motion, the particle-structure interaction plays a fundamental role on the global dynamic response. The complex mechanism through which the ensiled material interacts with the silo wall has been studied since the XIX century. Nonetheless, several issues are still to be addressed regarding “grain-silo systems” and structural failures still occur, with potential loss and spread of huge amount of the ensiled content. To this end, an extensive experimental campaign with several parametric shake table test runs has been

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 730900.

carried out. A wide spectrum of related aspects has been targeted, such as the dynamic characterization (frequency, damping ratio, amplification, etc.) of such complex silo-grain system, the experimental assessment of the static pressure (during and at the end of the filling phase), and the seismic dynamic over-pressures exerted by the ensiled material on the silo wall. Furthermore, the assessment of the benefits obtained introducing a seismic isolation system based on curved surface sliders at the base of the silo has been carried out.

In order to fully exploit the potential of this testing campaign, a fruitful collaboration between EUCENTRE and worldwide researchers as well as a deeply analyzed specific selection of a variety of shake table input signals were successfully carried out within the testing campaign preliminary phases.

List of Publications

- Journal and conference publications are currently either under review or in preparation.
- The SERA Deliverable D9.1 submitted on M24 of the project include detailed information on the above described experimental activity.

Access to Data and Services

All data will be included in the SERA DB.

WP 10-TA 3: TA Project FUTURE

Full-scale experimental validation of steel moment frame with EU qualified joints and energy efficient claddings under near fault seismic scenarios

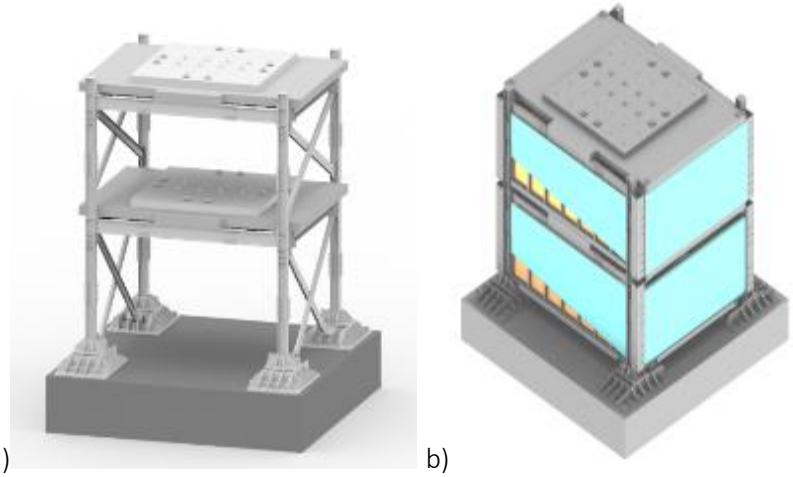
M. D'Aniello [(1)], R. Landolfo [(1)], L. Di Sarno [(2)], A. Le Maoult [(3)], G. Rastiello [(3)]

[(1)] Department of Structures for Engineering and Architecture, University of Naples Federico II, Napoli (Italy)
[(2)] University of Sannio, Benevento (Italy), University of Liverpool (UK)
[(3)] Energy Division - Mechanics & Thermal Unit (SEMT), CEA, University of Paris-Saclay (France)

Keywords

Steel moment resisting frames, Detachable Joints, ductile claddings, Near Fault earthquake, Seismic design

Figures



a) b)

Figure 1. FUTURE mock-up; overall layout without (a) and with cladding (b)

Main expected Results

The FUTURE testing campaign aims to qualify the behavior of steel moment frames equipped with different types of replaceable beam-to-column joints, as well as to investigate the influence of energy-efficient ductile non-structural claddings under near-fault (NF) seismic scenarios. Therefore, a 50-ton scale 2:3 model was designed and manufactured.

The experimental mock-up is a two-story one-bay steel frame (5 m x 5 m) that has been sub-structured from a reference steel building that is a typical example of archetype for multi-story office building of the standard EU practice. It has been designed to detach and to replace easily all components that will experience plastic deformation. In particular, three types of beam-to-column joints are examined, namely reduced beam section (RBS), haunched (H) and extended stiffened (ES) sections.

The mock-up is ready and some preliminary tests have already been conducted for signal testing (empty shake table). However, the experimental campaign has not started yet, as due to the unpredictable on-

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 730900.

going COVID-19 crisis which is currently affecting all Europe, especially Italy and France, the mock-up could not be delivered to CEA site (still blocked in Italy).

List of Publications

D'Aniello, M., Di Sarno, L., Fiorino, L., Tartaglia, R., Costanzo, S., Landolfo, R., Le Maoult, A., Rastiello G. (2019). Behaviour of steel moment resisting frames under near fault earthquakes: the "FUTURE" project. COMPDYN 2019, 7th ECCOMAS Thematic Conference on Computational Methods in Structural Dynamics and Earthquake Engineering. Papadrakakis, M., Fragiadakis, M., (eds.). Crete, Greece, 24–26 June 2019.

Access to Data and Services

All experimental data are freely available at http://ged_laboweb.sylos.com/GED_LaboWEB and on the European database at http://www.dap.series.upatras.gr/

WP 10-TA 3: TA Project SEREME

Seismic Resilience of Museum contEnts

M. Fragiadakis [(1)*], L. Di Sarno [(2)], A. Saetta [(3)], M.G. Castellano [(4)], I. Rocca [(3)], S. Diamantopoulos [(1)], V. Crozet [(7)], I. Politopoulos [(7)], T. Chaudat [(7)], S. Vasic [(7)], I.E. Bal [(6)], E. Smyrou [(6)], I. Psycharis [(1)], T.C. Hutchinson [(5)], L. Berto [(3)]

[(1)] School of Civil Engineering, National Technical University of Athens, Greece
[(2)] University of Sannio, Benevento (Italy), University of Liverpool, UK
[(3)] Department of Architectural Construction, University IUAV Venice, Italy
[(4)] Research & Development Supervisor, Technical Department, Selvazzano Dentro, Italy
[(5)] Department of Structural Engineering, University of California, San Diego, USA
[(6)] Energy Division - Mechanics & Thermal Unit (SEMT), CEA, University of Paris-Saclay, France
[(7)] Research Centre for Built Environment NoorderRuimte Hanze University of Applied Sciences Groningen, The Netherlands

Keywords

Earthquake Engineering, museum contents, statues rocking, shake table tests

Figure

Figure 3. General set up of the statues and busts on the shake table

Main Results

In the framework of SEREME project, an extensive experimental campaign on the seismic response of museum artefacts, with emphasis on statues and busts, was performed using AZALEE shake table of CEA in Saclay, France. The objective of this experimental campaign was to give insight on the seismic behaviour of statues and busts as well as to evaluate the effectiveness of two different mitigation

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 730900.

methods used to improve the seismic behaviour of these artefacts. A total of five couples of real scale marble artefacts were tested, three busts installed on marble pedestals and two statues. Seven different testing arrangements were considered during this experimental campaign and a total of 281 seismic tests were performed. Regarding the employed mitigation techniques, two different isolators types were used. First, a local isolation method, based on SMA wires, was used in order to enhance the seismic behaviour of a single artefacts. Then, three pendulum isolators were employed in order to isolate a floor on which a group of artefacts (2 or 3 artefacts) was installed. In order to give a direct evaluation of the isolators effectiveness, for each test configuration, a couple of two similar artefacts were tested together in an isolated and a non-isolated arrangement. Furthermore, to evaluate the influence of the frequency content of the excitation as well as the directionality of the seismic excitation, 12 different waveforms were applied to the shake table (seven uni-directional motions, three bi-directional motions and two tri-directional motions). Regarding the instrumentation, the artefacts motions were recorded using both accelerometers, gyroscopic and displacement sensors.

The achievement of this experimental campaign are:

- For high excitation intensity tests, the non-isolated artefacts are prone to show a complex rocking and sliding behaviour. The impact induced by the rocking motion can be a source of damage to the base of the busts.
- In most of the cases, the considered mitigation methods have been effective in the prevention of the rocking/sliding behaviour of the artefacts. As a result, these mitigation methods improved significantly the seismic behaviour of the artefacts.

List of Publications

Fragiadakis, M., et al. Seismic response assessment and protection of statues and busts. Arco Conference, May 28-30, 2020, Firenze, Italy.

Access to Data and Services

All experimental data are freely available at http://ged_laboweb.sylos.com/GED_LaboWEB and on the European database at http://www.dap.series.upatras.gr/

SERA
Seismology and Earthquake Engineering
Research Infrastructure Alliance for Europe

WP 11-TA 4: Project #7 – Transnational Access at LNEC

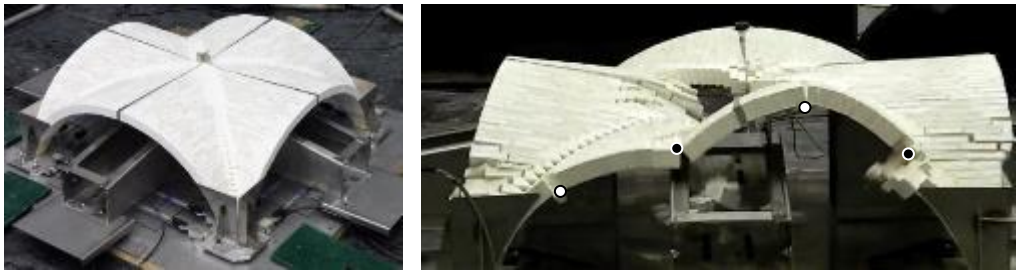
Seismic Response of Masonry Cross Vaults: shaking table tests and numerical validations

P.X. Candeias., A.A. Correia , A. Campos Costa, C. Calderini , N. Bianchini, M. Rossi , N. Mendes, P.B. Lourenço, P. Casadei

Keywords

Earthquake Engineering, shaking table, masonry structures, cross vaults, retrofitting

Figures



Figures: Masonry cross vault test specimen and collapse mechanism

Main Results

This report introduces one of the H2020 SERA project transnational access experimental activities, involving 3D shaking table tests on masonry cross vaults. Widely spread among monumental masonry buildings (mainly in churches and palaces), masonry cross vaults are some of the most vulnerable horizontal structural elements. Acting as a ceiling and a structural horizontal diaphragm with significant mass, vaults' mechanical behaviour affects the overall seismic response of buildings, in terms of strength, stiffness, and ductility. Moreover, their local damage and collapse may produce significant losses in terms of cultural assets and casualties.

The full experimental campaign consisted of three different testing phases and specimens: a 1:5 reduced scale cross vault made of 3D-printed blocks assembled with dry joints, a 1:1 scale model of a brick unreinforced masonry cross vault and a 1:1 scale model of a brick masonry cross vault reinforced with the TRM technique, covering the lack of knowledge in this field. The overall research project included the initial design of the test specimens, their construction, the preparation of the test setup, the shaking table tests and the analysis and post-processing of results.

The main focus of the research was the study of the shear failure along with the shell of the vault itself, which very often occurs during earthquakes in monumental buildings. From the experimental and numerical studies performed, it was possible to observe a systematic location of the hinges in concordance with Heyman's theory. The shear failure was obtained by designing specific boundary conditions, showing, as expected, the main concentrations of damage along the rib of the vault. The

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 730900.

capacity of the structure under dynamic loading is higher than the capacity obtained from previously performed quasi-static tests.

The expected outcomes have been satisfied, namely: evaluation of the maximum acceleration applicable to cross vaults, evaluation of the diaphragm stiffness and ultimate displacement capacity of cross vaults, identification of the damage mechanisms, evaluation of the role of the seismic input on the dynamic response of these vaults, comparison between static and dynamic tests and evaluation of the influence of the test type.

In conclusion, by improving the knowledge and the modelling/analyses approaches of vaulted masonry structures, this research contributes to a better safety assessment of heritage buildings and to a better design of strengthening interventions, thus contributing to an improvement of the safety and preservation policies of heritage buildings in the EU.

List of Publications

Tsionis G., *et al.* (2018) "Technical report on SERA Transnational Access activities TA1-TA10 (M12)," *Deliverable 8.1 (WP8-WP17), SERA – EU H2020 Project*. Available at http://www.sera-eu.org/en/home/

Tsionis G., *et al.* (2019) "Technical report on SERA Transnational Access activities TA1-TA10 (M24)," *Deliverable 9.1 (WP8-WP17), SERA – EU H2020 Project*. Available at http://www.sera-eu.org/en/home/

Tsionis G., *et al.* (2020) "Technical report on SERA Transnational Access activities TA1-TA10 (M36)," *Deliverable 10.1 (WP8-WP17), SERA – EU H2020 Project*. Available at http://www.sera-eu.org/en/home/

Bianchini N., Mendes N., Lourenço, P.B., Calderini, C. & Rossi, M. (2019) "Seismic assessment of masonry cross vaults through numerical nonlinear static and dynamic analysis," *7th International Conference on Computational Methods in Structural Dynamics and Earthquake Engineering (COMPDYN 2019)*, Crete, Greece.

Bianchini, N., Calderini, C., Rossi, M., Mendes, N., Candeias, P.X., Lourenço, P.B., Campos Costa, A. (2020)"Seismic assessment of masonry cross vaults through shaking table testing on a scaled model under different inputs," *14th World Congress in Computational Mechanics and ECCOMAS Congress*, Paris, France.

Bianchini, N., Mendes, N., Candeias, P.X., Calderini, C., Rossi, M., Lourenço, P.B., Campos Costa, A. (2020) "Seismic performance of masonry cross vaults through shaking table testing on a scaled model," *12th International Conference on Structural Analysis of Historical Constructions (SAHC 2020)*, Barcelona, Spain.

Access to Data and Services

The test results are disseminated to the wider scientific community through the open access experimental database of the SERA project.

WP 11-TA 4: Project #6 – Transnational Access at LNEC

(Towards the) Ultimate Earthquake Proof Building System: development and testing of integrated low-damage technologies for structural and non-structural elements

AA. Correia., P.X. Candeias., A. Campos Costa., S. Pampanin, J. Ciurlanti., S. Bianchi, D. Perrone, M. Palmieri, D. Grant, G. Granello, A. Palermo, A. Filiatrault

Keywords

Earthquake Engineering, shaking table, performance-based design, self-centering, dissipaters

Figure

Test specimen configurations for the 3 shaking table tests performed

Main Results

This report introduces one of the H2020 SERA project transnational access experimental activities, involving 3D shaking table tests of a two-storey 1:2 scaled fully prefabricated dry-assembled building. It contains two-bay timber-concrete low-damage seismic frames, post-tensioned rocking dissipative timber seismic walls and comprising different low-damage or high-performance non-structural components (fiber-reinforced gypsum and masonry partitions/glass and GFRC facades). The project aimed to promote a research effort within the European environment for the development of an integrated low-damage building system.

The high socio-economic impact of moderate-to-strong earthquakes and the increased public awareness of seismic risk have facilitated the acceptance and implementation of damage-control technologies, whose development is nowadays demanded. Performance-based design criteria and objectives need a shift towards a low-damage design approach and technical solutions for engineers and stakeholders to control the performance/damage of the entire building system, including superstructure, foundation systems and non-structural elements. Moreover, this new design philosophy should be considered to define an ultimate “earthquake-proof” building system.

The full experimental campaign consisted of three different testing phases and specimen configurations, i.e. skeleton building, skeleton building with internal gypsum partitions, and building

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 730900.

with an integrated system made of an internal masonry wall and exterior envelopes. The overall research project included the initial design of the test building and its structural and non-structural detailing, the construction of the specimen, the preparation of the test setup, the shaking table test and the analysis and post-processing of results.

Concerning the global performance, the specimen behaved as expected with demand parameters coherent with the ones calculated during the design process. Regarding the non-structural components, the in-plane behaviour confirmed the good response of these components due to the introduced non-structural detailing. The out-of-plane accelerations allowed to define the relative amplification factors which were estimated within a range of 2-3 for all non-structural systems when compared to the building levels, apart from the masonry infills where the amplification is found to be around 2.

The dynamic shaking table tests confirmed the seismic performance of the low-damage skeleton for timber-concrete structures. Furthermore, it proved the high potential for implementing an integrated low-damage or high-performance structural/non-structural building solution for the next generation of buildings. On the other hand, the observed (low) damage conditions will suggest improvements to the system detailing to be applied and studied in future research.

List of Publications

Tsionis G., *et al.* (2018) "Technical report on SERA Transnational Access activities TA1-TA10 (M12)," *Deliverable 8.1 (WP8-WP17), SERA – EU H2020 Project*. Available at http://www.sera-eu.org/en/home/

Tsionis G., *et al.* (2019) "Technical report on SERA Transnational Access activities TA1-TA10 (M24)," *Deliverable 9.1 (WP8-WP17), SERA – EU H2020 Project*. Available at http://www.sera-eu.org/en/home/

Tsionis G., *et al.* (2020) "Technical report on SERA Transnational Access activities TA1-TA10 (M36)," *Deliverable 10.1 (WP8-WP17), SERA – EU H2020 Project*. Available at http://www.sera-eu.org/en/home/

Bianchi S., Ciurlanti, J., Pampanin, S., Perrone, D. & Filiatrault, A. (2020) "Seismic demand and performance evaluation of non-structural elements in a low-damage building system," *17th World Conference on Earthquake Engineering*, Sendai, Japan.

Ciurlanti, J., Bianchi, S., Pampanin, S. (2020) "Shake-table tests of a timber-concrete low-damage building: analytical/numerical vs. experimental results," *17th World Conference on Earthquake Engineering*, Sendai, Japan.

Pampanin, S., Ciurlanti, J., Bianchi, S., Perrone, D., Palmieri, M., Grant, D., Granello, G., Palermo, A., Filiatrault, A., Campos Costa, A., Candeias, P.X., Correia, A.A. (2020) "Enhancing seismic safety and reducing seismic losses: overview and preliminary results of SERA Project – 3D shaking table tests on an integrated low-damage building system," *17th World Conference on Earthquake Engineering*, Sendai, Japan.

Access to Data and Services

The test results are disseminated to the wider scientific community through the open access experimental database of the SERA project.

SERA
Seismology and Earthquake Engineering
Research Infrastructure Alliance for Europe

WP 11-TA 4: Project #19 – Transnational Access at LNEC

Seismic Testing of Adjacent Interacting Masonry Structures

A.A. Correia, P.X. Candeias, F.L. Ribeiro, I. Tomić, A. Penna, M. DeJong,
C. Butenweg, I. Senaldi, G. Guerrini, D. Malomo, K. Beyer

Keywords

Earthquake Engineering, shaking table, unreinforced masonry, adjacent structures, dynamic interaction

Figures

Figures: Test specimen and numerical models

Main Results

Historical city centres throughout Europe have developed and densified during long periods. The densification caused the historical centres to be characterized by masonry building aggregates. In building aggregates, facades of adjacent buildings often share a structural wall. Furthermore, the connection between the older and the newer units is often made through weakly interlocking stones or by a dry joint. Since the densification was often a process spanning throughout long periods, it is not uncommon for adjacent units to be constructed of different materials, to have different distributions of openings and different floor and roof heights. However, advances in the development of analysis methods for such aggregates have been impeded by the lack of experimental data.

This report thus introduces one of the H2020 SERA project transnational access experimental activities, involving 3D shaking table tests of a half-scale stone masonry aggregate. It consists of two building units with a common wall and different floor heights. The walls are constructed as double-leaf stone masonry without interlocking between the leaves, except at corners and openings. The overall research project included the initial design of the building aggregate, the construction of the specimen, the preparation of the test setup, the shaking table test and the analysis and post-processing of results. It contributes significantly to the collection and dissemination of experimental data on the interaction of building units in order to understand better the phenomena involved in their dynamic behaviour.

To ensure that the results can be compared with previous test campaigns, the construction material was reproduced the one used for previous shaking table tests, as much as possible. Nevertheless, the research project includes a complete set of material characterization tests, including a large number of tests on mortar samples and wallettes tested in simple and diagonal compression.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 730900.

The experimental data produced is also valuable to calibrate adequately the substantial number of complex non-linear models and modelling approaches required to capture the buildings' response. There were numerous participants from academic and professional teams in the blind prediction competition organised within the project, which confirms the interest of the research carried out.

List of Publications

Tsionis G., *et al.* (2018) "Technical report on SERA Transnational Access activities TA1-TA10 (M12)," *Deliverable 8.1 (WP8-WP17), SERA – EU H2020 Project*. Available at http://www.sera-eu.org/en/home/

Tsionis G., *et al.* (2019) "Technical report on SERA Transnational Access activities TA1-TA10 (M24)," *Deliverable 9.1 (WP8-WP17), SERA – EU H2020 Project*. Available at http://www.sera-eu.org/en/home/

Tsionis G., *et al.* (2020) "Technical report on SERA Transnational Access activities TA1-TA10 (M36)," *Deliverable 10.1 (WP8-WP17), SERA – EU H2020 Project*. Available at http://www.sera-eu.org/en/home/

Tomić, I., Penna, A., DeJong, M., Butenweg, C., Correia, A.A., Candeias, P.X., Senaldi, I., Guerrini, G., Malomo, D., Beyer, K. (2020) "Seismic testing of adjacent interacting masonry structures," *17th World Conference on Earthquake Engineering*, Sendai, Japan.

Access to Data and Services

The test results are disseminated to the wider scientific community through the open access experimental database of the SERA project.

WP 12-TA 5: Transnational Access to structure lab reaction wall at University of Patras

S. Bousias, E. Strepelias, X. Palios, N. Stathas
University of Patras, Greece

Keywords

Earthquake engineering, Hybrid simulation, reaction wall

Figures

Figure 1. Project ARISTA

Figure 2. Project ARCO

Figure 3. Project HitFrames

Main Results

The scope of the ARISTA project (project team: Cyprus University of Technology, Ecole Centrale de Nantes, DENCO Structural Engineering) was to experimentally study the seismic behaviour of a 1:1.5 scaled three-storey two-bay RC frame with smooth bar reinforcement. The frame was designed using gravity loads only and lacked any seismic design or detailing. The experiment in one of the few worldwide, in which a specimen with smooth bar reinforcement and size (i.e., number of storeys and full scale) was tested. It provided invaluable information for design guidelines and code rules.

The ARCO project (project team: University of Liege, Liege, University of Lisbon, Aarhus University) focused on the effect of axial restraint on the seismic behaviour of short coupling beams. This effect is

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 730900.

generated by the interaction between the coupling beam and the adjacent shear walls. As the beam cracks under loading, it tends to extend in the longitudinal direction and pushes upon the walls. Because of the large stiffness of the walls, compression force develops in the beam, which limits the opening of the cracks. As a consequence of this effect, beams are characterised by a shear-dominated response, being susceptible to brittle shear failures. The only test variable was the level of axial restraint. A fourth beam was tested under a large inelastic pulse in one direction followed by a push to failure in the opposite direction. This unconventional cyclic loading scenario can be associated with a near-fault pulse-type ground motion.

The project HitFrames (project team: University Liverpool, University of Naples Federico II, University of Ljubljana, University College London, University of Toronto and FIP Industriale) investigated effective methods for the seismic assessment and retrofitting of existing non-compliant steel frames. Recent earthquakes in the Mediterranean region demonstrated that present steel, multi-storey, residential, framed buildings are designed primarily for gravity loads, exhibiting low energy absorption and inadequate dissipation capacity under seismic loadings. The low lateral stiffness and strength of the steel framed structures and the slender masonry infills induce significant lateral drifts, buckling and/or fractures to structural steel members. Additionally, the current provisions for the seismic performance assessment of existing steel structures are scarce and they do not account for the presence of the infills.

List of Publications

Palios, X., Strepelias, E., Stathas, N., Fardis, M.N., Bousias, S., Chrysostomou, C.Z., Kyriakides, N. "Experimental study of a three-storey concrete frame structure with smooth bars under cyclic lateral loading", Bulletin of Earthquake Engineering, BEEE (under review).

Di Sarno, L., Gutiérrez-Urzúa, F., Freddi, F., D'Aniello, M., Landolfo, R., Kwon, O-S., Bousias, S., Dolšek, M., Wu, R-W., Castellano, M.G. "Pseudo-Dynamic testing of existing steel frames with masonry infills: assessment and retrofitting with BRBs", XVIII ANIDIS Conference 2019.

WP 13-TA 6: Project #10 – SERENA

Seismic Response of Novel Integral Abutment-Bridges

G. Fiorentino [1], C. Cengiz [2], F. De Luca [2], M. Dietz [2], L. Dihoru [2], D. Lavorato [1], D. Karamitros [2], B. Briseghella [3], T. Isakovic [4], Ch. Vrettos [5], A. Topa Gomes [6], A. Sextos [2], G. Mylonakis [2, 7, 8] and C. Nuti [1, 3]

[1] Department of Architecture, Roma Tre University, Rome, Italy
[2] Department of Civil Engineering, University of Bristol, Bristol, UK
[3] College of Civil Engineering, Fuzhou University, Fuzhou, China
[4] Faculty of Civil and Geodetic Engineering, University of Ljubljana, Ljubljana, Slovenia
[5] Department of Civil Engineering, Technical University Kaiserslautern, Kaiserslautern, Germany
[6] Department of Civil Engineering, University of Porto, Porto, Portugal
[7] Department of Civil Engineering, Khalifa University, U.A.E.
[8] University of California at Los Angeles (UCLA), U.S.A.

Keywords

Seismic Soil-Structure Interaction, Integral Bridges, Shaking Table, backfill/pile isolation, Eurocode 8.

Figure

Figure 1. Maximum accelerations recorded by the sensors positioned in the backfill soil and on the bridge; comparison between two cases with piles connected to the foundation: without (a) and with (b) compressible inclusion layer behind the abutment wall (adapted from Fiorentino et al. 2019b)

Main Results

Integral Abutment Bridges (IABs) are characterised by the absence of bearing supports and expansion joints between the deck and the abutments/piers, thus reducing construction and maintenance costs. IABs are characterised by a complex Soil-Structure Interaction (SSI) with respect to conventional bridges; therefore, the static and dynamic effects of the SSI should be considered in the design. Despite

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 730900.

the large number of IABs worldwide and related numerical studies, few experimental tests were performed, and codes lack related seismic prescriptions, including Eurocodes.

Project SERENA aimed at conducting experimental shaking table tests on a scaled bridge model inserted into the large "shear stack" soil container of the EQUALS – BLADE Laboratory of the University of Bristol. The novelties of the project are the following:

1. the first dynamic test on a shaking table of an Integral Abutment Bridge model including Soil-Structure Interaction
2. the mitigation of earth pressures on the abutment walls and the overall effects induced by the introduction of a compressible inclusion between the soil and the abutment walls
3. the investigation of the effects of pile disconnection with/without compressible inclusion layers
4. evaluation of scaling criteria for dynamic SSI.

The bridge model was scaled to match the dimensions of the soil container on the shaking table. In doing so, attention was paid to the development of appropriate scaling laws that will allow extending the results obtained with the scaled model to real scale IABs. The results in terms of accelerations allow recognising some patterns in the seismic response of the model and the soil. In the backfill, it was found that the inclusion of layers of PU foam increases the accelerations in the soil while, on the other, its presence reduces the accelerations of the bridge, which are smaller than in the surrounding soil. After the tests, settlements in the configurations with compressible inclusion layers behind the abutment wall were larger. This result indicates the necessity of a careful design of approaching slabs. The pile disconnection is promising as well. Scaling laws here developed will permit to analyse real backward bridges. The results can be used as a first step towards developing engineering provisions for IABs which are absent from existing regulations such as Eurocode 1998.2 (Bridges). Further experimental and numerical analyses can be proposed based on this research such as the validation of scaling methodologies, use of different backfill soil, different geometries of backfill soil or the development of behaviour factor for IABS.

List of Publications

Fiorentino G., Cengiz C., De Luca F., Briseghella B., Lavorato D., Mylonakis G., Sextos A., Nuti C., Shaking Table tests on Integral Bridge Model including Soil-Structure Interaction, Proceedings of XVIII ANIDIS Conference, 15-19 September 2019, Ascoli Piceno, Italy.

Fiorentino G., Cengiz C., De Luca F., De Benedetti G., Lolli F., Dietz M., Dihoru L., Lavorato D., Karamitros D., Briseghella B., Isakovic T., Vrettos C., Topa Gomes A., Sextos A., Mylonakis G., Nuti C. (2019), Shaking Table Tests on an Integral Abutment Bridge Model: Preliminary Results, COMPDYN 2019, 7th ECCOMAS Thematic Conference on Computational Methods in Structural Dynamics and Earthquake Engineering, M. Papadrakakis, M. Fragiadakis (eds.), Crete Island, Greece, 24–26 June 2019.

Deliverable D10.1 - Technical report on SERA Transnational Access activities. Project # 10 - SERENA - Seismic Response of Novel Integral Abutment-Bridges.

Access to Data and Services

Data used in the publications are available in full within each publication. Data access can be granted through the SERA project data portal. Data upload onto Celestina software is ongoing.

WP 13-TA 6: Project #11 – 3DROCK

Statistical verification and validation of 3D seismic rocking motion models (3DRock)

M. F. Vassiliou [1], M. Broccardo [2], C. Cengiz [3], M. Dietz [3], L. Dihoru [3], S. Gunay [4], K. Mosalam [4], G. Mylonakis [3,5,6], A. Sextos [3], B. Stojadinovic [1]

[1] Department of Civil, Environmental, and Geomatic Engineering, ETH Zurich, Switzerland
[2] University of Liverpool, UK (formerly with ETH Zurich)
[3] Department of Civil Engineering, University of Bristol, Bristol, UK
[4] University of California at Berkeley (UCB), U.S.A.
[5] Department of Civil Engineering, Khalifa University, U.A.E.
[6] University of California at Los Angeles (UCLA), U.S.A.

Keywords

Rocking structures, seismic excitation, model verification, response modification, earthquake engineering

Figures

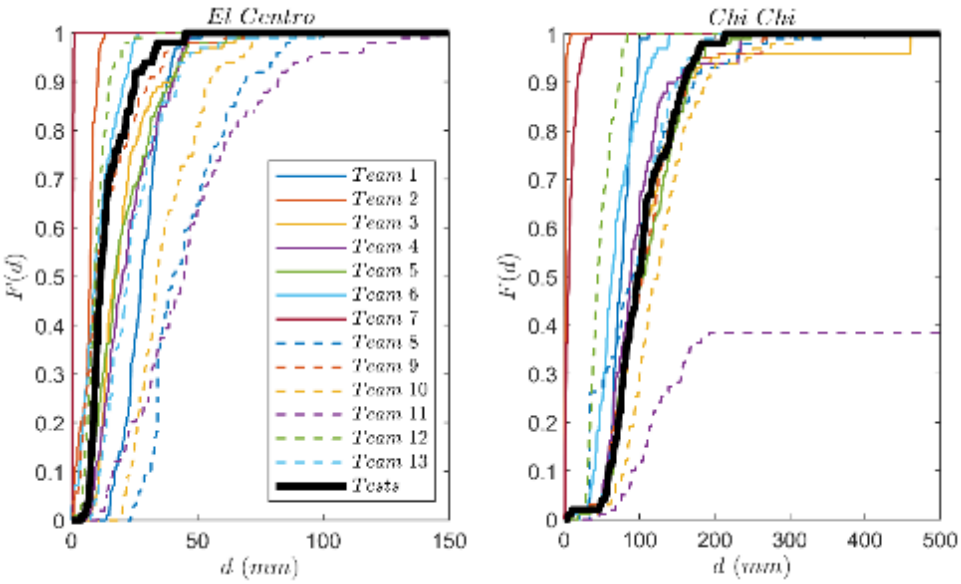


Figure 1. The cumulative distribution function of the specimen displacement (d) for the two utilized ground motion test sequences "El Centro" and "Chi Chi": tests and predictions of the teams

Main Results

The 3D rocking oscillator model is useful because it describes the seismic behavior of unanchored equipment and because unrestrained rocking has been suggested as a seismic response modification technique. A major critique against rocking systems has been that their responses are not only hard to

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 730900.

predict by existing numerical models, but that the response is inherently unpredictable. Therefore, in the context of earthquake engineering, the objective of this study is to answer two important questions: Is wobbling motion inherently unpredictable? If not, are existing models good enough to predict the response?

To this end, an experimental campaign has been designed to obtain observations of wobbling motion to be compared with those gained from numerical simulations. Two sets of models were studied: “Free Rocking” representing unanchored equipment; and “Wobbling Frame” representing a design approach that can be used for the rocking isolation of bridges or buildings. To constrain the uncertainty in the excitation, a stochastic model was used to generate synthetic ground motion ensembles that match the physical characteristics of recorded ground motions. Each ensemble contained 100 excitations. One ensemble was used to study the Free Rocking specimens and two ensembles were used to study the Wobbling Frame.

Numerical simulation of the tests on the Free Rocking specimens is currently being performed. The response of the Wobbling Frame was the subject of an international blind prediction contest. The contestants had to predict the Cumulative Distribution Functions (CDF) of the maxima of the responses. Thirteen teams using FEM, DEM and Rigid Dynamics models responded. Notably, the same model predicted the CDF of the response for one ground motion family well, while it performed poorly on the other (Fig. 1). This finding shows that there is space for improvement in modelling of wobbling structures. Interestingly, both FEM and DEM can overestimate or underestimate the response depending on the input parameters used.

Moreover, the best models used zero Rayleigh damping and only relied on friction between the contact surfaces to dissipate energy, showing that damping models should be physics-based. An analytical dynamics model that prevents sliding and twisting was found to consistently overestimate the response of this structure because it did not model sliding. A more involved investigation on the modelling parameters that optimize the prediction of the Wobbling Frame is the subject of current research.

List of Publications

Publications and openly accessible deliverables are in preparation.

Access to Data and Services

Data upload onto Celestina software is ongoing.

Blind prediction contest data is available at: https://peer.berkeley.edu/news-and-events/2019-blind-prediction-contest

WP 13-TA 6: Project #12 – REBOND

Response of as-Built and strengthened three-leaf masonry walls by Dynamic tests

F. Di Michele[(1)], E. Spacone[(1)], G. Camata[(1)], G. Brando[(1)], A. Sextos[(2)], A. Crew[(2)], G. Mylonakis[(2, 6, 7)], M. Dietz[(2)], L. Dihoru[(2)], H. Varum[(3)], G. Manolis[(4)] and P. Casadei[(5)]

[(1)] Department of Engineering and Geology, University G. d'Annunzio of Chieti-Pescara, Italy
[(2)] Department of Civil Engineering, University of Bristol, Bristol, UK
[(3)] Faculty of Engineering, University of Porto, Portugal
[(4)] Department of Civil Engineering, Aristotle University of Thessaloniki, Greece
[(5)] Kerakoll Group, Sassuolo, Italy
[(6)] Department of Civil Engineering, Khalifa University, U.A.E.
[(7)] University of California at Los Angeles (UCLA), U.S.A.

Keywords

Earthquake engineering, three-leaf masonry walls, effects of vertical ground motion component, masonry wall reinforcement

Figure

Figure 1. Typical masonry wall specimen tested.

Main Results

The main scope of the RE-Bond (REsponse of as-Built and strengthened three-leaf masONry walls by Dynamic tests) project was to investigate the effects of the vertical ground motion component on the response of three-leaf walls, representative of buildings found in historical canters in Central Italy. Squat rectangular and T-walls were tested on the shake table as-built and after reinforcement with composite cross ties. The selection of the recorded ground motion signal focused on near fault records with an important vertical component. The walls were designed to represent walls at the top level of a masonry building with low axial load. Also, the walls were designed to fail in shear. The tested specimens showed

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 730900.

indeed shear failure with clearly visible diagonal cracks. The wall strength decreased due to the presence of the vertical ground motion component with respect to the test with the horizontal component only. The cross ties improved the behaviour of the walls by increasing their strength. Reinforcement of the masonry walls was applied by the Italian Kerakoll group): GeoSteel connectors with mortar injections were added on the entire thickness of the longitudinal wall and diagonal steel connectors with mortar injections were added between the two orthogonal walls in T-walls. Reinforcement increased the seismic capacity by 20 % thanks to the presence of the connectors. Extensive numerical modelling of the tested walls accompanied the test. The test results are currently being interpreted.

List of Publications

Publications and openly accessible deliverables are in preparation.

Access to Data and Services

Data upload onto Celestina software is ongoing.

WP 13-TA 6: Project #21 – NSFUSE

Ductile steel fuses for the protection of critical non-structural components

A. Kazantzi [1], A. Elkady [2], Matt Dietz [3], L. Dihoru [3], R. De Risi [3], D. Vamvatsikos [1], D. Lignos [4], E. Miranda [5] and G. Mylonakis [3, 6, 7]

[1] School of Civil Engineering, National Technical University of Athens, Athens, Greece
[2] Faculty of Engineering and Physical Sciences, University of Southampton, Southampton, UK
[3] Department of Civil Engineering, University of Bristol, Bristol, UK
[4] École Polytechnique Fédérale de Lausanne, Lausanne, Switzerland
[5] Department of Civil and Environmental Engineering, Faculty of Civil and Geodetic Engineering, Stanford University, Stanford, USA
[6] Department of Civil Engineering, Khalifa University, U.A.E.
[7] University of California at Los Angeles (UCLA), U.S.A.

Keywords

Nonstructural component, steel fuses, peak floor acceleration, peak component acceleration, component ductility

Figures

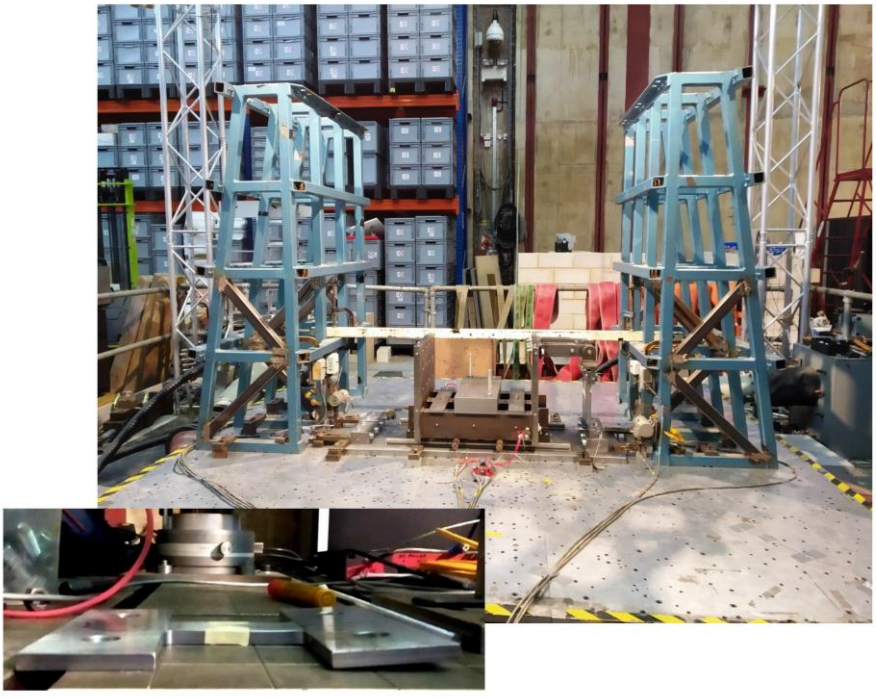


Figure 1. Ductile steel fuse tested on the shaking table

Main Results

Community-critical buildings often face lengthy functionality disruptions due to non-structural damage triggered by even low- or moderate-intensity earthquakes. The problem lies in the dynamics of narrowband excitations appearing at the floors (and ceilings) of buildings and the corresponding

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 730900.

resonant response of many rigidly-connected components, introducing component accelerations that can exceed by several orders of magnitude the (already amplified) peak floor response. In contrast, as was recently proven through analytical studies undertaken by members of this research team, a controlled yielding anchor could offer a reliable detuning effect that only requires a minor ductility of 1.5-2.0 to achieve substantial reductions in acceleration demands.

NSFUSE experimental project offered an actual verification of the concept at hand, by means of a series of one-dimensional earthquake simulation tests realized at the Bristol University shake table facility. The test specimen tested on the shake table was a Single-Degree-of-Freedom (SDOF) carriage-like configuration, that was able to move on two rollers supports. The test specimen was attached to its one end to two "fuse" plates, essentially acting as cantilevers to provide resistance to the sliding of the carriage. For targeting different vibration periods, the carriage was loaded with different masses, whereas by modifying the geometry of the steel fuses different stiffness and component ductility levels were attained. The shake table tests were conducted using narrow-band floor acceleration input signals that were recorded in instrumented buildings in California (USA) during three different earthquake events.

The NSFUSE experimental campaign provided concrete evidence for the benefits of designing the non-structural components (or their anchors) to respond in-elastically during earthquakes that are sufficiently strong to induce damages in such elements. In fact, it was showcased that:

(a) the a_p factor, which provides a measure of how much the peak component acceleration (PCA) is amplified relative to the peak floor acceleration (PFA). Hence, the ratio PCA/PFA could reach a peak that, for the case at hand of the component period being tuned with the fundamental period of the supporting structure, could be very high if the non-structural components were designed to respond elastically
(b) even small mobilized fuse ductility levels are enough to substantially reduce the acceleration demands for non-structural components attached to buildings and
(c) steel fuses were proven capable of developing a controlled yielding anchor mechanism.

All in all, the NSFUSE project offered ample evidence for the fuse concept and therefore to soon find its way in prospective design codes.

List of Publications

Kazantzi A.K., Vamvatsikos, D., Miranda, E. Evaluation of seismic acceleration demands on building non-structural elements, *Journal of Structural Engineering*, 2020a.

Kazantzi A.K., Vamvatsikos, D., Miranda, E. The effect of damping on floor spectral accelerations as inferred from instrumented buildings, *Bulletin of Earthquake Engineering*, 18:2149–2164, 2020b.

Miranda E., Kazantzi, A.K., Vamvatsikos, D. New approach to design acceleration-sensitive non-structural elements in buildings, 16th European Conference on Earthquake Engineering, Thessaloniki, Greece; 2018.

Access to Data and Services

Data upload onto Celestina software is ongoing.

WP 13-TA 6: Project #22 – SEBESMOVA3D

Seismic Behaviour of Scaled Models of Groin Vaults Made by 3D Printers

D. Foti [(1)], S. Silvestri [(2)], S. Ivorra [(3)], D. Theodossopoulos [(4)], S. Baraccani [(2)], V. Vacca [(1)], R. White [(5)], M. Dietz [(5)], G. Mylonakis [(5, 6, 7)]

[(1)] Department of Civil Engineering Sciences and Architecture, Technical University of Bari, Bari, Italy
[(2)] Department of Civil, Chemical, Environmental and Materials Engineering, University of Bologna, Bologna, Italy
[(3)] Department of Civil Engineering, University of Alicante, Alicante, Spain
[(4)] Edinburgh School of Architecture and Landscape Architecture, University of Edinburgh, Edinburgh, UK
[(5)] Department of Civil Engineering, University of Bristol, Bristol, UK
[(6)] Department of Civil Engineering, Khalifa University, U.A.E.
[(7)] University of California at Los Angeles (UCLA), U.S.A.

Keywords

Groin vault, shaking table test, 3D printed blocks, frequencies, SEBESMOVA3D

Figure

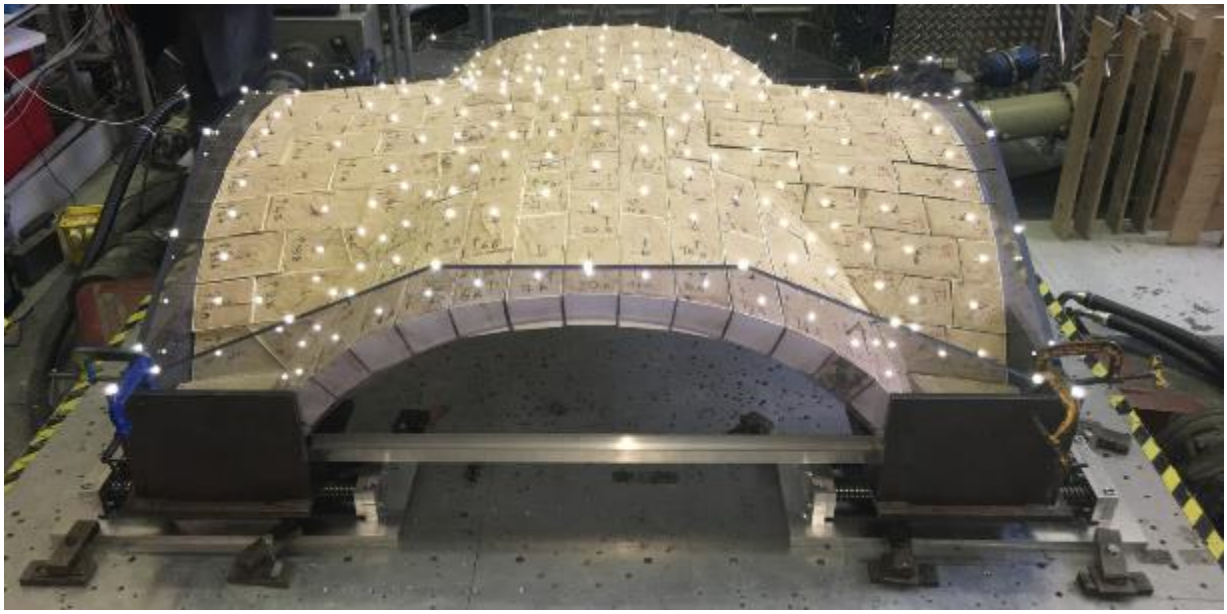


Figure 1. The vault specimen tested on the shaking table

Main Results

A huge number of shaking table tests was performed on a scaled groin vault model made of 3D printed plastic blocks filled with mortar.

The vault was built according to two support conditions (on four fixed supports and two fixed supports and two one-way moveable carriages equipped with lateral springs) as well as different boundary conditions along the four lateral arches (wooden panels, Plexiglas panels, cut Plexiglas panels and no panels) to account for different confinement levels.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 730900.

Random signals were systematically carried out to get the dynamic properties of the vault model. Harmonic inputs with different frequencies ranging between 1 Hz and 50 Hz were imposed in one horizontal direction with increasing amplitude, up to collapse.

The presence of a gum layer in-between two following blocks has a strong influence on the global behaviour. Furthermore, it seems to govern the dynamic response of the vaulted structure, especially for high-acceleration and low-frequency harmonic inputs. The results of the experimental campaign revealed a strongly non-linear behaviour.

The most important results can be summarised as follows:

1. The fundamental frequency of the vault model decreases with increasing acceleration.
2. Keeping all the conditions the same, configuration 2 (differential horizontal shear displacements at the supports through two moveable springs) reaches the collapse condition for a lower acceleration than configuration 1. The pseudo-static response of the vault induced by imposed shear displacements at its springings often represents the predominant cause of damage/failure, overshadowing the dynamic response of the vault itself, justifying the need for this series of tests.
3. The analysis of the cumulative displacements and the collapse acceleration values show that the vault made of plastic mortar bricks with gum-layer interfaces is not particularly susceptible to cumulative damage.
4. The vault with these specific geometries and support conditions seems to be more vulnerable to low-frequency (resonance) harmonic inputs if compared to seismic inputs.
5. The construction phases, as well as the fact that the seismic response of the vault with no panels along the lateral arches is similar to that of the vault weakly confined through the Plexiglas panels, indicate that the corner areas close to the springings are the critical ones, upon which attention should be paid to get static stability and higher seismic performances. This response is well known since ancient times when past repairs showed that these portions were constantly strengthened to be better embedded in the surrounding vertical masonry structures.

List of Publications

Foti, D., Silvestri, S., Baraccani, S., Ivorra, S., Theodossopoulos, D., Vacca, V., Campanella, V., Ochoa Roman, J.V., Cavallini, L., White, R., Dietz, M., Mylonakis, G. Experimental tests of a groin vault in dry-bonded voussoirs under dynamic excitation. 17th World Conference on Earthquake Engineering, 17WCEE Sendai, Japan. September13th to 18th 2020.

Access to Data and Services

Data upload onto Celestina software is ongoing.

WP 13-TA 6: Project #35 – SHATTENFEE

SHAking Table TEsting for Near Fault Effect Evaluation

A.L. Simonelli [(1)], M. Fragiadakis [(2)], A. Gajo [(3)], A.M. Kaynia [(4)], J. de Novais Bastos [(5)], G. Anoyatis [(6)], L. Di Sarno [(1, 7)], A. Penna [(1)], D. Aliperti [(1)], I. Taflampas [(2)], S. Diamantopoulos [(2)], F.G. Esfahani [(3)], P. Kowalczyk [(3)], M. Dall'Acqua [(1)], F. Fossi [(1)], E. Marotti [(1)], F. Zotti [(1)], R. De Risi [(8)], D. Karamitros [(8)], M. Dietz [(8)], C. Taylor [(8)], G. Mylonakis [(8, 9, 10)]

[(1)] University of Sannio, Benevento, Italy
[(2)] National Technical University of Athens, Athens, Greece
[(3)] DICAM University of Trento, Trento, Italy
[(4)] Norwegian Geotechnical Institute, Oslo, Norway
[(5)] Faculty of Architecture, University of Lisbon, Lisbon, Portugal
[(6)] KU Lueven, Brugge, Belgium
[(7)] University of Liverpool, Liverpool, UK
[(8)] Department of Civil Engineering, University of Bristol, Bristol, UK
[(9)] Department of Civil Engineering, Khalifa University, U.A.E.
[(10)] University of California at Los Angeles (UCLA), U.S.A.

Keywords

Earthquake engineering, Seismic hazard, Site effects, Near-fault effects, Modal identification.

Figures

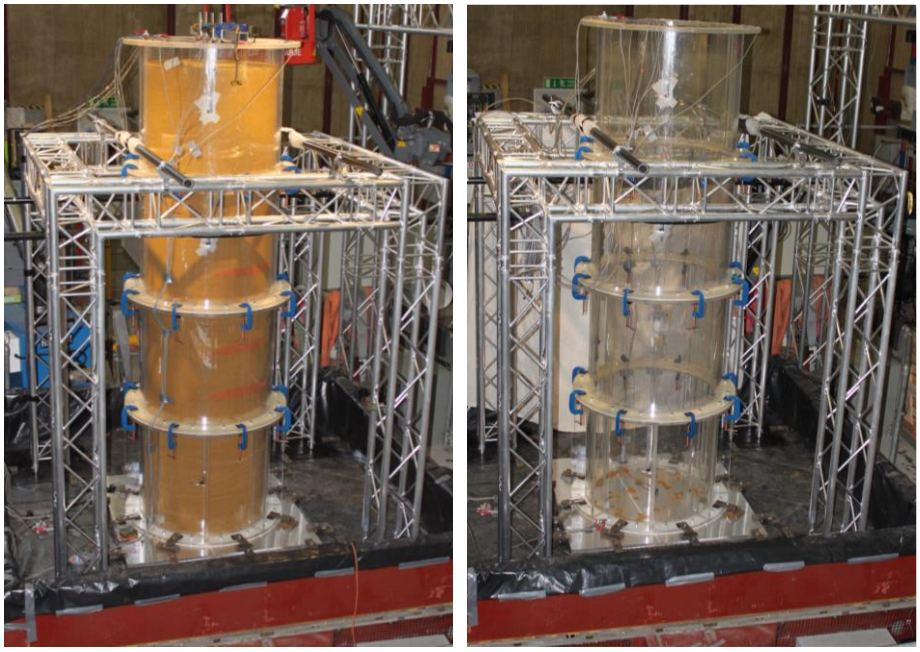


Figure 1. Test rig, comprising a 3.2 m high, 0.9 m diameter PERSPEX® cylinder and a 1:10 scaled pile model.

Main Results

The investigation of vertical ground motions, near-fault effects, and the ensuing soil-structure interaction is still scarce; therefore, the SHATTENFEE project aimed at investigating near-fault response of soil. To do so, the vertical dynamic behaviour of a typical soil deposit, with and without the presence

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 730900.

of a foundation pile, has been explored experimentally by using the 6-degree-of-freedom shaking table of the University of Bristol. A newly designed test rig, which comprises a 3.2 m high and 0.9 m diameter PERSPEX® cylinder, was utilised to experimentally analyse the vertical wave propagation of homogeneous soil in a 1:10 scaled model. For scaling the time by using frequency similitude between the prototype and the model, two values (3 and 7) were considered. A total of 209 tests were carried out during the experiments. Different types of dynamic functions and seismic records were used as input motion at the base of the cylindrical model. To perform the dynamic identification of the system, vertical noise functions and sweep functions (sinusoidal waveforms) were utilised. To assess the seismic response of the scaled model, natural records were also applied. Three near-fault vertical accelerograms were selected from the Italian Strong Motion Network (RAN database): L'Aquila 2009 (AQK station), Mirandola 2012 (MRN station) and Centro Italia 2016 (AMT station, near Amatrice).

The SHATTENFEE has investigated the vertical dynamic behaviour, in free-field conditions, of Leighton Buzzard Sand-B to estimate:

1. the fundamental vertical period of vibration (T_v)
2. compression wave velocity (V_p)
3. and vertical amplification.

The dynamic response of the homogeneous soil is studied by analysing and comparing the acceleration time-histories recorded at different levels of the soil column; thus, the amplification function is computed which, in turn, provides the natural frequency of the soil model. When a vertical noise function with an amplitude of 0.05 g was considered, a value of 46.5 Hz was determined for the soil column.

Accurate measurements of V_p were also performed during the experiments, allowing the evaluation of the soil stiffness and frequency variation with the level of excitation (soil nonlinearity in compression). The measurement of the V_p allowed the validation of the theoretical formula for the vertical period Tv ($Tv=4H/V_p$).

Finally, the accelerometric data recorded at the base (along the soil columns) and the soil surface (analysed both in the time and in the frequency domain) revealed that the vertical amplification is significant confirming the results obtained from the predictions of the numerical simulations.

List of Publications

List all publications or openly accessible deliverables relevant to your main results.

Access to Data and Services

Data upload onto Celestina software is ongoing

WP 13-TA 6: Project #36 – SSI-STEEL

Soil-Structures Interaction effects for STEEL structures

T. L. Karavasilis [1], G. Brando [2], A. Pagliaroli [2], S. Bhattacharya [3], A. Benavent-Climent [4], P. Kloukinas [5], G. Camata [2, 6], M. Mariotti [7], M. Dietz [8], D. Karamitros [8], G. Mylonakis [8, 9, 10],

[1] Department of Civil Engineering, University of Patras, Patras, Greece
[2] Department of Engineering and Geology, University G. d'Annunzio of Chieti-Pescara, Pescara, Italy
[3] Department of Civil and Environmental Engineering, University of Surrey, Guildford, UK
[4] Technical University of Madrid, Madrid, Spain
[5] Department of Civil Engineering and Science, University of Greenwich, Chatham, UK
[6] ASDEA Software Start Up Innovativa s.r.l., Pescara, Italy
[7] SARA electronic instruments s.r.l., Perugia, Italy
[8] Department of Civil Engineering, University of Bristol, Bristol, UK
[9] Department of Civil Engineering, Khalifa University, U.A.E.
[10] University of California at Los Angeles (UCLA), U.S.A.

Keywords

Soil-Structure Interaction, Steel Structures, Ductility Demand, Shaking table Tests, Earthquake Engineering

Figure

Figure 1. Dual steel frame (*DSF*) with a new brace-type damper made of a shape memory alloy material.

Main Results

The SSI-STEEL project (Soil-Structures Interaction effects for STEEL structures) deals with an experimental campaign to be carried out, through shaking table tests, on different steel structural

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 730900.

systems to achieve a better knowledge about the SSI effects on their dynamic linear and nonlinear responses. In particular, three structural types are investigated, those are: i) a Concentrically Braced Frame (*CBF*), ii) a Moment Resisting Frame (*MRF*) – also considering the presence of a beam reduced end sections – and iii) dual steel frame (*DSF*) with a new brace-type damper made of a shape memory alloy material.

Few similar experimental studies concerning SSI effects on steel frames are currently present in literature. They are often focused on Single-Degree-of-Freedom (SDOF) systems made of a column with a mass atop or, when more complex structures are considered, only investigate specific aspects influencing the structural response of steel structures, such as the deformation in the elastic field.

On the other hand, there are non-experimental studies that compare the SSI influence on the responses of different steel structural types designed according to the same criteria, as well as that also consider nonlinear phenomena such as buckling and yielding. These are the aspects that the project aims to investigate with the goal to lead the current knowledge to a larger extent and to propose modification factors, to be expressed as a function of the soil-to-structure relative stiffness, to be included in the current design formulations that are of interest for technicians. Therefore, the proposed research represents a significant breakthrough in the field of structural/geotechnics engineering, with evident returns in terms of Code/Provisions updates and meaningful design tools that will be used by engineers in the future.

Currently, the prototypes to be tested have been designed, manufactured and shipped to the University of Bristol (UBRI). Also, the most suitable accelerograms have been selected based on numerical analyses carried out in ABAQUS, FLAC and MIDAS software. Although ten (10) laboratory days have already been provided by the host, the shaking table tests have not been carried out yet, as UBRI and the earthquake lab closed following the escalation of the COVID-19 pandemic in the UK. The pandemic also restricted the visiting researchers who could not travel to Bristol. The tests will be carried out later, after the restrictions are lifted.

List of Publications

The following publications have been scheduled:

- SSI effects on Concentrically Braced Frames by Shaking table tests
- SSI effects on Moment Resisting Frames by Shaking table tests
- Dual Steel Frames with Strain Rate Dependent Dampers under SSI effects
- On the suitability of different Numerical Modelling Approaches of SSI effects in the light of shaking-table tests

Access to Data and Services

Data upload onto Celestina software is ongoing.

WP 14-TA 7: Multilateral cooperation within TA7 at IZIIS

Z. Rakicevic, A. Bogdanovic, R. Apostolska, I. Gjorgjiev, I. Markovski,
D. Filipovski, N. Naumovski, B. Petreski

Keywords

Earthquake engineering, shake table testing, floor-wall-interaction, self-centring system, polyurethanes

Figure

Figure 4. Collaboration, strong relations, sharing experience, and knowledge were the focus points of TA7

Main Results

Transnational access under the scope of the SERA project offered a combined and integrated collaboration between IZIIS and other respectable institutions from six different countries: Slovenia, Ireland, England, Greece, Turkey, and Poland. Directly involved in three different projects were the following user groups:

- Faculty of Civil and Geodetic Engineering, University of Ljubljana, Ljubljana, Slovenia
- Faculty of Civil and Geodetic Engineering, Department of Civil Engineering, University of California, Los Angeles
- Department of Civil Engineering, Democritus University of Thrace, Greece
- Istanbul Technical University, Turkey
- Cracow University of Technology (CUT), Poland
- G. D'Annunzio University of Chieti – Pescara, Italy
- Slovenian National Building and Civil Engineering Institute (ZAG), Ljubljana, Slovenia
- University of Nottingham, University Park Nottingham, UK

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 730900.

- Alma Mater Studiorum-Universita' di Bologna, Italy
- SIKA Poland Cracow, Poland
- KEBE SA, Head Offices-Factory Nea Santa, Kilkis, Greece
- FlexAndRobust Systems Ltd, Cracow, Poland
- National University of Ireland, Galway, Ireland
- Imperial College London, UK
- School of Engineering, Trinity College, Dublin, Ireland

It is important to note that very fruitful and close cooperation was established through exchange of knowledge and experience among the institutions and industrial companies involved in the research projects. Two PhD students from IZIIS worked in partnership for their doctoral thesis using the results from the experimental testing of the models. Outcomes will be publicized through publication in international scientific and engineering journals with an excellent track record by the primary means of ensuring that the project results will reach an audience as wide as possible in a durable way. Additionally, presence at the upcoming conferences is confirmed among the participants.

All these activities will ensure the availability of a key resource for upcoming researchers that can continue the research projects using the available sources as a base in the future work.

List of Publications

- Experimental Testing of a Novel Self-Centring Steel Braced Frame on the Shake Table in DYNLAB-IZIIS, Skopje, Republic of N. Macedonia, 17WCEE, (upcoming).
- Large Scale Shake Table Test of Slab-to-Piers Interaction in RC Coupled Walls, 17WCEE, (upcoming).
- Shake Table Testing of Self-Centring Concentrically Braced Frames, Eurosteel 2020 (upcoming).
- Flexible Joints Between RC Frames and Masonry Infill for Improved Seismic Performances – Experimental Tests on Shake Table, IB2MaC 2020 (upcoming)

Access to Data and Services

All data including results, pictures and other information will be available on Data Access Portal.

WP 15-TA 8: Seismic behaviour of anchored steel sheet-piling (SSP) retaining walls

R. Conti, A. Fusco, S.K. Haigh, S.P.G. Madabhushi, C. Prum, G. Caputo & P. El Boueiz

Figure

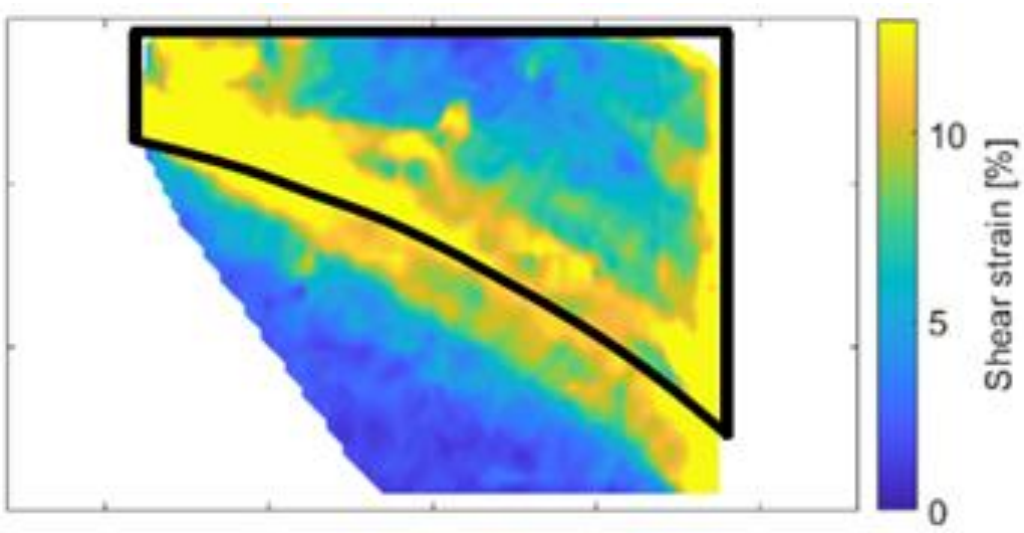


Figure 1. Comparison between predicted and observed failure mechanisms for an anchored retaining wall

Main Results

This project used the Turner Beam Centrifuge and Servo-Hydraulic shaker at the University of Cambridge to investigate the behaviour of anchored sheet pile retaining walls in the sand under earthquake loading. Tests on walls with a variety of geometries were carried out in plane strain conditions, at a centrifugal acceleration of 60 g, preparing the models within a homogeneous dry medium-dense layer (DR = 50 %) of fine-grained siliceous Hostun sand. Both the retaining wall and the anchor plate were modelled using aluminium alloy plates with a bending stiffness at prototype scale similar to that of an AZ28 steel sheet pile profile, while the tiebacks were modelled using four steel cables hinged at both ends. Displacement profiles within the backfill sand were measured using PIV photogrammetry techniques in order to illustrate the failure mechanisms mobilised during dynamic loading.

Table 1 reports, for each test, the critical acceleration and the expected failure mechanism according to the theoretical model proposed by Caputo et al. (2018), adopting two values for the soil peak friction angle, estimated using the empirical formula proposed by Bolton (1979). In the first two tests (AF02 and AF03), a local failure of the anchor system was expected, while a global failure mechanism was predicted for the last two tests (AF04 and AF05).

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 730900.

ID test	a_c [g] ($\varphi = 38°$)	a_c [g] ($\varphi = 39°$)	expected failure mechanism
$AF02$	0.21	0.24	anchor failure
$AF03$	0.12	0.16	anchor failure
$AF04$	0.145	0.165	global failure
$AF05$	0.095	0.11	global failure

Table 1. Estimated critical acceleration and expected failure mechanism for each test

From the analysis of the experimental data, it was possible to compute the evolution, during the applied earthquakes, of the internal forces in the structural members (axial force in the tieback and bending moment distribution in the wall) and the displacements of the anchor plate and the main wall. Moreover, from a preliminary analysis of the experimental results, it was possible to highlight the role played by the critical acceleration on the maximum internal forces and the maximum displacements experienced by the system during the applied earthquake.

Figure 1 shows the contours of shear strains computed during the strongest earthquake applied in test AF05 (earthquake EQ3). The shear strains mainly develop along a failure surface going from the bottom of the anchor wall to the toe of the retaining wall, suggesting a global failure mechanism of the whole anchor-soil-wall system. As shown in Figure 1, this observation is entirely consistent with the theoretical log-spiral failure surface proposed by Caputo et al. (2018).

List of Publications

Fusco, A., Viggiani, G.M.B., Madabhushi, S.P.G., Caputo, G., Conti, R. & Prum, C. (2019) Physical modelling of anchored steel sheet pile walls under seismic actions. Earthqauke Geotechnical Engineering for Protection and Development of Environment and Constructions, Silvestri & Moraci (Eds.). pp. 2502-2509

WP 16-TA 9: Euroseistest / EuroProteas

D. Pitilakis, A. Vratsikidis, A. Anastasiadis

Keywords

Soil-structure interaction, large-scale, field testing, foundation impedance functions, rubber-soil mixtures

Figures

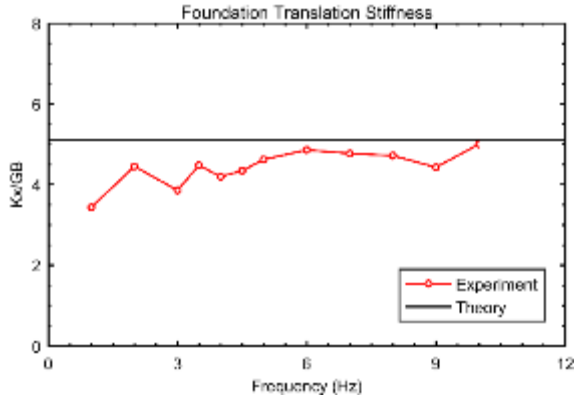


Figure 1. Comparison of experimental and theoretical horizontal foundation impedance function for horizontal translation

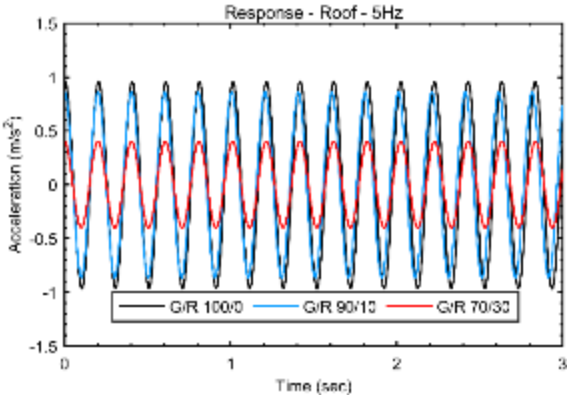


Figure 2. Influence of gravel (G) to rubber (R) per weight ratio mixture configuration in the recorded acceleration response of the roof

Main Results

Different projects were proposed and diverse tests were performed at the EuroProteas structure in Euroseistest: validation of 3D wave propagation models, calculation of foundation impedance functions, definition of design spectra considering soil-foundation-structure interaction, evaluation of 3d complex site effects, evaluation of the impact of structural rocking, foundation rocking isolation methods, investigation of rubber-soil mixtures as innovative isolation material, guidelines for metabarriers of seismic material, and investigation of scour effects.

Figure (a) shows the achieved comparison between the horizontal impedance functions from experimental recordings and from theoretical solutions (Pais & Kausel 1988) for a wide range of frequencies. Matching is satisfactory especially for frequencies between 2Hz and 10Hz.

Figure (b) shows the effect of the implementation of a rubber-soil mixture below the foundation on the recorded response at the roof of EuroProteas. The tested configurations have Gravel-to-Rubber weight ratios equal to 100/0, 90/10 and 70/30. A 50 cm thin layer of gravel-rubber mixture below the foundation with a gravel-to-rubber ration of 70/30 was found to cause a 60 % decrease in the recorded acceleration amplitude at the roof.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 730900.

List of Publications

Pitilakis, D., Vratsikidis, A. (2017). Dynamic system properties from real-scale free-vibration soil-structure interaction experiments. In Proceedings of the 7th International Conference on Advances in Experimental Structural Engineering. Pavia, Italy.

Vratsikidis, A., Pitilakis, D. (2018). Full-Scale Free- And Forced-Vibration Experiments At The EuroProteas SSI Facility: Experimental Data Exploitation. In Proceedings of the 16th European Conference on Earthquake Engineering, Thessaloniki, Greece

Pitilakis, D., Vratsikidis, A. (2018). Damping Calculation from Free-vibration Experiments At The Real-scale Structure Of EuroProteas. In Proceedings of the 16th European Conference on Earthquake Engineering, Thessaloniki, Greece.

Gatti F., Touhami S., Lopez-Caballero F., Pitilakis D. (2018). 3-D physics-based numerical investigation on the earthquake ground motion coherency in heterogeneous soil deposits. In Proceedings of the 9th Conference on Numerical Methods in Geotecnical Engineering, Porto, Portugal.

Vratsikidis A., Pitilakis D. (2019). Soil mass participation in soil-structure interaction by field experiments in EuroProteas. In: Silvestri, Moraci, editors. In Proceedings of the 7th International Conference on Earthquake Geotechnical Engineering, Rome, Italy, p. 681–8.

Palermo, A., Zeighami, F., Vratsikidis, A., Cheng, Z., Pitilakis, D., Marzani, A. (2019). Design of a medium-scale test for the assessment of a resonant seismic barrier within the ReWarD Project. In Proceedings of the 15th International Conference on Dynamical Systems - Theory and Applications, Lotz, Poland.

Access to Data and Services

All recorded data from the tests in EuroProteas and Euroseistest will be made available through the dedicated SERA-TA data portal (www.dap.series.upatras.gr).

WP 17-TA 10: Transnational access to the research infrastructure of NORSAR

J. Schweitzer
NORSAR

Keywords

Seismic arrays, signal processing, near-real time analysis, Earth structure, seismicity

Figure

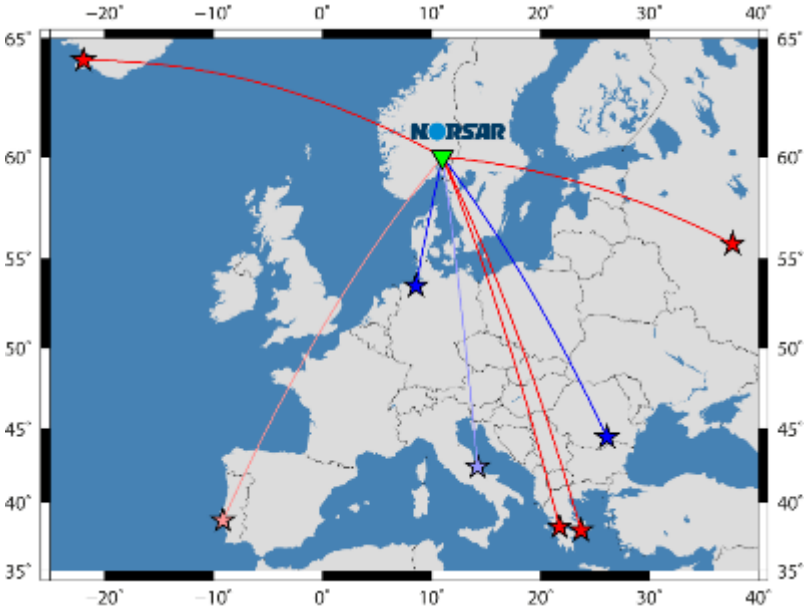


Figure 1. Map of European affiliation locations of TA visitors at NORSAR
(blue: female, red: male; lighter colours: visits in progress or planned for January 2020).

Main Results

Until now, six of planned eight TA projects at NORSAR have been finalized. The six users visiting NORSAR for these projects are all early career scientists either working on their PhDs (3) or with recently finalized PhDs (3). All finalized projects focused on different aspects of array-data analysis. Four visitors came with their own data, observed with different arrays in different environments:

- infrasound array data from the Romanian infrasound station, to be used as classifier to distinguish between earthquakes and explosions (quarries, mines)
- short period data from a temporary small aperture array in Russia, to detect and locate low magnitude seismicity in the Lena trough region, Siberia
- strong motion accelerometer near field observations from an array in Iceland, to investigate the characteristics of mainshock and aftershock sequence of a magnitude 6.3 earthquake in the South Iceland Seismic Zone

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 730900.

- broadband data from a small aperture array-like installation on the Peloponnese in Greece, to search for seismic tremor signals caused by slow motion earthquakes in the Ionian subduction zone
- The two other projects were about:
- the investigation of Moho depth and structure of the mantle transition zone (receiver function method) below southern Norway, with data observed by the large NORSAR array and other permanent and temporary seismic stations in southern Norway.
- testing a theoretically developed blind beamforming algorithm, with data from NORSAR's small aperture array ARCES in northern Norway

During the about one month long stays at NORSAR, all TA users became familiar with different aspects of seismic array-data processing: the influence of array geometry and instrumentation, the resolution of array specific measurements (backazimuth and slowness), different beamforming techniques, the influence of frequency contents on signal processing results, the separation of seismic signals from noise with arrays, and the importance of including the entire wavefield (vertical and horizontal components) in the analysis.

All users continue the analysis at their home institutions after the research visits. Most of the analysis was performed with NORSAR's array processing software package, which the TA users could freely copy for later usage at their home institutions.

(Status December 2019)

List of Publications

Dinescu, R., Ghica, D., Schweitzer, J., Näsholm, S.P., Popa, M., & Ionescu, C. (2019). Monitoring man-made hazards using data recorded with the Romanian seismic and infrasonic arrays. 16th EGU General Assembly, Vienna, Austria, April 2019

Dinescu, R., Ghica, D., Borleanu, F., Popa, M., Rogozea, M., & Chircea, A. (2019). Monitoring regional explosions with Romanian seismo-acoustic arrays. Case study: 09th of October 2018, Ukraine. Balkan Geophysical Society (*BGS*), Albena, Bulgaria September 2019

Goev, A.G. (2019). PhD thesis to be defended 24 December 2019.

Goev, A.G., Kosarev, G.L., Sanina, I.A., Riznichenko, O.Y. (2019). On the stability of modelling a velocity discontinuity with the receiver function method, Proceedings of the 7th Scientific and Technical Conference "Problems of the complex geophysical monitoring of the Far East of Russia", Petropavlovsk-Kamchatsky, 29 Sep – 5 Oct, 2019

Grecu, B., Ghica, D., Borleanu, F., Neagoe, C., & Dinescu, R. (2019). On the Use of Seismo-Acoustic Arrays for Environmental Monitoring in Romania. 27th IUGG General Assembly, Montreal, July 2019

Pikoulis, E.-V., Psarakis, E. & Schweitzer, J. (2018). Joint signal detection and parameter estimation in seismic arrays. 36th General Assembly, ESC, Malta, September 2018

Plötz, A. (2019). Local seismicity in the SW Laptev Sea Rift. AGU Chapman Conference on "Large-scale Volcanism in the Arctic: The Role of the Mantle and Tectonics", Selfoss, Iceland, October 2019

Access to Data and Services

All TA users had free access to NORSAR's database during their visits and these data are openly accessible via the Norwegian EIDA node (http://eida.geo.uib.no/fdsnws/dataselect/1/).

WP 18-VA 1: EMSC felt report webservice

M. Landès, R. Steed, R. Bossu

Keywords

Macroseismology, felt report, felt intensity, web service

Figure

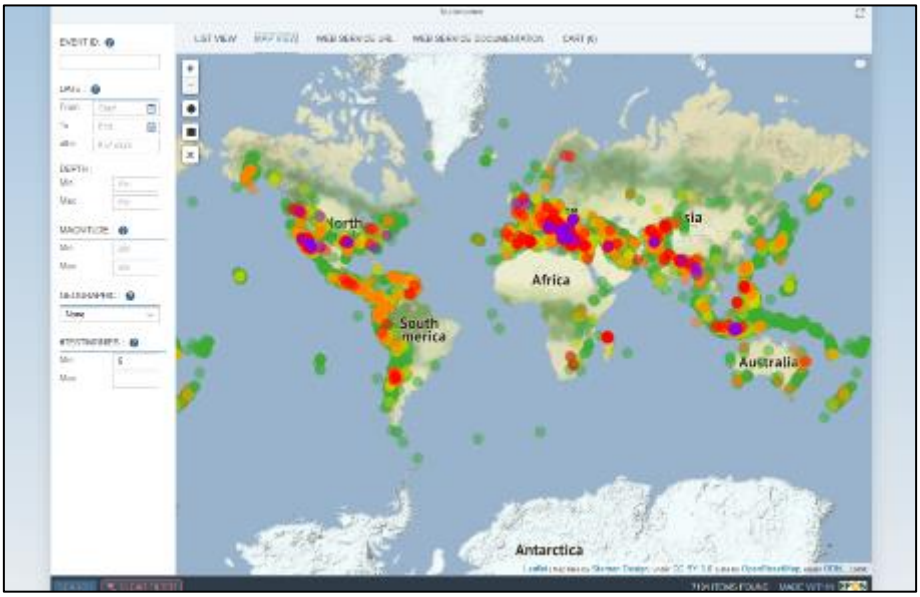


Figure 5. Map view of the felt report service. The left panel allow users to select felt events in time, in space, with magnitudes and by number of collected reports. The map facilitates spatial searches and plots the filtered events.

Main Results

Within the SERA project, the EMSC has developed and maintained a service that provides access to the eyewitness data collected in real time by EMSC.

People who feel an earthquake and want to share their experience have the opportunity to evaluate the level of shaking via EMSC's services by selecting from a collection of thumbnail images (felt reports). Bossu et al. 2016 gives a complete description of this collection system. This approach using cartoons replaces the more traditional online questionnaire on our mobile application LastQuake and on our mobile website (e.g. Bossu, et al., 2015). It is based on 12 thumbnail-sized images conceptualized by a professional cartoonist that aim to depict each level of the EMS-98 macroseismic scale in a culturally neutral way. These thumbnails are available to anyone who wants to integrate them in their collection system offering the chance to homogenize data collection amongst institutes. In addition to the felt intensity, each felt report has an individual geographical location either provided by the mobile device when the user has allowed it to be shared or estimated from a postal address given by the user.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 730900.

Felt reports are collected in real time and associated to seismic events received by the EMSC. Moreover, due to the popularity of the EMSC, felt reports are collected from all continents and, generally, almost 50 % of felt reports are collected only 10 minutes after the earthquake occurrence.

This service provides access to felt report data via a graphical user interface or via a web service (useful for scripting access). However, real time data is not available currently due to quality assurance concerns and a dedicated real-time service is under development for registered users.

The popularity of felt report data is increasing and beginning to interest the scientific community. Several ongoing studies are trying to incorporate felt intensities in the construction of shakemaps and to constraint rupture models. This service is a valuable resource for such endeavours.

List of Publications

Bossu R., Steed R., Mazet-Roux G., Roussel F., Etivant C., Frobert L., Godey S. The key role of eyewitnesses in rapid impact assessment of global earthquakes. (2015) Springer Natural Hazards, S. D'Amico (ed.) Earthquakes and Their Impact of Society 601-617

Thumbnail-Based Questionnaires for the Rapid and Efficient Collection of Macroseismic Data from Global Earthquakes, Rémy Bossu, Matthieu Landès, Fréderic Roussel, Robert Steed, Gilles Mazet-Roux, Stacey S.Martin, and Susan Hough. Seismological Research Letter. Oct 2016. doi: 10.1785/022016012

Access to Data and Services

All EMSC web services are available on the Seismic Portal via the "Web services" link: (https://www.seismicportal.eu/webservices.html). You can also access the felt report service directly at https://www.seismicportal.eu/testimonies-ws/. Some documentation and tutorials can be found on the EMSC github at https://github.com/EMSC-CSEM/webservices101

WP 19-VA 2: Federated infrastructure services for seismic waveform data in Europe

J. Bienkowski, R. Sleeman
KNMI (Royal Netherlands Meteorological Institute) and ORFEUS Data Center

Figure

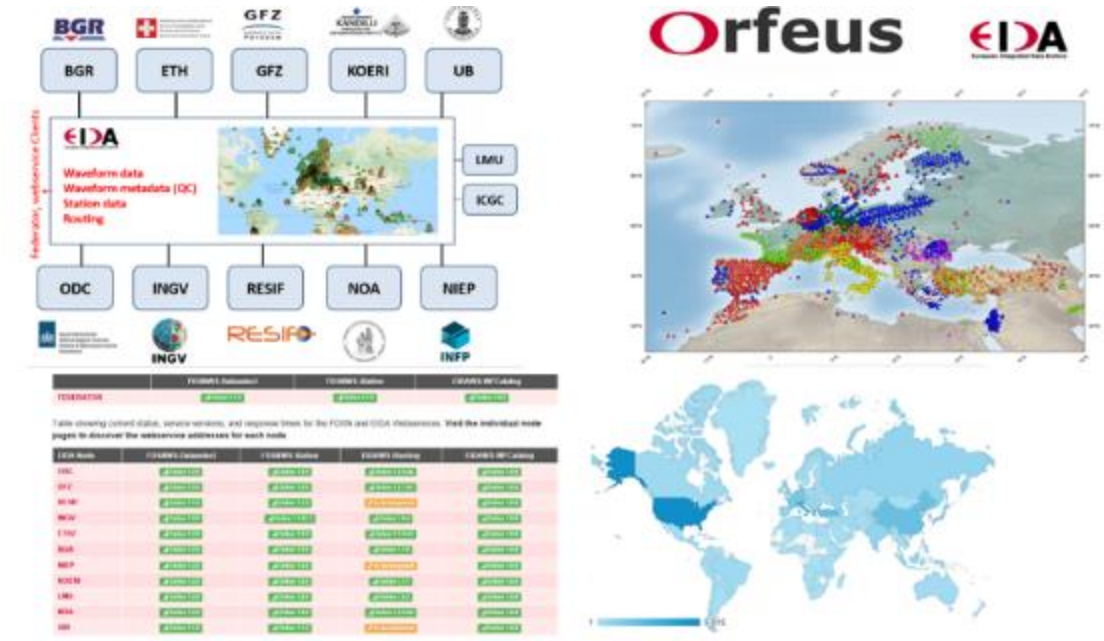


Figure 1. Overview of service provisioning through VA2. *Top-left:* Federation of European Data Archives (EIDA) providing transparent, standardized access to seismological waveform data collected and curated by (currently) 12 large European archives; *Top-right:* snapshot of seismic stations in Europe accessible through EIDA; *Bottom-left*: access to and status of all web services in EIDA, including the recently launched Federator; *Bottom-right*: global impact of services provided by VA2 for ORFEUS EIDA.

Main Results

The ORFEUS infrastructure is one of the biggest infrastructures in the world that provides seismological data. Furthermore, it derives products to the scientific research community in strong collaboration with European seismological observatories. The infrastructure is organized as a networked system of observatory infrastructures, waveform data archives and services. A key component is the federated, distributed European Integrated waveform Data Archive (EIDA) that transparently connects a number of large data centers in Europe, including the ORFEUS Data Center.

This unique, federated archive serves seismological waveform data from permanent and temporary networks of broad-band sensors and strong motion sensors deployed in Europe and beyond through dedicated, standardized webservices. Currently, EIDA holds beyond 400 TB of data of 107 permanent networks and 190 temporary networks, with more than 11'000 seismic stations in total. ORFEUS EIDA is technically compatible with the EPOS infrastructure and therefore ready to accommodate other types of data to serve a broader solid Earth user community (e.g. earthquake engineering).

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 730900.

The following services are offered to the (seismological) research community to provide (virtual) access to raw waveform data and related metadata:

a) ORFEUS website
b) interactive EIDA data portal (GUI)
c) EIDA standardized webservices
d) RRSM (Rapid Raw Strong Motion database)
e) StationBook

WP 20-VA 3: Access to data and services for engineering seismology

An easier way to get hold of strong-motion records, macroseismic data and seismogenic fault data

L. Luzi [(1)], M. Locati [(1)], R. Basili [(2)]

[(1)] Istituto Nazionale di Geofisica e Vulcanologia, Milano, Italy
[(2)] Istituto Nazionale di Geofisica e Vulcanologia, Roma, Italy

Figure

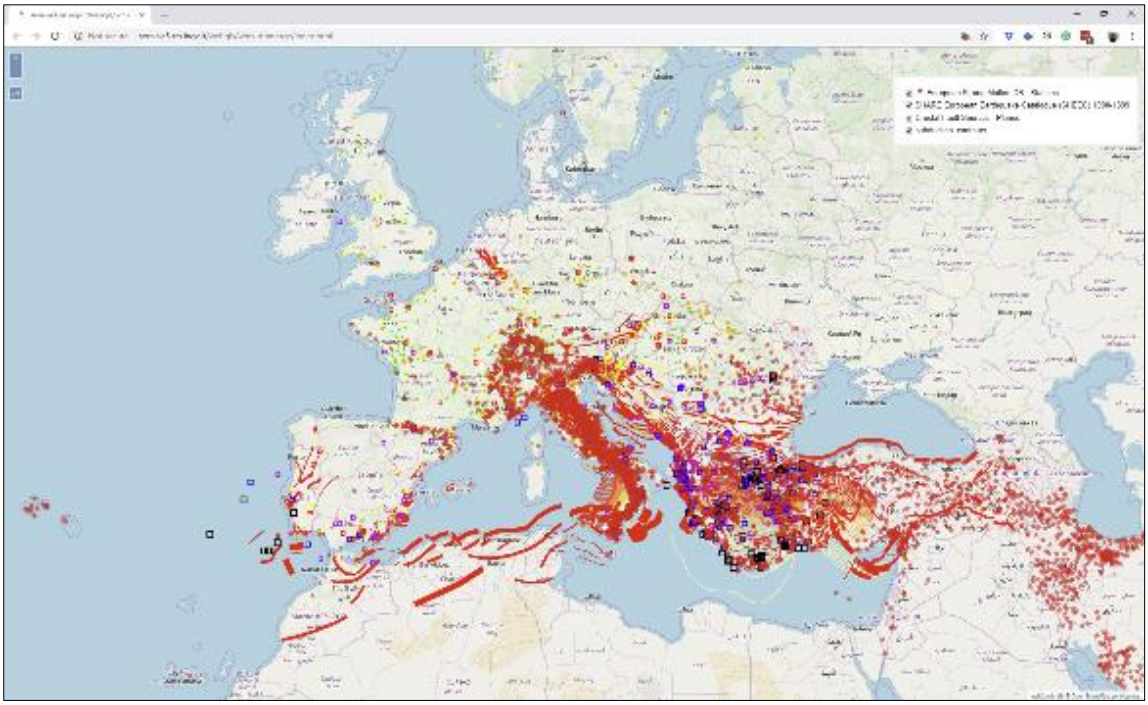


Figure 1. Map view of data provisioning through VA3: recording stations (ESM), historical earthquakes (AHEAD), and seismogenic sources (EDSF).

Main Results

A fundamental task for engineering seismologists is to access the information behind seismic hazard and risk models. In the past decades, the amount of open-access data has dramatically increased due to the advances in information technology and in the development of infrastructures to host data and promote their interoperability. As consequence, there is a significant improvement of dedicated thematic repositories and of tools that facilitate the user to access data and services.

SERA-VA3 aims to bring the data at the users' fingertips. It offers access to reliable and extensive data sets and services for the community of engineering seismologist as well as other specialists. They include the European Strong Motion Database (ESM), the European Archive of Historical Earthquake Data (AHEAD), and the European Database of Seismogenic Faults (EDSF).

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 730900.

A web portal works as a unified access point to data and services. This portal not only guides the visitors to the three original database portals, but it is also meant to provide an enhanced navigation through the data. The three services are technically compatible with the EPOS infrastructure and therefore ready to accommodate other types of data to serve a wider solid Earth user community, for example earthquake engineering.

WP 21-VA 4: The web platform of European Facilities for Earthquake Hazard and Risk

(www.efehr.org)

L. Danciu
ETH Zurich, Switzerland

Keywords

Earthquake hazard, earthquake risk, seismic hazard, seismic risk, European Seismic Hazard Model (ESHM20), European Seismic Risk Model (ESRM20), web-platform, European Facilities of Earthquake Hazard and Risk (EFEHR)

Figure

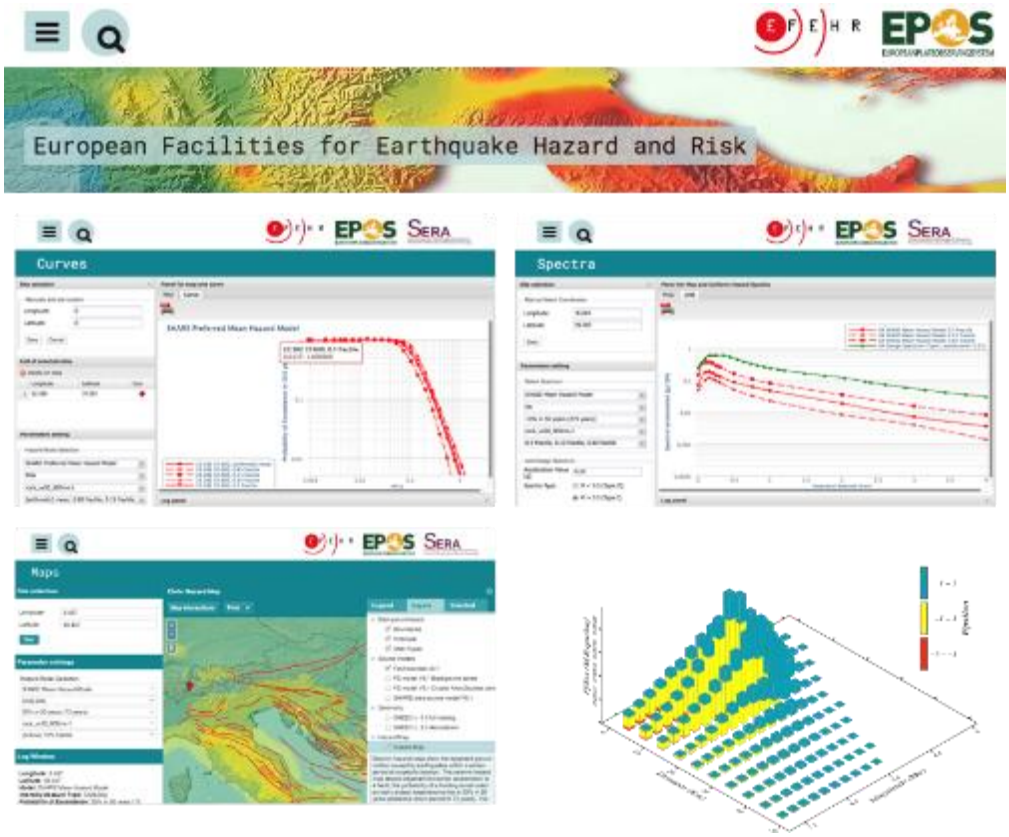


Figure 1. EFEHR web-portal: main web-interfaces to access the hazard curves (top left), uniform hazard spectra (top right), hazard maps (bottom left) and hazard disaggregation (bottom right)

Main Results

The web platform of European Facilities of Eartqhauke Hazard and Risk (EFEHR) provides access to specialized datasets, input models, results, documentation and information. Within SERA VA4 activities, the web-platform has been further developed and upgraded, from web-content to web-viewers (i.e.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 730900.

hazard curves, maps and uniform hazard spectra). The web-services metadata has been upgraded to meet the EPOS-ICS requirements ensuring access in a fully discoverable, searching metadata environment of the EPOS main services. Model Development Tools (MDTs) and components for building and running the hazard models with OpenQuake are also provided. The web-traffic analytics of the EFEHR web-portal indicates a preference for users to access the hazard maps and uniform hazard spectra. The visitors are distributed worldwide. Oftenly, the visitors are consulting the hazard values at a specific site, rather than downloading entire sets of results and/or models. The hazard map viewer is the most used web application. Especially, after a destructive earthquake in the Euro-Mediterranean region occured, e.g. the 2019 M6.4 earthquake in Albania, the traffic of the web application increases shortly after the occurrence of an earthquake. The EFEHR data and models are collected and stored from completed scientific projects for long-term archiving, documentation, accessibility and use in research, support decision making and mitigation actions.

Access to Data and Services

EFEHR web-portal provides a single access point for data, models and results. No user authorization is required. Currently, the EFEHR web-portal provides open access to the following models:

- The 2020 European Hazard and Risk Model developed within the SERA JRA3 and JRA4
- The 2013 European Seismic Hazard Model (ESHM13, Woessner et al 2015)
- The 2014 Earthquake Model of the Middle East (EMME14, Giardini 2018)
- The 2015 Swiss Hazard Model (SuiHaz15, Wiemer et al 2015)
- The 1999 Global Hazard Map of the Global Seismic Hazard Assessment Program (GSHAP, Giardini 1999)

WP 22-VA 5: Virtual access to the data and applications of anthropogenic seismicity and related hazards

M. Sobiesiak, P. Sałek, S. Lasocki

Keywords

Induced seismicity, anthropogenic hazards, comprehensive datasets on anthropogenic seismicity, EPOS Thematic Core Service Anthropogenic Hazards, IS-EPOS Platform

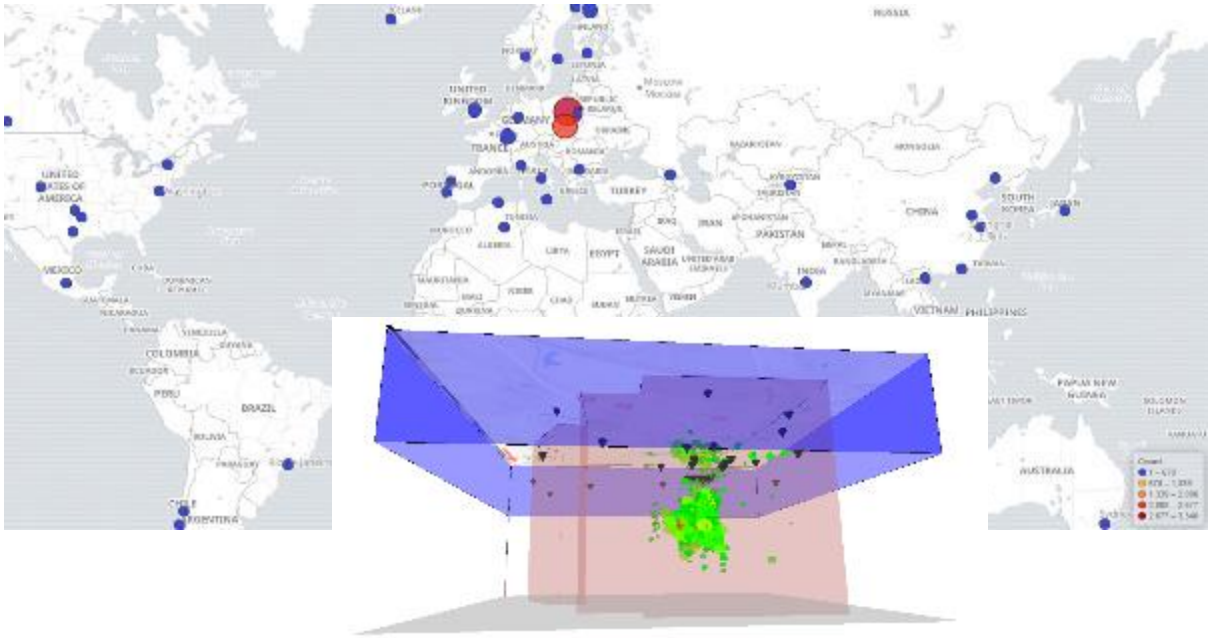


Figure 1. Background: map of global user logins. This map demonstrates the global usage of the IS-EPOS platform that integrates research infrastructure of EPOS TCS AH. Foreground: example of what is possible to do with the platform. Figure shows a 3D sketch of induced seismicity distribution in Bobrek Coal Mine, Poland.

Main Results

Within the framework of Virtual Access (VA5) of WP22 in the SERA project, we are providing 19 new episodes of anthropogenic hazards. In total, 25 episodes from 10 different countries are openly available. These are up to now nine episodes more than originally planned. An episode of anthropogenic seismicity contains seismological catalogues, event based or continuous waveforms of seismic signals, technological data on seismicity inducing industrial activities, geological and tectonic settings, and information on environment. This facilitates research aiming at understanding the interactions between the parameters of the industrial activities and the anthropogenic seismicity. The virtual access gives researchers and other interested or concerned groups in society a chance to gain information on detailed knowledge. The number of registered users of IS-EPOS platform is 1094.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 730900.

Access to Data and Services

Access to the website of IS-EPOS platform is through https://tcs.ah-epos.eu/

List of episodes, available for SERA members and the general public:

Name of episode	Type	Location
Asfordby	underground mining	GB
Bobrek Mine	underground coal mining	PL
Czorsztyn	shallow water reservoir	PL
Cotton Valley	hydrocarbon extraction	USA
Gazli	hydrocarbon field	UZ
Gisos-Cerville	underground solution mining	FR
Groningen Field	hydrocarbon production	NL
Gross Schoenebeck	geothermal energy experiment	GE
Lacq Gas Field	conv. Hydrocarbon extraction	FR
LGCD	underground copper mine	PL
Lubocino	shale gas	PL
Monteynard	water reservoir	FR
Northwich	salt extraction cavities	GB
Oklahoma	hydrocarbon extraction	USA
Preesall Mine	salt extraction cavities	GB
Preese Hall	shale gas	GB
Pyhasalmi Mine	hydrocarbon extraction	SU
Song Tranh	deep water reservoir	VIE
Starfish	underground gas storage	FR
The Geysers	geothermal field	USA
The Geysers Prati 9 and Prati 29 cluster	geothermal field, enhanced catalogue	USA
Thoresby Colliery	underground coal mine	GB
USCB	underground coal mining	PL
Vouglans	water reservoir	FR
Wysin	shale gas	PL

For further details please contact Mr. Piotr Sałek: psalek@igf.edu.pl

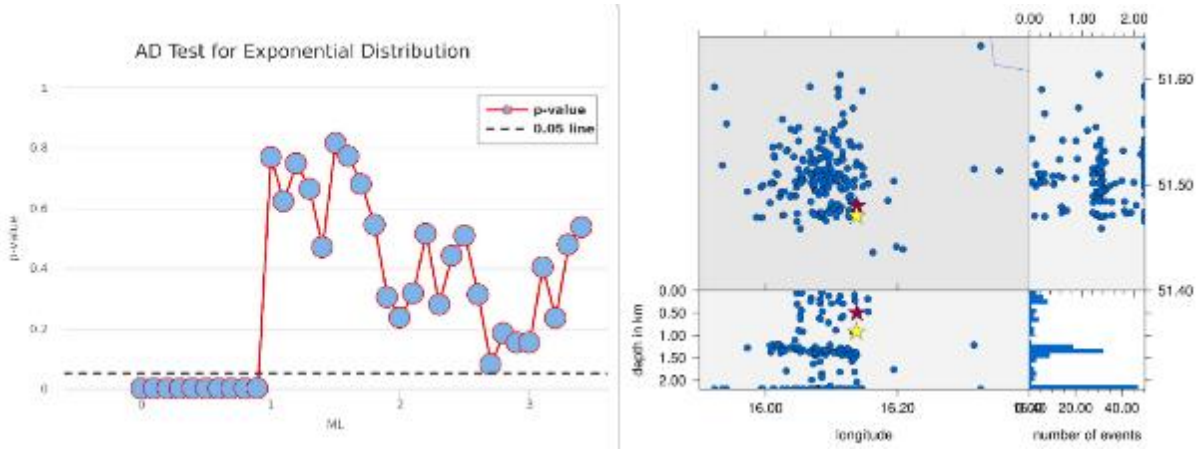
WP 23-JRA 1: Induced seismicity

K. Leptokaropoulos [(1)], M. Sobiesiak [(1)], S. Lasocki [(1)],
N. Poiata [(2)], K. Palgunadi [(2)] , P. Bernard [(2)], C. Satriano [(2)]

[(1)] Institute of Geophysics Polish Academy of Science (IG-PAS)
[(2)] Centre National de la Recherche Scientifique (CNRS)

Keywords
Statistical toolboxes, induced seismicity in mines, enhanced seismic data set, Rudna and Garpenberg mines

Figures



Figures: (*Left frame)* Example from Toolbox 1 (Magnitude Distributions). The graph shows the application of the Anderson-Darling test for magnitude distribution as applied to the data set from Song Tranh 2 water reservoir, Vietnam. (*Right frame)* Blue dots mark the spatial distribution of located events during half an hour after a large mine collapse on 15th of Sept., 2018 in Rudna mine. Stars give the locations of the main (red) and the first aftershock (yellow). The features lined out by the seismicity are the major production level (horizontal alignment), and probably shafts (vertical alignments).

Main Results

IG-PAS contributed to JRA1 with the development and implementation of two Matlab software toolboxes for studying earthquake clustering and magnitude complexity, which are applicable to both natural and anthropogenic seismicity cases. Each software comprises two separate applications, developed in three individual versions: One interactive standalone version (V1), one function-like version (V2) and one online version (V3) integrated within the IS-EPOS platform. All programs together with auxiliary scripts, complete user guide documentation and sample data are freely available via GitHub. In addition to the aforementioned software, an application of the methodology connected with Toolbox 2 was performed and submitted for publication.

A second topic IG-PAS contributes to JRA1 is the investigation of induced seismicity through mining activities in the deep Rudna copper mine, Poland. The mine is known for the occurrence of intermediate magnitude events of up to M4, causing considerable damages and even fatalities. By applying the automated detection and location algorithm of the BackTrackBB software (Poiata et al., 2016), in

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 730900.

collaboration with CNRS, we could demonstrate that we are able to monitor induced seismicity and signals from mining activities with a surface network in a sufficient resolution to line out the major mine features. Several enhanced data sets could be achieved with a much larger amount of located events than in previous routine seismicity catalogues.

CNRS developed and applied a full-waveform-based automatic method for improved detection and location of microseismic events that makes use of continuous seismic records from an in-mine seismic network, and can be adjusted to a near-real-time monitoring scheme. The method consists of two steps:

1. event extraction and amplitude ratio-based preliminary location
2. event relocation by using a coherency-based back projection approach

The event extraction, based on multi-band signal characterization implemented in the first step, allows us to overcome the challenge of high sampling rate data (8 kHz), reducing the volume of transferred data and providing an energy-based signal classification scheme. This approach allows us to remove a significant number of machinery noise sources. The technique is developed and tested with the Institut National de l'Environnement Industriel et des Risques (INERIS) on the case study of the Garpenberg mine (Sweden) monitored by a local seismic network and maintained by INERIS. We demonstrated the improvement in event detection capacity by a factor of 50, compared with the standard triggered-based monitoring schemes. This increased number of detected microseismic events permits us to investigate the migration pattern of induced microseismicity that is generated in response to production blast.

List of Publications

Palgunadi, K.H., Poiata, N., Kinscher, J., Bernard, P., De Santis, F. & Contrucci, I. (2019). Methodology for full waveform near real-time automatic detection and localization of microseismic events using high (8 kHz) sampling rate records in mines; application to the Garpenberg Mine (Sweden), *Seismol. Res. Lett.* 91 (1): 399-414.

Leptokaropoulos, K. (2020). Magnitude distribution complexity and variation at The Geysers geothermal field, submitted to *Geophys. J. Int.*, under revision.

Access to Data and Services

- Access to Statistical Toolboxes (codes, sample data, documentation) can be found at: https://git.plgrid.pl/ projects/EA/repos/sera-applications/browse
- The BackTrackBB full-waveform detection and location software used in the analysis is available from Git-Hub (http://backtrackbb.github.io) on open-source basis

WP24-JRA 2: Analysis of network performance for investigations of earthquake statistics

Toward harmonized local magnitude attenuation function for Europe using massive events datasets

D. Bindi, R. Zaccarelli, A. Strollo, G. Di Giacomo, J. Quinteros and F. Cotton
GFZ German Research Centre for Geosciences

Keywords

Earthquake ground motion, seismic source observations, harmonized magnitude scale, regional attenuation, engineering seismology.

Figures

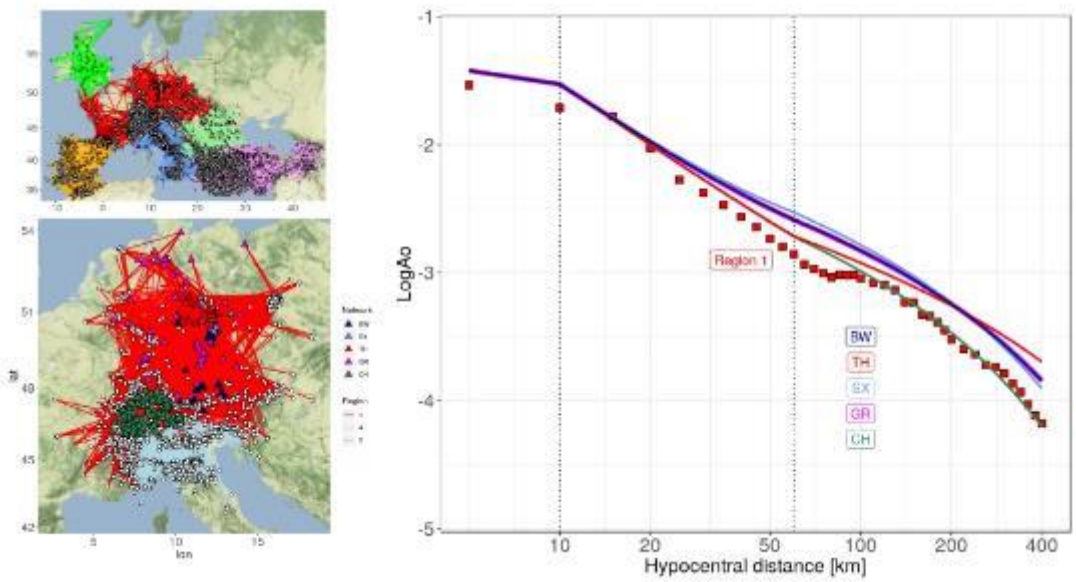


Figure 1. Harmonized local magnitude scale for Europe. *Top left*: source to station ray paths considered to derive the non-parametric attenuation models regionalized into six macro-domains indicated with different colours; points indicate the location of the analysed earthquakes (about 12 thousand). *Bottom left*: example of parametric analysis performed over 5 network, four operating on Germany (network codes TH, GR, SX, BW) and the fifth in Switzerland (network code CH). *Right*: comparison among the parametric magnitude functions obtained for the five considered networks (coloured lines) and the non-parametric model derived for central Europe (region 1, shown with red paths in the left panels). Figure modified from Bindi et al. (2019).

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 730900.

Main Results

In the last two decades, the development of international infrastructures for data sharing (e.g. EIDA- European Integrated Data Archive; IRIS- Incorporated Research Institutions for Seismology) and the standardization of the formats for data archiving and dissemination (FDSN- International Federation of Digital Seismograph Networks) allowed the seismological community to overcome the difficulties in merging data from different networks and countries. In this study, we took advantage of the EIDA to develop the first harmonized local magnitude scale for central and southern Europe, and to quantify regional differences in the attenuation models (Bindi et al., 2019). Using an open-source tool developed to carry out this task and similar (Zaccarelli et al., 2019), we created a local data base including about half million selected waveforms with related metadata, corresponding to about 12'000 earthquakes occurred in Europe in the magnitude range from 2 to 7. The calibration of regional non-parametric attenuation functions highlighted significant regional differences in the rate of attenuation among the six considered macro-areas. Within the macro-areas, crustal heterogeneity affects the propagation of seismic waves differently, for example later arrivals impact the ground motion at different distance ranges.

In order to compare the magnitudes provided by different seismological observatories in Europe, a parametric approach has also been developed considering adjustments to the attenuation coefficients at the level of each single network. Following this approach, more than 70 different parametric magnitude scales were derived following, for the first time in Europe, a harmonized approach without political or infrastructural borders. The possibility to refer to a harmonized magnitude scale makes easier the operation of comparing and merging catalogues provided by different networks. Furthermore, it allows to jointly analyse amplitudes recorded at stations belonging to different networks operating in adjacent regions. The newly derived magnitude scale can be used as reference magnitude scale for applications where local to moment magnitude scale conversions are required for seismic hazard assessment purposes. For this reason, future work will investigate the possibility to compare the magnitudes obtained from the homogenized calibration functions with those reported in the ISC bulletin, as collected from several European networks.

List of Publications

Bindi, D., Zaccarelli, R., Strollo, A., Di Giacomo, G. (2019). Harmonized local magnitude attenuation function for Europe using the European Integrated Data Archive (EIDA), Geophysical Journal International, 218, 1, 519-533. https://doi.org/10.1093/gji/ggz178

Zaccarelli, R., Bindi, D., Strollo, A., Quinteros, J. and Cotton, F., (2019). Stream2segment: an open source tool for downloading, processing and visualizing massive event-based seismic waveform datasets, Seimol. Res. Letters 90 (5): 2028–2038, 10.1785/0220180314

Access to Data and Services

- The software stream2segment is free available at: https://geofon.gfz-potsdam.de/software/stream2segment/
- The attenuation coefficients of the calibrated magnitude models are available at: https://gfzpublic.gfz-potsdam.de/pubman/item/item_4224891
- Only open data have been used to derive the models, available from EIDA https://www.orfeus-eu.org/data/eida/

WP 25-JRA 3: Update of the 2020 European Seismic Hazard Model (ESHM20)

L. Danciu
ETH Zurich, Switzerland

Keywords

Earthquake hazard, seismic hazard assessment, European Seismic Hazard Model (ESHM20), seismogenic sources, ground motion characteristic models, seismic hazard

Main Results

The 2020 European Seismic Hazard Model (ESHM20) provides an updated version of the earthquake hazard assessment of the Euro-Mediterranean region. The model has been developed on the basis of the most recent datasets, which means earthquake catalogues, active faults and ground shaking recordings. In addition, tectonic and geological information as well as models (seismogenic sources, ground shaking) were also used. A full probablistic framework was adopted to develop and implement the seismic hazard model with focus on cross-border harmonization. Furthermore, the ESHM20 development phase involved several regional workshops where the national experts have been consulted and their feedback was acknowledged and considered.

The newly developed seismogenic source model encompasses fully harmonized as well as cross-borders seismogenic sources and is following the recent national earthquake hazard models. The inherent uncertainties in characterizing the earthquake rupture forecast are handled by a complex logic tree, which consists of two main models (branches): an area source-based model and a hybrid fault-smoothed seismicity model. The ground motion characteristic model is built upon the most complete ground shaking recordings in Europe. It aims at capturing the effects of source and attenuation path of the expected ground shaking at a site. The regional variability of ground shaking is assessed based on the most updated dataset of ground motion recordings across Europe. A novel statistical approach was developed to assess the regional ground motion characteristics and the overall uncertainties are handled in a backbone logic tree. Finally, a complex input model, handling the intrinsic epistemic uncertainties of both seismogenic sources and ground shaking models, was used for assessing the earthquake ground shaking across the entire Euro-Mediterranean region. The open-source hazard library of OpenQuake was used, which facilitates the transparency of the models and allows to fully reproduce the results.

A full set of hazard results such as hazard curves and maps as well as uniform hazard spectra is provided for the entire region covered by ESHM20. Note that the results calculated through the ESHM20 represent ground shaking hazard forecasts on EC8 rock site class B with a V_{S30} of 800 m/s. Two additional hazard maps describing the spatial distribution of the engineering spectral factors (i.e. S_{alpha} and S_{beta}) are also provided with a uniform probability of exceedance of 10 % in fifty years. These two factors will form the basis of the future update of the European Seismic Design Code (CEN-EC8) aiming to reduce the potential of human casualties and economic losses from severe ground shakings in a long-term view.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 730900.

Access to Data and Services

All datasets, key components and results are open for access and re-use at the web-platform of European Facilities of Earthquake Hazard and Risk (www.efehr.org).

List of Publications

A special issue describing the efforts undertaken to develop the 2020 European Seismic Hazard Model is planned and its content will be communicated in the next months.

WP 26-JRA 4: European Exposure data for seismic risk modelling

H. Crowley, V. Despotaki, D. Rodrigues, V. Silva, D. Toma-Danila, E. Riga, A. Karatzetzou, S. Fotopoulou, L. Sousa, S. Ozcebe, P. Gamba, & Contributors)

Keywords

Seismic risk, European exposure, buildings, population

Figure

Figure 1. Interactive European Exposure Model

Main Results

One of the main results of JRA4 that has been achieved relates to the development of the European Exposure Model, which provides the geographical distribution of population, replacement cost of buildings, and total number of buildings (residential, commercial, industrial), and their distribution between different construction materials. The data presented in the figure above is within administrative level 0 (country) boundaries, but it has also been developed at a higher resolution that will be released at the end of the SERA project. This version of the model shown above has been integrated within the Global Earthquake Model (GEM) Global Exposure Map (v2018.1) that was used in the Global Seismic Risk Map (v2018.1). The datasets employed to develop this exposure model were publicly provided through national institutions and local experts. The European Exposure Model is intended to be a dynamic product, such that it may be updated when new datasets and models become available.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 730900.

This European Exposure Model has been released through the new European Seismic Risk Service (https://eu-risk.eucentre.it) which is part of the European Facilities for Earthquake Hazard and Risk (EFEHR), a non-profit network of organisations and community resources aimed at advancing earthquake hazard and risk assessment in the European-Mediterranean area. The new risk service of EFEHR has been set up with the main objective of providing interactive access to the seismic risk products that will be developed by the end of the SERA project, which in addition to exposure data and models will include the following:

- European capacity curves, fragility, consequence and vulnerability models.
- European seismic risk results in terms of average annual loss (AAL), probable maximum loss (PML), and risk maps in terms of economic loss and fatalities for specific return periods and indicators of the Sendai Framework for Disaster Risk Reduction.
- Methods and data to test and evaluate the components of seismic risk models.
- Documentation on all of the datasets and models.
- Scientific support on the development of the models and seismic risk computations.

List of Publications

Crowley, H., Rodrigues, D., Silva, V., Despotaki, V., Marins, L., Romão, X., Castro, J.M., Pereira, N., Pomonis, A., Lemoine, A., Roullé, A., Tourlière, B., Weatherill, G., Pitilakis, K., Danciu, L., Correira, A.A., Akkar, S., Hancilar, U., Covi, P. (2019). "The European Seismic Risk model 2020 (ESRM20)," *Proceedings of 2nd International Conference on Natural Hazards and Infrastructure*, ICONHIC 2019

Crowley, H., Despotaki, V., Rodrigues, D., Silva, V., Toma-Danila, D., Riga, E., Karatzetsou, A., Sousa, L., Ozcebe, S., Zugic, Z. & Gamba, P. (2019). "Exposure model for European Seismic Risk Assessment," *Earthquake Spectra*, *accepted for publication*.

Access to Data and Services

You can access the European exposure data through interactive viewers (https://maps.eu-risk.eucentre.it/) or through web services. For example, you can bring the exposure layers shown in the figure above into QGIS by first copying the WMS or WMTS links you find on this page: https://eu-risk.eucentre.it/web-services/. Then, in the Browser of QGIS you should right click the WMS/WMTS option and choose 'New Connection' and copy the URL in the box that pops up (giving it an appropriate name).

SERA
Seismology and Earthquake Engineering
Research Infrastructure Alliance for Europe

WP 27-JRA 5: Advancements in experimental and numerical study of braced steel frames subjected to fire after earthquake

P. Covi [1] [*], N. Tondini [1], M. Korzen [2], M. Lamperti Tornaghi [3], G. Tsionis [3], P. Pegon [3], J. Molina [3], M. Peroni [3], G. Abbiati [4], L. Danciu [5], M. Antonelli [6], B. Gilardi [7]

[1] University of Trento, Department of Civil, Environmental and Mechanical Engineering, Italy
[2] Bundesanstalt für Materialforschung und -prüfung (BAM), Germany
[3] European Commission, Joint Research Centre (JRC), Ispra, Italy
[4] Aarhus University, Department of Engineering, Denmark
[5] Swiss Seismological Service (SED), Switzerland
[6] Etex Building Performance S.p.A., Italy
[7] Xella Italia S.r.l, Italy
[*] corresponding author, email: patrick.covi@unitn.it

Keywords

Fire following earthquake, earthquake engineering, fire engineering, concentrically braced steel frames, large-scale tests, pseudo-dynamic testing, sub-structuring.

Figures

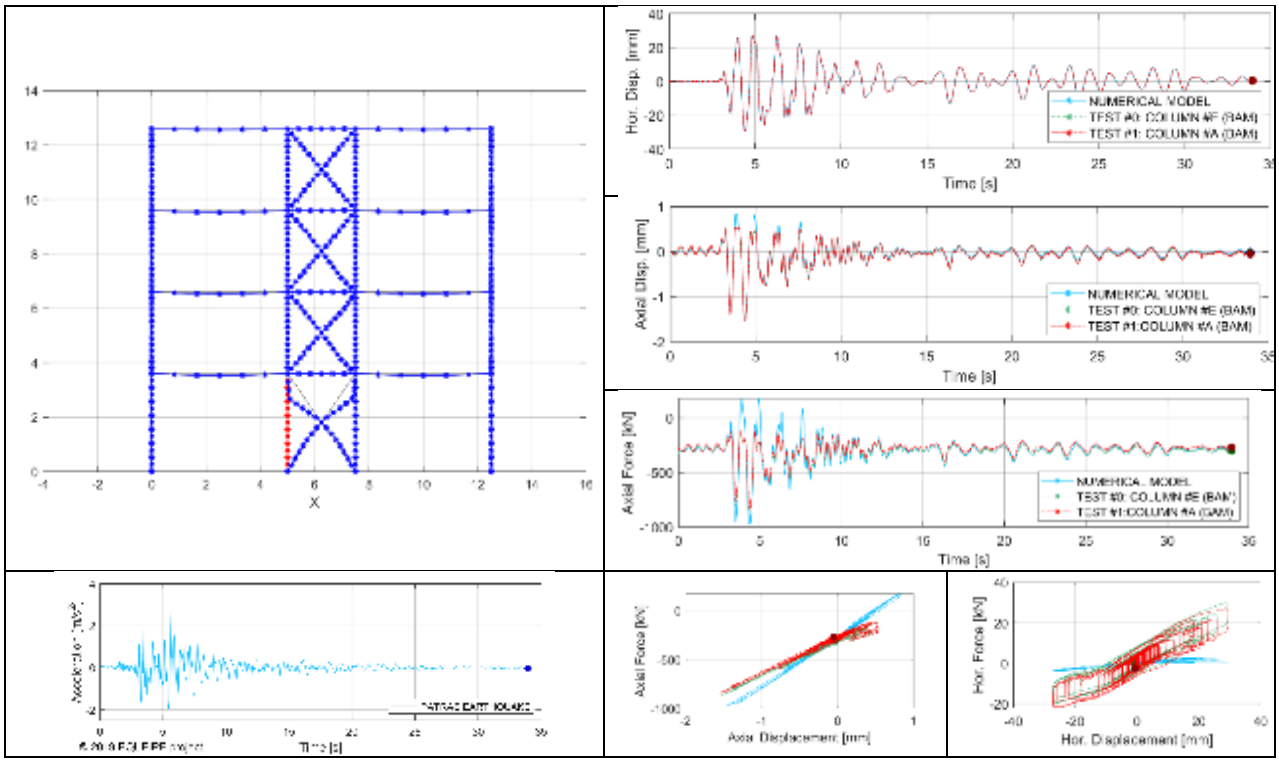


Figure 1a Test #0 and #1. Comparison between results obtained after the seismic hybrid test on column without fire protection and the numerical model before the calibration (Positive axial force is tension and negative axial force is compression).

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 730900.

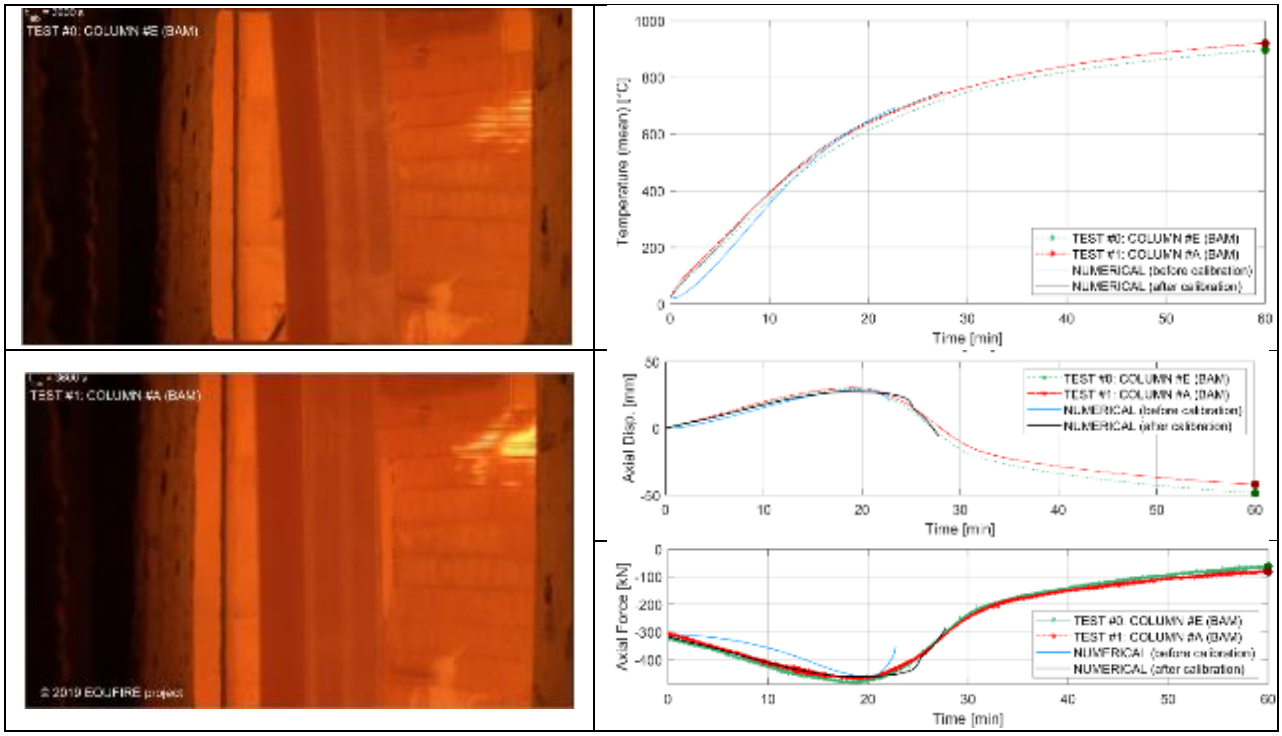


Figure 1b Test #0 and #1. comparison between results obtained from hybrid FFE tests on column without fire protection and the numerical model before and after the calibration. (Positive axial force is tension and negative axial force is compression).

Main Results

The EQUFIRE project aims to study the post-earthquake fire performance of steel frame structures and is part of the Transnational Access activities of the SERA project at the ELSA Reaction Wall of the Joint Research Centre. A four-storey three-bay steel frame with concentric bracing in the central bay illustrated in Fig. 1a was selected as a case study.

The internal column at the ground floor of the braced frame was substructured at the BAM (Federal Institute for Materials Research and Testing / Bundesanstalt für Materialforschung und -prüfung) facilities, while the rest of the structure was numerically simulated. Five fire following an earthquake (FFE) tests were conducted at BAM in October and November 2019:

- Test #0 Column E: “without fire protection system”
- Test #1 Column A: “without fire protection system”
- Test #2 Column B: “fire protection system, PROMATECT-H, seismic installation”
- Test #3 Column C: “fire protection system, PROMATECT-H, normal installation”
- Test #4 Column D: “seismic-resistant sprayed vermiculite-type fire protection”

The mechanical loading of the columns was achieved by six servo-hydraulic control loops representing two rotation degrees of freedom perpendicular to each other for bending at the upper and lower bearing as well as one channel for bottom axial and one for top horizontal loading.

The comparison between the numerical model and the hybrid test demonstrated good agreement between the partitioned solutions under seismic and fire conditions. There is a little difference in negative vertical displacement, due to the fact that tension (negative) axial force was not allowed during the test as illustrated in Fig 1a. That’s because the axial actuator of the furnace is not designed to give tension axial forces to the specimen but only compression axial forces (By way of explanation, the axial actuator of the facility can “push” the specimen but cannot “pull” it).

The test data were used to calibrate the numerical model and they will also serve for the next tests at the ELSA Reaction Wall (JRC). The comparison between experimental and numerical data before and after calibration is presented in Fig. 1b. The calibration process consisted of modelling the base joint based on its actual initial stiffness and of applying the recorded steel temperature evolution in the columns.

Meanwhile, other three FFE tests were carried out with the same specimen proprieties but with different type of fire protections.

The tests with the protected column showed some cracks on the fire protection due to the combination of seismic and fire conditions. However, those cracks are not large enough to compromise fire resistance. In this respect, more damage to the bracing system is expected during the tests at ELSA - JRC. The experimental activities at the ELSA Reaction Wall comprise pseudo-dynamic tests on a full-scale specimen of the first storey of the building, while the upper three storeys will be numerically simulated. The tests will be held at the beginning of 2020.

List of Publications

Abbiati, G., Covi, P., Tondini, N., Bursi, O.S. & Stojadinovic, B. "A Finite Element Tearing and Interconnecting-Based Algorithm for Hybrid Fire Testing" - COUPLED 2019: VIII International Conference on Coupled Problems in Science and Engineering, Sitges (Barcellona), 3-5 June 2019

Abbiati G., Covi, P., Tondini, N., Bursi, O.S & Stojadinović, B. “Real-Time Hybrid Fire Simulation Based on Dynamic Relaxation", Journal of Engineering Mechanics, 2019 (Paper under review)

WP 28-JRA 6: Real-time earthquake shaking

A. Zollo, M. Böse, R. Bossu, C. Cauzzi, T. Dahm,
B. DeLouis, A. Michelini

Keywords

Real-Time Earthquake shaking, Rupture kinematics, shake-maps, qualitative impact assessment

Figure

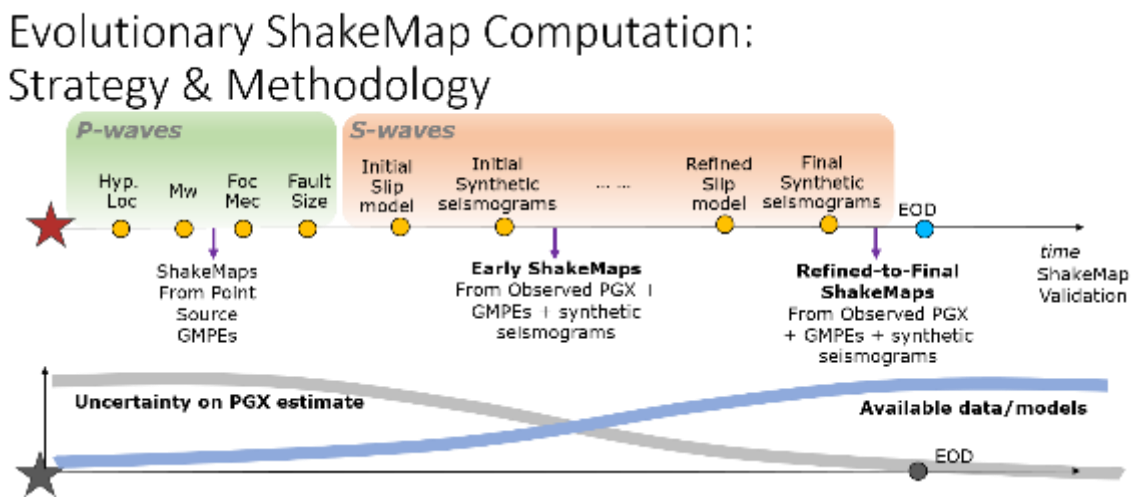


Figure 6. Schematic description WP 28 objectives. (top) At the occurrence of an event, moving on the timeline in the P-waves time window fast estimates of the hypocenter, magnitude and fault geometry are computed. During the recording of the S-wave phase, the closest real PGx estimates become available. The S-waves recording, along with the previous estimates, are hence used to compute refined source models with complementary approaches. Finally, these models are to compute refined synthetic seismograms and the final Shake Maps. (bottom) The definition of a refined source model is expected to reduce the uncertainty on the PGx estimates a few minutes after the end of the event.

Main Results

In the past decade, real-time seismology has moved from providing post-event information within minutes from earthquake occurrence, to issuing event information during or shortly after the rupture.

We compare the performance of four independent algorithms in the calculation of finite-fault models, through their application to the 2016-2017 Central Italy earthquake sequence and a dataset of 19 large global earthquakes. We show that two algorithms (developed at ETH Zurich (ETHZ) and Università degli Studi di Napoli Federico II (UNINA) using near-source accelerometric stations) can provide robust finite-fault models within 10 to 15 seconds from the event occurrence, for earthquake early warning applications. Other two algorithms (developed at GFZ Potsdam and Instituto Nazionale di Geofisica e Vulcanologia (INGV), using regional/global broadband waveforms) can provide more detailed finite-fault models within 10-20 minutes from event origin, for rapid response applications.

The testing attenuation models from earthquakes recorded in Central Italy confirmed the strong frequency dependence of ground motion residuals and variability, and the complementarity of the

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 730900.

magnitude scales considered in the Ground Motion Prediction Equation (GMPE). Since the source parameter stress drop is observed to improve the ground shaking prediction, a procedure is proposed by GFZ for the rapid assessment of the shaking potential which uses the seismic moment and the radiated energy measured over the seismograms. The development of numerical Green function databases was integrated into a python based simulation toolbox, in order to simulate ground motion parameter for different earthquake scenarios rapidly. The feasibility of a European ShakeMap system has been further tested and realized by prototype implementations at ETHZ, INGV and the National Observatory of Athens (NOA).

The Swiss Seismological Service (SED) at ETHZ finalised the upgrade of the Earthquake Early Warning Display (EEWD) to integrate source information from Real-time Finite Fault Rupture Detector (FinDer) and to include ground shaking estimates consistent with the FinDer rapid simplified finite fault representation as a line segment.

We explored two different strategies (SLIPNEAR CNRS and Back-Projection UNINA) for the rapid estimation of the earthquake source models. The final goal is to use these refined, kinematic source models for the computation of synthetic seismograms and shake maps, with the aim of reducing the uncertainties on the ground shaking prediction. The SLIPNEAR and Back-Projection are shown to provide complementary images of the source. These projections allow constraining the main patches of low-frequency slip and the high-frequency asperities (such as the arrest phase) respectively.

To compute evolutionary updated ground shaking prediction, the rapid estimates of the magnitude, location and fault geometry allow updating the point-source shaking prediction by applying Joyner & Boore distance-based GMPEs. Meanwhile, this early geometrical description and, at a later stage, the source inversions is used by UNINA to compute shaking prediction through sets of forward source modelling. The final aim is to integrate over different time scales (from EW to Rapid Response) real data, attenuation law and simulated PGx by using a ShakeMap-based interpolation scheme.

The final main outcome of this WP is the provision of rapid estimates of exposure and qualitative assessments of impact deriving for an earthquake and its strong ground shaking. The partners have developed independently procedures for rapid assessments using very diverse approaches:

- to detect earthquake damage from the lack of crowdsourced data, make very fast location and magnitude estimate of felt earthquakes (EMSC)
- Rapid calculation of exposure qualitative assessment of impact using the tools provided by SesDARO (the near real-time system for estimating the seismic damage in Romania, NIEP) and the ARISTOTLE project (INGV)

Within the framework of SERA, WP 28 has developed various services to ease the access to public databases of main infrastructures potentially affected by relevant ground shaking. We are expecting that those services will provide more complete descriptions of exposure and impact assessment.

Both INGV and the SED have started the migration their institutional ShakeMap systems to the new USGS version 4.0 that features the improved interpolation method described by Worden et al. (2018) and makes use of the ground motion models as implemented in OpenQuake (Pagani et al., 2014). The transition of the European prototype system to v4.0 is planned along with further community building activities.

List of Publications

Böse, M., Smith, D.E., Felizardo, C., Meier, M-A., Heaton, T.H., Clinton J.F. (2018). *FinDer v.2: Improved real-time ground-motion predictions for M2–M9 with seismic finite-source characterization,* Geophysical Journal International, 10.1093/gji/ggx430.

Bossu, R. & Steed, R. & Roussel, F. & Landès, M., Fuenzalida, A., Matrullo, E., Dupont, A., Roch, J. & Fallou, L. (2018). *App Earthquake Detection and Automatic Mapping of Felt Area 1*. Seismological Research Letters, 90. 10.1785/0220180185.

Colombelli, S., Carotenuto, F., Elia, L., & Zollo, A. Design and implementation of a mobile device app for network-based earthquake early warning systems (EEWSs): application to the PRESTo EEWS in southern Italy. Nat. Hazards Earth Syst. Sci., 20, 921–931, 2020, https://doi.org/10.5194/nhess-20-921-2020.

Festa, G., Picozzi, M., Caruso, A., Colombelli, S., Cattaneo, M., Chiaraluce, L., Elia, L., Martino, C., Marzorati, Supino, M. & Zollo, A. (2018). *Performance of Earthquake Early Warning Systems during the 2016-2017 Mw 5-6.5 Central Italy Sequence* Seismological Research Letters, 10.1785/0220170150.

Nazeri, S., Colombelli, S. & Zollo, A. (2019). *Fast and accurate determination of earthquake moment, rupture length and stress release for the 2016-2017 Central Italy seismic sequence,* Geophysical Journal International, https://doi.org/10.1093/gji/ggz097.

Picozzi, M., Bindi, D., Spallarossa, D., Di Giacomo, D. & Zollo, A. (2018). *A rapid response magnitude scale for timely assessment of the high frequency seismic radiation*, Scienitfic Reports, 10.1038/s41598-018-26938-9.

Robert, J., Steed, R., Fuenzalida, A., Bossu, R., Bondár, I., Heinloo, A., Dupont, A., Saul, J. & Strollo, A. (2019). *Crowdsourcing triggers rapid, reliable earthquake locations*, Science Advances, 10.1126/sciadv.aau9824.

Scala, A., Festa, G.& Del Gaudio, S. (2018). *Relation Between Near-Fault Ground Motion Impulsive Signals and Source Parameters,* Journal of Geophysical Research - Solid Earth 10.1029/2018JB015635.

Spallarossa, D., Kotha Sreeram, R., Picozzi, M., Barani, S. & Bindi, D. (2018). *On-site Earthquake Early Warning: a partially non-ergodic perspective from the site effects point of view*, Geophysical Journal International, 10.1093/gji/ggy470.

Subach G. (2018). *Study of the uncertainties associated to the Building Damage Prediction equation,* Master Thesis, University Grenoble Alpes.

Scala, A., Festa, G., Vilotte, J-P., Lorito, S. & Romano, F. (2019). Wave Interaction of Reverse-Fault Rupture With Free Surface: Numerical Analysis of the Dynamic Effects and Fault Opening Induced by Symmetry Breaking, Journal of Geophysical Research: Solid Earth, 10.1029/2018JB016512

Tarantino, S., Colombelli, S., Emolo, A. & Zollo, A. (2019). Quick determination of the earthquake focal mechanism from the azimuthal variation of the initial P-wave amplitude, Seismological Research Letters, 10.1785/0220180290.