SERA
Seismology and Earthquake Engineering
Research Infrastructure Alliance for Europe

DELIVERABLE

D1.6 Final report of the Scientific Advisory Board

Work package	WP1 (ETH)
Lead	ETH
Authors	SERA Scientific Advisory Board: Prof. E. Rathje, Prof. M. Dolce, Prof. P. Bisch
Reviewers	N/A
Approval	N/A
Status	Final
Dissemination level	Public
Delivery deadline	30.04.2020
Submission date	14.05.2020
Intranet path	DOCUMENTS/DELIVERABLES/SERA_D1.6_Final_report_SAB.pdf

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

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Summary

The Scientific Advisory Board (SAB) for the Seismology and Earthquake Engineering Research Infrastructure Alliance for Europe (SERA) consists of Prof. Philippe Bisch from École de Ponts, Paris Tech, Paris, France, Prof. Mauro Dolce from the Department of Civil Protection in Rome, Italy, and Prof. Ellen Rathje from the University of Texas in Austin, Texas USA. The SAB attended the 1st SERA Annual Meeting held in Bucharest, Romania on April 25 and 26, 2018, one of the SAB members (P. Bisch) attended remotely the 2nd SERA Meeting held in Edinburgh on May 15 and 16, while two SAB members (P. Bisch and M. Dolce) attended the final meeting, held in videoconference due to the COVID-19 lockdown, on April 23 and 24, 2020. The SAB reviewed the documents provided by the SERA Management Office at ETH Zurich, including the presentations and the deliverables.

In general, the SAB is impressed by the breadth of activities encompassed by the ambitious SERA project and has appreciated the successful conclusion of the project, although some few activities still need some further work for their total completion, even because of the COVID-19 pandemic emergency.

1 Joint Research Activities (JRA)

The Joint Research Activities (JRA) consist of the following work packages (WP):

- JRA-1: Physics of the earthquake initiation
- JRA-2: Characterizing the activity rates of induced and natural earthquakes
- JRA-3: Updating and extending the European Seismic Hazard Model
- JRA-4: Risk modelling framework for Europe
- JRA-5: Innovative testing methodologies for component/system resilience
- JRA-6: Real-time earthquake shaking

The JRA work packages are interdisciplinary and incorporate everything from basic earthquake science to earthquake engineering to social science.

JRA1 has improved the resolution and understanding of fault slip process and earthquake initiation, working on test beds for natural and induced seismicity, developing and testing new methodologies and automated tools, characterizing cross-coupling between seismic and aseismic deformation, considering the role of fluids and of slow slip transients and improving statistical predictive models. JRA2 mainly worked on the harmonization of magnitudes (Mw, ML) in Europe and the development of scales, on new methods to analyse catalogues, on aftershock's definitions and declustering methods used in PSHA analysis and on networks capabilities at various scales. The final product of JRA3 is a new European Seismic Hazard reference model (ESHM20), as an update and extension of the 2013 European Seismic Hazard Model (ESHM13), fully harmonised across national borders, as well as fully transparent and available through the EFEHR platform (VA4). A beta version of some of the hazard maps have been presented at the final meeting, as the final hazard model will be available by summer 2020. JRA4 pursued one of the key objective of SERA, i.e. a new European Seismic Risk Model (ESRM20), including physical and socioeconomic factors, based on ESHM20, and considering a new soil amplification model and updated exposure and vulnerability databases. Only intermediate results and tests were presented at the final meeting, as the completion of JRA4 will follow JRA3 final results. JRA5 has explored several different earthquake engineering topics, from the potential for city-laboratory based multi-hazard research, to experimental testing by HDS and shaking tables, and to resonant metamaterial-based earthquake risk mitigation of large-scale structures and infrastructure systems for power industry. Finally JRA6 has improved the capabilities for early warning and rapid response by setting methods to improve the assessment of earthquake location, seismic moment, mechanism and fault size, ground shaking over a large range of spatial and temporal scales, evolutionary rupture kinematics, Peak Ground Motion shaking and a qualitative impact based on continuously updated web services.

The results obtained are all valuable for each single topic dealt with, and provide significant steps ahead considered by themselves. Perhaps a greater effort could have been made to strengthen the interactions and connections between some WPs. On the other hand, their development fostered cooperation among different scientific communities and the full sharing of methods and results.

A strong key objective of **JRA-3** was to provide hazard maps compatible with the definition of seismic design action in Eurocode 8, accepted by all members of CEN/TC250/SC8. It is an extension of the corresponding activity of the SHARE project. It was one of the concerns of the Commission, which is simultaneously funding the SERA project and the development of Eurocode 8. The consideration of hazard maps in the code, based on research results, was a request addressed to both organizations. The participants in JRA3 have incorporated the new definition of response spectra possibly introduced in the version of Eurocode 8 under development, which would allow European construction stakeholders to benefit from maps compatible with these definitions. The harmonization with the national seismic hazard models, where existing, is a delicate question that needs to be addressed very carefully, as is the compatibility at the borders.

As above said, the SAB could not see the final results of JRA3 and JRA4, including risk maps of the European Seismic Hazard Model ESHM20 and the European Seismic Risk Model ESRM20. In general terms, it must be highlighted how uncertainty is crucial in the treatment of the two topics. Particularly for ESRM20, the uncertainties associated to the assessment of exposure and vulnerability, with different approaches according to the availability of more or less detailed data, and the consideration of proxies for site amplification, according to the scale of the geological maps used in their quantification, need special attention. These uncertainties are added to the not negligible ones associated with the ESHM20 model, which provides the hazard component of ERSM20.

2 Transnational Access (TA)

A large number of research infrastructures, exactly ten, have been involved in the Transnational Access (TA) program. They are characterised by a wide variety of facilities, with the capability to deal with different important aspects of earthquake structural and geotechnical engineering. In particular, access to five shaking tables, two reaction wall systems, one bearing tester, one geotechnical centrifuge, an done very well-characterised and monitored test site are available. Moreover, one seismological array is offered for seismological studies.

The criteria used for the selection of the proposals appear well sounded, as they are mainly related to their scientific value, importance and competitiveness, transnational interest and synergies.

Focusing on earthquake structural engineering projects, the TA research program included tests on different “objects” at different scales. Reinforced concrete, masonry, or steel structures/structural parts tested at full or reduced scale have been studied. Special structural devices, mainly seismic isolation or energy dissipation devices have also been considered, to assess their specific behaviour under seismic actions or to study the response of structures or other objects (e.g. statues, silos) seismically protected by them. Soil-structure interaction tests for different types of soils and structures (e.g. tunnels, retaining walls) have also been carried out. Different testing techniques have been used, based on facility availability, the type of tested “objects”, and the aim of the research.

The TA research portfolio has a very wide range of objects, activities and scopes, with a huge involvement of researchers and research institutions. This has produced important scientific exchanges in the European scientific community, besides useful and interesting improvements in understanding the seismic behaviour of a very large number of case studies.

It is very satisfying to note that the projects thus supported have clearly displayed practical results, since most of them mention Eurocode 8 as one of the main stakeholders. It is clear that some projects may influence the ongoing development of the code in the short term. Beyond the development of Eurocode 8, they are of interest for earthquake engineering in general, for example for the assessment and retrofitting of existing structures, especially in historic centres. They can be classified into four categories:

Those with short-term impact, for example:

- (TA1) Testing of a full-scale two-storey flat slab structure, while a chapter on this type of structure is introduced in the code.
- (TA2) Full-scale steel silo filled with wheat.

Some projects are part of a development of techniques that can impact the code in its longer-term development, for example:

- (TA6) Integral Abutment Bridges (integral bridges are being developed in Eurocode 8).
- (TA3) Experimental validation of steel moment frame with EU qualified joints and energy efficient claddings.

Other projects have an obvious societal interest, even if they are not directly linked to the development of construction rules, for example:

- (TA3) Seismic response of museum artefacts.
- (TA4) Monumental masonry cross vaults (assessment of heritage buildings).
- (TA4) Masonry building aggregates in historical city centres.

Some projects have been interested in testing new construction or retrofitting methods, for example:

- (TA2) Variable friction seismic isolation devices.
- (TA4) Tests of a two-storey 1: 2 scaled fully prefabricated dry-assembled building.
- (TA6) Ductile steel fuses for the protection of critical non-structural components.

These are just a few examples here. It is important that a research project like SERA can lead to practical results that improve the safety of European citizens and the economy of the projects.

Access to the facilities offered to researchers is a very effective means of targeting projects that interest the entire community. SERA selects the projects, the centres owning the facilities participate in setting up the experiments and in their interpretation. This makes it possible to involve a large population of European researchers who bring their projects and thus to deal with problems which arise in different regions of the continent.

Two recommendations were given by the SAB to add value to the enormous scientific experimental work by the TA project. To respond to one of them, possible stakeholders for each experimental project have been specified. This also provides indications on the main purposes for which each experiment had been conceived and was carried out. On the contrary, there has apparently been no attempt to coordinate and harmonize the choice of the seismic inputs for the various tests, which would have been useful to make comparison of the seismic behaviour of different structures tested in different projects.

3 Networking Activities (NA) and Virtual Access (VA)

The Scientific Advisory Board was impressed by the breadth of topics covered by the Networking Activities (NA) and Virtual Access (VA) activities and wants to emphasize the importance of these projects for science developments and advances far into the future. These efforts have the potential to leave a lasting legacy towards supporting research that leads to a better understanding of seismic issues across Europe.

The **Networking Activities (NA)** are geared to improve the availability and access to data, with a focus on integrating datasets into the framework of the European Plate Observatory System (EPOS). The five NA components involve:

- NA-1: Outreach programs for schools
- NA-2: Expanding access to European seismic monitoring data
- NA-3: Integrating deep seismic sounding (DSS) data into the EPOS framework
- NA-4: Maintenance, operation, and expansion of the SERIES experimental database and integration into the EPOS framework
- NA-5: Developing standards for the site characterization of strong-motion and seismic stations.

Generally, the NA projects have made progress towards their goal of improving access to various data products from across Europe. Activities were focused on backend infrastructure or metadata schema that facilitate integration of these datasets, as well as user-facing functionalities that facilitate use of the data.

NA-1 successfully organized school outreach programs across Europe. NA-2 expanded the earthquake waveform data available in the European Integrated Data Archive (EIDA) and EIDA can be accessed through EPOS. NA-3 engaged the DSS community to identify available datasets and discuss open access to these data. NA-4 added some enhanced capabilities of the SERIES virtual database. NA-5 developed an XML standard to describe the site conditions at seismic stations and it is planned to make this standard part of the station metadata available through EIDA/ORPHEUS.

Despite the activities described above, for some of the NA projects the progress is limited and the connections with EPOS appear tenuous. Specifically, neither DSS data (NA-2) nor SERIES experimental data (NA-4) are available through EPOS. Although "roadmaps" may have been developed towards that goal, there has been no progress towards implementation. Additionally, it is not clear that any data from any of the SERA TA experiments are (or will be) made available through the SERIES database (currently, only 5 datasets are publicly accessible). It is unfortunate that these projects ended without any progress towards improved access to DSS and SERIES data.

The **Virtual Access (VA)** activities provide online access to the main European data and products from seismology and engineering seismology. Specifically, these activities include:

- VA-1: Access to earthquake catalogue products operated by EMSC
- VA-2: Access to seismic waveform data operated by ORFEUS/KNMI
- VA-3: Access to the European Strong Motion database, the European Archive of Historical Earthquake Data, and the European Database of Seismogenic Faults operated by INGV
- VA-4: Access to earthquake hazard and risk tools and products operated by EFHER/ETHZ
- VA-5: Access to data and products of anthropogenic seismicity by IGPAS

The VA projects have been very successful in reaching their goals. Each project has enhanced their online interfaces and can report impressive usage statistics. Importantly, each project engaged a technical domain expert to provide an external assessment of the project progress, available web services, and generated data products. These external evaluations provided each project with important feedback throughout the project, which helped keep each project on track. Unfortunately, VA-4 did not implement the SAB recommendation of providing disaggregation information with their hazard data.

4 Conclusions

The several complex aspects that characterize seismological and earthquake engineering studies have been well represented in the very ambitious and wide spectrum SERA project. The enormous work done and the practical results achieved once again emphasize the strong need for further studies in order to reduce the large epistemic uncertainties still present in the seismic hazard and risk forecasting capabilities.

SERA incorporated a significant component dedicated to seismic hazard and risk analysis. This development is an improvement over previous projects. This effort should be extended in the future, in particular by developing the following aspects:

- Continue to develop fragility curves specific to existing structures in the European regions concerned. This is very important for a realistic risk assessment.
- Analyse more in depth the historic seismicity, in particular to assess the importance of the site effects.
- As risk mitigation is part of the economies of states and regions, economists should be associated with it, the search for a social optimum in terms of risks depending on what a community is capable of implementing.

Such developments, which would probably require a slightly different organization from that of SERA, with new participants, would help to put in place public policies to, on the one hand, mitigate the risk linked to existing infrastructure, and on the other hand, deploy adapted regulations for the imposition of standards on new constructions.

A big effort has been made to improve the knowledge in seismology and earthquake engineering topics, through different theoretical and experimental approaches. In practical terms related to disaster risk reduction, particularly important are the set up of new models for seismic hazard and seismic risk in Europe, this latter including also social vulnerability aspects. The final products will be available in few months. Large uncertainties, however, are envisaged due to the still limited knowledge on the earthquake forecasting and on asset exposure and their seismic vulnerability. Moreover, socio-economic aspects deserves further and more in-depth consideration in the future. In the dissemination of these results, the resolution and precision of the risk model should be clearly stated in order to prevent misuses. The scale of representation of the results (e.g. national and subnational, but not sub-urban) shall be consistent with the uncertainty levels.

Support for access to infrastructures is fundamental, since it allows research teams who would not have the financial means to do so to have access to significant experimental means and to carry out their projects. SERA has shown that this is very effective and allows research teams from all over Europe to carry out projects of very different sizes and nature, fostering significant progress, often in the short term. This type of support is fundamental for the development of experimental research in Europe in the field of earthquake engineering and should be extended in the long term.

Access to seismology and earthquake engineering data is critical for the continued advancement in seismic research. In particular, requiring experimental data to be published in open data repositories substantially expands the research investment because these data are available to the full research community for many years to come. It is recommended to fully support the long-term publication and preservation of seismology and earthquake engineering data, and to actively engage researchers in these efforts.

Finally, the SAB strongly recommends that further coordinated research in seismology and earthquake engineering be promoted by the European Commission, in order to improve basic knowledge, foster data sharing, reduce epistemic uncertainties in assessment and estimations.

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