



EUROPEAN ASSOCIATION FOR EARTHQUAKE ENGINEERING

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WG 13: Seismic assessment, design and resilience of industrial facilities

The tremendous impact of natural hazards, such as earthquakes, tsunamis, flooding which triggered technological accidents, referred to as natural-technological (NaTech) events, was demonstrated, for instance by the recent Tohoku earthquake and the following Fukushima disaster in 2011 or by the UK's 2015 winter floods. The NaTech problem is quite relevant as up to 10% of industrial accidents, involving the release of Chemical, Biological, Radiological, Nuclear and high yield Explosives (CBRNE) substances, were triggered by natural hazards. Earthquakes occupy a leading position in the list of natural hazards with NaTech potential, leading to serious damages of the process equipment and multiple and simultaneous releases of hazardous substances in industrial facilities. Adequate prevention, preparedness and response are specifically needed to prevent damages, mitigate their consequences and to improve the resilience of industrial facilities and communities to NaTech hazards.

The proposed Working Group intends to offer the scientific and professional community with a clear overview of the problems and the available solutions and tools. With experts in the fields of seismology, earthquake engineering, resilience and Na-tech risks, this WG will be a good occasion to familiarize with this important topic and be in contact with the resilience and risk calculation community that is working on industrial plants and consequences to seismic events. The outcome of the WG provides a contribution to the development of seismic codes, including seismic design and innovative protection systems of major-hazard industrial plant components, and supports the implementation of the Seveso III Directive 2012/18/EU which regulates the control of major accident hazards involving dangerous substances under seismic events. Furthermore, the WG aims to bring together researchers, professional engineers and decision makers of authorities in order to discuss the challenges of existing industrial facilities and to compile technical documents. The work of the WG is limited to non-nuclear industrial facilities. However, existing guidelines and concepts already successfully implemented in the nuclear power plant industry will be considered.



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WORKING GROUP TEAM

Coordinator: Dr. Fabrizio Paolacci, PhD, Associate Professor at the Roma Tre University, Chair of the Seismic Engineering Technical Committee of the ASME PVP division

Co-Coordinator: Prof. Dr.-Ing. Christoph Butenweg, Professor FH Aachen University of Applied Sciences, Chairman of the Center for Wind and Earthquake Engineering, RWTH Aachen University

Name	Symbol	WG Members
ROMA TRE UNIVERSITY		Fabrizio Paolacci Antonio Caputo Research Fellows: Daniele Corritore, Silvia Alessandri
UNIVERSITY OF AACHEN		Christoph Butenweg Benno Hoffmeister
UNIVERSITY OF TRENTO		Oreste Bursi Nicola Tondini
ARISTOTLE UNIVERSITY OF THESSALONIKI		Kyriazis Pitilakis Sotiris Argyroudis
NATIONAL TECHNICAL UNIVERSITY OF ATHENS		Michalis Fragiadakis Dimitrios Vamvatsikos
UNIVERSITY OF LJUBLJANA		Matjaz Dolsek
BOGAZICI UNIVERSITY - KOERI		Eren Uckan
UNIVERSITY OF BELGRADE		Marko Marinković
GEZBE UNIVERSITY		Bulent Akbas
UNIVERSITY OF BRISTOL		Anastasios Sextos
SDA-ENGINEERING GMBH		Britta Holtschoppen
SEISMOLOGICAL RESEARCH CENTRE OF THE OGS ISTITUTO NAZIONALE DI OCEANOGRAFIA E DI GEOFISICA SPERIMENTALE, SGONICO		Stefano Parolai
GFZ GERMAN RESEARCH CENTRE FOR GEOSCIENCES		Fabrice Cotton
Expert Geotechnics		Inquired
Expert Plant engineering		Inquired



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Research Topics

- Performance-based design of industrial facilities.
- Seismic design procedures for special structures and components considering interactions between the primary structural systems and components (pipes, vessels, pumps, tanks, ...).
- Seismic assessment and mitigation strategies for resilience enhancement of critical components in industrial installations, focusing on seismic hazard, vulnerability and damage analysis, loss of containment and hazard material release, consequence analysis.
- Design of critical non-structural components.
- Seismic safety evaluation, uncertainties and reliability analysis of facilities and subsystems.
- Fragility curves and probabilistic risk assessment of multi-component systems.
- Application of innovative passive and active seismic protection systems for facilities and their installations (e.g. seismic isolation, meta-foundations, energy dissipation systems, shut-down devices, ...)
- Seismic assessment procedures for facilities and critical components.
- SSI effects on industrial facilities in seismic prone-areas.
- Improvement of seismic codes and standards related to industrial facilities.
- Methodologies to enhance the overall resilience of industrial facilities to recover quickly from catastrophic seismic events.
- Closing of gaps in both the theoretical understanding and the practical implementation of strategies to manage NaTech events.
- Development of holistic approaches including probabilistic seismic hazard analysis, structural and non-structural performance, technical reliability and operability. The development is based on the interdisciplinary expertise of the WG.



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Activities

The working group will pursue the following activities:

- Preparation of preliminary guidelines for seismic design/assessment of industrial facilities
- Organization of a Working Group meeting once a year.
- Spread the knowledge through workshops and seminars also in collaboration with other relevant associations (e.g. Seismic Engineering Technical committee of ASME PVP division, Japanese Association of Earthquake Engineering, Pacific Earthquake Engineering Research Centre, ...).
- Organization of special sessions at the European and World Conference on Earthquake Engineering, or other relevant conferences (e.g. ASME PVP conference, SEDIF).
- Preparation of special issues on the Bulletin of Earthquake Engineering and other relevant journals.
- Organisation and editing of books on risk and resilience calculation for critical industrial installations.
- Preparation of research projects for EU research programs (e.g. H2020, ERASMUS+).
- Organization of workshops with presentations, round table discussions and other similar activities. It is intended to involve young researchers.

The financial support will be pursued from national and international organizations to assure the necessary continuity in the WG activities.



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SHORT CURRICULUM VITAE OF THE COORDINATOR

Fabrizio Paolacci is Associate professor in Structural Engineering at the Roma Tre University – Department of Engineering. His main scientific interests are mainly focused on risk assessment and mitigation strategies for civil and industrial infrastructures subjected to natural hazards. He has gained a long-standing experience in managing national and International research projects. He is chair of the Seismic Engineering Technical Committee of ASME and is author of more than 100 papers on international peer-review journals and conferences.

LIST OF RELEVANT PUBLICATIONS OF THE COORDINATOR (2016 – 2019)

Journal Papers

1. Bursi O.S., Paolacci F., Shahin R., Alessandri S., Tondini N., (2016), Seismic Assessment of Petrochemical Piping Systems Using a Performance-Based Approach, **Journal of Pressure Vessel and Technology**, Vol. 138:3 - DOI: **10.1115/1.4032111**
2. Paolacci F., Uckan E., Akbas B., Shen J.J., Corritore D. (2016) Seismic vulnerability mitigation of liquified gas tanks using concave sliding bearings, **Bulletin of Earthquake Engineering** Volume 14, Issue 11, pp 3283–3299, DOI: **10.1007/s10518-016-9939-y**
3. Phan H.N., Paolacci F., Bursi O.S., Tondini N., (2017) Seismic fragility analyses of elevated steel storage tanks supported by reinforced concrete columns, **Journal of Loss Prevention in the Process Industries** 47 (2017) 57-65, DOI: **10.1016/j.jlp.2017.02.017**
4. Alessandri et al, (2018) Probabilistic Risk Analysis of Process plants under Seismic loading based on Monte Carlo Simulations, **Journal of Loss Prevention in the process Industries**, Vol 53 – pp. 136-148, DOI: **10.1016/j.jlp.2017.12.013**
5. Phan H.N., Paolacci F., Corritore D., Alessandri S., (2018), Seismic vulnerability analysis of storage tanks for oil and gas industry, Science & technologies-oil and oil products pipeline transportation, Vol.8:2, pp. 161-171, DOI: **10.28999/2541-9595-2018-8-2-161-171**
6. Paolacci F., Giannini R., Alessandri S., Corritore D., (2018), An experimental investigation on the seismic response of a new pier-to-deck connection for composite short-medium span bridges, submitted to **Journal of Traffic and Transportation Engineering**, Volume 5, Issue 6, December 2018, Pages 439-453, DOI: **10.1016/j.jtte.2018.10.002**
7. Abbiati G., Cazzador E., Alessandri S., Bursi O.S., Paolacci F., De Santis S., (2018), Experimental characterization and component-based modeling of deck-to-pier connections for composite bridges, submitted to **Journal of**
8. Phan H.N., Paolacci F., Alessandri S., (2019), Enhanced seismic fragility analysis of unanchored steel storage tanks accounting for uncertain modeling parameters, submitted to **Journal of Pressure Vessel and Technology**. Volume 141 | Issue 1, DOI: **10.1115/1.4039635**
9. Caputo A. C., Paolacci F., Bursi O.S., Giannini R., (2019), Problems and perspectives in seismic QRA of chemical process plants for decision making, submitted to **Journal of Pressure Vessel and Technology**. Volume 141 | Issue 1, DOI: **10.1115/1.4040804**.
10. Bursi O.S., Paolacci F., Taniguchi T., (2019), Guest Editorial Special Issue: Na-Tech Risk Assessment Methodologies and Mitigation Solutions in the Process Industries, Volume 141 | Issue 1, DOI: **10.1115/1.4041284**

International Conference Papers

11. C73. Phan H.N., Paolacci F., P. Hoang P.H., (2016), Probabilistic Seismic Response And Damage Analysis Of Elevated Tanks, EASEC 14, 6-8 January 2016, Ho Chi Minh City, Vietnam
12. Phan H.N., Paolacci F., P. Alessandri S., Hoang P.H., (2016), Vulnerability-based design of sliding concave bearings for the seismic isolation of steel storage tanks, Proceedings of the ASME 2016 Pressure Vessels and Piping Conference, PVP2016, July 17-21, 2016, Vancouver, British Columbia, Canada
13. Phan H.N., Paolacci F., P. Alessandri S., (2016), Fragility analysis methods for steel storage tanks in seismic prone areas, Proceedings of the ASME 2016 Pressure Vessels and Piping Conference, PVP2016, July 17-21, 2016, Vancouver, British Columbia, Canada
14. Phan H.N., Paolacci F., (2016), Efficient intensity measures for probabilistic seismic response analysis of anchored above-ground liquid steel storage tanks, Proceedings of the ASME 2016 Pressure Vessels and Piping Conference, PVP2016, July 17-21, 2016, Vancouver, British Columbia, Canada
15. Alessandri S., Caputo A., Corritore D., Giannini R., Paolacci F., (2016), Seismic quantitative risk assessment of process plants through monte carlo simulations. Proceedings of the ASME 2016 Pressure Vessels and Piping Conference, PVP2016, July 17-21, 2016, Vancouver, British Columbia, Canada
16. La Salandra V., Di Filippo R., Bursi O., Paolacci F., Alessandri S., (2016), Cyclic Response of Enhanced Bolted Flange Joints for Piping Systems, Proceedings of the ASME 2016 Pressure Vessels and Piping Conference, PVP2016, July 17-21, 2016, Vancouver, British Columbia, Canada.



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17. Daniele Corritore, Silvia Alessandri, Renato Giannini, Fabrizio Paolacci, (2017), PRIAMUS: A new tool for the probabilistic risk assessment with Monte Carlo simulations of Process Plants under Seismic Loading
18. ANIDIS Conference, Pistoia, 2017.
19. Caputo, A.C., Paolacci, F. (2017), A method to estimate process plants seismic resilience (2017) American Society of Mechanical Engineers, Pressure Vessels and Piping Division ASME PVP 2017 Conference, Hawaii, USA, Vol. 8, DOI: 10.1115/PVP2017-65464
20. Marino, A., Ciucci, M., Paolacci, F., (2017), Smart technologies for integrated natural risk management: Innovative methodologies and remote sensing (2017) American Society of Mechanical Engineers, Pressure Vessels and Piping Division PVP, ASME PVP 2017 Conference, Hawaii, USA, Vol. 8, DOI: 10.1115/PVP2017-66198
21. Phan, H.N., Paolacci, F., Mongabure, P., (2017), Nonlinear finite element analysis of unanchored steel liquid storage tanks subjected to seismic loadings (2017) American Society of Mechanical Engineers, Pressure Vessels and Piping Division PVP, ASME PVP 2017 Conference, Hawaii, USA, Vol. 8, DOI: 10.1115/PVP2017-65814
22. Caprinuzzi, S., Ahmed, M.M., Paolacci, F., Bursi, O.S., La Salandra, V., (2017), Univariate fragility models for seismic vulnerability assessment of refinery piping systems, American Society of Mechanical Engineers, Pressure Vessels and Piping Division PVP2017, Hawaii, USA, Vol. 8, DOI: 10.1115/PVP2017-65138
23. Alessandri, S., Caputo, A.C., Corritore, D., Renato, G., Paolacci, F., Phan, H.N., (2017), On the use of proper fragility models for Quantitative Seismic Risk Assessment of process plants in seismic prone areas (2017) American Society of Mechanical Engineers, Pressure Vessels and Piping Division PVP2017, Hawaii, USA, Vol. 8, DOI: 10.1115/PVP2017-65137
24. Phan H.N., Paolacci F., (2018), Fluid-structure interaction problems: an application to anchored and unanchored steel storage tanks subjected to seismic loadings, 16th European Conference on Earthquake Engineering, Thessaloniki, Greece, 18-21 June 2018
25. Caprinuzzi S., Žižmond J, Paolacci F, Dolšek M., (2018), A study on the seismic vulnerability of a selected petrochemical plant piping system, 16th European Conference on Earthquake Engineering, Thessaloniki, Greece, 18-21 June 2018
26. Caprinuzzi S., Žižmond J, Paolacci F, Dolšek M., (2018), A study on the seismic vulnerability of a selected petrochemical plant piping system, 16th European Conference on Earthquake Engineering, Thessaloniki, Greece, 18-21 June 2018
27. Paolacci F., Ciucci M., (2018), Seismic behaviour of torsionally coupled structures equipped with viscoelastic dampers, Proceedings of the ASME 2018 Pressure Vessels and Piping Conference PVP2018, July 15-20, 2018, Prague, Czech Republic
28. Paolacci F., Corritore D., Caputo A.C., Bursi O.S., Kalemi B., (2018), A probabilistic approach for the assessment of LOC events in steel storage tanks under seismic loading, Proceedings of the ASME 2018 Pressure Vessels and Piping Conference PVP2018, July 15-20, 2018, Prague, Czech Republic.

Editor of books

29. F.Paolacci, Furuya O., (2016), " Volume 8: Seismic Engineering, ASME 2016 Pressure Vessels and Piping Conference, July 17–21, 2016, Vancouver, BC, Canada
30. F.Paolacci, Furuya O., (2017), " Volume 8: Seismic Engineering, ASME 2017 Pressure Vessels and Piping Conference, July 17–21, 2017, Waikoloa, Hawaii, USA