PEC

Post-Emergency, multi-hazard health risk assessment in Chemical disasters

December 2016.02

Greetings!
Welcome to the second newsletter of the PEC project. This issue covers the period from July to December 2016 and gives you an overview of the progress we have made in our study of multi-hazard health risk assessment in chemical disasters.
Your engagement is very important to us. Therefore, we would like to encourage all interested parties to support us in our endeavour and to constructively collaborate in achieving the study results for the benefit of the society as a whole. We hope that you find this information useful and we are looking forward to hearing your feedback.

Task A is now complete
Task A “Hazard and event definition” is the first of the seven project work packages and covers the period from January to June 2016. The key objectives of this task were to identify a sample area with real exposure to natural or man-made disasters, to define disaster and identify hazard for earthquake, floods, man-made and industrial chemical disasters. This task has been completed in December 2016 according to the planned project plan.

Task B is underway
Task B “Effect on the construction system” focuses on structural models and

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aims to deliver seismic and flooding fragility analysis techniques, define the susceptibility of the structures included in plants, estimate the fragility related to disasters, evaluate possible damages by critical structures and infrastructures in the event of terroristic attacks and map out contamination related to damages in the event of earthquake, flooding and terroristic attacks. Activities related to the first three Actions of Task B have been finalized providing a quantitative assessment of the risk on the plants structures and infrastructures following natural (earthquake and flooding) as well as manmade disasters. Work related to definition of multi-hazard contamination risk map for the study area is underway and will be completed in the first months of 2017. In the next sections the main results obtained are quickly summarized. For the full documentation please visit our web site **www.pec-echo.eu**

Fragility curves for storage tanks and mechanical model validation in the event of earthquake

After a seismic event, in order to evaluate the amount of material stored in the tanks that spills into the environment, the first element required are the fragility curves elaborated for these structures. The fragility of the storage tanks has been described as the probability of reaching or exceeding a certain damage limit condition for a given severity of the ground shaking. During these months, fragility curves have been de-rived selecting as representative parameter of the ground motion severity the Peak Ground Acceleration (PGA). Fragility curves have been calculated for different types of storage tanks. Fragility curves have been validated by the comparison with curves published in the technical literature and by a sophisticated mechanical FE model. The storage tanks have been sub-classified as a function of the ratio between diameter (D) and height (H), D/H as follows:

- class 1: 0.7 ≤ D/H ≤1;
- class 2: 1 < D/H ≤1.5;
- class 3: 1.5 < D/H ≤ 2;
- class 4: D/H > 2.

The following damage mechanisms are taken into account:

- The buckling of the wall as a consequence of elastic or elastoplastic mechanism known in the technical literature as “Diamonds shaped” buckling or “Elephant foot” buckling”, respectively;
- The toppling of the storage tank.

Figure 1 reports an example of the fragility curves on soil for unanchored tanks for class 2 (1<D/H≤1.5) and for each limit state.

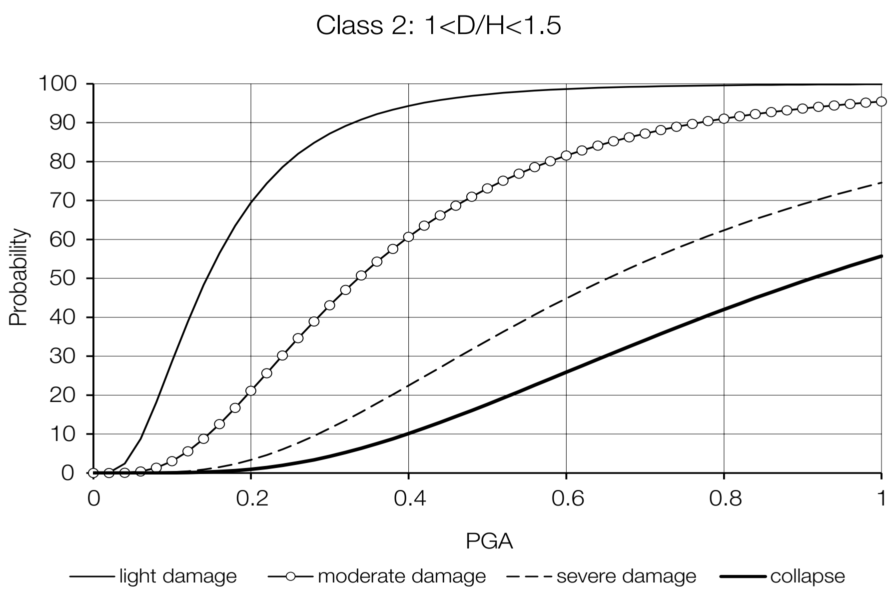

Figure 1

Mechanical model validation

Several computational strategies, either based on high-definition finite element models or simplified mechanical idealizations, can be used to reproduce the complex response of industrial storage structures, whose behavior is governed by a combination of many interacting phenomena. Two different geometrical configurations (Figure 2) were first considered to investigate the response of cylindrical steel tanks that represent one of the most common form of storage structures in the Italian scenario. The behavior of both squat tanks and slender tanks was thus explored, and high-fidelity finite element simulations were performed in compliance with past experimental tests to validate the mechanical representation proposed for fragility analysis. Also, parametric analyses were carried out to corroborate even further the trends emerged from the set of fragility models derived on the basis of a well-known and computationally efficient approach.

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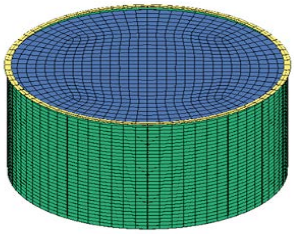
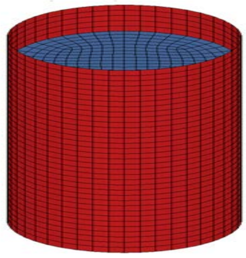


Case-study 1, squat tank (H/R = 1)

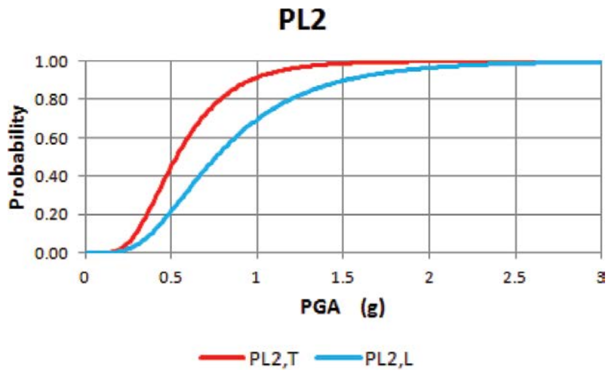


Case-study 2, slender tank (H/R = 4)

Figure 2

Definition of structural models and seismic fragility analysis techniques for horizontal and vertical vessels in the event of earthquake

Seismic fragility curves for horizontal and vertical vessels has been also developed. Fragility curves for horizontal vessels are defined with a simplified approach that considers the vessels as rigid elements in which the fundamental period of vibration is defined considering a simplified Soil Structure Interaction for an equivalent single degree of freedom system. The deterministic parameters considered are: connection bolts resistance, steel properties, pressure and fluid content density, soil properties. Radiuses of the vessel are randomly generated with Monte Carlo simulation from a uniform distribution considering an average value of 1.0 m and a variation of +/- 25%. Ratio between length and diameter, L/D, is assumed to be 3.0 for all the statistically independent vessels. Soil structure interaction is considered by introducing in the equivalent single degree of freedom system the degradation of the rotational stiffness of the foundation: an equivalent linear analysis is then performed iterating the expected rotational stiffness of the foundation until convergence. For each degrading curve of the foundation rotational stiffness, lower, medium and best estimate parameters are considered. Finally, three different vessels to support connection configurations are considered. A set of 90 statistically independent vessels are finally obtained. Fragility curves are then obtained with incremental Response Spectrum analysis considering the following failure mechanisms: foundation rotation, piping rotation and connection capacity. Two performance levels are considered: Performance Level 1, PL1, as first leakage of fluid content, and Performance Level 2, PL2, as complete collapse of the structure. Fragility curves are performed for both longitudinal (L) and transverse (T) direction and they are reported in Figure 3.



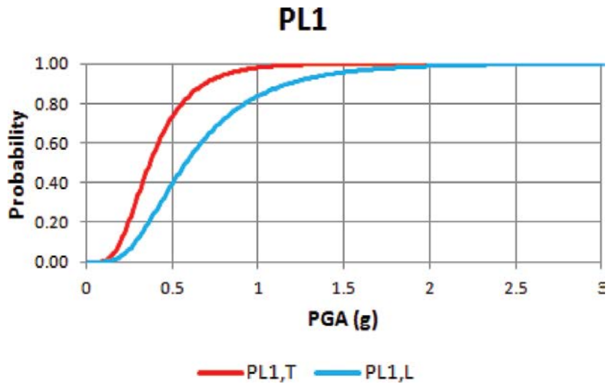


Figure 3

Fragility functions of storage tanks in the event of flooding

This study presents a structured methodology - based on previous studies- with the aim to develop and combine fragility functions for a broader range of flood-induced failure modes. In the PEC application, the failure modes of aboveground storage tanks have been modeled using limit state equations (LSEs) based on the physics-of-failure relationships including load-resistance forces. The LSEs have been coupled with Monte Carlo simulation to generate data required to develop fragility functions using logistic regression. Having the failure probabilities (fragility functions) of individual failure modes such as floating and shell buckling, a Bayesian network methodology has been developed to calculate the total failure probability of vessels.

For illustrative purposes, three flood conditions have been considered:

I. Flood 1: high water condition, where S > 1 m and V = 0.25 m/s.
II. Flood 2: high flow condition, where V > 2 m/s and S = 0.5 m.
III. Flood 3: high risk condition, where S = 1 m and V = 1 m/s.

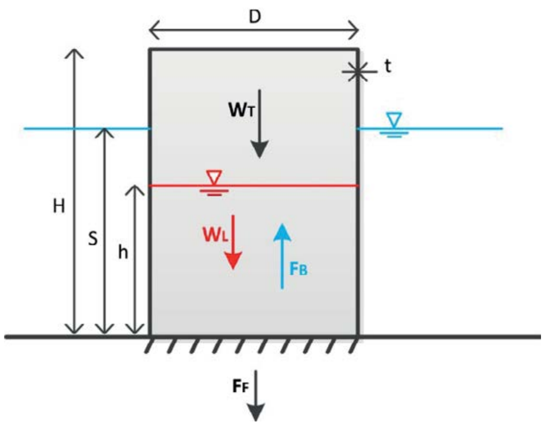


Figure 4: Schematic of the load-resistance forces considered for tank floatation.

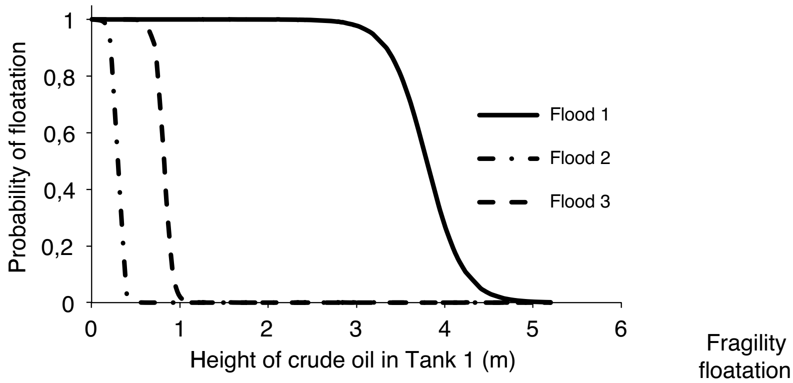


Figure 5: Fragility curves of floatation subject to three floods.

Man-made risk assessment

While attempting to increase safety of industrial plant, actual approaches focus the attention on the issues arising from process deviation; it is not so common to include in a safety assessment also external causes, and particularly effect of terroristic attacks on process plant are usually not included. The developed analysis in PEC took into consideration two main cases (bomb attack and terroristic attack) considered as representative of this typology of events and, based on available information, and on reasonable assumptions, quantified the primary and secondary effects of this event on the plant.

- **Primary effect:** immediate effects of the event on the plant; in case of bomb attack they are the effect of explosion of the bomb, while in case of terroristic attack a characteristic damage to the equipment (in terms of hole dimension) has been assumed and the discharged material has been quantified;
- **Secondary effect:** the secondary effect is the effect of the analyzed scenario on other plant equipment. Particularly, in case of bomb attack the damages on other Plant structure/items related to explosion have been estimated, while in case of terroristic attack the effect related to potential fire scenarios derived by the loss of containment from damaged structures have been quantified in terms of impact to nearby equipment.

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Fire and explosion modelling

The effects of explosions have been quantified by means of TNT Model, a experimental method developed by Marshall (1976). The model allows obtaining the distances at which the overpressure thresholds are reached giving as input the explosive mass. The obtained distances have been plotted on the Plant layout to identify potential impact on nearby equipment. On the other hand, the discharge of flammable substances can results in a pool fire, and the associated effect have been estimated by means of DNV Phast software, a specific software for industrial accident consequences modelling. Also in this case obtained results in terms of radiations have been plotted on the Plant layout in order to identify potential domino effect.

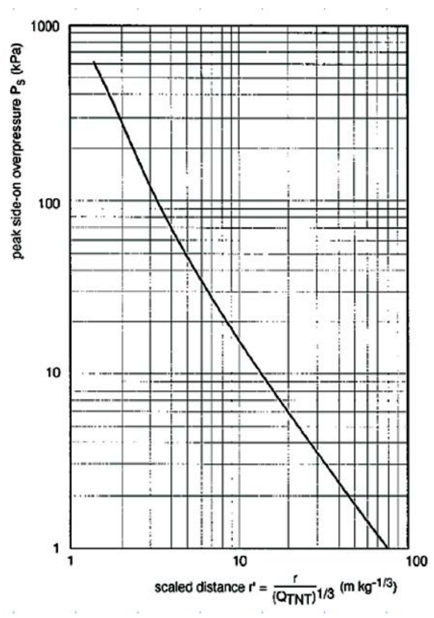

Figure 6: TNT Method – Peak Overpressure Curve.

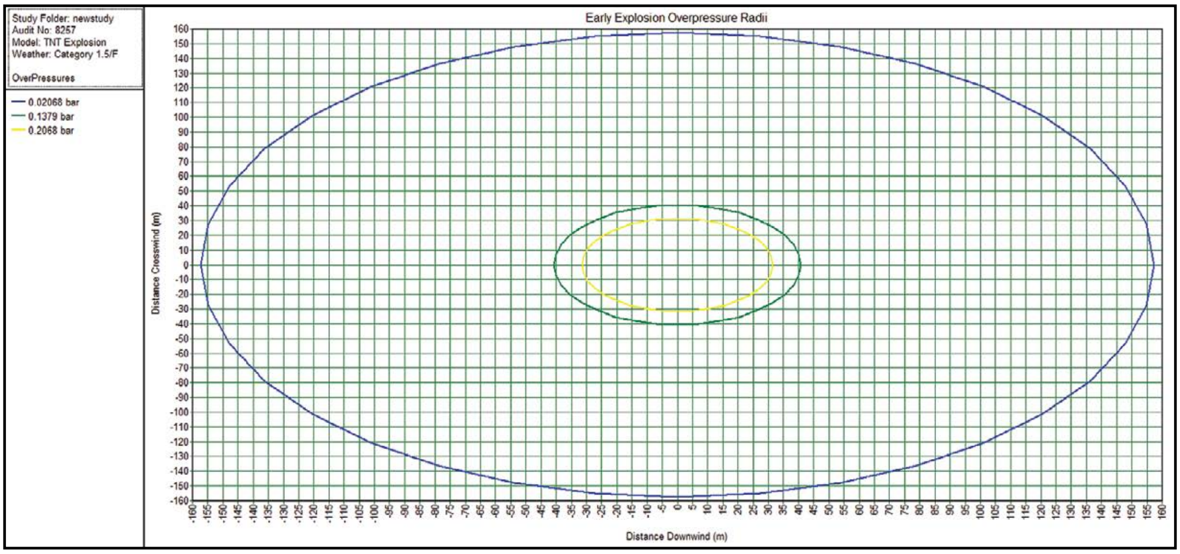

Figure 7: Overpressure plot from DNV Phast.

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PEC Publications

Click on the titles to download the project reports:

- **Deliverable A.1** – Definition of Study Area.
- **Deliverable A.2** – Hazard identification for earthquakes.
- **Deliverable A.3** – Hazard identification for floods.
- **Deliverable A.4** – Anthropogenic hazard identification.
- **Deliverable A.4 - Attachment A** – Fault Tree Analysis.
- **Deliverable A.4 - Attachment B** – HEART Worksheets.
- **Deliverable B.1** – Definition of the structural models and seismic fragility analysis techniques available for the specific case study.
- **Deliverable B.2** – Definition of the susceptibility of the structures included in plants and estimation of the fragility related to disasters.
- **Deliverable B.3** – Report on the evaluation of possible damages suffered by critical structures and infrastructures as consequence of a terroristic attack.

Or visit **www.pec-echo.eu** for all downloadable material.

Task G – publicity

Communication and dissemination of the research results is a major part of the project. This Task aims to delelop a dissemination and result exploitation plan, communication tools, monitor the progress of dissemination and study the exploitation of joint scientific results. The main communication and dissemination tool is the project website, **www.pec-echo.eu**

On the website you can find information about the structure of the project, methods, workplan and links to the partners. There is also a section with all project results, such as deliverables, published papers and presentations. There you can find the **project flyer** as well as the **dissemination and results exploitation plan**. Finally, there is a news and events section, where announcements of key scientific events (e.g. workshops, conferences) are reported.

The website is continuously updated with the latest news and deliverables. If you have any documents you would like to have available or would like to add on the PEC website, please do not hesitate to contact us on **pececho@gmail.com**.

Events

- Annual Congress of Engineers, The Hague, Netherlands, 30 November 2016, **https://www.kivi.nl/jaarcongres2016**

19th MESAEP Symposium

MESAEP, the **Mediterranean Scientific Association of Environmental Protection**, will host the 19th International Symposium on Environmental and Health Inequity from 4 to 6 October 2017 in Rome, Italy. This year's focus will be on environmental and health inequity; science in the service of society. The Symposium will feature specialized sessions in:

1. Environmental and health inequities – socio-economic determinants of exposure.
2. Sustainable natural resource and waste management.
3. Environmental health and well-being.
4. Climate change mitigation and air pollution abatement – towards win-win solutions.
5. Indoor and outdoor air pollution.
6. Water and soil pollution and control.
7. Ecotoxicity and biodiversity.
8. Energy, environment and sustainability.
9. Environmental economics, policy and education.
10. Natural and man-made environmental disasters.
11. New and emerging technologies for environmental and health applications and a panel discussion on migration and environment.

The program of the symposium will include plenary and keynote lectures, and voluntary oral and poster presentations.

Registration will open soon at mesaep.org
For more information about the Symposium, instructions and deadlines, download the 1st circular announcement or visit: **http://www.enve-lab.eu/index.php/19th-mesaep-symposium-on-environmental-and-health-inequity/**

Contact us

We want to hear from you! Please do not hesitate to send us your feedback, comments or questions on **pececho@gmail.com**