Progetto DPC-ReLUIS 2022-2024 WP3

PROTEZIONE CIVILE
Presidenza del Consiglio dei Ministri
Dipartimento della Protezione Civile

WP3 Task 5: NaTech Risk for Industrial Facilities

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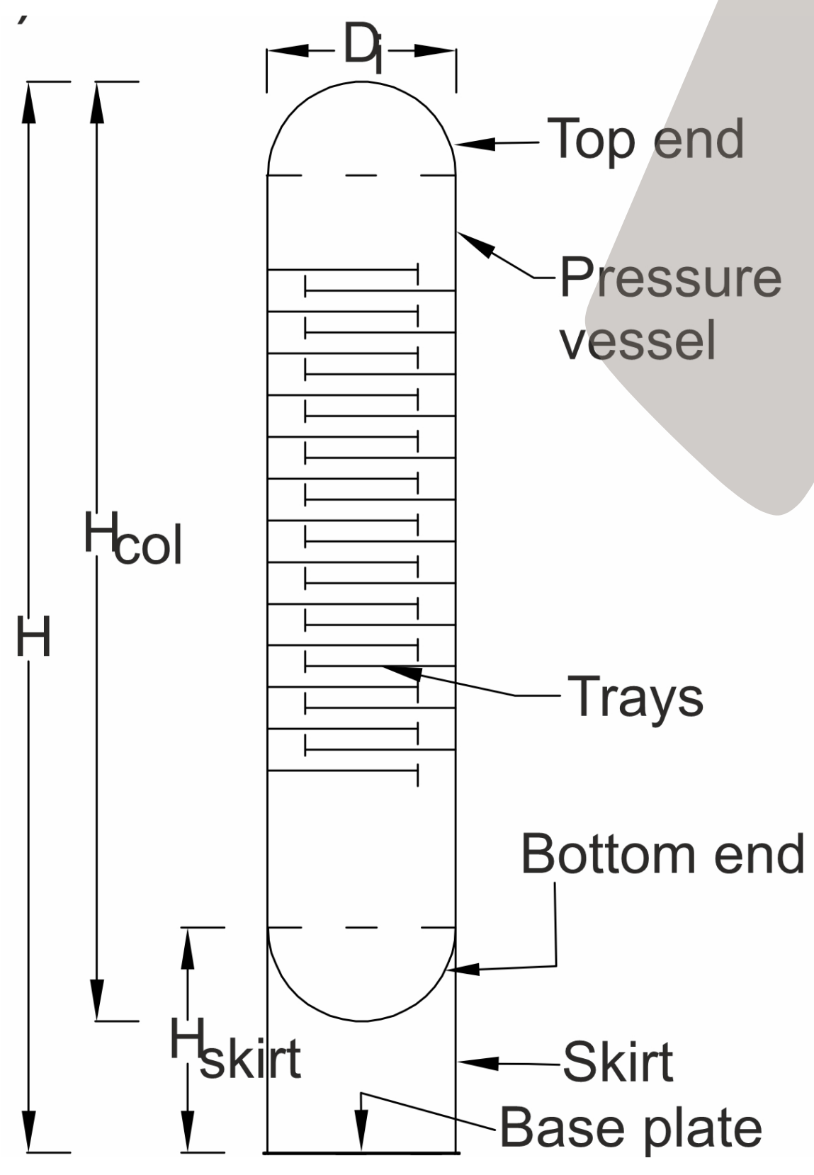
Seismic Risk Assessment for Process Towers

1 SCOPE

The aim of this activity was to develop seismic fragility functions for process towers. Dynamic analysis was conducted using a selection of hazard-consistent ground motion records, on a joystick-type structural model. Fragility functions were derived based on the dynamic analysis results.

2 PROCESS TOWERS



Process towers are vertical steel structures consisting of a pressurised vessel welded on a skirt-type supporting structure. The skirt is connected to the foundation via an annular base plate anchored to the concrete via anchor bolts. Fig.1 shows a schematic drawing of the facility examined, while Fig.2 presents the detail of the foundation connection designed using a simple bearing plate.

Fig.1: Schematic cross-section of a pressure vessel

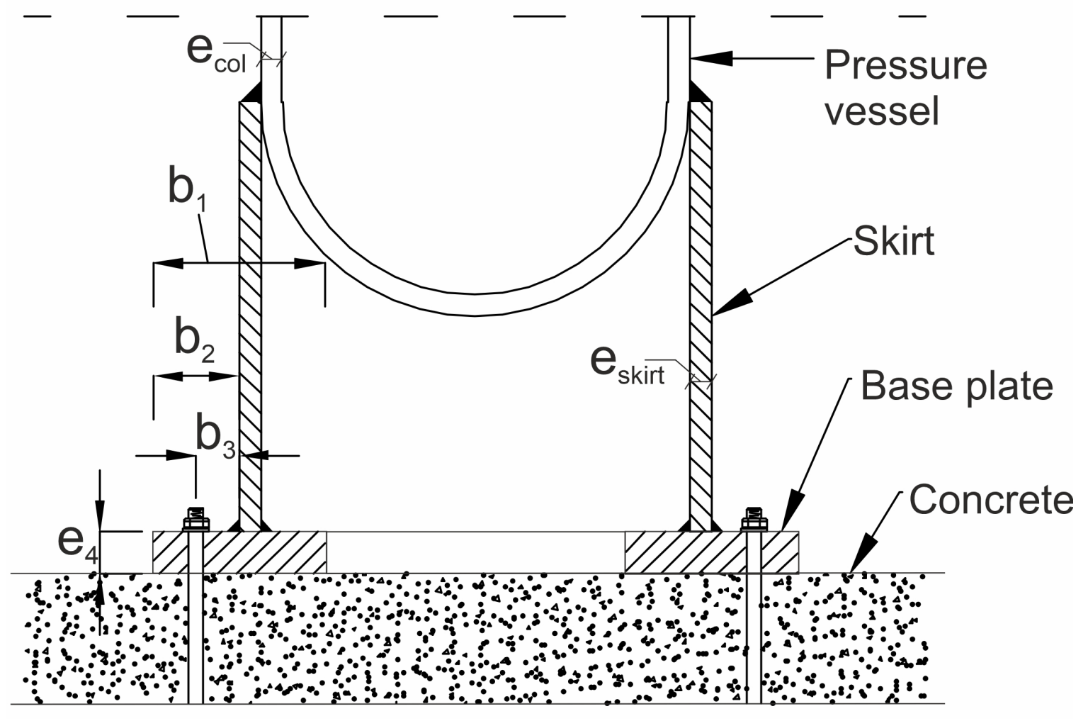


Fig.2: Detailing of the foundation connection.

3 JOYSTICK MODEL

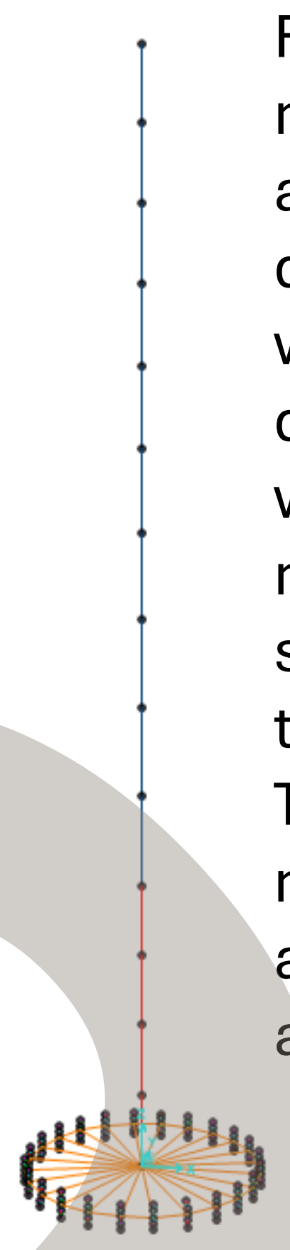


Fig.3 shows the joystick-type model used for the structural analysis. This is a multi-degree-of-freedom-system in which the mass of the tower is discretized along the height, while the anchorage system is modelled with nonlinear springs, connected to the tower with rigid beam spokes. The model considers material nonlinearities at the anchors and contact nonlinearity after anchor failure.

Fig.3: Joystick model.

4 DYNAMIC ANALYSIS

Multi-stripe analysis, MSA, (Jalayer 2003) was performed considering the failure mechanisms shown in Fig.4.

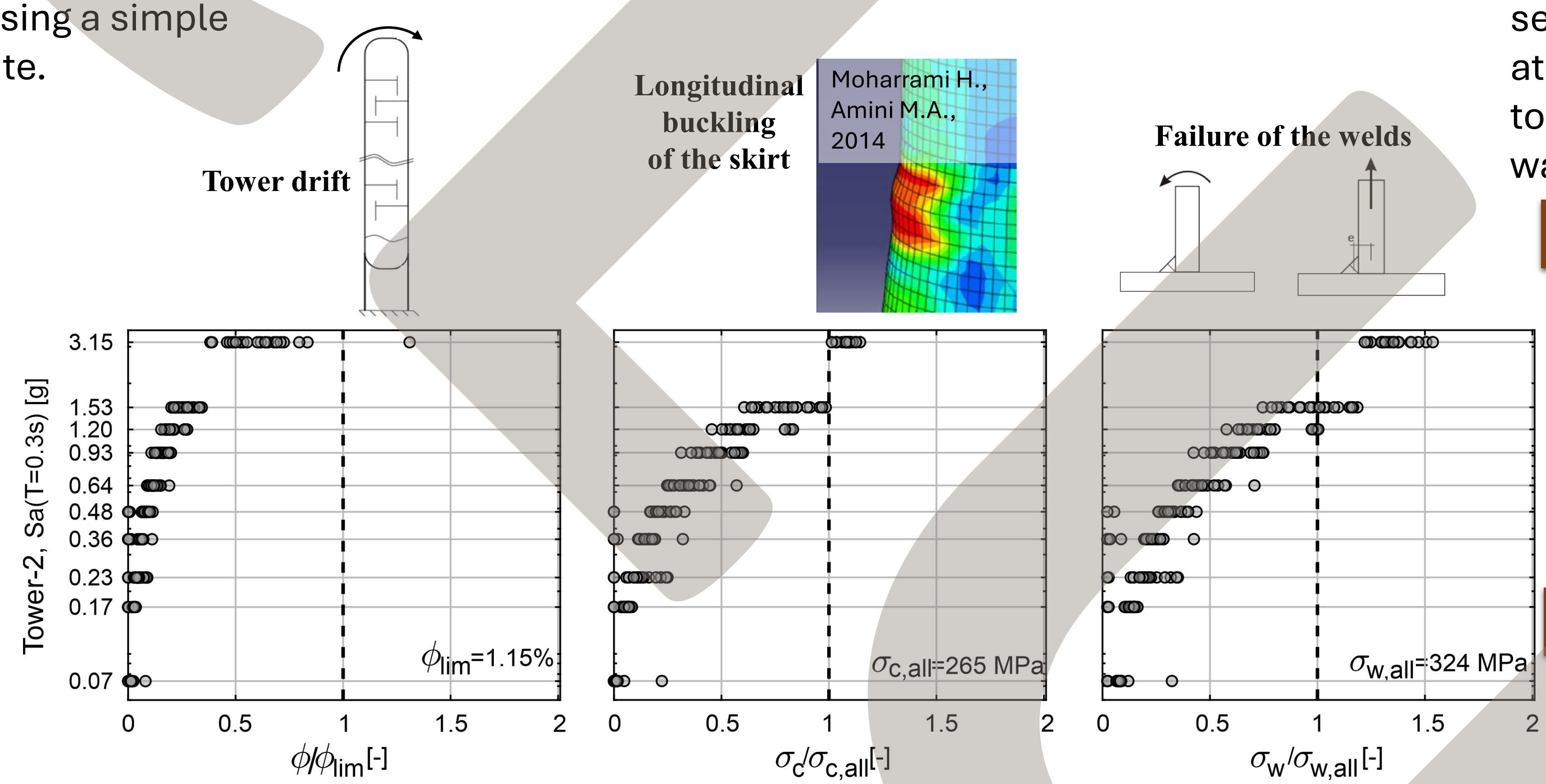
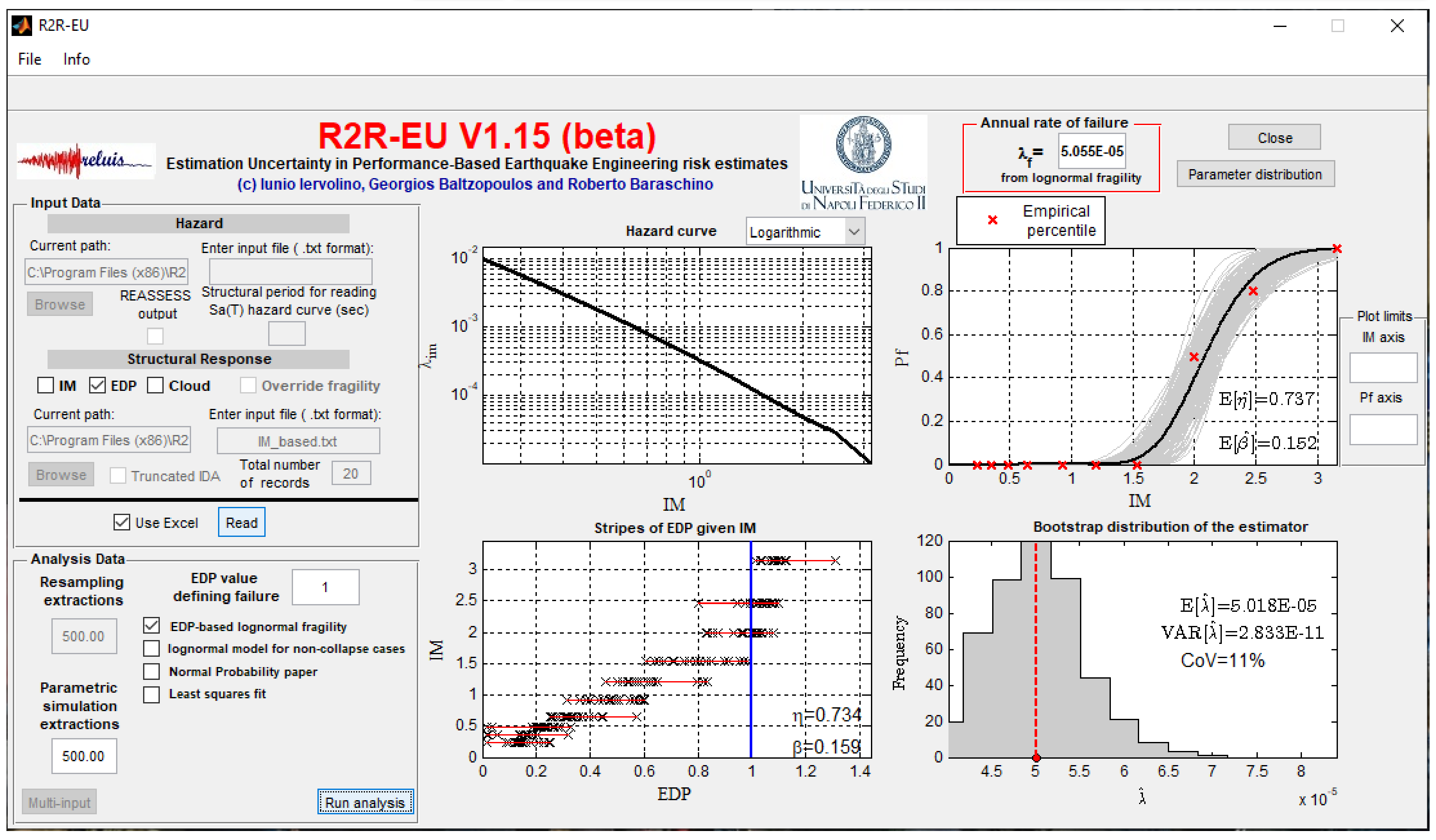


Fig.4: Example of Multi-stripe analysis for the process towers.

5 SEISMIC FRAGILITY DERIVATION



R2R-EU V1.15 (beta)
Estimation Uncertainty in Performance-Based Earthquake Engineering risk estimates
(c) Iunio Iervolino, Georgios Baltzopoulos and Roberto Baraschino

Input Data
Hazard
Current path: C:\Program Files (x86)\R2
Enter input file (.txt format):
REASSESS output ☐
Structural period for reading Sa(T) hazard curve (sec)
Structural Response
☐ IM ☑ EDP ☐ Cloud ☐ Override fragility
Current path: C:\Program Files (x86)\R2
Enter input file (.txt format): IM_based.txt
☐ Truncated IDA
Total number of records: 20
☑ Use Excel

Analysis Data
Resampling extractions: 500.00
EDP value defining failure: 1
☑ EDP-based lognormal fragility
☐ lognormal model for non-collapse cases
☐ Normal Probability paper
☐ Least squares fit
Parametric simulation extractions: 500.00

Annual rate of failure
λ_f = 5.055E-05
from lognormal fragility

× Empirical percentile

E[λ̂]=5.018E-05
VAR[λ̂]=2.833E-11
CoV=11%

Fig.5: R2R Software screen for the derivation of the seismic fragility functions and the failure rate.

R2R software (Baraschino et al. 2020) was used to fit a log-normal fragility model to the dynamic analysis results, using maximum likelihood for estimating the parameters. Fig.5 shows in the lower left the oerall MSA results and at the top right the seismic fragility curve. In addition, assuming the tower located at Ravenna, Italy, integrating the seismic hazard curve, at the top left of Fig.5, with fragility curve, the structural failure rate was evaluated, and the value is inside the red box in Fig.5.

6 CONCLUSIONS

The results showed that:

- Towers with lower operating pressure suffer of large drift while towers with high pressure were more susceptible to weld failure or buckling of the skirt. Higher pressure translates into larger mass of the pressure vessel.

7 REFERENCES

Jalayer F., 2003, Direct Probabilistic Seismic Analysis: Implementing Non-Linear Dynamic Assessments, PhD Thesis, Stanford, USA.
Baraschino R., Baltzopoulos G., Iervolino, I., 2020, R2R-EU: Software for fragility fitting and evaluation of estimation uncertainty in seismic risk analysis.

Tsunami Fragility for Anchored Atmospheric Storage Tanks

1 SCOPE

This aim of this activity was to develop fragility functions for anchored atmospheric storage tanks under tsunami action. These were obtained for storage tanks with different aspect ratios, for different filling levels.

2 FINITE ELEMENT MODELS

Three archetype tanks, in Fig.6, were modelled using four-node finite element for the shell wall and the base plate, while the anchorage system was modelled with nonlinear springs.

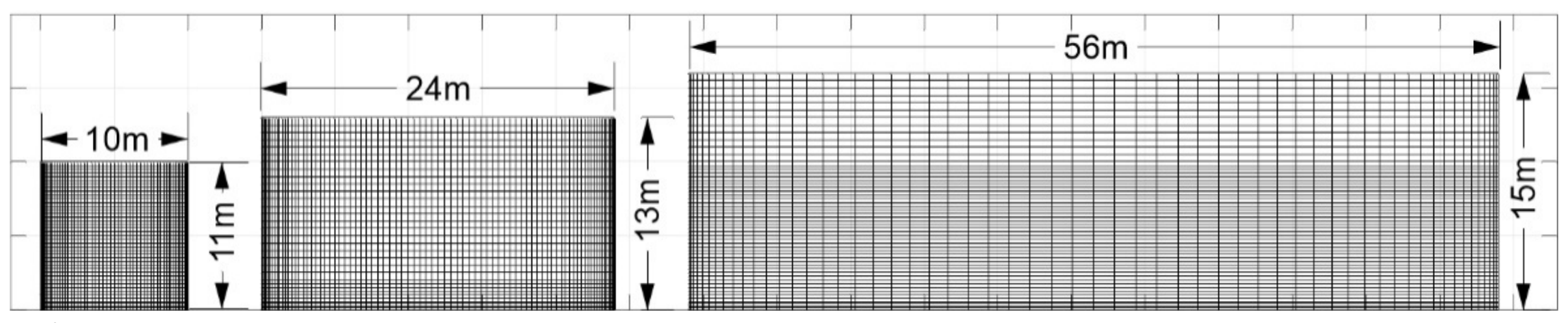
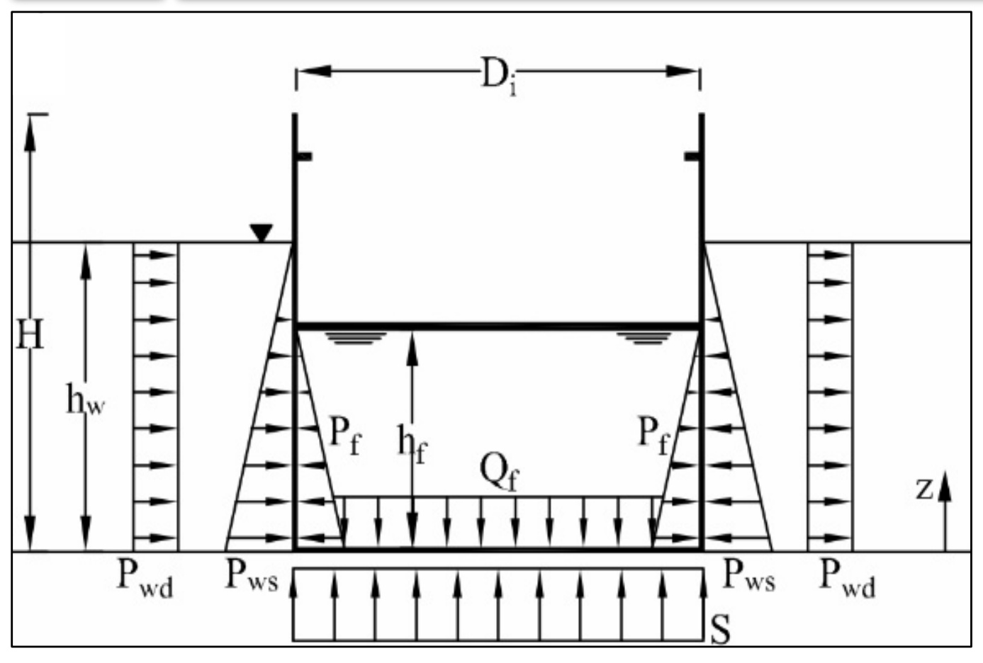


Fig.6: Finite element models for anchored storage tanks.

3 TSUNAMI ACTION



Tsunami action was modelled following a quasi-static approach comprising a distinguishing hydrostatic and hydrodynamic component (Fig.7).

Fig.7: Tsunami pressures.

4 FAILURE MECHANISMS

Tsunami pressures may trigger a series of structural damage such as shell buckling, concrete cone breakout, tension and shear rupture of the steel (Fig.8). All mechanisms are assumed to lead to loss of content.

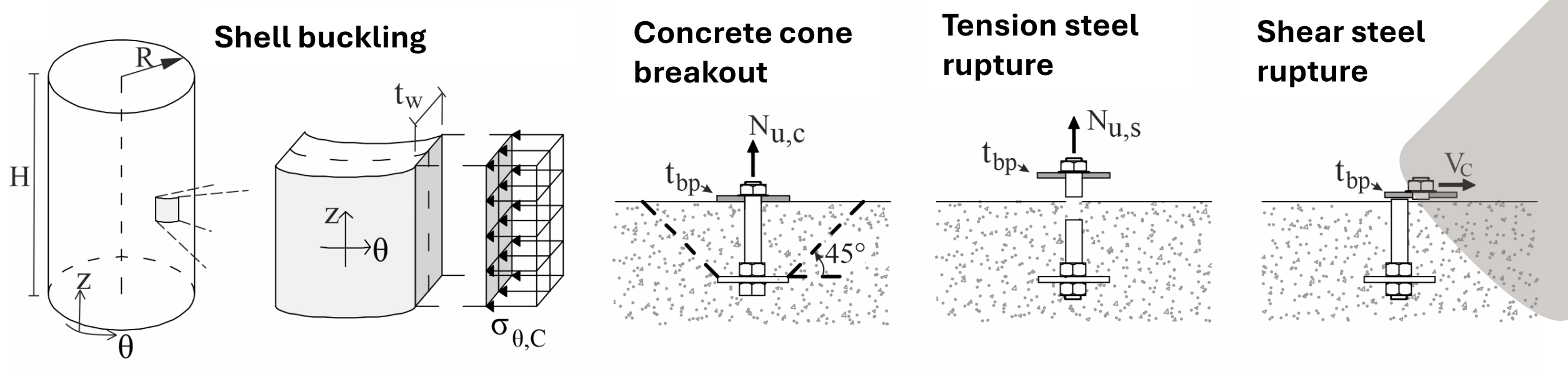


Fig.8: Failure mechanisms.

5 INFLUENCE OF FAILURE MECHANISMS

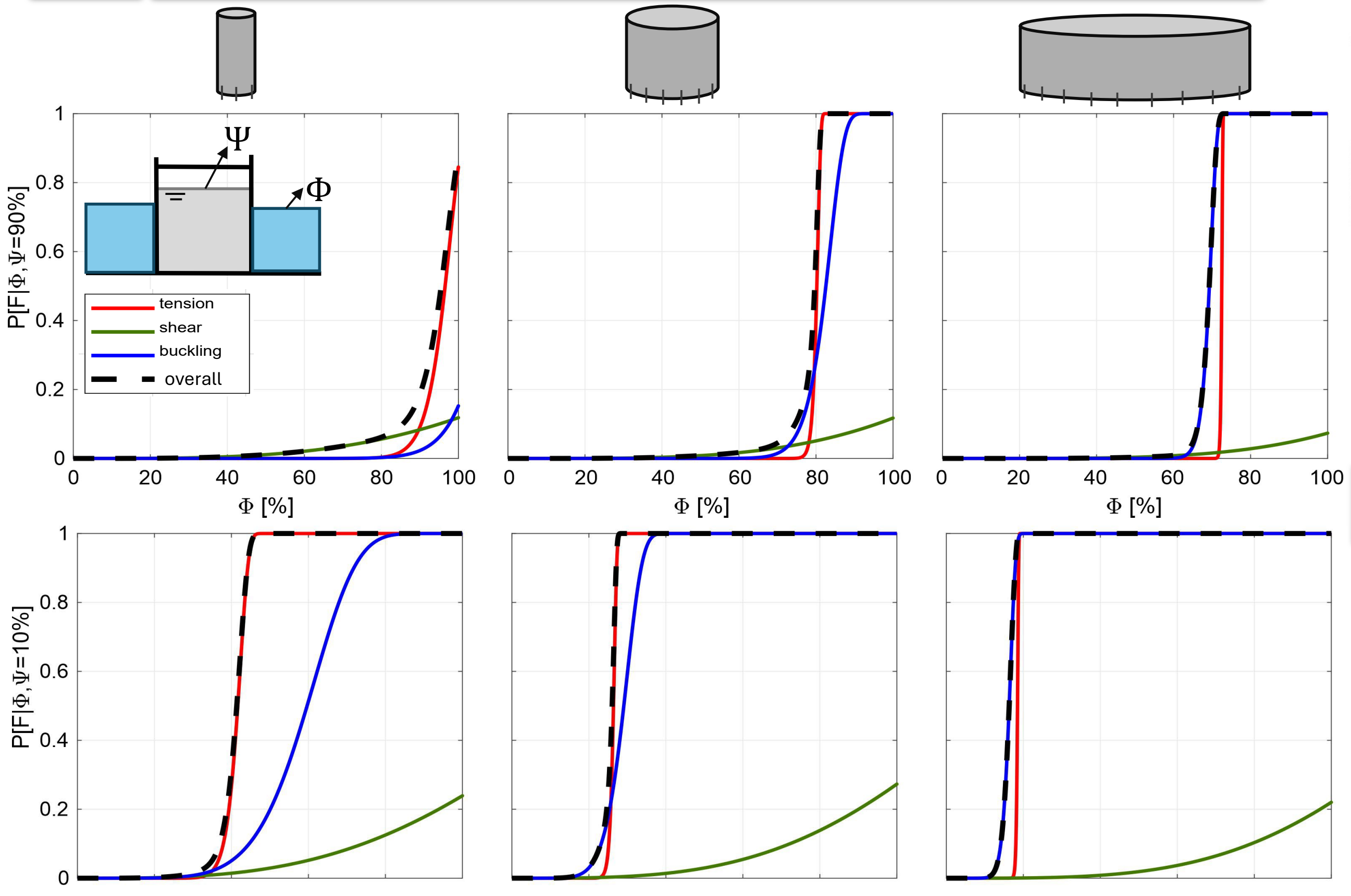
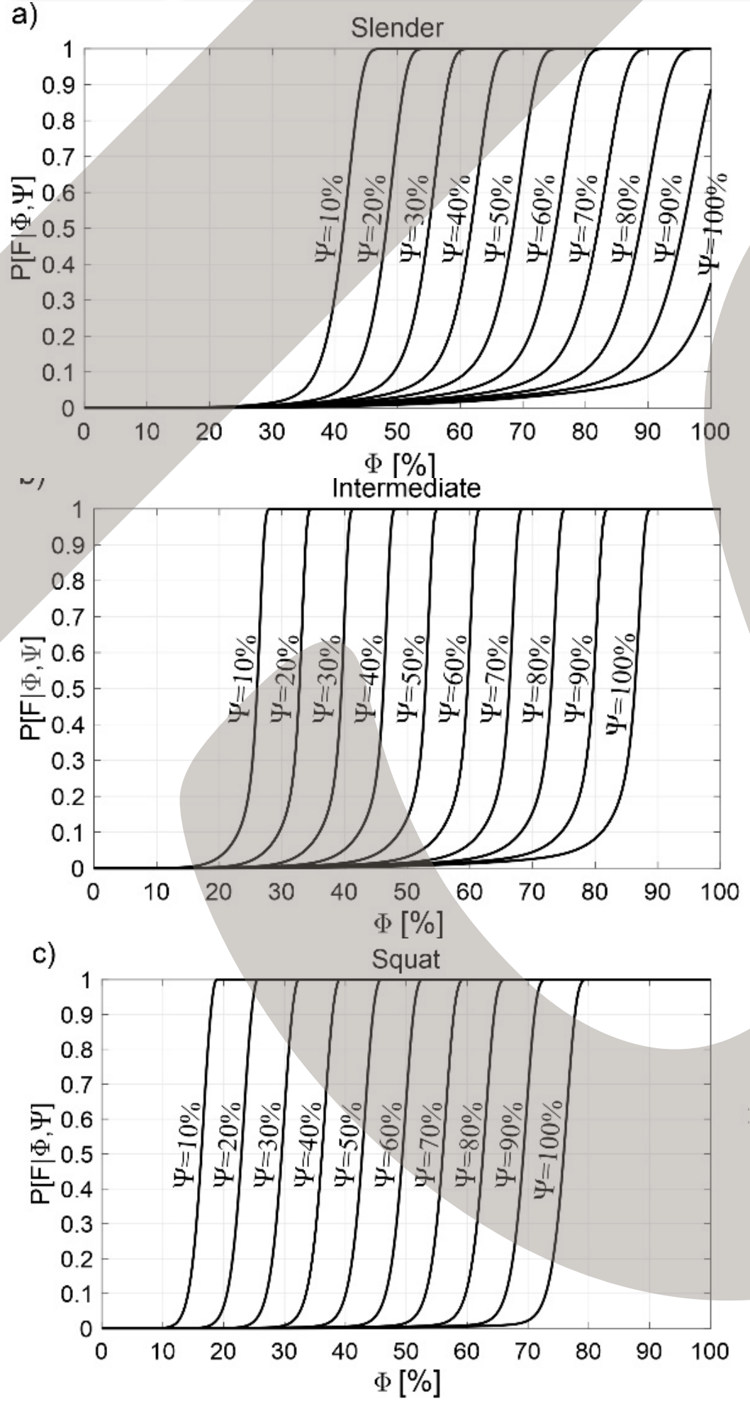


Fig.9: Fragility curves for failure mechanisms for two filling levels.

6 TSUNAMI FRAGILITY CURVES



The fragility curves in Fig.10, were obtained by fitting a parametric (Weibull) model to nonlinear static analysis results. The fragilities depend on two dimensionless parameters: the filling level Ψ and the inundation level Φ. These curves are site-specific because were obtained developing conditional hazard models for a site chosen as case-study.

Fig.10: Tsunami fragility curves for filling levels for the three archetype tanks.

7 CONCLUSIONS

The results show that:

- Anchored atmospheric storage tanks under tsunami action are more vulnerable for low filling levels.
- Slender tank is governed by tension failure, squat tank by shell buckling, while intermediate tank does not have a predominant mechanism.

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