SEISMIC VULNERABILITY AND DESIGN OF SILOS AND TANKS

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The research group is involved in the study of the seismic behaviour of:

1. flat-bottom silos containing grain material
2. tanks containing fluids

GRAIN SILOS

According to Eurocode 8, the seismic design of flat-bottom circular silos containing grain-like material is based on a rough estimate of the inertial force imposed on the structure by the ensiled content during an earthquake: 80% of the mass of the content multiplied by the peak ground acceleration.

First, the research group performed analytical considerations of the horizontal shear force mobilised within the ensiled material during an earthquake. The analyses were developed by simulating the earthquake ground motion with time constant vertical and horizontal accelerations and were carried out by means of simple dynamic equilibrium equations that take into consideration the specific mutual actions developing in the ensiled grain. The results indicated a radically reduced estimate of this load suggesting that, in practice, the effective mass of the content is significantly less than that specified by Eurocode 8 (Figs. 1 and 2).

Second, a series of laboratory tests were developed at the EQUALS Lab of the University of Bristol (UK) that featured shaking table and a silo model. The tests were conducted in order to obtain some experimental data to verify the proposed theoretical formulations and to compare with the established code provisions. Several tests have been performed with different heights of ensiled material – about 0.5 mm diameter Ballotini glass – and different magnitudes of grain–wall friction (Fig. 3). The results indicate that in all cases, the effective mass is indeed lower than the Eurocode specification, suggesting that the specification is over conservative, and that the wall–grain friction coefficient strongly affects the overturning moment at the silo base (Fig. 4).

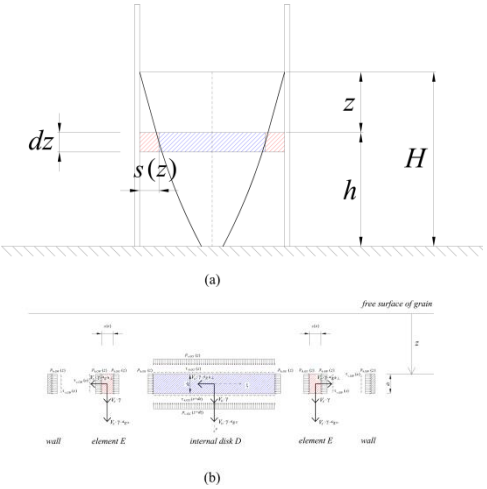

Fig. 1. Vertical longitudinal section of the silo model and forces (Silvestri).

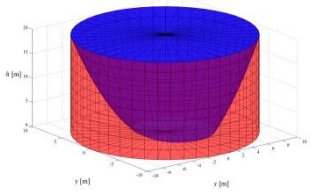

Fig. 2. The red portion is the amount of grain that is completely sustained by the lateral walls of the silo (Silvestri).

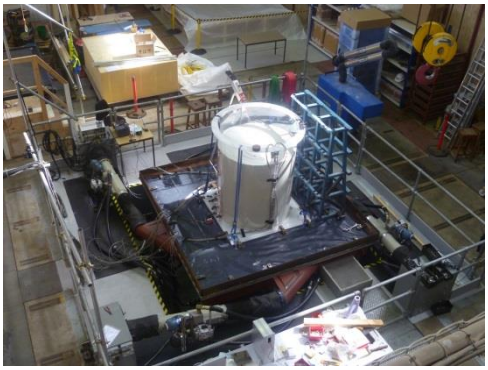

Fig. 3. Shaking table tests at the EQUALS Lab of Bristol (UK) (Silvestri).

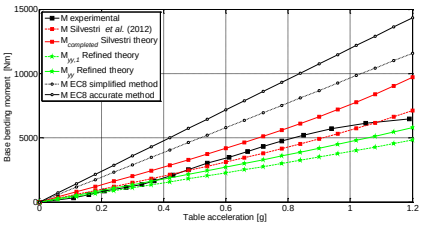

Fig. 4. Comparison between the experimental overturning moment and the predicted values by the theory and by the Eurocode 8 methods (Silvestri).

LIQUID TANKS

The research group studied the behaviour of fluid-containing tanks during ground-motions. In particular models based on the added mass method were developed in order to carry out non-linear dynamic analyses aimed at predicting the onset of buckling on steel tanks (Fig. 5). The methods developed were used to investigate the efficiency and sufficiency of various ground-motion intensity measures. Fragility curves were then derived, using non-linear incremental dynamic analyses, for a set of case study tanks. The research group has also collected a large database containing information on the damage level and the loss of content in tanks struck by earthquakes. Those data are being used in order to derive parametric fragility models. The group has also proposed a procedure for the seismic-related quantitative risk analysis of industrial plants. Uncertainties are propagated, in the proposed procedure, using the theory of fuzzy sets.

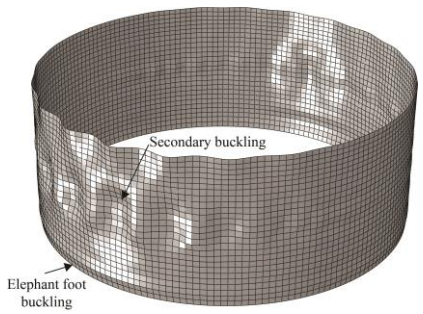

Fig. 5. Numerical simulation of the buckling of a cylindrical tank during a ground-motion (Buratti).

MAIN PUBLICATIONS

Silvestri, S., Gasparini, G., Trombetti, T., and Foti, D. (2012). On the evaluation of the horizontal forces produced by grain-like material inside silos during earthquakes. Bulletin of Earthquake Engineering, 10(5), 1535-1560.

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Pieraccini, L., Silvestri, S., and Trombetti, T. (2015). Refinements to the Silvestri's theory for the evaluation of the seismic actions in flat-bottom silos containing grain-like material. Bulletin of Earthquake Engineering, 13(11), 3493-3525.

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Buratti N., Ferracuti B., Savoia M., Antonioni G., Cozzani V. (2012) A Fuzzy-Sets Based Approach for Modeling Uncertainties in Quantitative Risk Assessment of Industrial Plants Under Seismic Actions. Chemical Engineering Transactions. Vol. 26, pp. 105-110.

RESEARCH PROJECTS

European research project SERIES (2010-2011) Transnational Access Use of Shaking Tables: "Assessment of the seismic behaviour of flat bottom silos containing grain-like materials (ASESGRAM)", EQUALS Laboratories (Bristol, UK), Lead User: Prof. Dora Foti, Politecnico di Bari, Local: Prof. Tomaso Trombetti. European Community's Seventh Framework Program [FP7/2007-2013] under grant agreement n° 227887 for the SERIES Project.

Project ReLUIS-DPC 2014-2018, founded by the Italian Department for Civil Protection, Task 2.2.3: Chemical and nuclear plants and lifelines. National coordinator: prof. M. Savoia.

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