Editorial: Structural response to gas-extraction induced seismicity

In 1959 one of the world's largest gas fields was discovered in the province of Groningen in the northern part of The Netherlands. Since then gas has been extracted from the field. Initially, this led to gradual subsidence but later, since the '90's, it also resulted in low-magnitude, shallow earthquakes. In 2012 the Huizinge earthquake of magnitude 3.6 at Richter's scale served as a wake-up call. Since then, research into the seismic capacity of building stock has been intensified, both with a view to near collapse states and potential casualties, i.e. the safety issue asking for seismic assessments and if required structural upgrading, and with a view to the lower damage states, i.e. the problem of house owners experiencing cracks and consequent nuisance in claiming and repair processes.

The research and the build-up and dissemination of knowledge took place along three lines. Firstly, the production company NAM, a joint venture of Shell and Exxon cooperating with the Dutch state, conducted a comprehensive Hazard & Risk study with multiple international organizations. It aimed to improve regional risk forecasts aiding the Minister in his decisions to balance the allowed annual level of gas extraction versus the safety risk and required strengthening of houses. This research was multi-scale and experimental-computational in nature, all the way from the basic material level, via structural component behaviour of masonry piers, spandrels and floor systems, up to the large-scale house level with full-scale assemblies being tested at shake tables and in push-over. Structural analysis methods and advanced nonlinear finite element methods were validated against lab tests. Secondly, seismic assessments and, if required, structural upgrading plans were developed for individual houses, with a view to practical implementation as follow-up to the regional risk study. Initially, NAM took responsibility for this line in their Structural Upgrading stream, which was later transferred to the Centrum Veilig Wonen (CVW) and subsequently to the National Coordinator Groningen (NCG). Here, consultants and contractors build up knowledge, contribute and interact, also supported by lab testing in that Structural Upgrading stream. Thirdly, the Ministry of Internal Affairs has activated the Dutch Normalisation Institute (NEN) to integrate the research contributions and transform them into a practical guideline, the Dutch Seismic Code (Nationale Praktijk Richtlijn, NPR) offering structural analysis methods for induced seismicity. The first version was issued in 2015, the second in 2018 with a further update in

2020. Herein, tiered analysis approaches have been set out, ranging from simple in-plane lateral mechanism analysis and kinematic out-of-plane analysis, up to more advanced nonlinear push-over and fully nonlinear dynamic time history analyses.

This HERON gives examples of local contributions to the above research lines. Please note that the selection of contributions is limited; the total research effort has been much wider, with major inspiration and results coming from EU Centre in Pavia to the H&R research line mentioned above, and from BECA New Zealand to the second and third research line mentioned above.

The first contribution describes the reliability based code making process. It starts from a target Individual Risk level of 10^{-5} per year, and then describes the way loads, resistance and their uncertainties are treated along with the various building collapse states, towards a consistent safety format. The second contribution is an example of research into drift limits compatible with that safety format. A large data-set of clay and calcium silicate masonry pier lab tests has been collected and utilized to derive near collapse drift limits for masonry piers that undergo rocking failure. The third contribution looks further into a subset of those in-plane wall test data. New tests on calcium-silicate brick masonry and thin layer calcium-silicate element behaviour are presented, showing overall a fair ductility, but more brittle splitting behaviour in case of large element block masonry. The fourth contribution gives an example of research into strengthening techniques. Bed-joint reinforcement repointing has been studied experimentally with a view to increasing the ultimate displacement capacity and also for reducing the width and length of cracks that may occur from repeated light earthquakes. The final contribution deepens the underlying physics of crack initiation and propagation for the lower damage states, as typical to repeated induced seismic action. Using a newly defined scalar damage parameter, lab tests with high-resolution digital image correlation along with computational modelling has been used to derive probabilities of light damage for different peak ground velocities. Please note that further information on the five contributions and the underlying research data can be found at www.tudelft.nl/citg/structural-response-to-earthquakes

The selection of contributions covers both the experimental and modelling character of the research, at multiple scales, and addresses the ultimate near collapse limit state as well as the serviceability related lower damage states. As such, it is hoped that the issue gives a balanced impression of local research contributions in this field since 2014.

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