MOX-Report No. 16/2020

Earthquake ground motion modelling of induced seismicity in the Groningen gas field

Paolucci, R.; Mazzieri, I.; Piunno, G.; Smerzini, C.; Vanini, M.;

Ozcebe, A.G.

MOX, Dipartimento di Matematica
Politecnico di Milano, Via Bonardi 9 - 20133 Milano (Italy)

mox-dmat@polimi.it http://mox.polimi.it

EARTHQUAKE GROUND MOTION MODELLING OF INDUCED SEISMICITY IN THE GRONINGEN GAS FIELD

R. Paolucci[1], I. Mazzieri[2], G. Piunno[1], C. Smerzini[1], M. Vanini[1], A.G. Özcebe[3]

[1] Department of Civil and Enviromental Engineering, Politecnico di Milano, Piazza Leonardo da Vinci 32, 20133 Milan, Italy
[2] MOX, Department of Mathematics, Politecnico di Milano, Piazza Leonardo da Vinci 32, 20133 Milan, Italy
[3] EUCENTRE - European Centre for Training and Research in Earthquake Engineering, Pavia, Italy

ABSTRACT
A key element in the seismic hazard and risk assessment due to induced earthquakes in the Groningen gas field is a ground motion model (GMM). Although significant efforts have been devoted to the construction of an empirical GMM, there is a growing interest in reducing its uncertainty through data-driven approaches. In the framework of the KEM research program launched by the Ministry of Economic Affairs and Climate Policy of the Netherlands, the authors explored the use of 3D physics-based numerical approaches to characterize earthquake ground motion in the Groningen area and to shed light on the potential impact of the specific geologic conditions, characterized by irregular geologic interfaces and thick layers of soft deposits at ground surface. Within the wider scope of this research, this paper is focused on the construction and validation of a large-scale (20 km × 20 km), heterogeneous 3D seismic wave propagation model for the Groningen area, based on the significant bulk of available geological, geophysical, geotechnical and seismological data.
Results of physics-based numerical simulations are validated against the ground motion recordings of the Jan 8, 2018, M_L 3.4 Zeerijp earthquake – the third largest event to date in the area. Taking advantage of suitable models of slip time functions at the seismic source and of the detailed geophysical model, the numerical simulations are found to reproduce accurately the observed features of ground motions at short epicentral distance (R_{epi} < 10 km), in a broad frequency range, up to about 10 Hz. To achieve this level of accuracy, the total number of degrees-of-freedom was up to about 1 billion, implying taking advantage of high performance computing facilities. A sensitivity analysis is also addressed to discuss the impact of key modeling assumptions, specifically, the role of 3D underground geological features ("tunnel valleys"), the stochastic variability of shallow seismic velocities and the amplitude and frequency dependence of the quality factor. Amongst others, results point out crucial aspects in deriving GMMs for induced seismicity in Groningen, such as the magnitude and distance dependence of site amplification functions associated with 3D wave propagation features, as opposed to the standard assumption of vertically propagating plane waves.

KEYWORDS
Induced seismicity, Groningen gas field, earthquake ground motion, physics-based numerical simulations, high-performance computing.

MOX Technical Reports, last issues

Dipartimento di Matematica
Politecnico di Milano, Via Bonardi 9 - 20133 Milano (Italy)

15/2020 Fumagalli, I.; Fedele, M.; Vergara, C.; Dede', L.; Ippolito, S.; Nicolò, F.; Antona, C.; Scrofani,
An Image-based Computational Hemodynamics Study of the Systolic Anterior Motion of the Mitral Valve

13/2020 Pozzi S.; Domanin M.; Forzenigo L.; Votta E.; Zunino P.; Redaelli A.; Vergara C.
A data-driven surrogate model for fluid-structure interaction in carotid arteries with plaque

14/2020 Calissano, A.; Feragen, A; Vantini, S.
Populations of Unlabeled Networks: Graph Space Geometry and Geodesic Principal Components

12/2020 Azzolin, L.; Dede', L.; Gerbi, A.; Quarteroni, A.
Effect of fibre orientation and bulk value on the electromechanical modelling of the human ventricles

08/2020 Antonietti, P. F.; Facciolà, C.; Verani, M.
Polytopic Discontinuous Galerkin methods for the numerical modelling of flow in porous media with networks of intersecting fractures

09/2020 Rea, F.; Ieva, F.,; Pastorino, U.; Apolone, G.; Barni, S.; Merlino, L.; Franchi, M.; Corrao, G.
Number of lung resections performed and long-term mortality rates of patients after lung cancer surgery: evidence from an Italian investigation

10/2020 Bonaventura, L.; Carlini, E.; Calzola, E.; Ferretti, R.
Second order fully semi-Lagrangian discretizations of advection--diffusion--reaction systems

11/2020 Antonietti, P.F.; Facciola', C.; Houston, P.; Mazzieri, I.; Pennes, G.; Verani, M.
High-order discontinuous Galerkin methods on polyhedral grids for geophysical applications: seismic wave propagation and fractured reservoir simulations

06/2020 Domanin, M.; Piazzoli, G.; Trimarchi, S.; Vergara, C.
Image-based displacements analysis and computational blood dynamics after endovascular aneurysm repair

05/2020 Artioli, E.; Beiraoda Veiga, L.; Verani, M.
An adaptive curved virtual element method for the statistical homogenization of random fibre-reinforced composites