



HAL
open science

The Non-Smooth Contact Dynamics method applied to the mechanical simulation of a jointed rock mass

Ali Rafie, Marc Vinches, Frédéric Dubois

► **To cite this version:**

Ali Rafie, Marc Vinches, Frédéric Dubois. The Non-Smooth Contact Dynamics method applied to the mechanical simulation of a jointed rock mass. ENOC 2011, Jul 2011, Rome, Italy. hal-00806657

HAL Id: hal-00806657

<https://hal.science/hal-00806657>

Submitted on 2 Apr 2013

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

The Non-Smooth Contact Dynamics method applied to the mechanical simulation of a jointed rock mass

Ali Rafiee^{*}, Marc Vinches^{**} and Frédéric Dubois^{***}
^{*}, Zanzan University, Zanzan, Iran

^{**}Centre des Matériaux de Grande Diffusion, Ecole des Mines d'Alès, France

^{***}Laboratoire de Mécanique et Génie Civil, UMR 5508 CNRS - Université de Montpellier 2, France

Summary. A jointed rock mass geometrical model is built, based on the fracture systems characteristics obtained from field measurements. This model is composed of three-dimensional polyhedra interacting with each other by contact laws, in the frame work of the Non-Smooth Contact Dynamics method. The stability assessment of the walls of a stone quarry in France is presented, as a case study.

Modelling a fractured rock mass as a collection of distinct blocks

Modelling a fractured rock mass hardly qualifies as an emerging nonlinear dynamics-enabled engineering application. As a matter of fact, P. Cundall [1] is widely considered as one of the pioneers in this field back in the 1980's, with the development of a smooth Distinct Element Method (DEM). However, the necessity to take into account the three-dimensional nature of most real engineering problems, dealing with rock mechanics, soon made use of the potential of the Non-Smooth Contact Dynamics (NSCD) method to deal with models comprising several thousand contacts, under dynamical loads. The NSCD method is mainly distinguishable from the original smooth DEM due to the following features:

- An implicit scheme for integrating the time discretized dynamical equation.
- A non-regularized interaction law (Signorini unilateral contact and Coulomb dry friction)
- The possibility for finite element discretization in order to take into account the mechanical behaviour of rock blocks (elastic, elasto-plastic, visco-plastic behaviour).

the references [2 - 5] provide a detailed presentation of the NSCD method.

The results of numerical analyses dealing with granular materials are extremely sensitive to: (a) the geometrical definition of the solids, (b) their mechanical and physical properties, and (c) the input loading function [6]. We will thus consider several aspects of these three steps in the following paragraphs.

Geometrical definition of the solids: the rock mass geometrical model

The case study concerns the stability analysis of the walls of an ophite quarry, situated in the Atlantic-Pyrenees department, in the South-West of France, in the Souraïde municipality. The methodology concerning the description of the fracture systems can be found in [7] for the fracture clustering method, and in [8] for the geostatistical analysis

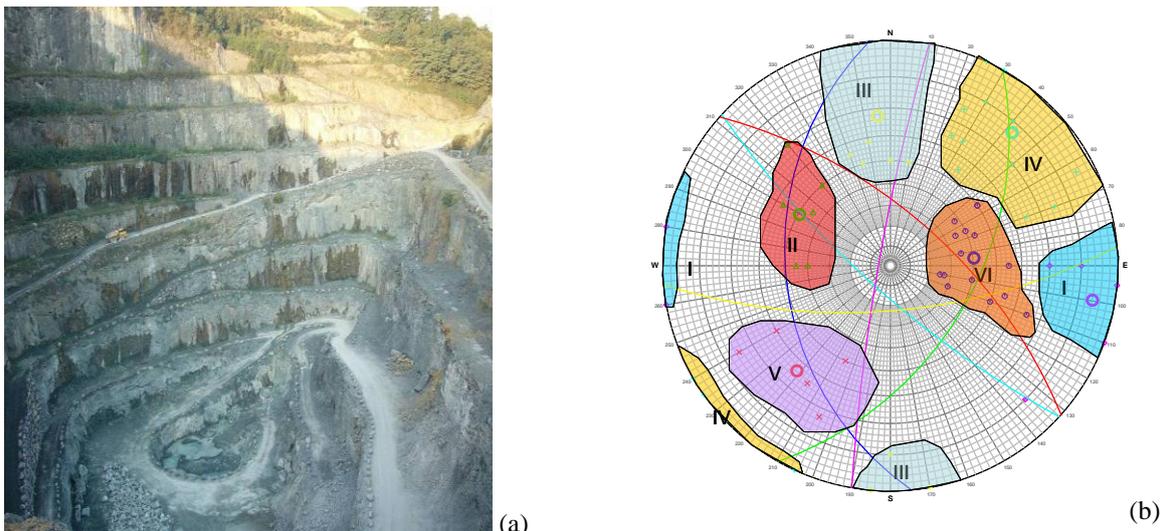


Fig.1 (a) General view of the site. (b) Main fracture sets in the quarry (upper hemisphere projection)

Mechanical and physical properties of the blocks, and contact laws

For the rock mass characteristics, the friction coefficient equals 0.5 and the rock mass density equals 3.2 g/cm³. The *in situ* friction coefficient for this type of rock is approximately 0.78 but in the simulations presented in this study, the value 0.5 was considered for safety reasons

Rigid type elements were used for boundaries of the models and the dynamic simulation of earthquake oscillation was applied to the lower boundary of the model in the normal and tangential directions.

For calculations using finite element mesh,(not presented in this short paper) the typical values of elastic modulus and Poisson's ratio for ophite in this quarry were considered 70 GPa and 0.2, respectively. This elastic modulus is relatively low with respect to values determined experimentally for ophite. The friction coefficient was considered equal to 0.5, in order to assess the dynamical behaviour of the slope in the worst mechanical conditions.

Input of the dynamic load

In this study, we simulated the seismic load by continuous sinusoidal pulses which were applied simultaneously normally and tangentially to the lower boundary of the rock slope. The direct input of accelerograms is possible [9].

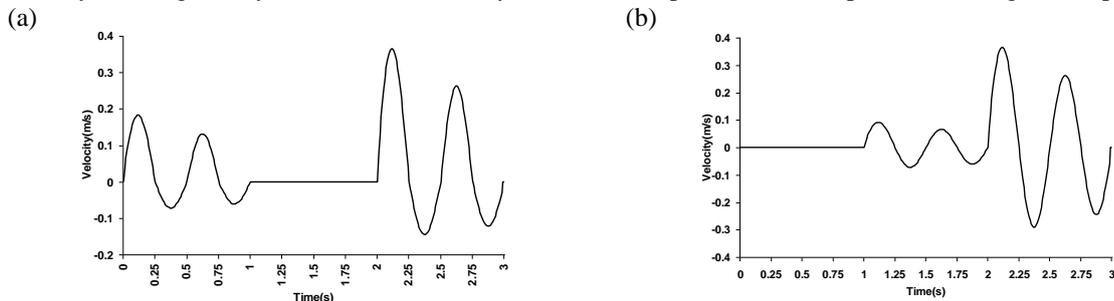


Fig.2: (a) vertical and (b) horizontal earthquake velocities (m/s) input versus time at the base element of the model..

Fig.2 shows the sinusoid graphs used for the generation of the seismic oscillations for 3 seconds. In comparison with a real earthquake, its intensity may appear to be high.

3D modelling was performed for a section of the quarry and for a model that considers the first bench. The results of displacements in the vertical direction derived from both the gravity acceleration and the application of the intensive earthquake with velocity variations illustrated in Fig. 2 are shown in Fig.3. As can be seen, there is a great instability in the second bench level.

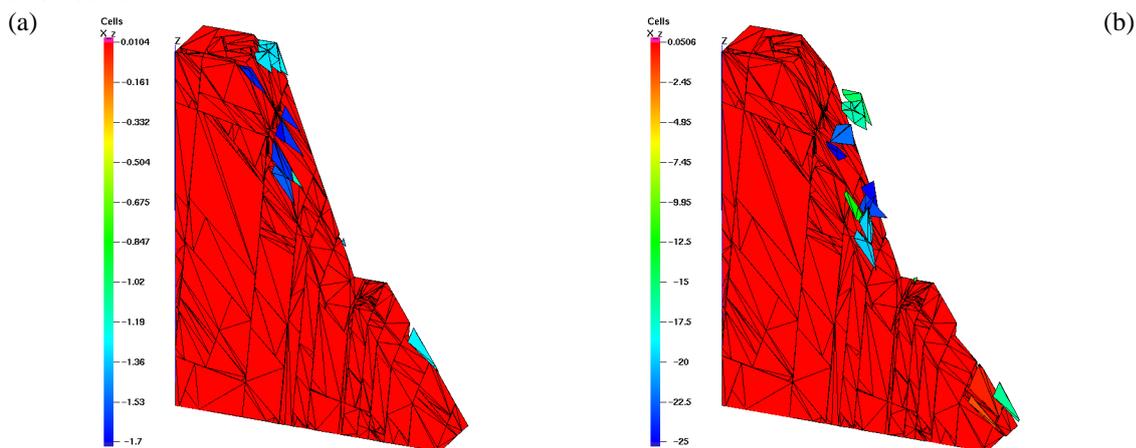


Fig.2: Vertical displacements in meters for the 3D section, (a) after the first second, (b) after three seconds.

References

- [1] Cundall P. A. (1980) UDEC a generalized distinct element program for modelling jointed rock. *Report PCAR-1-80, Peter Cundall Associates, European Research Office, US Army Corps of Engineers.*
- [2] Moreau J.J. (1988) Unilateral contact and dry friction in finite freedom dynamics. *International Centre for Mechanical Sciences, Courses and Lectures. 302:1-82*, (Editors: J.J. Moreau, P.D. Panagiotopoulos, Springer, Vienna).
- [3] Jean M., Moreau J.J.(1991) Dynamics of elastic or rigid bodies with frictional contact and numerical methods. *Publications du Laboratoire de Mécanique et d'Acoustique de Marseille, France*, 9-29, (Editors: R. Blanc, P. Suquet, M. Raous)
- [4] Jean M. and Moreau J.J. (1992) Unilaterality and dry friction in the dynamics of rigid body collections. *Proceedings of the Contact Mechanics International Symposium*, 31-48 (Editor A. Curnier).
- [5] Jean M. (1995) Frictional contact in collections of rigid or deformable bodies: numerical simulation of geomaterial motions. *Mechanics of Geomaterial interfaces*, 463-486
- [6] Heuze F, Morris J (2007) Insights into ground shock in jointed rocks and the response of structures there-in. *International Journal of Rock Mechanics & Mining Sciences*, **44**:647-676.
- [7] Jimenez-Rodriguez R, Sitar N. (2006) Spectral method for clustering of rock discontinuity sets, *International Journal of Rock Mechanics & Mining Sciences*; **43**:1052-1061.
- [8] Rafiee A., Vinches M. (2008) Application of Geostatistical Characteristics of Rock Mass Fracture Systems in 3D Model Generation. *International Journal of Rock Mechanics and Mining Sciences*, **45**:644-652.
- [9] Rafiee A., Vinches M., Bohatier C. (2008) Modelling and analysis of the Nîmes arena and the Arles aqueduct subjected to a seismic loading, using the Non-Smooth Contact Dynamics method, *Journal of Engineering Structures*, **30**:3457-3467.