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Evaluation of relative density effects on liquefiable sands using PM4Sand model

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To simulate the behaviour of saturated sands under cyclic loading, the PM4Sand constitutive model (version 3.1) formulated by Boulanger & Ziotopoulou [1], is used. The model can realistically reproduce the pore pressure build-up, accumulation of strain as well as triggering of liquefaction. The effect of different relative densities on liquefaction resistance is evaluated by comparing the results of a site response analysis performed on a soil column characterized by a saturated sand layer and subjected to given earthquake signals. The analyses are performed using the finite element code PLAXIS.

Aim

To show the role that the relative density in the PM4Sand model plays on the liquefaction potential, through:

- cyclic DSS tests using a single stress point constitutive driver;
- finite element-based one-dimensional site response analyses.

The constitutive model

The PM4Sand model is an elasto-plastic, stress-ratio-controlled, critical state compatible, bounding surface plasticity model, based on the Dafalias -Manzari model [2]. The PM4Sand model has become available in the geotechnical finite element software PLAXIS 2D [3].

Characteristics:

- 4 surfaces: the yield, bounding, dilation and critical state surface;
- current state defined by ξ_R (relative state parameter index equal to D_R - $D_{R,\,CS}$), evolving with the mean effective stress and/or void ratio;
- primary parameters to be calibrated are the shear modulus coefficient G_0, the relative density D_R, the contraction rate parameter h_{p0}**;**
- default values are assumed for the secondary parameters.

Effect of the relative density on Cyclic DSS tests

- undrained stress-controlled cyclic DSS tests;
- anisotropic consolidation with K_0 equal to 0.5;
- initial vertical stress σ'_v equal to 100 kPa;
- different shear stress amplitude for different D_R (Table 1), equal to the value that triggers liquefaction at 3% shear strain, applying 15 uniform cycles.

D_R	$(N_1)_{60}$	G_0	$CRR_{M=7.5,\ 1atm}$	h_{p0}
0.35	6	476	0.090	0.53
0.55	14	677	0.147	0.40
0.75	26	890	0.312	0.64

Table 1. PM4Sand primary parameters: values and cyclic resistance ratios for different D_R.

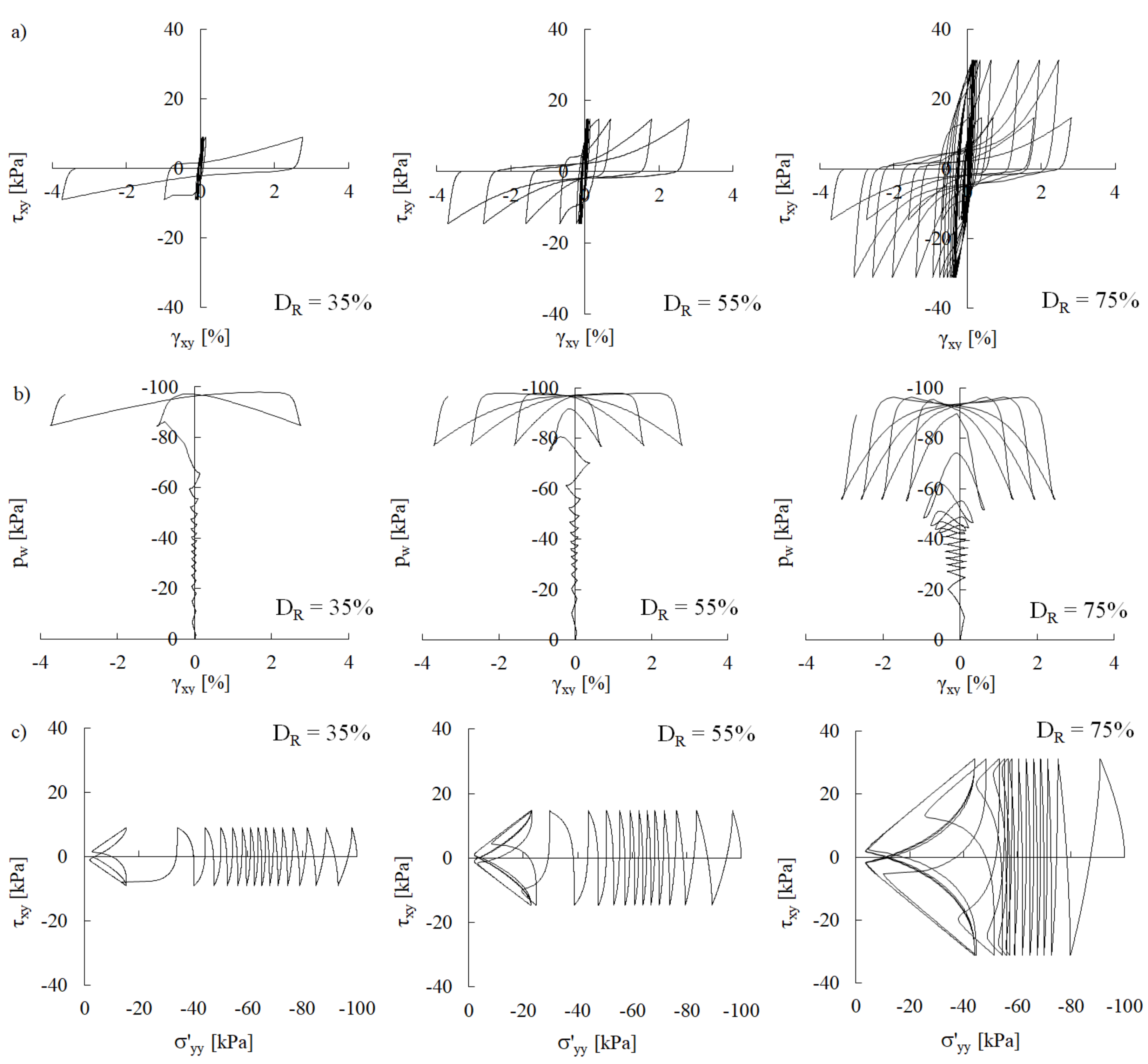

Figure 1 - Results from cyclic DSS test for 3 different relative densities. Shear stress vs. shear strain (a), pore pressure vs. shear strain (b), shear stress vs. vertical effective stress (c).

Effect of the relative density in a one-dimensional site response analysis

- soil column with tied degrees of freedom as lateral boundary condition;
- 3 different outcrop motions (Loma Prieta, Kalamata and Northridge earthquakes): a_{max} = 0.3g, different frequency content and duration.

Results and conclusion

- the model is capable of accumulating shear strains and excess pore pressures while the effective vertical stress tends to zero, leading to liquefaction after 15 stress-controlled loading cycles (Figure 1);
- generated butterfly shape during final loops, when the stress state moves up and down along the failure envelope (Figure 1);
- the cyclic resistance ratio increases with increasing D_R (Figure 1);
- the loose and medium loose sands liquefy in the case of all three selected earthquakes (Figure 2);
- the evolution of the pore pressure ratio, r_u, shows that the onset of liquefaction occurs at different times based on the characteristics of the earthquake, but it seems to be independent from the relative density of the saturated sand (Figure 3);
- the dense sand does not liquefy: after an initial increase of r_u, the excess pore pressures are partially dissipated (Figures 2 and 3).

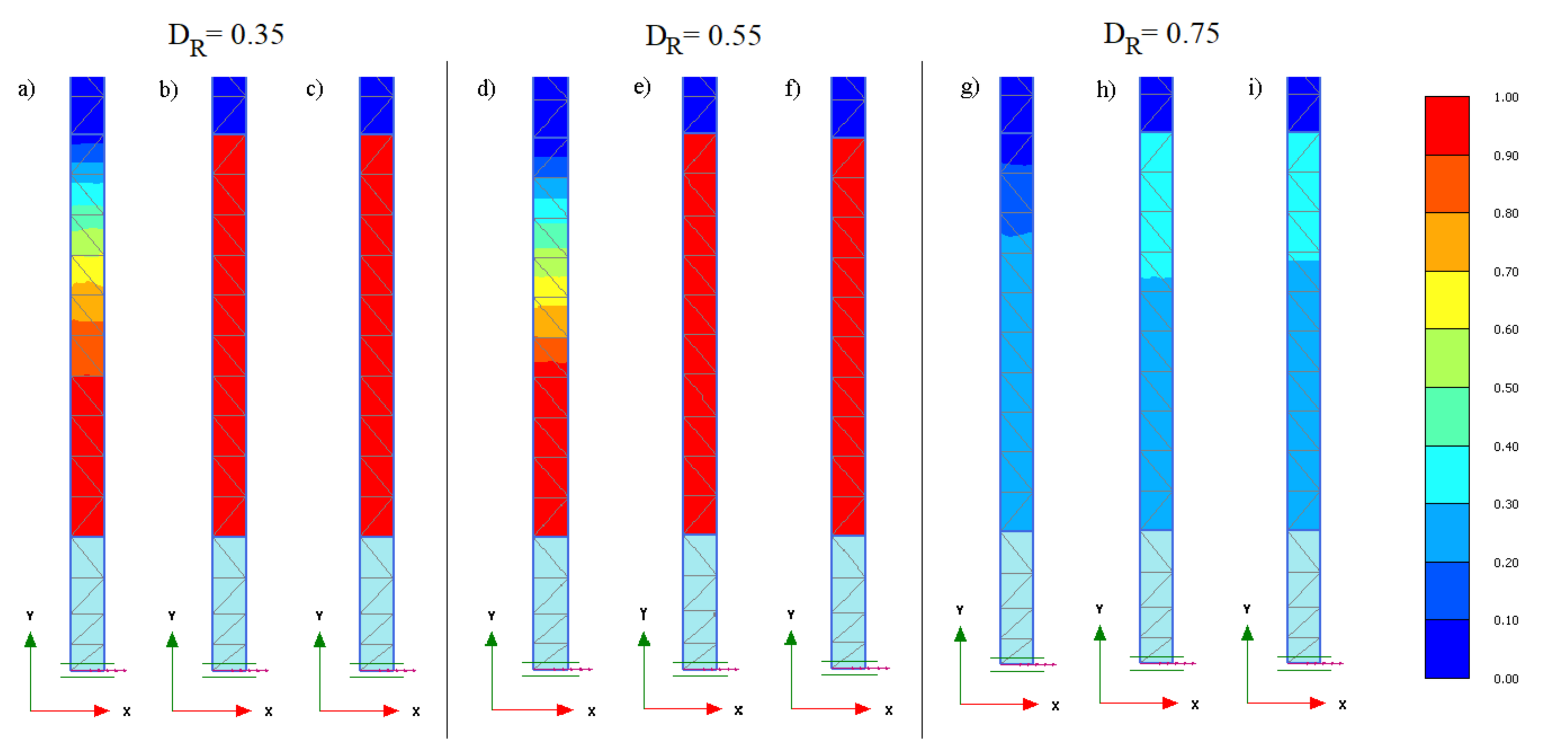

Figure 2 - Maximum pore pressure ratio contours for Loma Prieta earthquake (a, d, g), Kalamata earthquake (b, e, h) and Northridge earthquake (c, f, i) for different relative densities.

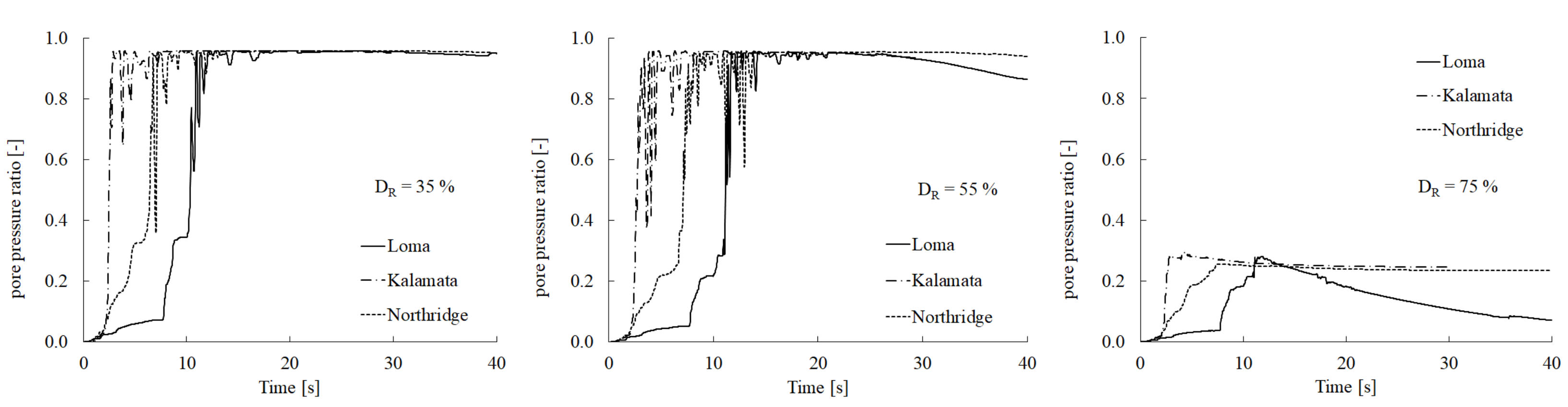

Figure 3 - Comparison of the pore pressure ratio evolution for loose (left) and medium loose (center) and dense (right) sand, for different earthquake recordings.

References

[1] Boulanger, R.W. & Ziotopoulou, K. 2017. PM4Sand (Version 3.1): A sand plasticity model for earthquake engineering applications. Report *No. UCD/CGM-17/01*, Center for Geotechnical Modeling, Department of Civil and Environmental Engineering, University of California, Davis, CA.

[2] Dafalias, Y.F. & Manzari, M.T. 2004. Simple plasticity sand model accounting for fabric change effects. *Journal of Engineering Mechanics,* ASCE, 130(6), 622-634.

[3] Vilhar, G., Laera, A., Foria, F., Gupta, A. & Brinkgreve, R.B.J. 2018. Implementation, Validation, and Application of PM4Sand Model in PLAXIS. *GEESD V. Geotechnical Special Publication*. GSP 292. 200-211.

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