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Liquefaction damage potential for seismic hazard evaluation in urbanized areas

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ABSTRACT

The liquefaction susceptibility of granular soils under seismic actions is commonly estimated by means of the liquefaction safety factor and recently by the potential index also. Since its original formulation the potential index has been developed and modified according to both deterministic and probabilistic approaches in order to draw liquefaction microzonation maps. In this study a new approach to potential index definition is proposed in order to relate the liquefaction potential prediction to the loss of bearing capacity for shallow foundation. Such new method has been used to estimate the so called liquefaction damage potential P_{DL} at Barletta site, located in Puglia Region, where strong seismic events may occur.

1. Introduction

Over the last forty years significant enhancements have been developed in understanding the liquefaction phenomenon as shown by some comprehensive overview papers [1–4]. From practitioner standpoint, according to Eurocode 8 [5] an index of safety against liquefaction (FSL) is required for designing purpose; thus, for such exigency, many contributions have been devoted to update the simplified methods [3]. Such methods are commonly based on the calculation of ratio between the soil resistance to liquefaction, named cyclic resistance ratio (CRR), and the seismic action, which is responsible for liquefaction, named cyclic stress ratio (CSR):

$$\mathrm{FSL} = \frac{\mathrm{CRR}}{\mathrm{CSR}} \tag{1}$$

Both CRR and CSR can be evaluated at chosen depths according to well known formulations recently updated. With respect to the CSR calculation, the most used formula – suggested by Idriss and Boulanger [2] – is the one that refers to a 7.5 moment magnitude and an effective vertical stress σ'_{v0} equal to 1 atm:

$$CSR_{M=7.5,\ \sigma=1} = 0.65\left(\frac{\sigma_{v0} a_{max}}{\sigma'_{v0}}\right)\frac{r_d}{MSF}\frac{1}{K_\sigma} \tag{2}$$

$$MSF = 6.9\exp\left(-\frac{M}{4}\right) - 0.058 \tag{3}$$

$$\ln(r_d) = \alpha(z) + \beta(z)M \tag{4}$$

$$\alpha(z) = -1.012 - 1.126\sin\left(\frac{z}{11.73} + 5.133\right)$$
$$\beta(z) = 0.106 + 0.118\sin\left(\frac{z}{11.28} + 5.142\right) \tag{5}$$

$$K_\sigma = 1 - C_\sigma \ln\left(\frac{\sigma'_{v0}}{P_a}\right) \le 1 \tag{6}$$

$$C_\sigma = \frac{1}{18.9 - 2.55\sqrt{(N_1)_{60}}} \le 0.3 \tag{7}$$

where σ_{v0} and σ'_{v0} are the total and effective stresses at the chosen depth, a_{max} is the maximum acceleration expected at the site, r_d is the stress reduction coefficient, which takes into account the deformability of the soil that varies according to the depth (see Fig. 1 and Eqs. (4) and (5)) up to 34 m depth; MSF (that must be taken MSF $\le$ 1.8) is the magnitude scaling factor of the considered earthquake, measured by M that is the magnitude expressed by the moment magnitude scale (Eq. (3)). MSF is needed, (in Eq. (2)), whenever the seismic event magnitude differs from 7.5. Thus, this factor modifies the equivalent uniform shear stress according to the greater or lower magnitude of the considered seismic event. Finally K_σ is the overburden correcting factor for cyclic stress ratios according to Eq. (6) and (7).

Furthermore, in Eq. (2) a_{max} represents the seismic action at the investigated site. It can be calculated by a local amplification study performed by means of numerical code as EERA [6] or

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