SIMPLIFIED METHOD FOR EVALUATION OF SOIL-STRUCTURE INTERACTION EFFECTS IN LIQUEFIABLE SOILS

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The liquefaction phenomenon is one of the conditions which cause the nonlinear behavior of soils (e.g., Kramer, 1996). There are many samples of structural damages in the world in which the main reason for instability was pore-pressure buildup during an earthquake. However, the effect of pore-pressure buildup has usually not been considered in the substructure method. In this paper, the horizontal, vertical, and the rotation deformation of structures were elaborated in the substructure method for liquefaction conditions. The soil nonlinear behavior in liquefaction phenomenon was estimated using equivalent linear method based on (Khodakarami and Lashgari, 2018). It was used to predict pore-pressure buildup and stiffness of soil during earthquake. For this purpose, a computer code was developed to resolve the governing equations (NIST, 2012) of the MDOF system by the Newmark-β method. The deformations degrees of freedom were shown in Figure 1. As shown in this figure, the horizontal springs were connected in series form. The verification of the results by a centrifuge study (Mehrzad et al., 2016) indicates that this developed code can provide reasonable results and this method is valid when the soil is completely liquefied.

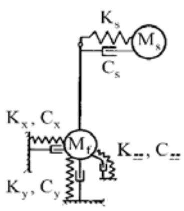

Figure 1. Free-body diagram of MDOF system.

Based on the Structural Engineers Association of California (SEAOC), two different types of structures including the 3 and 9-story structures with the moment-resisting frame system (NIST, 2012; Naeim, 1989) were used to analyses during seismic records. The soil properties and seismic records are respectively shown in Tables 1 and 2.

The seismic records were selected based on the different seismic hazard levels (Livaoglu, 2008).

Table 1. Properties of the soil.

Soil type	ξ	$E_{soil}(kN/m^2$	$G_{soil}(kN/m^2$	$\gamma_{soil}(kN/m^2)$	ν	$V_s(m/s)$
S1	5	500000	192310	1900	0.35	309.22
S2	5	150000	57690	1900	0.35	169.36
S3	5	75000	26790	1800	0.4	120.82

Table 2. Characteristics of used earthquake records.

Earthquake name	year	PGA (g)	Magnanimous (R)	Effective time	Seismic hazard level	Time step
Tabas (E_1)	1978	0.047	7.35	24.2	low	0.011
San Fernando (E_2)	1971	0.1	6.61	11.3	medium	0.00365

The horizontal stiffness, displacement and excess pore water pressure were shown for Tabas earthquake in Figure 2. In this paper, the models were named $S_iE_jN_kD_0$, where S is the soil type, E is earthquake number, N is the number of floors and D is the burial depth. Figure 2 indicates that the higher the seismic hazard level can significantly increase the horizontal displacement of structure when generation of pore water pressure in liquefaction condition. Accordingly, it is necessary that the substructure method was modified for liquefaction conditions in soil-structure interaction analyses.

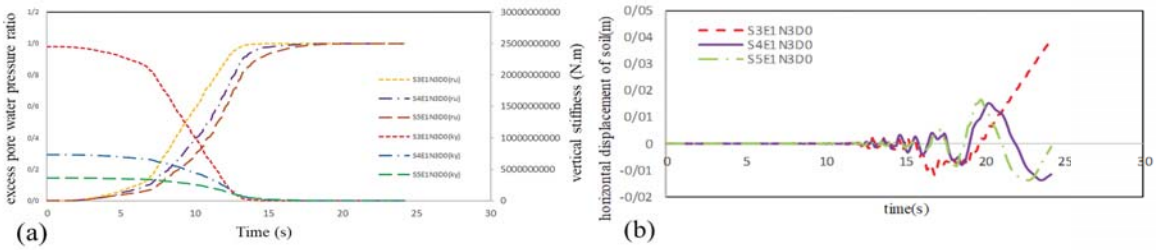

Figure 2. (a) Horizontal stiffness and excess pore water pressure of soil diagram (b) horizontal displacement of soil diagram for three-story structure during the Tabas earthquake.

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