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THE EFFECT OF SOIL PARAMETERS ON THE RESPONSE OF STRUCTURES SUBJECTED TO MULTICOMPONENT EARTHQUAKE EXCITATION

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In order to consider the uncertainty in the ground motion direction with respect to the structure main axes, i.e. incident angle, two simplified approaches have been followed by designers: 1) Considering 100% of seismic force in one direction superimposed by a percentage, e.g. 30% or 40% of the prescribed force in the orthogonal direction, i.e. so-called 100/30 or 100/40 rules (AASHTO, 2010); 2) Computing the response of a structure for 100% of seismic force in two orthogonal directions and calculating the maximum probable response by Square Root of the Sum of the Squares (SRSS) method (Wilson et al., 1995).

Over the last decades, several investigations have been performed to evaluate the accuracy of such approaches to combine the response of structures due to multicomponent earthquake excitation. An explicit formula to determine the critical angle of ground motion excitation and corresponding maximum response of structures has been derived by analytical approach (Lopez et al., 2000). For a number of five-story concrete buildings with elastic material, critical angles for stated maximum responses were determined (Fernandez-Davila et al., 2000). Performing nonlinear time-history analyses for bridges, the 100/30, 100/40, SRSS combination rules and their accuracy were evaluated (Bisadi & Head, 2011). Kostinakis et al. (2018) studied the seismic incident angle's effect on the response of buildings with symmetric plan subjected to bi-directional horizontal excitation to specify responses which were not influenced compared to the ones with largely influenced. Furthermore, for an embankment dam the effect of incident angle of ground motions on the engineering demand parameters was investigated by performing equivalent linear analysis (Davoodi & Sanjari, 2019).

In this paper, the seismic response of a number of steel frames, with 4m×4m dimensions in plan and 3.5 m height, subjected to multicomponent earthquake excitation was investigated using a numerical model in OpenSees. For elastic materials of beams and columns, a number of nonlinear time-history analysis was performed while 0.05 damping ratio was applied using Rayleigh damping parameters. The soil beneath the foundation was simulated adopting Cone Model to represent the four soil types discussed in the Iranian Standard No. 2800, 4th edition (BHRC, 2014), as shown in Table 1. The Cone Model introduced by Wolf (1998) is based on the Spring-dashpot-mass model to consider the translational, rotational and rocking motions of soil-foundation-structure connection instead of fixed base.

The results obtained for paired-time histories of Tabas earthquake were compared to the corresponding ones obtained by the above-mentioned combination rules. In addition, to illustrate the effect of Soil-Foundation-Structure Interaction (SFSI) on the responses, the results of the Fixed Based (FB) model were compared to the corresponding models considering SFSI by utilizing Cone Model.

The axial force in column No. 1 for different SFSI conditions and subjected to multicomponent of Tabas earthquake scaled to 0.4 g was calculated and presented in Table 2. As indicated in Table 2, considering SFSI for a structure the results of conventional approaches to calculate the seismic force in orthogonal direction, i.e. 100/300 or SRSS, is closer to paired time histories.

Table 1. Parameters of the soil underneath the foundation, Iranian Standard No. 2800, 4th edition (BHRC, 2014).

Type	Description	Density (kg/m3)	Shear Wave Velocity (m/sec)
I	Rock	2700	900
II	Very dense sand or gravel	2100	500
III	Moderately dense sand or gravel	1800	250
IV	Loose sand	1200	30

Table 2. Axial force in the column No. 1, calculated using different combination methods for the building frame subjected to Tabas earthquake and considering SFSI for different soil parameters.

Soil-Foundation-Structure connection, Soil Type	F_0 (kN)	F_{90} (kN)	F_{SRSS} (kN)	$F_{100/30}$ (kN)	$F_{100/40}$ (kN)	F_{Paired} (kN)
Fixed Based	23.7	12.5	26.8	27.4	28.7	33.6
SFSI, Type I	20.6	13.3	24.5	24.5	25.9	26.7
SFSI, Type II	20.5	13.3	24.4	24.4	25.9	26.7
SFSI, Type III	20.4	13.3	24.3	24.3	25.7	26.6
SFSI, Type IV	18.2	12.2	21.9	21.9	23.1	19.2

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