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Soil-structure interaction effects on the seismic performances of reinforced concrete moment resisting frames

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Abstract

The paper investigates the influence of Soil-Structure-Interaction (SSI) effects on the seismic performances of 2D reinforced concrete (RC) moment resisting frames (MRFs), which were investigated by means of non-linear dynamic analyses. The goal was pursued by means of a parametric study in which (1) the soil properties, (2) the modelling technique of the SSI effects, (3) the seismic design level of the structures were varied. The soil classes suggested by Eurocode 8 were taken as reference to define the mechanical properties of soil. As concerns the SSI modelling, both a sub-structures approach and a direct approach were considered. Finally, structures of 4 and 8 floors designed for vertical loads only or according to the Italian regulations for constructions (NTC-08) were considered. RC-MRFs founded on soft soils were considered, because SSI effects on the seismic response are expected higher. The study shows that SSI affects the seismic demand in terms of maximum base shear and maximum inter-story drift ratio with different significance depending on the modelling approach.

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Keywords: Soil Structure Interaction; Dynamic Analyses; RC Moment resisting frames

1. Introduction

In this paper, the results of a parametric study performed with the aim to investigate the effects of the Soil-Structure Interaction (SSI) on the seismic performances of reinforced concrete (RC) moment resisting frames (MRFs) are shown. Nonlinear dynamic analyses were performed varying (i) the soil properties, (ii) the modelling technique of SSI effects, (iii) the seismic

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design level of the structures. As concerns the soil, the different classes suggested by Eurocode 8 [1] were referenced, while as concerns the modelling technique of SSI effects, both a "direct" approach and a "sub-structures" were considered. Finally, structures of 4 and 8 floors designed for vertical loads only or according to the current Italian regulations for constructions [2] were considered. Before showing the results of the analyses, the reference structures are introduced, as well as the selected records and the mechanical properties of the soil deposits assumed for the numerical analyses. Moreover, some explanations about the numerical models implemented in OpenSees are provided.

2. Analyses

Four different 2D RC MRFs were selected as reference structures. They can be considered as inner frames of "in-plan" regular 3D buildings. The structures were designed according to different seismic code levels, in order to capture different periods of construction. Two of them were designed for gravity loads only (i.e. with no seismic provisions) according to [3], while two were designed with high level of seismic details according to the current Italian seismic code [2]. Table 1 summarizes the main characteristics of the reference structures, namely the total mass, the concrete and steel strength adopted in the numerical models and the fundamental elastic period. Further details about the structures analyzed in the study can be found in [4]. As concerns the soil properties, two types of clays (medium and soft), sortable respectively as soil type C and D according to [1] (see Table 2), were considered in order to obtain significant SSI effects [5].

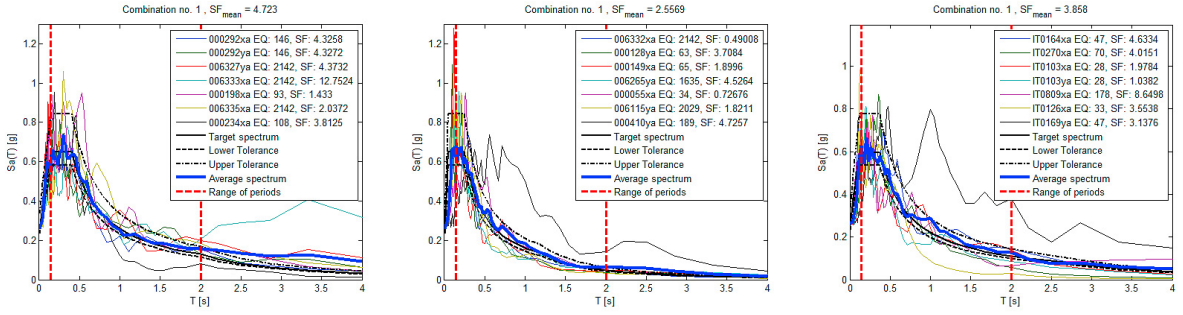
Table 1. Reference structures: main properties

Building	Total Mass (t)	f_c (MPa)	f_y (MPa)	$T_{1,fix}$ (s)
No Code - 4 Floors	290.6	17	380	0.97
No Code - 8 Floors	647.2	17	380	1.14
With Code - 4 Floors	292.9	25	450	0.65
With Code - 8 Floors	692.8	25	450	0.92

Table 2. Soil properties

	Soil Type C	Soil Type D
Height of the deposit	30 m	30 m
Type of Soil	Clay	Clay
Plasticity Index	15%	100%
Shear Wave Velocity (V_{s0})	250 m/s	160 m/s
Density (ρ)	2.0 t/m^3	1.6 t/m^3
Cohesion (c)	65 kPa	49 kPa

A set of 21 records was used for the dynamic analyses. In particular, three different sets of seven accelerograms were chosen by means of the software Rexel [6], respectively compatible on average with the Eurocode 8 type 1 spectrum (Group1), Eurocode 8 type 2 spectrum (Group 2) and Italian D.M. 14/01/2008 (Group 3). All the records refer to site conditions classified as rock according to EC8 (soil type A) with moment magnitude (M_w) and epicentral distance (R) that range between $5.0 < M_w < 7.0$ and $0 < R < 30$ km respectively. The compatibility with the response spectra was checked in the period range from $0.15\text{ s} < T < 2.0\text{ s}$ (see Fig.1).



Group 1 – EC8 type 1 spectrum b) Group 2 – EC8 Type 2 spectrum c) NTC 08 spectrum

Fig. 1. Selected records: compatibility