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Linear soil–structure interaction of coupled wall–frame structures on pile foundations

Sandro Carbonari [a], Francesca Dezi [b], Graziano Leoni [c,*]

[a] D.A.C.S., Marche Polytechnic University, Ancona, Italy
[b] D.E.T., University of San Marino, San Marino
[c] SAD, University of Camerino, Ascoli Piceno, Italy

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ABSTRACT

The effects of soil–structure interaction on the response of coupled wall–frame structures on pile foundations subjected to moderate earthquakes are investigated in this paper. A linear finite element procedure for a complete dynamic interaction analysis is developed in the frequency domain accounting for soil–pile interaction and radiation damping. The procedure allows accounting for the actual deformability of the soil–foundation system and modification of the input motion due to the embedded foundation. The free-field motion is obtained by means of a local response analysis, which accounts for site amplification. The procedure is adopted to study the effects of compliant pile foundations on the seismic damageability of a coupled wall–frame system. Three different soil profiles are considered and real accelerograms are used as input motions. The calculated results, expressed in terms of the response parameters most significant for the description of damage (such as displacements, inter-storey drifts, accelerations and stress resultants), are compared with those obtained from a conventional fixed-base model. Applications demonstrate that performing complete soil–structure interaction analyses may be crucial for the correct evaluation of the behaviour of such systems.

1. Introduction

Coupled wall–frame structures are seismic-resistant systems widely adopted in buildings due to their structural efficiency. The dynamic behaviour of such systems is very different from that of frames or shear-wall structures because of interactions between the structural components (walls and frames). On one hand, cantilever shear walls are able to absorb a great amount of the total seismic base shear while reducing the inter-storey drifts at the lower storeys while the energy dissipation associated to the flexural damage of the wall is limited since it only develops at the base. On the other hand, frames assure small displacements at the upper storeys and offer a great contribution to energy dissipation. Once a suitable degree of restraint is ensured at the base of the wall, the interactions between walls and frames guarantee successful seismic behaviour. Pile foundations are usually considered to be rigid enough to guarantee the restraint against rocking motions.

Conventional fixed-base models are used to predict the seismic response of these systems although the dynamic Soil–Structure Interaction (SSI) may in fact significantly affect their behaviour. Ignoring the real deformability of the soil–foundation system and site amplification effects may lead to erroneous evaluations of structural displacements, including rocking movements, and member stress resultants, affecting the damage of structural and non-structural elements as well as the lateral loads carrying mechanism.

Even if Eurocode 8 (EC8) [1] has acknowledged that SSI may significantly affect the seismic response of structures and suggests accounting for the flexibility of the soil–foundation system in the design, it also states that for the majority of common building structures, the effects of SSI tend to be beneficial, since they reduce the bending moments and shear forces in the various members of the superstructure [2]. This is valid for a large number of situations but cannot be generalised to all structural typologies and seismic environments, since SSI and site effects may result in a detrimental combination [3–5]. The importance of taking into account the foundation compliance in the evaluation of the structural response has been recognised since the early 70s [6–10]; in the case of coupled wall–frame systems the wall foundation rocking may strongly affect the shear force and bending moment distributions. Furthermore, the contributions of SSI should be evaluated taking into account not only member stress resultants but also other response quantities including displacements.

Even if many works dealing with the SSI effects on the seismic response of structures are available in the technical literature, most of them adopt simplified models for the superstructure analysis (e.g. single degree of freedom system for bridge piers

* Corresponding author.
E-mail address: graziano.leoni@unicam.it (G. Leoni).

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