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Pseudo-dynamic tests on low-rise shear walls and simplified model based on the structural frequency drift

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ABSTRACT

Twelve low-rise shear walls, with the same aspect ratio of 0.4 but with different structural parameters including the design frequency, reinforcement ratio and normal force, have been submitted to pseudo-dynamic (PSD) tests conducted at the ELSA laboratory of the Joint Research Centre. The focus of this testing campaign was to study the engineering margin for shear walls depending on the relative position of their structural frequency with respect to the excitation peak. After presenting the parameters of the PSD tests, three methods for identifying the structural frequency drift observed as damage occurs have been used in this paper: a numerical identification from a nonlinear pushover analysis, and two methods from experimental data, a system identification method based on an error output model and a more direct identification method based on the secant stiffness of force–displacement cycles. For each shear wall, a relationship $f(X)$ between the structural frequency and the maximum of the top-displacement is derived from the previous methods and the consistency between the three approaches has been checked. Finally, these $f(X)$ curves have been employed in a single degree of freedom model for predicting time–history top-displacements. The predictions turn out to be quite satisfactory, in particular when $f(X)$ relationship is identified by the error output model.

1. Introduction

Periodic elongations of RC structures during strong ground shaking, or in other words natural frequency shifts, have been largely observed in numerous *in situ* experimental studies as well as laboratory tests. Periodic elongations of RC framed building structures which have suffered moderate to heavy damage, have been examined by Masi and Vona [1]. They showed that moderate seismic events can cause rather low period elongation of 15%–30%, equivalent to a frequency shift from 13% to 23%, identified from *in situ* tests on instrumented buildings.

On the other hand, Calvi et al. [2] gathered *in-situ* observations into a state-of-the-knowledge on the periodic elongation of RC buildings during strong ground shaking. The change in frequency was either reported as that recorded during the ground motion by using a system identification technique on sliding time windows, or the difference between the frequencies identified by low level vibration tests before and after the seismic event. Instrumented buildings which experienced moderate to strong earthquakes mainly concern north American buildings. Clinton et al. [3] published a summary of a well-known instrumented building, the Milikan library [4], and showed a frequency shift of 15%–30% when subjected to particularly strong ground motions. Others authors underlined changes in frequency of 32% (Naeim, [5]) on buildings which suffered structural damage, whilst high frequency shifts have been reported been by Mucciarelli et al. [6] reaching 50% during Italian earthquakes. Trifunac et al. [7,8] also found large frequency shifts on buildings in California, pointing out the likely influence of the nonlinearities of the foundation soil and the difficulty to split properly the influences of structural and soil/foundation nonlinearities in the resulting frequency shift identified from *in-situ* experimental studies.

Nonetheless, laboratory tests highlighted large frequency shifts due to the sole structural damage. For example, Zembaty et al. [9] showed a frequency shift of 70% using a system identification technique from data obtained for a full size concrete frame subjected to seismic excitation on a shaking table. Pinho [10] also noted a frequency shift of 57% relative to large-scale walls tested on a shake table up to collapse. Infilled RC frames can even experience larger frequency shifts attaining 83% as described by Hashemi and Mosalam [11].

Based on these observations, it is obvious that such strong frequency decreases as damage occurs, play a major role in the

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