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Short communication

Selection of earthquake records for the non-uniform excitation of bridges

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ABSTRACT

Currently, there is no research effort on the efficient selection of earthquake records for the non-uniform excitation of bridges. The present investigation addresses this topic. Initially, the physics of the bridge response to asynchronous seismic excitations are illustrated. Next, two basic criteria are presented to provide insight into the selection of reference ground motions for the simulation of asynchronous excitations. The first criterion is the ratio of the zero-crossings of the reference ground displacement time series (n) to the total duration of the ground shaking (t), which can be evaluated by visual inspection of the displacement time series, and the second is the peak ground displacement. The former criterion is an indicator of the degree of sensitivity of the simulated displacement time series at various separation distances to the loss of coherency, and the numerical results of the present study indicate that the simulated waveforms of earthquake displacements with n/t greater than unity are highly dependent on coherency, i.e. become significantly modified by coherency, and, consequently, are more crucial for the pseudo-static response of bridges subjected to asynchronous seismic excitations. The latter criterion is also directly related to the magnitude of the pseudo-static force induced in the bridge structure. Finally, a brief discussion on the selection strategy of earthquake records for the seismic assessment of bridges is provided.

1. Introduction

The selection of uniform vs. non-uniform seismic excitation is an important consideration in the seismic assessment of bridges [36,37]. As seismic waves travel from the source to the ground surface, their characteristics, such as amplitude and phase, change depending on their path [3,9,18]. The spatially varying seismic ground motions (SVSGMs) are caused by the wave passage, extended source, scattering and attenuation effects, surface and subsurface topography, and spatial/temporal variability in soil properties. As a rule of thumb, SVSGMs are not considered influential in the seismic excitation of small-scale structures, if the soil properties are approximately uniform along the structure. However, the numerical results of an investigation by Heredia-Zavoni and Barranco [19] showed that they may be even crucial in the seismic response of ordinary buildings. SVSGMs affect the structural response by modifying the contribution of higher modes of vibration, and inducing pseudo-static forces in the structure [35]. For bridges with stiff deck and flexible columns, the columns will be subjected to very high flexural, shear force and deformation demands, and, on the other hand, for bridges with flexible decks and stiff columns, the deck will be subjected to excessive in-plane bending [32]. There are various factors that may affect the non-uniform excitation of bridges, such as rotational ground motions; soil-structure interaction; non-uniform damage at piers, bearings and foundations, and pounding [11,14,28,29].

The effect of the SVSGMs has been partially addressed in most bridge design codes that recommend an increase of the seating length [4,6,20]. Currently, Eurocode 8-Part 2 [10] is the only design code that proposes simplified and analytical procedures for the incorporation of the SVSGM effect in seismic analyses. The reliability of the proposed methodology has been discussed in the literature [13,36], and methods have been set forth to improve the accuracy of the simplified procedure [12,24,30]. The analytical procedure proposed by Eurocode 8-Part 2 [10] recommends a simulation approach for generating SVSGMs. Since recorded time series at closely spaced locations are rare, the seismic analysis of bridges is usually conducted using simulated ground motions consistent with a prescribed spatial variability model (e.g. [9,23,27]) for the region of interest. The SVSGMs are artificially generated by means of unconditional or conditional simulation methods (e.g. [8,17,22,34]). Conditional simulations represent more realistic ground motions than unconditional ones, because they are based on a reference (seed) time series, which can be an actual recorded or a synthetic ground motion [36].

The record-to-record variability is the most important uncertainty in seismic assessments (e.g. [11]), and, as a consequence, there are

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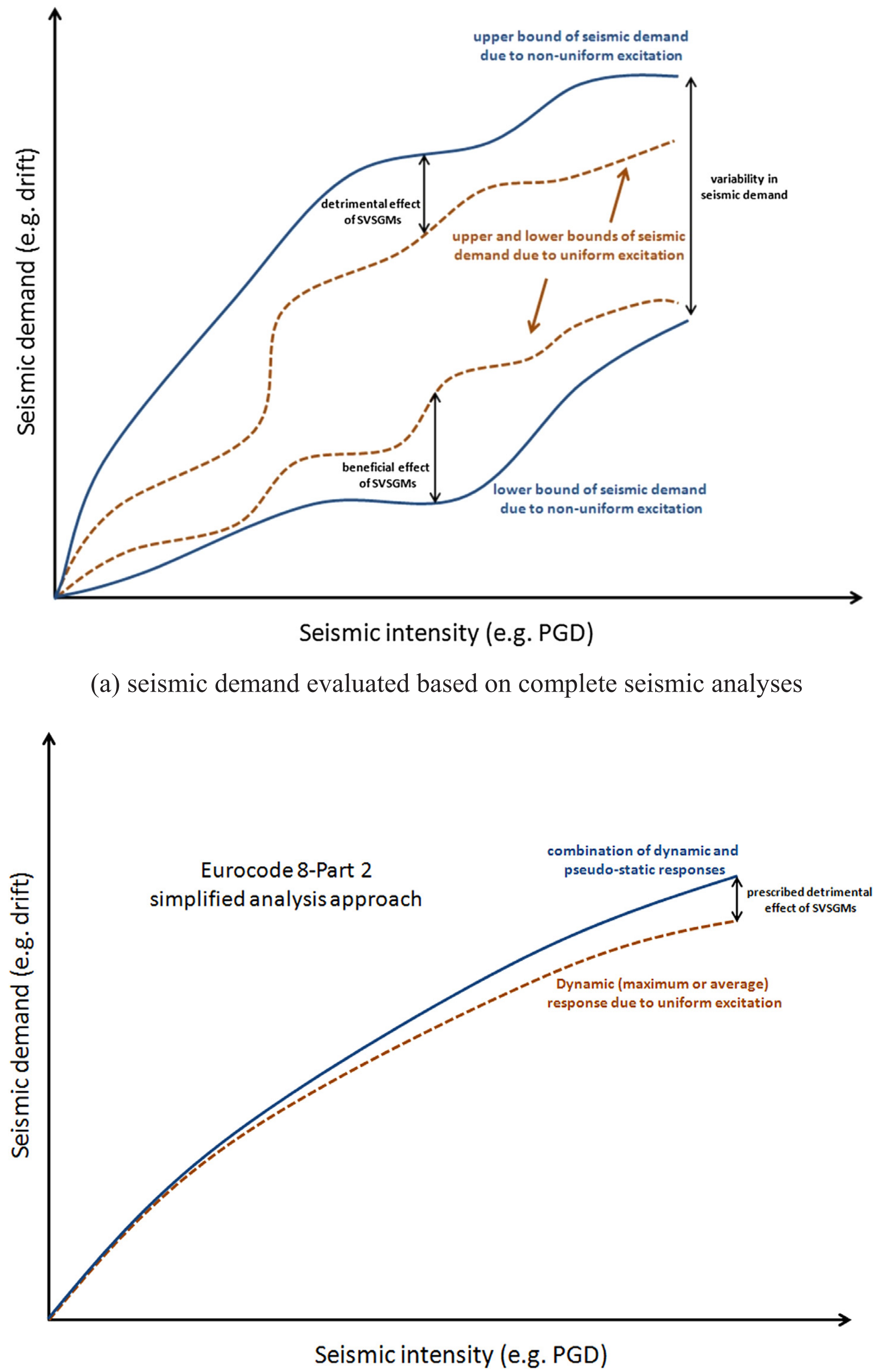

(a) seismic demand evaluated based on complete seismic analyses

(b) seismic demand evaluated based on the simplified procedure proposed by Eurocode 8-Part2 (10)

Fig. 1. Typical variations in the seismic demand of bridges due to the uniform and non-uniform excitations.

extensive studies on the appropriate selection of earthquake records for the uniform seismic excitation of structures (e.g. [1,7,15,21,38]). However, no research effort has addressed the selection of the reference time series for the non-uniform seismic excitation of multiple-support structures, which is the focus of the present study.

2. Seismic response of bridges under non-uniform excitations

There is no agreement on the beneficial or detrimental influence of non-uniform excitations on the seismic response of bridges compared to that of uniform ones. The only common consensus in the literature is that the effect of the SVSGMs on the seismic behavior of bridges is very complicated, and can significantly increase the uncertainty in the