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Engineering design earthquakes from multimodal hazard disaggregation

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ABSTRACT

To define reference structural actions, engineers practicing earthquake resistant design are required by codes to account for ground motion likely to threaten the site of interest and also for pertinent seismic source features. In most of the cases, while the former issue is addressed assigning a mandatory design response spectrum, the latter is left unsolved. However, in the case that the design spectrum is derived from probabilistic seismic hazard analysis, disaggregation may be helpful, allowing to identify the earthquakes having the largest contribution to the hazard for the spectral ordinates of interest. Such information may also be useful to engineers in better defining the design scenario for the structure, e.g., in record selection for nonlinear seismic structural analysis. On the other hand, disaggregation results change with the spectral ordinate and return period, and more than a single event may dominate the hazard, especially if multiple sources affect the hazard at the site. This work discusses identification of engineering design earthquakes referring, as an example, to the Italian case. The considered hazard refers to the exceedance of peak ground acceleration and 1s spectral acceleration with four return periods between 50 and 2475 year. It is discussed how, for most of the Italian sites, more than a design earthquake exists, because of the modeling of seismic sources. Furthermore, it is explained how and why these change with the limit state and the dynamic properties of the structure. Finally, it is illustrated how these concepts may be easily included in engineering practice complementing design hazard maps and effectively enhancing definition of design seismic actions with relatively small effort.

1. Introduction

Earthquake resistant design in international seismic codes relies widely on a target spectrum to define seismic actions on structures. Being a synthetic representation of ground motion, the design spectrum should implicitly include information about the features of the seismogenetic sources determining the seismic hazard at the construction site. Nevertheless, prudently, the practitioner is often required to also account explicitly for them, for example, when dealing with ground motion record selection as an input for the nonlinear seismic structural analyses (e.g., [1,2]). For example, Eurocode 8 [3], or EC8, provides that: *In the range of periods between 0.2T_1 and 2T_1, where T_1 is the fundamental period of the structure in the direction where the accelerogram will be applied, no value of the mean 5% damping elastic spectrum, calculated from all time histories, should be less than 90% of the corresponding value of the 5% damping elastic response spectrum.* Moreover, accelerograms should be *adequately qualified with regard to the seismogenetic features of the sources* […].

In most of the cases, it is unlikely that the engineer has the information and/or is able to qualify the input ground motions with respect to the seismological features of the seismic sources.[1] However, if the design spectrum is related to probabilistic seismic hazard analysis (PSHA), it is possible to obtain *design earthquakes* (DEs) in terms of magnitude, location and other parameters such as faulting style, hanging/foot wall, etc.

In fact, PSHA allows one to compute the average return period of ground motions exceeding a given intensity measure (*IM*) threshold at the considered site [4]. On the other hand, if the return period of seismic action for design purposes is defined *a priori*, and if the *IM* is the elastic spectral acceleration at different structural periods, it is possible to build the uniform hazard spectrum (UHS), i.e., the response spectrum with a constant exceedance probability for all ordinates, e.g., 10% in 50 year (or, equivalently, 475 yr return period) in the case of design for life-safety structural performance [5]. UHS is not the only possible PSHA-based design spectrum [6], but it is, to

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[1] EC8 actually requires information about seismic source also in choosing between two possible design spectrum shapes stating that: *If the earthquakes that contribute most to the seismic hazard defined for the site for the purpose of probabilistic hazard assessment have a surface-wave magnitude, Ms, not greater than 5.5, it is recommended that the Type 2 spectrum is adopted.*

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