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Displacement spectra and displacement modification factors, based on records from Greece

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ABSTRACT

Elastic and inelastic displacement spectra (for periods up to 4.0 s) are derived, using a representative sample of acceleration records from Greece, carefully selected based on magnitude, distance and peak ground acceleration criteria, and grouped into three ground type categories according to the Eurocode 8 (EC8) provisions. The modification factor for the elastic design spectrum adopted in EC8 for accounting for damping is verified herein and is found to be satisfactory in the short to medium period range and less so in the long period range. The equivalent viscous damping ratio concept is also evaluated and is found to lead to underestimation of inelastic displacement spectra. Finally, based on the previously derived elastic and inelastic spectra, equations suitable for design and/or assessment purposes, are proposed for the corresponding displacement modification factors.

1. Introduction

During the last decade or so, a large emphasis has been placed on the proper evaluation of the displacement a structure will experience when subjected to an earthquake ground motion that is selected in the framework of design or assessment of the structure. This is mainly due to the fact that limit states (or performance objectives) for the structure can be conveniently and meaningfully expressed in terms of displacements. There are two interrelated, still distinct, situations wherein estimation of displacements is a key issue.

First, in inelastic static (pushover) analysis, currently considered as a valuable tool for seismic assessment of structures, a target displacement is necessary for quantifying the seismic demand on the structure analyzed [1–3]. This is typically evaluated on the basis of the maximum displacement of a single-degree-of-freedom (SDOF) system subjected to the ground motion(s) selected for assessment. The estimate of target displacement should account for the inelastic response of the structure as well as for the difference between the displacement of the SDOF system and that of the 'monitoring point' selected for the actual, multi-degree-of-freedom (MDOF), structure. The effect of inelasticity on the displacement of the SDOF system can be estimated either through an 'equivalent linearization' procedure, as in ATC-40 [2], or through a displacement modification factor that depends on ductility, as in ASCE-FEMA 356 [3].

In another situation, the so called 'direct displacement-based' design [4], or assessment [5], methods require reliable displacement spectra for a broad range of damping ratios, since the expected inelastic response of the structure is conveniently accounted for through a properly damped elastic spectrum and a ductility-dependent equivalent period of the structure (equivalent linearization approach); such elastic spectra for high damping ratios are also important for seismic isolation studies.

Previous works on elastic and inelastic displacement spectra so far concentrated on datasets from North America [6,7], while (to the writers' best knowledge) only one study was based on records mainly from Europe [8]. Although the dataset used in [8] is larger than the one used herein (it included records from all over Europe plus some from the Middle East), several of the records used herein were not included in [8]; notably, 24% of the records used in the present study is from earthquakes that occurred since 1999, a period not covered in the dataset of [8]. Furthermore, that previous study [8] has focussed on one particular version of displacement-based design method and derived the displacement modification factor in terms of the equivalent period of the inelastic system, rather than its initial one, which precludes comparisons with other similar studies such as [1,6,7]; in contrast, the present study addresses both the issue of elastic displacement spectra for several damping ratios and that of the displacement modification factor in terms of the initial period (common to both the elastic and the inelastic system), which is consistent with current trends worldwide and facilitates comparisons with previous studies.

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