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Effects of moment magnitude, site conditions and closest distance on damping modification factors

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ABSTRACT

Damping modification factors (DMF) are used to adjust response spectral values corresponding to damping 5% of critical to other damping levels. Ground motions recorded are orderly grouped according to moment magnitude, site conditions and closest distance. Near-fault motion records with closest distance closer than 10 km are not included in this paper. Based on the classification, the effects of the three seismological parameters on the median DMF are investigated. Consequently, the influence of site class reduces with increasing earthquake magnitude, and the effect of closest distance generally can be neglected with closest distance closer than 100 km except for rock sites. Except for soft soil sites, moment magnitude has a more significant effect than closest distance and site conditions, and the median DMF from acceleration spectra are most sensitive to seismological parameters. For soft soil sites, the median DMF only vary a little with moment magnitude and closest distance.

1. Introduction

Different damping elastic response spectra in structure engineering are required for the design of base-isolated structures and structures with supplementary damping devices, as well as for performance-based design approaches that use equivalent linearization.

The damping modification factors (DMF) are usually defined as functions of the damping ratio and, in some cases, the response period [1–8]. Some of these have been adopted in seismic codes (e.g., Newmark and Hall [1] formulation adopted in the ATC-40 [9] and FEMA-356 [10]; Bommer et al. [6] equation adopted in the EC8 [11]; Ramirez et al. [7] expression adopted in the NEHRP [12,13]). Recently, Lin et al. [14] evaluated five different models of the DMF [1,3,4,15,16] using 216 ground motions recorded on firm sites in California. Cardone et al. [17] evaluated seven different formulations of the DMF [1,4–7,16,18] based on the European, Californian and Japanese earthquake strong-motion databases.

Recently, considering the effects of seismological parameters on the DMF, several scholars further studied DMF. Lin and Chang [16] investigated the effects of site classification (site Classes A–D according to the NEHRP [12]) on the mean DMF. As for the damping modification factors derived from displacement response spectra (DMF_d), the DMF_d for site Classes AB and D are very similar, whereas the DMF_d for site Class C is generally slightly greater than those for the site Classes AB and D. As for the damping modification factors derived from true acceleration response spectra (DMF_a), The DMF_a are more sensitive to site conditions than DMF_d. Bommer and Mendis [19] showed the DMF_d reduce with increasing earthquake magnitude and site-to-source distance using predictive equations and stochastic simulations, which further reflects the dependence of DMF on duration. Besides, the effect of site conditions does not show a consistent pattern. Nevertheless, Bommer and Mendis, taking the recordings from Mexico City of the 1985 Michoacán earthquake as an example, stressed that site effect on the DMF was very pronounced in some cases. The DMF_d proposed by Cameron and Green [20] varied as a function of general site classification, earthquake magnitude and tectonic setting when damping ratios are greater than 2%, whereas the DMF_d for $\xi=1\%$ also depended on site-to-source distance.

Recently, Stafford et al.[21] proposed equations, as a function of significant duration and number of cycle, to estimate DMF for various damping ratios. The results indicate the duration measures are more efficient than the numbers of cycles for predicting DMF, and that significant errors may be introduced if one uses the DMF recommended in codes when considering either very short or very long duration motions as well as for motions containing low or high numbers of equivalent load cycles. Hatzigeorgiou [22] proposed expressions for $DMF_{d,}$ DMF_v and DMF_a. The results show that effect of the source distance can be practically ignored, and that The DMF decrease for site conditions from hard rock to soil. Besides, Hubbard and Mavroeidis [23] proposed a conservative model for the DMF subjected to near-fault ground motions with distinct velocity pulses.

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