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Wave-passage effects on strength-reduction factors for design of structures near earthquake faults

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Abstract

Wave-passage effects are described for strength-reduction factors near faults, for fault-normal and fault-parallel strong-motion displacements. It is shown that the common design rules for selection of the strength-reduction factors are usually conservative and approximately describe the reduction amplitudes near faults of strong earthquakes for fault-normal pulses. However, for fault-parallel displacements, the same reduction factors are not conservative and must be changed. It is recommended that for design close to active faults, the strength-reduction factors for all components of motion should be constant for long periods and equal to $(2\mu-1)^{1/2}$, where μ is ductility. For periods shorter than about 1 s, these strength reduction factors should be further reduced by 30–40%.

Keywords: Strength-reduction factors; Differential motions; Non-linear response; Near field; Earthquake motion; Design of structures

1. Introduction

For many design analyses, the earthquake shaking can be specified at a single point, and the spatial variation of motion at multiple supports of structures may be neglected. When the distances between the multiple support points are large (e.g., bridges, dams, tunnels, long buildings), the effects of differential motions become important and should be considered in dynamic analyses [1]. Spatial and temporal stochastic representations of strong earthquake motion required for such analyses have been investigated [2–4]. The consequences of differential ground motion have been studied for the response of beams [5–7], bridges [8–10], simple models of three-dimensional structures [11], long buildings [12–15] and dams [16–18]. However, with few exceptions, engineering applications of the response spectrum method ignore the wave-propagation effects in the foundation soil, or they consider only a simplified stochastic representation of the differences in motion among separate supports [19–21]. Okubo et al. [22] were among the first to measure and interpret finite ground strains of recorded earthquake motions for plan dimensions representative of intermediate and large buildings. They showed that for short-period (stiff) structures, finite ground strains lead to increased base shears. Zembaty and Krenk [23,24] studied the same model via random vibration-based shear force response spectrum, addressing explicitly the contribution of quasi-static and dynamic terms in the response. They showed that although the relative response of the structure is reduced in the case of differential motion of supports (due to "averaging" of spatially correlated motions), the shear forces in the columns, which for stiff structures primarily depend upon the quasi-static contribution to the response, might be significantly larger than for synchronous excitation.

Simple analyses of two-dimensional models of long buildings suggest that when $a/\lambda < 10^{-4}$, where a is wave amplitude and λ is the corresponding wavelength, the wave-propagation effects on the response of simple structures can be neglected [14]. For shorter waves, but

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