Seismic vulnerability assessment of multi-degree-of-freedom systems based on total input energy and momentary input energy responses

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Abstract: In energy-based seismic evaluation and design, input energy as a seismic demand parameter and hysteretic energy are two important factors. Previous studies for seismic assessment and design based on energy approach have been generally limited to single-degree-of-freedom (SDOF) structures. The purpose of this paper is to find a suitable energy-based parameter for estimation of the damaging potential of ground motion in reinforced concrete frames of multi-degree-of-freedom (MDOF) systems. In this regard, 40 common reinforced concrete frames subjected to four different earthquakes have been analyzed. The results indicate that maximum momentary input energy is a more appropriate parameter than maximum total input energy for estimation of structural damage in short-duration earthquakes or those in which the major damage to structures happens within a short duration of ground motion. In addition, in earthquakes with a wide frequency range, the predominant period of ground motion in Fourier spectrum is shown to be the period corresponding to maximum input energy.

Key words: total input energy, momentary input energy, damage index, multi-degree-of-freedom (MDOF) system.

Résumé : Deux facteurs sont importants pour l'évaluation et la conception sismiques basées sur l'énergie induite : l'énergie sismique et l'énergie hystérèse. Les études précédentes sur l'évaluation et la conception sismiques basées sur l'énergie étaient généralement limitées aux structures à un seul degré de liberté (« SDOF »). Le but du présent article est de trouver un paramètre adéquat basé sur l'énergie pour estimer le potentiel de dommages causés par le mouvement du sol dans les charpentes en béton armé des systèmes à plusieurs degrés de liberté (« MDOF »). À cette fin, 40 charpentes en béton armé ordinaire ont été soumises à quatre différents séismes et ont été analysées. Les résultats indiquent que l'énergie induite instantanée maximale est un paramètre plus approprié que l'énergie induite totale maximale pour estimer les dommages aux structures dans les séismes de courte durée ou ceux dont le dommage principal aux structures survient aprés une courte durée de mouvement du sol. De plus, dans les séismes ayant une large plage de fréquence, la période prédominante de mouvement du sol dans le spectre de Fourier s'avère être la période correspondante à l'énergie d'entrée maximale.

Mots-clés : énergie induite totale, énergie induite instantanée, indice des dommages, système à plusieurs degrés de liberté (« MDOF »).

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1. Introduction

The dynamic damage potential of ground motions is evaluated by structural response. In this regard, it is necessary to indicate what characteristics of ground motions are most appropriate for such evaluation. Generally, the damage potential of ground motions is measured by the maximum acceleration or velocity. However, after the catastrophic earthquakes of Kobe (Japan) and Northridge (USA), the relationship between damage potential of earthquakes and structural damage has become the subject of many recent studies.

Akiyama (1985) has presented the application of an energy-based design procedure, where it was shown that the total input energy spectrum specific to each ground motion that is independent of an inelastic force–displacement relationship, ductility factor, and structural damping, is a suitable index to investigate structural damage and damage potential of ground motions. Bertero and Bertero (1992) presented the conceptual earthquake-resistant methodology for the design of reinforced concrete buildings. In this methodology, total input energy, inelastic design response spectra, and energy dissipation obtained through damping energy and plastic hysteretic energy are considered simultaneously to discuss damage potential of ground motions and damage indices of structures.

Based on recent studies (Fajfar and Vidic 1994; Decanini and Mollaioli 1998, 2001; Yabana and Hagiwara 1992; Hagiwara 2000; Chai and Fajfar 2000; Chou and Uang 2000; Manfredi 2001; Hori and Inoue 2002; Reinoso et al. 2002; Ordaz et al. 2003), it has been widely recognized that the use of the energy approach allows the proper selection of design ground motions and consequently improves seismic hazard assessment procedures to optimize structural design. In

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