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DESIGN CLASSIFICATION OF HORIZONTAL AND VERTICAL EARTHQUAKE GROUND MOTION (1933-1994)

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1. INTRODUCTION

One of the most important decisions the seismic design engineer must make is the selection of the design earthquake. Conceptually, this should be the ground motion, selected from all possible ground motions at a particular site, that will drive the structure to its critical response and thereby result in the highest damage potential. The quantification of this concept, however, is not easy.

One of the primary goals of this study is to help the design engineer with this important task by classifying earthquake records taken from an extended database of more than 5,500 earthquake records according to selected parameters. The parameters considered in this study which can be used to characterize the severity and damage potential of earthquake ground motions can be grouped into the following three main categories: (a) instrumental values obtained either directly or with some simple calculations from the digitized and corrected version of the instrument record, (b) spectral values obtained from the parametric integration of the equation of motion of elastic and inelastic single-degree-of-freedom systems, and (c) spectral values obtained considering the energy balance equation for elastic and inelastic systems.

Instrumental parameters include peak ground acceleration (PA), peak ground velocity (PV), and peak ground displacement (PD). Of these, the one most often associated with the severity of a recorded ground motion is the peak ground acceleration. However, it has generally come to be recognized that this is a poor parameter for evaluating damage potential. For instance, a large recorded peak acceleration may be associated with a short-duration impulse of high-frequency (acceleration spike). In this case, most of the impulse is absorbed by the inertia of the structure with little deformation. On the other hand, a more moderate acceleration may be associated with a long-duration impulse of low-frequency (acceleration pulse) which results in a significant deformation of the structure.

For this reason, Anderson and Bertero (1987) have suggested the use of maximum incremental velocity (IV), and maximum incremental displacement (ID) for characterizing the damage potential of earthquake motions in the near-fault region. Incremental velocity represents the area under an acceleration pulse. Hence, the larger the change in velocity, the larger is the acceleration pulse. In a similar manner, the area under the velocity pulse is equal to the incremental displacement. The final instrumental parameter considered in this study is bracketed duration (Bolt 1969; Page and others 1972). To measure bracketed duration corresponding to a given acceleration level, usually 0.05g, the first and last occurrences of accelerations equal to or larger than this value are marked on the acceleration trace. The time duration between these two markings is called bracketed duration corresponding to the given value of acceleration. In this study, bracketed

duration corresponding to 0.05g is evaluated for all records and bracketed duration corresponding to 0.10g, 0.15g, 0.20g, 0.25g, and 0.30g is evaluated for selected subsets of 141 horizontal and 83 vertical components.

Response spectrum analysis is currently the most popular method of dynamic response analysis (Naeim and Paz, 1994). Ground motion parameters based on response spectra which are evaluated and reported in this study include the effective peak acceleration (EPA) and effective peak velocity (EPV). These parameters which were initially defined in ATC 3-06 (Applied Technology Council, 1978) are based on average response spectral ordinates in selected period bands (0.1-0.5 seconds for EPA and about 1.0 second for EPV). Also included in this report are elastic and/or inelastic response spectra curves and tables developed for a selected subset of 141 safety-level horizontal and 83 vertical components. Tables are provided for mean spectral acceleration corresponding to 5% damping in 10 period bands. These period bands collectively span the period range of 0.10 to 6.0 seconds for horizontal components and 0.05 to 3.0 seconds for the vertical components are reported in a set of tables . In addition, two types of inelastic response spectra are presented for the horizontal components : (a) constant-strength response spectra, and (b) constant-ductility response spectra.

The inelastic constant-strength response spectra are obtained by plotting the maximum displacement ductility demands against initial natural period, considering elasto-plastic, single degree of freedom systems with different yield seismic resistance coefficient, C_y. This coefficient is defined as the ratio of the yield base shear to the effective weight of the structure. Response spectrum curves are presented for C_y values of 0.05, 0.10, 0.20, and 0.40.

For constant-ductility response spectra, the yield seismic resistance values corresponding to a constant displacement ductility demand, μ, are plotted as a function of period. Response spectrum curves corresponding to displacement ductility demand values of 1 (elastic systems), 2, 4, 6, and 8 are presented.

One of the more significant shortcomings of current design spectra, both elastic and inelastic, is the fact that they do not account for the duration of input ground motion. This is a significant characteristic that can be addressed by the use of energy spectra which reflect the possibility of high energy dissipation demand with long duration.

Impulse type ground motions result in a sudden burst of energy into the structure which must be dissipated immediately. This is usually characterized by one large yield excursion with few reversals. On the other hand, a sinusoidal type ground motion of longer duration requires a more steady dissipation of energy over a longer period of time with numerous yield reversals. This type of information cannot be obtained from current earthquake

response spectra.

Hysteretic energy spectra give a more reliable indication of damage potential. Current code provisions for earthquake resistant design depend on inelastic behavior to reduce the magnitude of the lateral forces. However, parameters currently used by these codes are inadequate for assessing the damage potential and the degree of inelastic deformation. For these reasons, the authors feel that the development of input energy spectra and hysteretic energy spectra for the selected set of 141 safety-level horizontal components presented in this report, will be a major step for improving current earthquake resistant design procedures and placing the design criteria on an energy basis. Furthermore, to better aid energy-based selection of critical earthquake records, tables are presented that identify earthquake records with largest mean input and hysteretic energy content in 10 period bands which collectively span the period range of 0.10 to 6.0 seconds.