Motion-Damage Relationships for Loss Estimation

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Overview

Currently proposed Performance-Based Earthquake Engineering approaches (FEMA 1997) consist on verifying 3 or 4 discrete performance levels of the structure (e.g. operational, immediate occupancy, life safe, near collapse) when subjected to discrete levels of ground motion intensity (e.g. frequent, rare, very rare). The Pacific Earthquake Engineering Research (PEER) Center is developing a methodology to provide improved information about the seismic performance of structures in order to help owners, financial institutions and other interested parties make better decisions regarding their structures. A particular component of this PEER effort is aimed at the development of a methodology that will describe the seismic performance of buildings in a continuum way, and more specifically will permit the estimation of expected annual losses.

The methodology involves four basic "steps": (1) Estimation of the seismic hazard at the site; (2) Estimation of structural response parameters in different locations of the structure as a function of the ground motion intensity; (3) Estimation of the level of damage in structural and nonstructural components as a function of structural response parameters; (4) Estimation of expected annual losses as a function of the level of damage in structural and nonstructural components of the structure. The methodology follows a fully probabilistic approach in each of these four "steps". Here a brief summary of the work in progress related to the development of motion-damage relationships is described.

Applicability

This loss-estimation methodology is being developed in the context of the evaluation of the seismic performance of a 7-story perimeter moment-resisting reinforced concrete frame building representative of older construction that is being used as a testbed. Hence, the motion-damage relationships that are being developed are only representative of this type of construction. However, the methodology to develop these relationships is applicable to other types of components.

Motion-Damage Relationships

In order to estimate the damage to a building it is first necessary to obtain an estimation of the response of the structure. In the proposed methodology this is achieved through a probabilistic structural response analysis. Details of this type of analysis are described elsewhere (Miranda et al. 2001). Once a probabilistic estimation the response of the structure is available it is possible to obtain an estimation of the damage to different components of the building through the use of

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motion-damage relationships. One possibility is to use fragility curves that describe, for a given structural or non-structural component, the probability of experiencing a certain level of damage conditioned to the component having experienced a certain level of response. In the methodology the level of structural response is described in terms of *Engineering Demand Parameters* (EDP), which are structural response parameters that describe the intensity of the motion of the structure.

Three types of EDP are being considered: (i) peak interstory drift ratio (IDR); (ii) peak absolute floor velocity (PAFV); (iii) peak absolute floor acceleration (PAFA). Multiple studies have shown that practically all structural damage and damage to many types of nonstructural components is well correlated with interstory drift ratios. On the other hand there are other nonstructural elements, particularly those who are suspended from the floor systems, such as piping, ceilings, etc. whose damage is better correlated with absolute accelerations. Meanwhile, the damage to building contents susceptible to sliding or overturning is sensitive to absolute velocities and accelerations. Probabilistic estimates of these three EDP need to be computed for every story/floor in the building.

The possible damage to structural and non-structural components is described in terms of *Damage Measures* (DM) that are describes in terms of probabilities of experiencing a certain damage state in a given structural or non-structural component. Thus, the fragility curves relate the conditional probability of damage measures to EDPs. Damage states vary depending on the type of component and are being selected to correspond to the actions that need to be taken in the component after damage has taken place.

Three different sources of information are being considered for the development of the fragility curves: (1) using results from experimental research that describes the damage of a particular component as a function of EDP; (2) using results of damage surveys of instrumented buildings that describe their performance after an earthquake, where the EDP can be obtained from the earthquake records; (3) using results of damage surveys of buildings that are not instrumented but that are located at a close distance from a recording station. In the latter case, EDPs can be obtained from time history analyses of the structure using the records obtained in the vicinity of the building. In the development of fragility functions of structural components

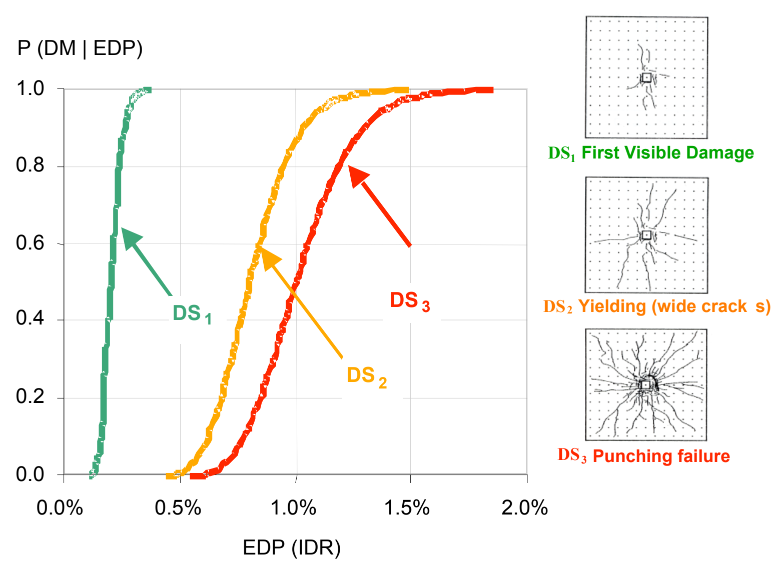

Figure 1. Fragility function for a slab-column connection with an intermediate level of gravity loads.

only the results of experimental research are being used. However, for the case on nonstructural components the other two sources of information are also being used.

Figure 1 shows the preliminary results of the fragility function that relates the structural damage in a reinforced concrete slab column connection as a function of the imposed interstory drift ratio. For this type of structural component a whole family of fragility functions are being developed using the results of 8 experimental programs with a total of 73 specimens.

Figure 2 shows the results of a fragility function that describes three damage states for drywall partitions consisting of 5/8" gypsum boards and 3-5/8" metals frames

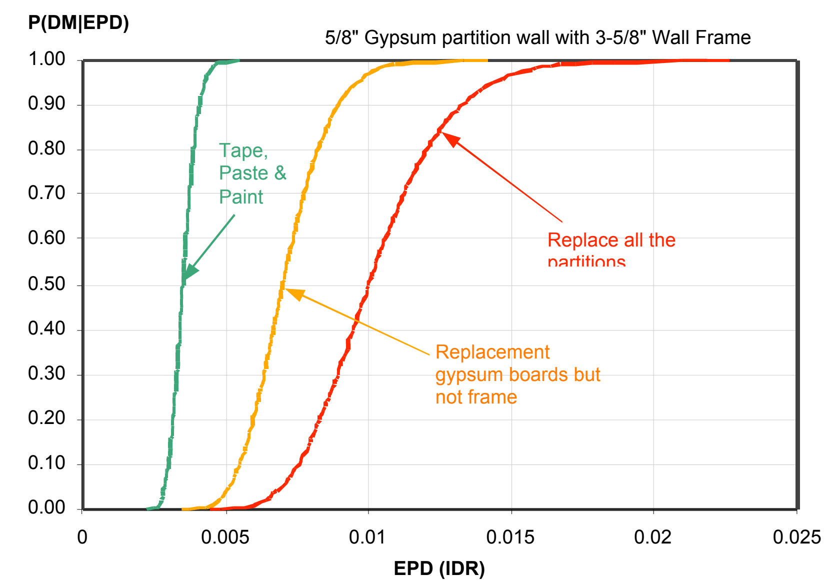

Figure 2. Fragility function for a specific type of drywall partition.

For further information

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Acknowledgment

This work was supported by the Pacific Earthquake Engineering Research Center through the Earthquake Engineering Research Centers Program of the National Science Foundation under Award Number EEC-9701568. This financial support to the authors is gratefully acknowledged.

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Keywords

Loss estimation, expected annual losses, fragility curves, structural members, nonstructural components, evaluation, existing buildings.