Influence of Aftershocks on Non-Linear Seismic Response of Non-Deteriorating SDOF Systems

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Introduction

Earthquakes have claimed approximately eight million lives over the last two thousand years (Dunbar, Lockridge, & Whiteside, 1992).

Seventy-five percent of earthquake-related human casualties are caused by the collapse of structures (Coburn & Spence, 2002).

Building codes in the United States do not explicitly account for the influence of aftershocks in the estimation of seismic demands used for design. It is assumed that if a structure can withstand a main shock, it can endure an aftershock without collapse.

In order to reduce the risk of injuries, loss of lives, and financial losses linked to the collapse of structures, a deeper level of understanding of the dynamic response of structures exposed to aftershock hazards is needed.

Problem Statement

The goal of this study is to understand the response of Single-Degree-of-Freedom (SDOF) systems designed to withstand main shock (MS) hazards when they are exposed to additional hazards posed by aftershocks.

Methods

This study consists of the statistical quantification of engineering demand parameters vs. response history analyses with a set of recorded main-shock aftershock (MS-AS) sequences.

Ground motions were classified according to site characteristics. This final set consists of 12 MS-AS sequences for hard rock and rock, 84 for very dense soil and soft rock, and 65 for regular stiff (Figure 2a), with each sequence having two horizontal components.

Ductility:

Figures 3 and 4, showing displacement ductility response for difference strength reduction factors (R Factors), demonstrates that aftershocks influenced the overall ductile response of the system.

Comparative Analysis: MS vs. MS+AS

Damping Ratios:

Figures 9 and 11 were derived using the same MS and AS records but at different damping ratios. Both plots, however, are almost identical. This suggests that the relative difference between MS and MS-AS sequence response is weakly dependent on the damping in the analysis of the ductile response of SDOF systems.

Ductility & Peak Displacement Ratios:

Figures 9 and 10 indicate that the effect of aftershocks on the ductility and peak displacement responses for periods between 0.05 to 0.85 seconds is not very significant when compared to the responses obtained using MS ground motions only. This observation applies to systems with R Factors less than 6. At periods less than 0.35 seconds and greater than 0.85 seconds aftershocks have shown to produce a significant increase in both ductility and peak displacement demands.

Residual Displacement Ratios:

Figure 12 demonstrates that the overall residual displacement experienced by the system due to main shock-aftershock sequences is greater than with the main shock alone. At certain periods, the response drops below a value of 1 indicating that the after shocks countered the impact of the main shock and stabilize the system to some degree.

Conclusions

This study—a base case scenario—demonstrates that, with respect to ductility, peak displacement, and residual displacement, the effect of the aftershock is significant in the response of the system. Significant observations include:

- Aftershocks may counter the impact of the main shock and help stabilize the system to some degree, at shorter periods of vibration.
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