A Forensic Study to Apportion Damage due to Multiple Sequential Earthquakes

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Summary

This paper presents an analytical approach to isolate contribution of multiple earthquakes to the overall damage caused to a structure. In this study, the buildings' lateral force resisting systems are idealized as a single degree of freedom (SDOF). The SDOF is defined using a nonlinear force-deformation curve to represent the structures' response to lateral earthquake loads. A nonlinear analysis was conducted using the SDOF model subjected to the sequential ground motion time history. The energy dissipated through hysteresis response loops was calculated at the end of each earthquake. The amount of dissipated energy directly correlates to the damage sustained by lateral load resisting system since earthquake energy is dissipated through the inelastic actions of the structure. This approach can quantify the relative contribution of multiple sequential earthquakes to the overall damage based on the energy dissipated by the building during each event.

Keywords: Earthquake Engineering, Damage Allocation, Nonlinear Analysis, Forensic Investigation

1. Introduction

The purpose of this paper is to introduce an approach to quantify the relative contribution of multiple earthquakes or major earthquakes and their aftershocks to damage to the buildings. Similar studies have attempted to quantify damage contribution from sequential earthquake events. These studies are performed to separate damages from major earthquakes and their aftershocks and to determine the residual capacity of the structure after each event. The New Zealand Earthquake Commission (EQC) [1] developed an apportionment methodology after the Canterbury earthquakes. A review of the EQC's methodology shows that it is simply a qualitative assessment based on visual observation of damage subsequent to each event or comparing the damage with other properties in the area where the extent of damage and when it occurred is known. Wilson, Bradley, Belliss [2] at the University of Canterbury developed a method to determine the cumulative ground motion effects of the Canterbury earthquake sequence on structures. This study uses a nonlinear single-degree-of-freedom (SDOF) model to represent the structure. A nonlinear time history analysis of the SDOF subject to Canterbury earthquake sequence ground motion determines the displacement demand for a range of structural periods and ductility. The displacement demand from each event is then used to determine relative contribution of each event to the overall damage of the structure. Brooke and Davidson [3] developed an analytical method for determining relative damage ratios for a series of earthquakes. In this method, the structure is represented by a linear SDOF. The contribution of each earthquake to damage is determined by proportioning of the calculated earthquake displacement demands that are larger than the prescribed damage threshold.

Energy dissipated by the structure during earthquakes has been used as an indicator of the residual seismic capacity after major earthquakes (Kang and Maeda [4]) and (Nakano et al [5]). Park et al.,

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