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# DAMAGE ACCUMULATION IN A TWO-STORY WOOD-FRAME BUILDING IN SEQUENCES OF INDUCED EARTHQUAKES

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**ABSTRACT**

In this study, a nonlinear model of a two-story multifamily wood-frame residential structure is subjected to recordings of sequences of induced earthquakes in order to quantify changes in fragility and accumulation of damage throughout multiple earthquake loadings. Initial efforts consisting of ground motion selection, building design, numerical modeling, and preliminary results are presented. Damage is quantified through a seismic loss estimation procedure that accounts for damage to nonstructural and structural components of the building. Examining damage accumulation from sequential earthquake shaking enables us to explore how the occurrence of damage in an earthquake, even to relatively small levels, may increase a structure's susceptibility to collapse or damage in subsequent ground shaking. Ultimately, the goal is to compare damage fragilities and seismic losses as a function of the building's initial damage state.

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In this study, a nonlinear model of a two-story multifamily wood-frame residential structure is subjected to recordings of sequences of induced earthquakes in order to quantify changes in fragility and accumulation of damage throughout multiple earthquake loadings. Initial efforts consisting of ground motion selection, building design, numerical modeling, and preliminary results are presented. Damage is quantified through a seismic loss estimation procedure that accounts for damage to nonstructural and structural components of the building. Examining damage accumulation from sequential earthquake shaking enables us to explore how the occurrence of damage in an earthquake, even to relatively small levels, may increase a structure's susceptibility to collapse or damage in subsequent ground shaking. Ultimately, the goal is to compare damage fragilities and seismic losses as a function of the building's initial damage state.

## Introduction

The deep disposal of wastewater associated with oil and gas production has been responsible for an increase in seismicity in parts of the U.S. This induced seismicity has dramatically increased the seismic hazard [1] and the risk to infrastructure [2] in places like Oklahoma and southern Kansas since about 2009. These induced earthquakes are generally of low magnitude ($\leq M_W$ 5.8), but are frequent and have often occurred in swarms. Swarms result from the migration of injected fluids and pore water pressures along already critically stressed faults [3].

This study aims to quantify how a building's seismic fragility changes and damage accumulates when subjected to a swarm of induced earthquakes. The study examines a two-story multifamily wood-frame building using nonlinear simulation models subjected to recorded ground motion sequences from induced earthquakes in dynamic analysis. Damage is quantified through seismic losses, *i.e.* repair costs, in an effort to assess damage even when the structural system itself may be undamaged or lightly damaged. Damage accumulation is examined from event to event in the swarm to explore how the occurrence of even small levels of damage in an earthquake may potentially change a structure's susceptibility to increased damage in subsequent shaking.

## Ground Motion Selection

This study uses recorded ground motions from confirmed induced earthquakes in Oklahoma and

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