Fragility of Residential Chimneys in Induced Earthquakes

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Chimney Fragility in Induced Earthquakes

Observed Chimney Damage

- Induced earthquakes have caused damage to infrastructure in OK and KS.

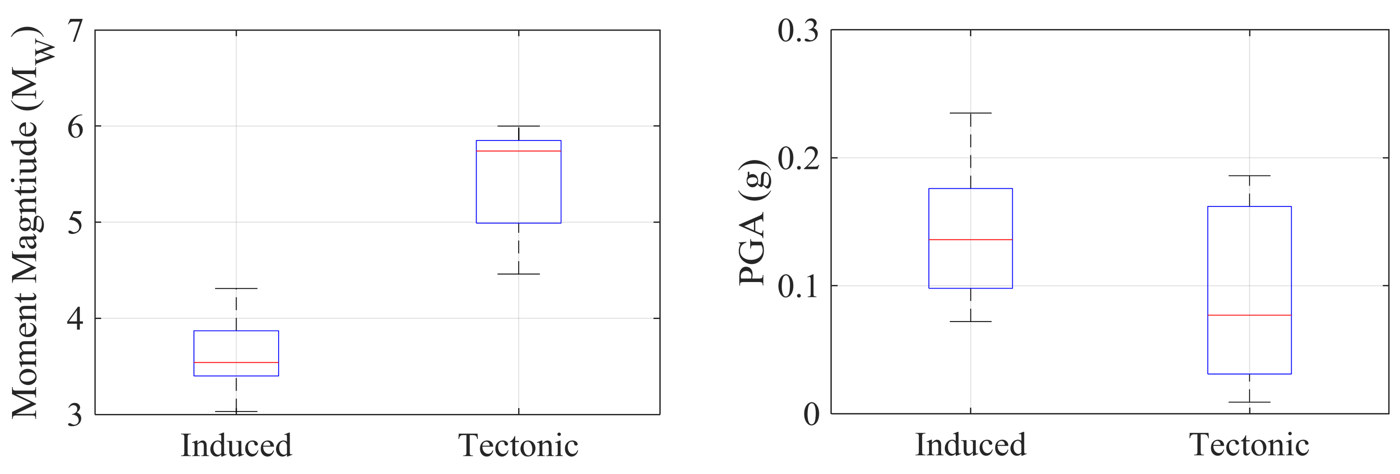
- Residential chimneys were a common building component that sustained damage.

Collapsed chimney from the 2011 Prague, OK M_W 5.7 Earthquake. (Gallucci 2014)

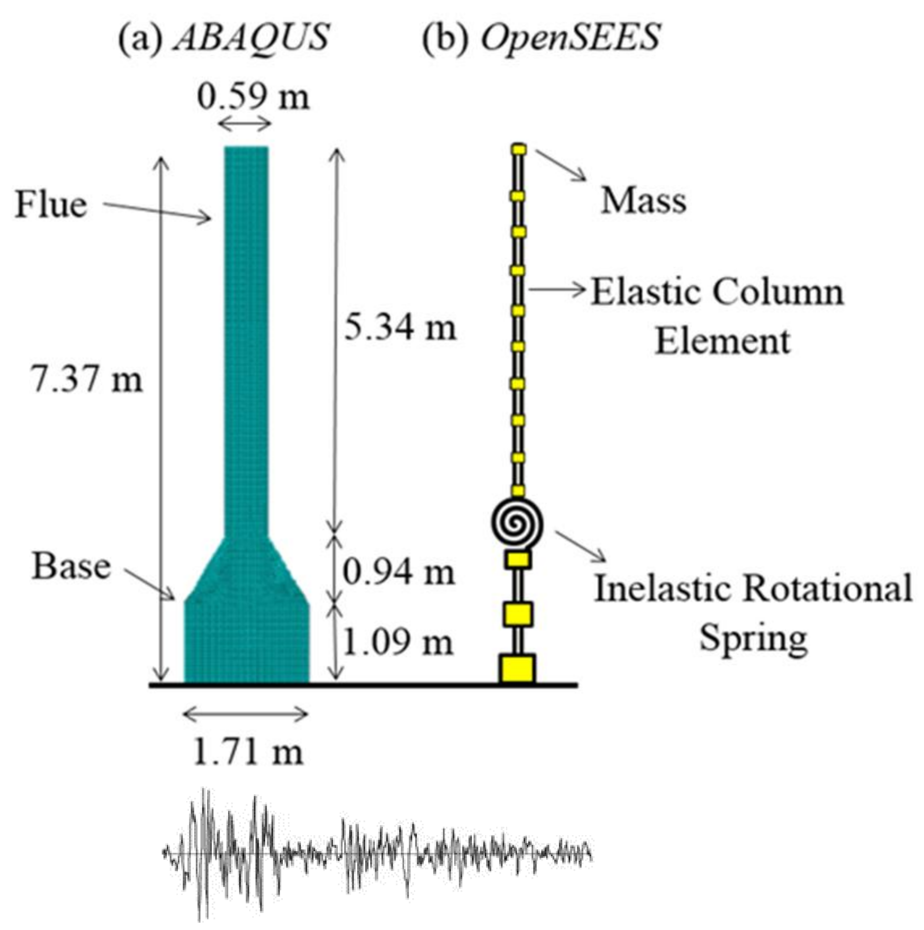
Research Question - Do induced ground motions pose different risks to infrastructure when compared to similar tectonic (natural) ground motions?

Collection of Induced and Tectonic Ground Motions

- 70 strong motion records of induced earthquakes from Oklahoma and southern Kansas (Rennolet et al. 2016).
- 30 strong motion records of tectonic earthquakes mainly from the central and eastern US (CEUS) (NGA-East and CESMD).



Chimney Model



- Modeled a finite element chimney in *ABAQUS* (a).
- Calibrated a simpler *OpenSEES* model to the *ABAQUS* model for repeated dynamic analysis (b).

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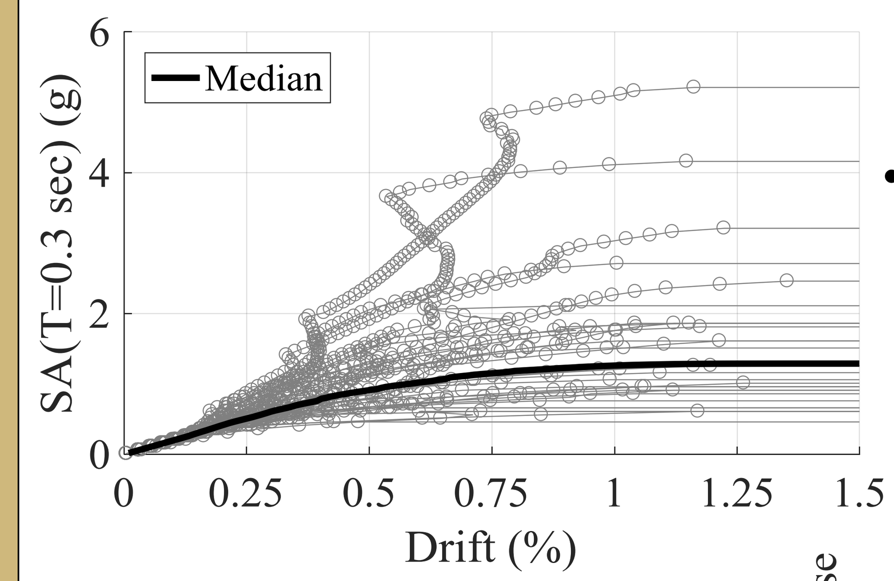
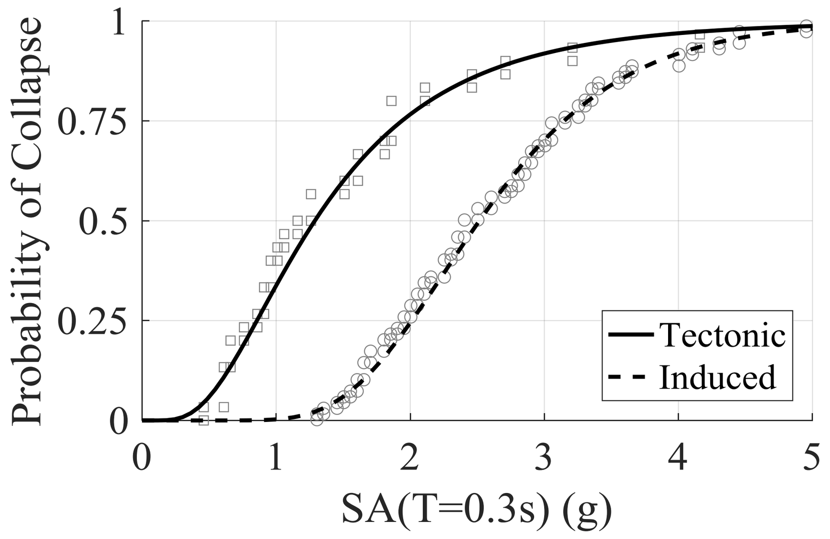
Simulation of Chimney Response

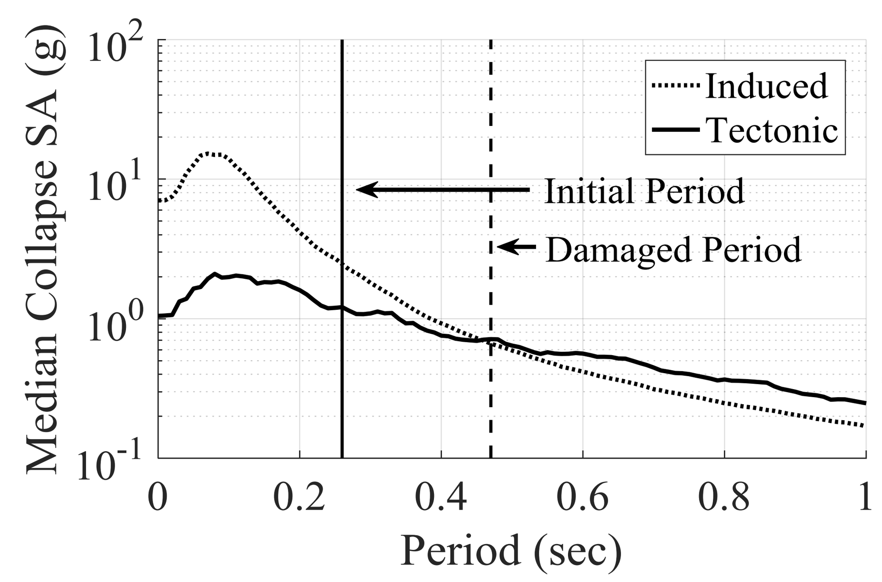


- Incremental dynamic analysis (IDA) was used to scale records until collapse levels.



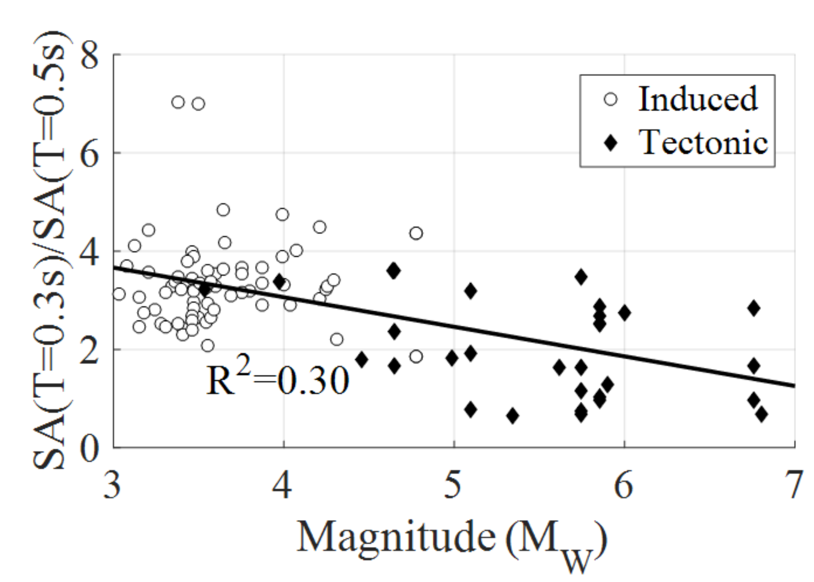
- Collapse fragility curves were produced showing induced ground motions appear less damaging.

What is causing the difference in response between the two sets?



- Frequency Content – higher long period energy in tectonic ground motions produce larger seismic forces as the period lengthens due to damage.
- Duration of Shaking – longer durations for tectonic motions cause more cycles of vibration.

- Magnitude higher magnitudes of the earthquakes in the tectonic set were the major contributor to the differences seen in frequency content.



Conclusions

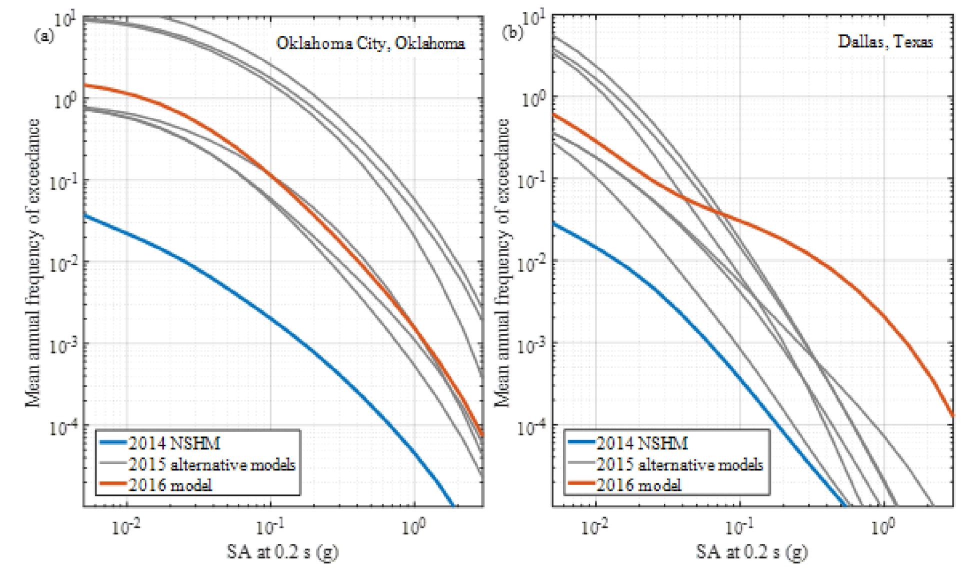
- Dynamic analysis shows that **tectonic motions are more damaging** than induced motions for this chimney.
- **BUT** this is mostly **due to differences in magnitude** and frequency content in the record set.

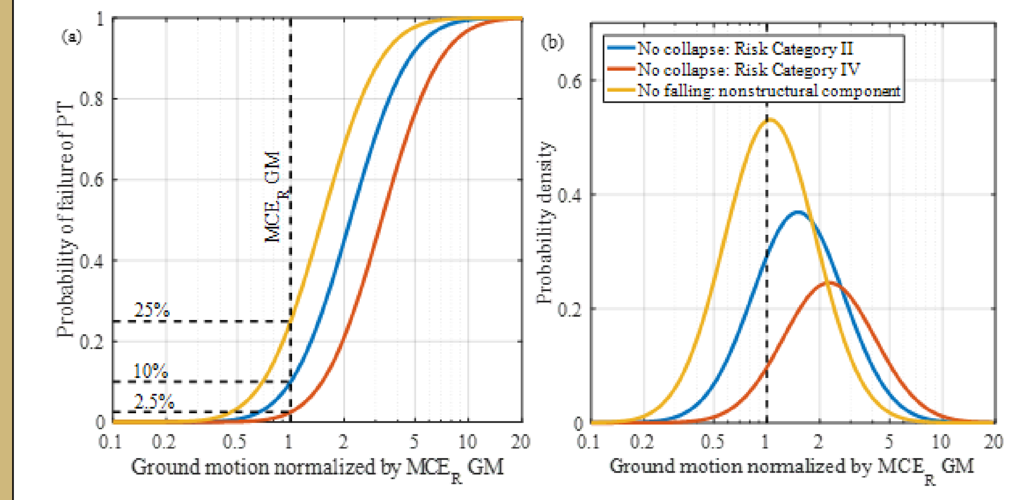
Increases in Life-Safety Risks

Research Question - What are the potential impacts of the induced seismicity on buildings and the public considering risk of a) building collapse and b) falling of nonstructural building components?

Increased Seismic Hazard & NEHRP Fragility Curves

- Seismic hazard shows higher frequencies of exceedance in Oklahoma and Texas when comparing the 2016 and 2014 USGS National Hazard Models.

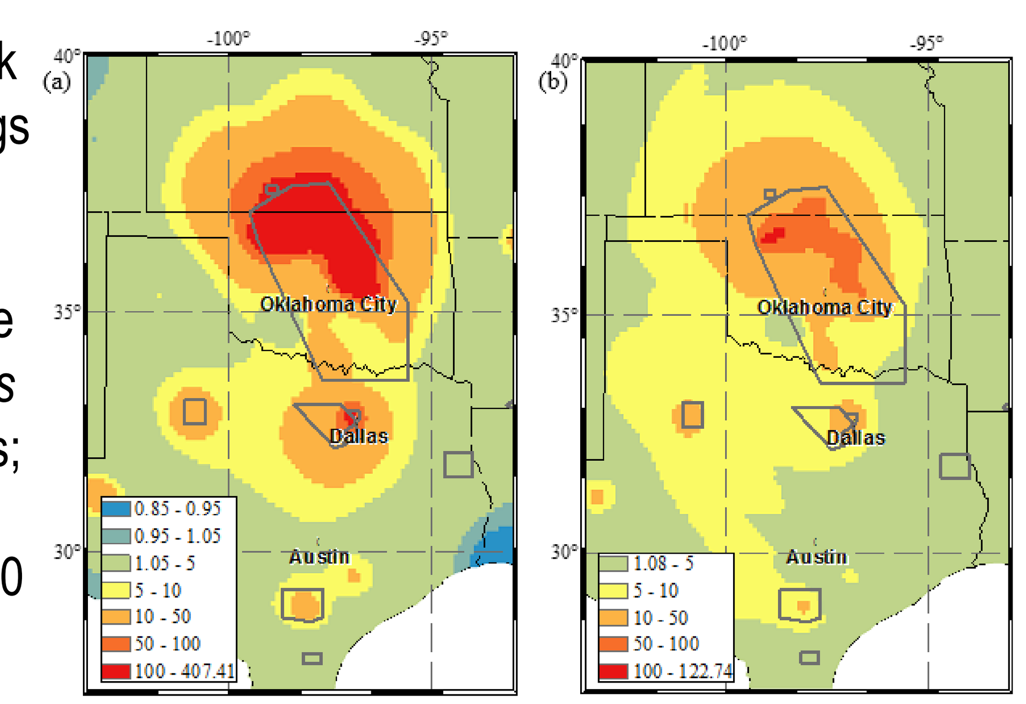




- Building fragility curves as defined *2015 NEHRP Provisions*.
- Life-safety targets of no collapse (structural) and no falling hazard (nonstructural) are shown.

Increased Collapse Risk

- Ratio of the collapse risk for ordinary-use buildings from the 2016 hazard model, divided by that implicitly accepted in the *2015 NEHRP Provisions* for buildings of: (a) 0.2 s; (b) 1.0 s. Collapse risk increased more than 100 times in some cases.



Conclusions

- The findings show that the life-safety risks for regions close to active (potentially) induced seismicity zones can be significantly higher than the levels accepted in the *2015 NEHRP Provisions*, in some cases more than 100 times.
- The risks for short-period buildings are increased more significantly by ground motions from induced earthquakes than the risks for moderate-period buildings.