Response of Typical Oklahoma Bridges to Recent Earthquakes


School of Civil Engineering & Environmental Science
University of Oklahoma, Norman, OK

SS41 Impacts of Induced Seismicity on Infrastructure Systems
Friday, June 29, 2018
Oklahoma DOT’s Response Protocol

Previous ODOT Protocol

<table>
<thead>
<tr>
<th>Magnitude Range</th>
<th>Inspection Radius (miles)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.0 to 4.9</td>
<td>5</td>
</tr>
<tr>
<td>5.0 to 5.5</td>
<td>25</td>
</tr>
<tr>
<td>5.6 +</td>
<td>50</td>
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• Oklahoma DOT tasked us with revising these inspection radii
Smart Inspection Radii – Approach

Within **what distance** from the earthquake epicenter can we expect damage?
CAPACITY – Fragility Curves

- Inspection deemed necessary for $S_1 > 5.56\% g$
  - Input from Caltrans (California DOT)
  - Comparison of CA to non-CA bridges in HAZUS
Smart Inspection Radii – Approach

Within **what distance** from the earthquake epicenter can we expect damage?
DEMAND – Ground Motion

• USGS provides ShakeMaps of ground-motion intensity *after* an earthquake
• Need GM predictions *a priori*
• Existing attenuation models (or GMPEs) shown to over predict
  – Campbell (2003)
**DEMAND – OK-biased GMPE**

- Magnitude-dependent *bias factor* (Worden et al. 2010) for OK earthquakes

- 40 ground motion time-histories acquired using SOD
  - M4.0+ events from Feb. 27, 2010 – June 20, 2015
DEMAND – Demand Attenuation Curves

Demand Curves

(a) 

Radius [km]

(b) 

Magnitude

Inspection Radius [km]

S_D1 [%g]

5.56

4.0

4.5

5.0

5.5

6.0

100

10

1

0.1

0.01

0.001
Interim Response Protocol  (circa April 1, 2016)

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<tr>
<td><strong>Magnitude Range</strong></td>
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<tr>
<td>4.9 to 5.3</td>
</tr>
<tr>
<td>5.4 to 5.8</td>
</tr>
<tr>
<td>5.9 to 6.2</td>
</tr>
<tr>
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FOR IMMEDIATE RELEASE
Date: Thursday, March 31, 2016
Press Release # 16-012

ODOT firms up earthquake bridge inspection process

The Oklahoma Department of Transportation is relieved by the results of a recent scientific study that has aggressively inspected bridges and infrastructure for the past few years and learned a great deal through this process about this relatively new phenomenon in our state.

Infrastructure Engineers Inc., a team of consultants that worked closely with researchers from the University of Oklahoma, validated ODOT’s inspection process. Additionally, the year-long study of earthquake data revealed there is no structural damage occurring on bridges after tremors below magnitude 4.7, indicating that bridge inspections are unnecessary below this level. The department will continue to inspect bridges after earthquakes, but starting at a threshold of 4.7 magnitude events.

“We were conservative in our approach to bridge inspections, but now we have the science to know with more certainty that 4.0- to 4.6-magnitude earthquakes present no danger to transportation infrastructure in the state,” said Casey Shell, ODOT chief engineer. “This change in protocol allows the department to better focus its resources.”
Executive Director Mike Patterson reported that all highway bridges were safe for traffic following the 5.6 earthquake near Pawnee on Saturday, Sept. 3. Immediately following the tremor, ODOT crews from two field divisions mobilized to inspect more than 180 highway bridges within a 30 mile radius of the epicenter. Inspections revealed that two bridges had cosmetic damage, but remained structurally safe. The agency also offered assistance to local governments for the inspection of city and county bridges.

"Over the last few years, ODOT has been working to create a refined earthquake inspection protocol with the help of the Oklahoma Geological Survey, California Department of Transportation and other experts," Patterson said. "The agency was well-prepared, our crews responded quickly and our state's transportation infrastructure is safe and secure."
M5.8 Pawnee Earthquake (3 Sept 2016)

Source: W.L. Peters (ODOT)

Source: GEER (2016)
M5.8 Pawnee Earthquake

spectral response acceleration, $S_a$ (g)

- station data
- NQ.KAN15
- OK.BCOK
- epicenter

period, $T$ (sec)
Typical Oklahoma Bridge

Construction Material

No. of Spans

Lengths
Typical Oklahoma Bridge

SH-11 Bridge over Tiger Creek

Peak Responses

Bolt clearance

GS.OK005

Yield curvature 4.17
Thank you! Questions?

References:
ShakeCast Report

Magnitude 5.8 - OKLAHOMA
Origin Time: 2016-09-03 12:02:44 GMT
Latitude: 36.42510 Longitude: -96.92910
Depth: 5.557 km

These results are from an automated system and users should consider the preliminary nature of this information when making decisions relating to public safety. ShakeCast results are often updated as additional or more accurate earthquake information is reported or derived.

Summary of Potential Impacts: DIV4

Total number of facilities analyzed: 34
Summary by impact rank:
- High: 0
- Medium-High: 0
- Medium: 0
- Low: 34
- Below Threshold: 0

The following table shows the facility identification, name, epicenter distance, inspection priority, PGA, PGV, PSA1s, and Vns30 values for each facility:
ShakeCast-OK (cont.)

(b)

- Old Protocol (50 miles): 366 bridges
- Interim Protocol (30 miles): 167 bridges
- ShakeCast: 38 bridges
FOR IMMEDIATE RELEASE

Date: Monday, Aug. 7, 2017

“This technology is one of the biggest advances in ensuring public safety that I’ve seen in my 30-year career at the department,” said Casey Shell, ODOT chief engineer. “By comparing state bridge data with the severity of an earthquake’s ground motions, ShakeCast will allow us to inspect fewer bridges but with a much greater degree of confidence that we could quickly find any potential damage.”

created by the U.S. Geological Survey. ShakeCast is in the final stage of a two-year, two-phase, nearly $850,000 contract with Infrastructure Engineers Inc. of Edmond to assist the department in developing an earthquake response protocol. Formalizing the plan, providing final training and an additional four years of system maintenance will conclude the contract.

The ShakeCast program will enable the nearly 300 trained ODOT employees to quickly determine which bridges to inspect first after an earthquake. If conditions warrant, key ODOT employees will receive a software-generated inspection priority order based on several factors including ODOT bridge data such as bridge condition, age and proximity to an earthquake’s epicenter, combined with USGS seismic movement data and magnitude rating.

Previously ODOT visually inspected all bridges within 5 miles of any earthquake epicenter between 4.4 to 4.7 magnitude. The inspection radius increased with the earthquake magnitudes. Generally, with a 4- to 5-magnitude earthquake no damage has been found. Going forward with ShakeCast, the inspections will identify only specific bridges susceptible to damage, allowing for a faster and more pinpointed response.