EERI Technical Case Studies Webinar: September 19, 2017 Mexico Earthquake

Performance of Bridges

Mark Yashinsky
Caltrans Office of Earthquake Engineering
PERFORMANCE OF BRIDGES DURING THE 9/19/2017 PUEBLA, MEXICO EARTHQUAKE
In Mexico:

- More than 70% of the bridges in Mexico were constructed before 1970 without any seismic design criteria.
- No bridge retrofit program has occurred since then to address this vulnerability.
- Most new bridges in Mexico are designed using the American Association of State Highway and Transportation Officials (AASHTO) Bridge Design Specifications (BDS), which includes some seismic design criteria.
- Bridges also have to comply with local codes such as the Normas Técnicas Complementarias para Diseño por Sismo (Complementary Technical Standards for Earthquake Design) (NTS), which is part of the Mexico City Building Code or with the CFE (Civil Engineering) Seismic Design Manual.
- Most bridges performed well during the September 19th 2017 earthquake. Only a few cases of damage or collapse were reported. However, ground shaking was small during this earthquake. We identified many bridges with short seats, poorly detailed reinforcement, and/or with unreinforced masonry members. How will these bridges perform during the much larger earthquakes that can occur on the Cocos Fault?
- Countries try to protect their citizens from many of the risks that threaten them. War, famine, and disease have killed the most people, but can countries be expected to protect it’s citizens from all risks? Highway damage from earthquakes only causes a few casualties a year but the cost to retrofit all existing bridges is large. That’s why engineers are moving to a probabilistic world to allow them to better manage all of society’s risks.
In California:

- More than 70% of the bridges in California were constructed before 1970 with a minimal seismic design.
- At least three bridge retrofit programs have occurred since then to address different vulnerabilities.
- All new bridges in California are designed using Caltrans Seismic Design Criteria (SDC).
- Caltrans SDC requires that all bridges are designed with 1: Continuity (to carry seismic forces to capacity protected connections and to ensure displacement capacities are larger than demands), 2: Ductility (to provide sacrificial elements to protect the structure), 3: Balance (to prevent the force from damaging stiffer elements), 4: Medium Period (so bridges can’t be damaged by the large acceleration or large displacement portions of the response spectra).
- Caltrans SDC allows considerable damage to ductile members to protect bridges from collapse.

Among the ideas that have been developed recently are 1: sustainability and 2: resilience to allow bridges to remain in service following earthquakes and 3: accelerated construction to provide seismic resistance while allowing bridges to be rapidly constructed, especially after earthquakes.

We’re now going to look at bridge performance during the 9/19/2017 earthquake. Ideas about managing risk and acceptable seismic performance should be considered while studying these bridges.
PERFORMANCE OF BRIDGES DURING THE 9/19/2017 PUEBLA, MEXICO EARTHQUAKE
PERFORMANCE OF BRIDGES DURING THE 9/19/2017 PUEBLA, MEXICO EARTHQUAKE
The ground motion was low and engineered structures like bridges performed very well, with a few exceptions.

1: A pedestrian overcrossing in Mexico City collapsed during the earthquake, unfortunately falling onto a taxi.

PERFORMANCE OF BRIDGES DURING THE 9/19/2017 PUEBLA, MEXICO EARTHQUAKE

Several damage locations were reported for the Metro Train Viaduct. One location had road cracks due to column rocking (for floating foundations), several locations showed damage to the superstructure (due to pounding and from weird shear keys) and at another site a single column bent was severely damaged. All sites are summarized below.
PERFORMANCE OF BRIDGES DURING THE 9/19/2017 PUEBLA, MEXICO EARTHQUAKE

2: Metro Elevated Train Viaduct, continued.
PERFORMANCE OF BRIDGES DURING THE 9/19/2017 PUEBLA, MEXICO EARTHQUAKE

2: Metro Elevated Train Viaduct, continued.
PERFORMANCE OF BRIDGES DURING THE 9/19/2017 PUEBLA, MEXICO EARTHQUAKE

2: Metro Elevated Train Viaduct, continued.
PERFORMANCE OF BRIDGES DURING THE 9/19/2017 PUEBLA, MEXICO EARTHQUAKE

2: Metro Elevated Train Viaduct, continued.
3: Collaborator Prof. Miranda of Stanford shared some photos of the Circuito Interior Avenida Rio Churubusco (19.3696, -99.12248), a long road just north of Mexico City. Parallel box girder overcrossings on pier walls rocked during the earthquake (the pier walls were too stiff to bend) and a masonry abutment was damaged.
PERFORMANCE OF BRIDGES DURING THE 9/19/2017 PUEBLA, MEXICO EARTHQUAKE

3: East End of Avenida Rio Churubusco Overcrossing.
PERFORMANCE OF BRIDGES DURING THE 9/19/2017 PUEBLA, MEXICO EARTHQUAKE

3: East End of Avenida Río Churubusco Overcrossing
PERFORMANCE OF BRIDGES DURING THE 9/19/2017 PUEBLA, MEXICO EARTHQUAKE

3: Avenida Rio Churubusco Overcrossing.
In the photo above we can see that the undercrossing has a long center span over the roadway and two very short spans with masonry abutments at the ends. It seems like the piers and the abutments couldn't laterally support the long center span, which resulted in rocking of the piers and damage to the abutments.
PERFORMANCE OF BRIDGES DURING THE 9/19/2017 PUEBLA, MEXICO EARTHQUAKE

Viaduct Tlaplan is an elevated north-south freeway that goes through the center of Mexico City. This long viaduct was carefully inspected after the earthquake, but the only thing they noticed was that water started leaking from the soffit after the earthquake, perhaps because the deck drains were never completed.
PERFORMANCE OF BRIDGES DURING THE 9/19/2017 PUEBLA, MEXICO EARTHQUAKE

4: Viaduct Tlaplan began leaking water after the earthquake.
PERFORMANCE OF BRIDGES DURING THE
9/19/2017 PUEBLA, MEXICO EARTHQUAKE

5: POC by Multifamiliar Tlalpan
PERFORMANCE OF BRIDGES DURING THE 9/19/2017 PUEBLA, MEXICO EARTHQUAKE

5: POC by Multifamiliar Tlalpan
PERFORMANCE OF BRIDGES DURING THE 9/19/2017 PUEBLA, MEXICO EARTHQUAKE

5: POC by Multifamiliar Tlálpán
The single span, 125 ft long highway bridge on Mexico City-Acapulco Highway 95D, south of Cuernavaca (50 miles south of Mexico City) collapsed. The bridge was demolished by the time the Main GEER team visited on October 4, 2017. The team observed that the site conditions were composed of low plasticity sandy silt.
PERFORMANCE OF BRIDGES DURING THE 9/19/2017 PUEBLA, MEXICO EARTHQUAKE

7: Puente Ticumán (15 miles southeast of Cuernavaca).

Alejandra wrote: Its a classic embankment failure. Bridge is in good condition. Minor cracking prior to the earthquake.

What the workers told me.
1) Bridge was designed by Japanese Consultants.
2) Bridge was NOT designed for heavy loads.
3) BRIDGE was being use for heavy loads (farming industry).
4) There’s a steel bridge that runs parallel to this one and its the one that is currently being used by the locals (alternate route).
5) They will only fix the entrance/exit to the bridge so people can use it for the moment
6) A total reconstruction of the bridge will take place next year and they are thinking about using drilled shafts.
7) LOTS of bees!
7: Puente Ticumán (15 miles southeast of Cuernavaca).

It appears that the masonry wingwalls failed and the suddenly unrestrained embankment slid down the hill.
PERFORMANCE OF BRIDGES DURING THE 9/19/2017 PUEBLA, MEXICO EARTHQUAKE

9: Undamaged bridge in San Juan Pilcaya (18.8268, -98.6038)
PERFORMANCE OF BRIDGES DURING THE
9/19/2017 PUEBLA, MEXICO EARTHQUAKE

9: Bridge closed to vehicles in San Juan Pilcaya (18.8268, -98.6038)
PERFORMANCE OF BRIDGES DURING THE 9/19/2017 PUEBLA, MEXICO EARTHQUAKE

9: Closer view of bridge closed to vehicles in San Juan Pilcaya (18.8268, -98.6038)
Acknowledgements

- Thanks to Jonathan Bray at GEER for selecting me to be on the first team into the site 5 days after the earthquake (and paying for my expenses).
- Thanks to Mark Mahan at Caltrans for allowing me to take time off from work to investigate this earthquake.
- Thanks to Omar Plata and Maggie Ortiz-Millan at EERI for asking me to talk about what I learned after the 9/19/2017 Mexico Earthquake.

- More information available at: