Lifeline Systems Performance – 2017
Puebla, Mexico Earthquake

C. Davis\textsuperscript{1}, G. Ayala\textsuperscript{2} A. Kwasinski\textsuperscript{3}, A. Tang\textsuperscript{4}, H. Wang\textsuperscript{5}

\textsuperscript{1}Chief Resilience Officer, Los Angeles Department of Water and Power
\textsuperscript{2}Professor, Dept. of Civil Engineering, UNAM, Mexico City
\textsuperscript{3}Professor, Dept. of Electrical & Computer Engineering, Univ. of Pittsburgh
\textsuperscript{4}Consultant, L&T Consulting, Canada
\textsuperscript{5}Asst. Professor, School of Civil & Construction Engr., Oregon State Univ., Corvallis

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ASCE Lifelines Investigation Team

**Allyson Pyrch** – Co-Lead, Geotechnical, EEW, Interdependencies, Transportation, Emergency Resp.

**Craig Davis** – Co-Lead, Water, Wastewater, Gas & Liquid fuels, Fires

**Haizhong Wang** – Transportation

**Jeff Bruce** – Geotechnical, Geologic setting, Seismicity, Transportation

**Andre Barbosa** – Hospitals, Schools, EEW, Transportation, Emergency Response

**Janise Rodgers** – Hospitals, Schools, Emergency Response

**Alex Tang** – Communications, Electric Power

**Alexis Kwasinski** – Electric Power, Communications

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Lifeline Systems in this Presentation

Electric Power
Telecommunications
Transportation
Potable Water
Wastewater and Drainage
Gas and Liquid Fuels
September 2017 Earthquakes in Mexico

7 Sept. 2017
Mw 8.2 Chiapas Eq

19 Sept., 2017
Mw 7.1 Puebla Eq
Electric Power

INFORMATION PROVIDED BY ALEXIS KWASINSKI, UNIVERSITY OF PITTSBURG
Effects on Electric Power Grid

Chiapas M 8.2 (Sept 7 2017)

- Near the Pacific coast, so seismic design for newer equipment was for PGA = 0.5g, which was about the same PGA observed during this event.
- Juchitan 2 Substation had a toppled 230 kV transformer, a broken 230 kV current transformer, and a broken 230 kV circuit breaker.
- Most wind farms on the coast of Oaxaca were taken out of service.
Effects on Electric Power Grid

Puebla M 7.1 Sept 19 2017

• 37 substations with damage. Major damage at 6 substations and widespread damage at one substation (YTP).

• Moderate or low shaking at damaged substations.

• 6 Transmission steel lattice towers with damage.

• 1 High voltage cable with damage.

• Transmission: widespread equipment failures at one substation (400 kV), some equipment failures (400 kV and 230 kV) at six substations (400 kV and 230 kV)
Effects on Electric Power Grid

Puebla M 7.1 Sept 19 2017

- Sept 19. Power outages: Peak at 4.78 million customers (about 35% of all CFE customers) over seven states lost power
- Sept 20\textsuperscript{th}: 95% of all customers restored.
- Sept 23\textsuperscript{rd}: 99% of all customers restored.
Telecommunications

INFORMATION PROVIDED BY ALEX TANG, L&T CONSULTING
# Telecommunications Performance

<table>
<thead>
<tr>
<th>Landline</th>
<th>Earthquake M=8 Sept 1985</th>
<th>Earthquake M=7.1 Sept 2017</th>
</tr>
</thead>
<tbody>
<tr>
<td>Central Office Building</td>
<td>One CO with significant structural damage and top floor of one CO collapsed</td>
<td>No damage reported</td>
</tr>
<tr>
<td>Equipment in CO</td>
<td>Most of the equipment in these two locations sustained serious damages</td>
<td>No damage reported</td>
</tr>
<tr>
<td>Cables</td>
<td>Cables severed between COs within one complex was observed</td>
<td>Utility poles collapse in several locations</td>
</tr>
<tr>
<td>Performance</td>
<td>Serious call congestion with greatly reduced circuit capacity.</td>
<td>Call congestion was noted but not serious*, internet services did not experience disruption</td>
</tr>
<tr>
<td>Recovery</td>
<td>Approximately 10 months</td>
<td>------</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Wireless</th>
<th>Earthquake M=8 Sept 1985</th>
<th>Earthquake M=7.1 Sept 2017</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standalone Cell Sites</td>
<td>Wireless not widely available</td>
<td>No damage, power outage reported but not serious</td>
</tr>
<tr>
<td>Roof top Cell Sites</td>
<td>Wireless not widely available</td>
<td>One cell site collapsed (more than 2 service providers)</td>
</tr>
<tr>
<td>Cables</td>
<td>---------------</td>
<td>No damage reported</td>
</tr>
<tr>
<td>Performance</td>
<td>---------------</td>
<td>Voice call (911) congestion noted (cell phone not working!), text messaging performed well</td>
</tr>
<tr>
<td>Recovery</td>
<td>---------------</td>
<td>Less than 2 days</td>
</tr>
</tbody>
</table>

* There are more wireless users. Landline customers decreasing. Wireless customers increasing.
Observations/Recommendations
- Lessons learned from 1985 earthquake applied to the system (buildings and equipment) resulted in good performance
- Wireless voice call congestion was short, due to …..
- Smart phone (wireless) text messaging Apps complimented the voice call
- Micro-cell sites within the City core (business area) provide some redundancy
- Roof top cell sites on commercial buildings remain the greatest risk
- Mobile cell sites (COW) minimized power outage problems.
- Backup power to Cell Sites needs to be expanded to more sites**
- Both landline and wireless IT services were not interrupted

** Currently only some cell sites (higher traffic) are equipped with backup power.
Telecommunications Performance

Cell Sites on roof of residential building (potential high risk sites)

Micro-cells in business center (all depend on commercial power)

COW (Cell on Wheels)
Telecommunications Performance (Lessons Learned)

Long distance CO gateway top floors collapsed (1985)

CO building cable ducts damaged with severed cables, switching equipment and trays toppled. (1985)
Transportation

INFORMATION PROVIDED BY HAIZHONG WANG, OREGON STATE UNIVERSITY
Transportation System Performance

Observations/Recommendations
- Mobile phone network was down
- Stoplights ceased to function as electricity failed, the city’s streets had turned into one vast traffic jam
- The difference between the sidewalk and the pavement of the road disappears and people start walking everywhere (Jesus Iglesias, a civil engineer)
- Five of thirteen metro lines were closed immediately after the earthquake due to electricity failure, but the service was quickly restored.
- BRT lanes and bike sharing plans are not just progressive ways of reducing pollution and traffic; they are central to a city’s capacity for disaster response.
- Parks and plazas proved themselves to be not just pleasant public amenities, but crucial safety valves.
- Multimodal collaboration in response: When cars could pass through the streets, they would arrive in the parks to drop off supplies; cyclists would fan out to disperse them.
- Motorcycle clubs swung into action, using motorcades to open lanes for emergency vehicles on avenues crammed with cars largely immobilized by street closures and malfunctioning stoplights.
- Mexico City Airport’s service was disrupted for several hours and reopened at 4pm.

Source: https://www.citylab.com/environment/2017/09/parks-and-bicycles-were-lifelines-after-mexico-citys-earthquake/541320/
Mexico City Airport Damages and Disruptions

Terminal 2 at Mexico City Airport

Highway Bridge Damages

(See Mark Yashinsky’s EERI Webinar: Performance of eight bridges in Mexico City and Morelos by Mark Yashinsky, Caltrans)
Mexico City’s subway system lost five of its 13 lines due to electricity failure, making the BRT lines the only transport option aside from walking and cycling in many parts of the megalopolis. The BRT system continued working at 70 percent capacity that first afternoon and night, according to Jesus Padilla, CEO of CISA, which operates of Line 1 of Mexico City’s Metrobus.

“The confined lanes of the Metrobus were the only way for our ambulance services to get around Mexico City after the earthquake,”

The system survived the 1985 Mexico City Earthquake

Sources: https://www.citylab.com/environment/2017/09/parks-and-bicycles-were-lifelines-after-mexico-cities-earthquake/541320/
Ground Cracks on Streets
Bicycles were Lifelines in Mexico Earthquake Responses

A volunteer wearing a dust mask rides a bike in the Roma neighborhood of Mexico City, Wednesday, September 20, 2017
Water Systems

INFORMATION PROVIDED BY CRAIG DAVIS, LADWP, AND GUSTAVO AYALA, UNAM
Comisión Nacional del Agua (ConAgua)

ConAgua is responsible for national water resources and operates 8 supply systems providing bulk water to the Valley of Mexico.

Three of the 8 systems were damaged from Sept. 19, 2017 earthquake:

- Mixquic-Santa Catarina
- Tlahuac-Nezahualcóyotl
- Texcoco-Peñon

26 repairs in 22 kilometers of the two aqueducts making up Mixquic-Santa Catarina and Tlahuac-Nezahualcóyotl (reported on October 5, 2017, while work was still underway).

SACMEX reported 30 breaks on Tlahuac-Nezahualcóyotl alone (October 23, 2017).

Aqueducts are segmented reinforced concrete pipe.

Texcoco-Peñón had wells impacted by electrical transformer failure (7) and well collapse (2). Transformers replaced by helicopter at 2 of the most important wells.

Tlahuac-Nezahualcóyotl branch had 3 collapsed wells.
Sistema de Aguas de la Ciudad de México (SACMEX)

SACMEX is responsible for the supply and delivery of potable water within Mexico City (CDMX)

11 repairs in the Chalco-Xochimilco Aqueduct and 9 repairs in the Xochimilco aqueduct

22 repairs in the primary distribution networks, diameters 40 to 122 cm

2,615 repairs in the secondary network as of October 4, 2017, with some continued leaks appearing as pressures increased

21 transformers owned by SACMEX failed, damaging 42 pumps

Very severe cracks in the Santa Catarina water treatment plant

Operations disrupted for days from loss of power from CFE
Comisión del Agua del Estado de México (CAEM)

CAEM is responsible for the water resources within the State of Mexico.

12 municipalities of the State of Mexico declared in disaster area, primary damages were from:
  ◦ rupture of pipes
  ◦ fissures in the storage tanks in the municipalities
  ◦ ruptured lines of from landslides

Tenancingo, Tepetzingo, and Zumpahuacán municipalities lost all water supplies and Valle de Chalco had severe problems

Severe water supply problems in Nezahualcóyotl-Los Reyes municipalities, from state and federal systems
  ◦ Steel transmission line (42” dia.) damaged by compression failure at 9 locations in 9/19/17 Eq. and 2 locations in 9/7/17 eq
  ◦ Same line had 1 mechanical coupling repair
  ◦ Same line had 6 air/vacuum valve repairs

42” butt-welded steel pipe, Courtesy Nezahualcóyotl
Service Losses & Emergency Water Distribution

Service Losses:
- Not certain how many customers lost water from the Sept. 19, 2017 earthquake.
- CDMX had over 3 million 300 thousand people without service on Sept. 19, 20, 2017
  - All services restored sometime before Nov. 11, 2017
- State of Mexico
  - Likely several million people without water following the earthquake and restored at slower rate than CDMX
  - 500,000 people in Nezahualcóyotl still had no water on Nov. 16, 2017
  - Several hundred thousand people in other municipalities also remained without water in Nov. 2017

Emergency Water Distribution:
- ConAgua provided tanker trucks and barrels for emergency water, for 500,000 people in CDMX and State of Mexico, delivered over 25 Million liters of water
- SACMEX 561 million liters between 9/20/17 and 10/22/17
Wastewater and Drainage Systems

INFORMATION PROVIDED BY CRAIG DAVIS, LADWP, AND GUSTAVO AYALA, UNAM
SACMEX

SACMEX is responsible for the collection and disposal of sewage and drainage water within CDMX

2-72” diameter collectors were damaged

8 repairs in the treated water network

Cracks in four treatment plants, The Llano, Cerro de la Estrella, San Juan de Aragón and La Lupita

Failure on the San Sebastián Canal, in Xochimilco, and the National Canal in Iztapalapa
  - two kilometers of fractures in the banks, flooding parts of Xochimilco

15 transformers failed in the drainage system, impacting operations

Operations disrupted for days from loss of power from CFE

Flooding in Xochimilco,
Nezahualcóyotl

1.22 m in diameter pipe damaged from several cm offset. Backed up sewage into collection lines.

About 14 sinkholes appeared after earthquake
Gas and Liquid Fuel Systems

INFORMATION PROVIDED BY CRAIG DAVIS, LADWP, WITH SUPPORT FROM ALEXIS KWASINSKI, UNIVERSITY OF PITTSBURG
Gas and Liquid Fuel Systems

Most use propane (liquid petroleum, LP) which it is distributed in trucks and stored in homes either in cylinders or in stationary propane tanks.

Only about 330,000 services in the metropolitan area of Mexico City (Fenosa, 2010). Unable to communicate with them, but no known damages to system to report.

Power grid operators are the largest costumers for natural gas, had no loss of gas service from Sept. 19, 2017 earthquake.

PEMEX pipeline (about 6” dia) damaged from ground fissures in CDMX following Sept. 19 event.

Fire Department noted there were reports of 1000 gas leaks and fires:
- About 100 to 150 ignitions, some became fires
- Most fires came from propane containers in homes, some exploded.