

2017 CENTRAL MEXICO EARTHQUAKE RECONNAISSANCE REPORT

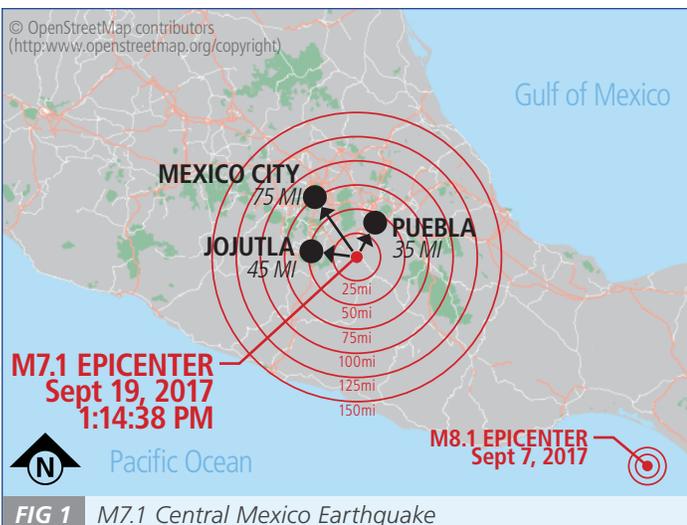


On September 19, 2017, at 1:14 p.m. (local time) exactly 32 years to the day after the tragic M8.0 1985 earthquake, central Mexico was struck by a M7.1¹ intraplate earthquake (Fig. 1). It struck only two hours after a citywide earthquake drill and put a dramatic end to commemoration activities taking place throughout the city. This was the second earthquake in a matter of weeks – an M8.1 earthquake located in the Chiapas Region, approximately 467 miles from Mexico City, had struck on September 7. As a result of normal faulting at

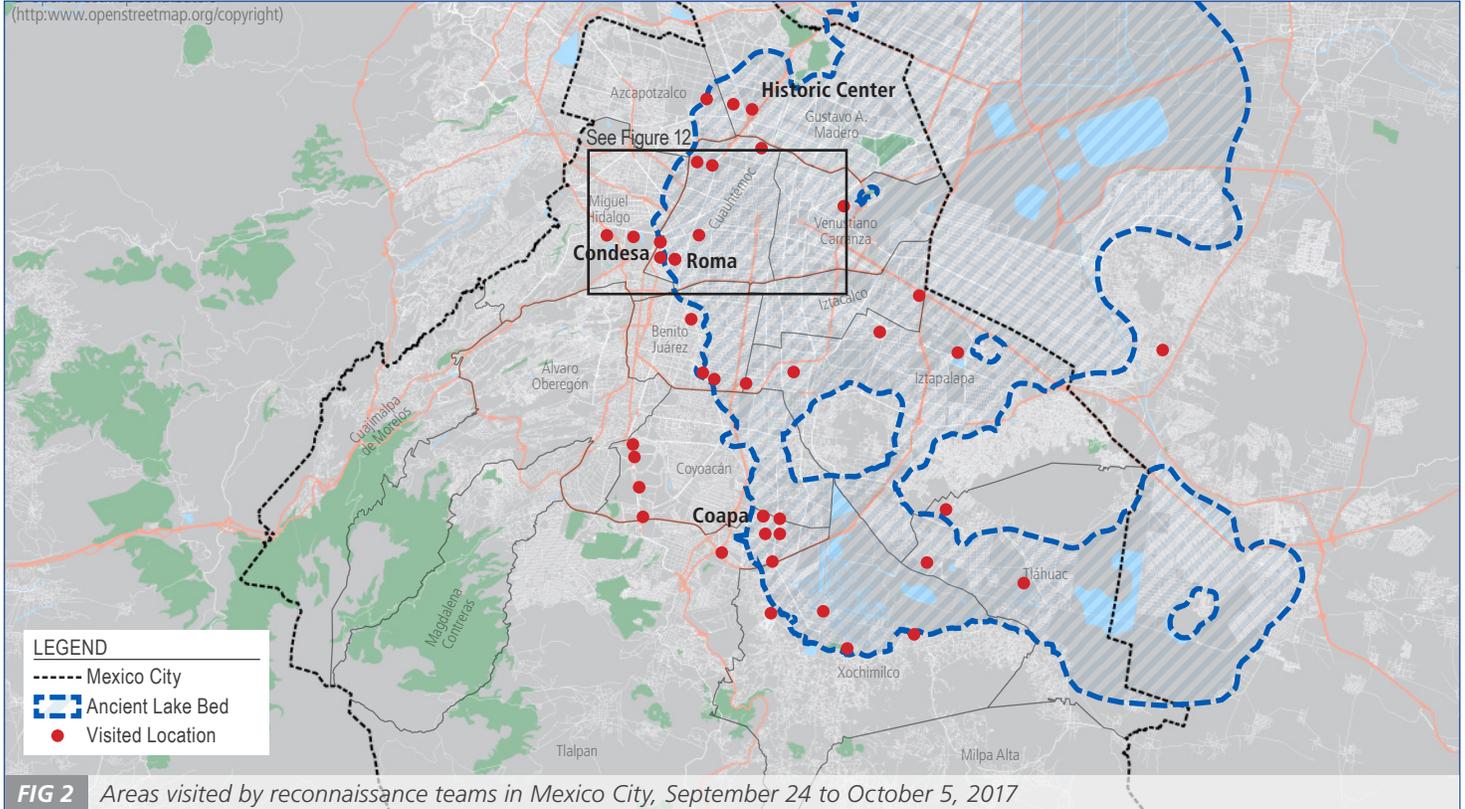
a 51-km depth, the strong shaking on the 19th lasted for 20 seconds resulting in 369 fatalities (228 Mexico City; 74 Morelos; 45 Puebla; 15 in State of Mexico; 6 Guerrero; 1 Oaxaca) and damaging approximately 5,812 buildings and houses, causing about US\$2 billion in direct losses as of January 2018.

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Earthquake Reconnaissance Overview



In an effort to help with the recovery activities and learn from this latest earthquake, Reid Middleton sent two reconnaissance teams (Figs. 3 and 4) comprised of eight Reid Middleton engineers and three earthquake engineering colleagues. Reid Middleton participants were David Swanson, David Gonzalez, Erik Bishop, Kenny O'Neill, Drew Nielson, Kevin Galvez, Nicole Trujillo, and Darin Aveyard from Reid Middleton's Everett, San Diego, and Honolulu, offices. Also joining the team were Humberto Caudana, a post-doctoral researcher in the Structural Engineering Department at UCSD, Brian Knight, Principal at WRK Engineers, Erica Fischer, an Assistant Professor at Oregon State University in the Civil and Construction Engineering Department, and Mark Pieriepiekarz, president at MPP Engineering. The overlapping teams were in Mexico from September 24 to October 5, 2017 and observed structural damage to buildings and infrastructure throughout Mexico City (Fig. 2) and surrounding towns.

STATISTICS

Buildings Inspected 12	Houses Inspected 20	Hardhats Worn 11	Miles Walked ~80 miles
Sites Visited 12	Cities Visited Mexico City, Puebla, Jojutla, Cuernavaca		

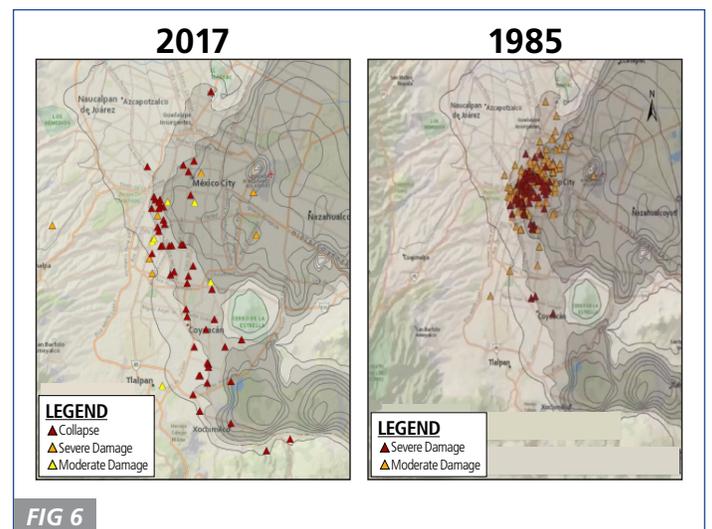
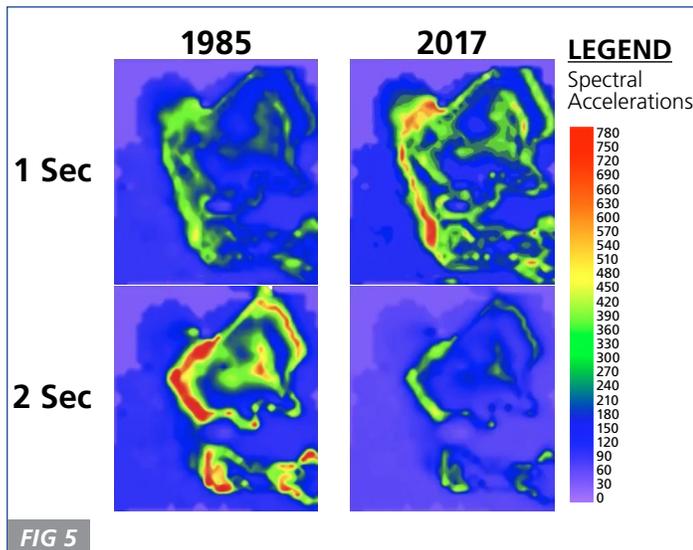


Previous Earthquake Comparison

The 2017 M7.1 Central Mexico earthquake was very different than typical strong earthquakes in Mexico. The M7.1 earthquake was an intraplate earthquake with larger spectral accelerations for short-period structures of about 1 second. Structures with a 1-second period corresponded to buildings with 7 to 10 stories. In contrast, the 2017 M8.1 and the 1985 M8.0 earthquakes had epicenters located in the subduction zone, further from the city, and produced larger spectral accelerations for longer period structures of about 2.0 seconds². After the 1985 M8.0 earthquake,

buildings of 5 to 7 stories matched the 2-second natural period of the earthquake. The spectral accelerations in the Mexico City Valley for the 1985 M8.0 and 2017 M7.1 earthquakes are shown in Fig. 5.

The distribution of building damage is shown in Fig. 6 for the M7.1 Central Mexico and the 1985 M8.0 Guerrero earthquakes. The 1985 M8.0 earthquake structural building damage was mainly in the lakebed zone with deep deposits of clay. In contrast, the 2017 M7.1 earthquake had building damage in the lakebed zone with stiffer soil.



2017 EARTHQUAKES ^{1, 4}						
SEPT 19, 2017 AT 1:14 PM	TYPE	DEPTH	MAGNITUDE	CASUALTIES	BUILDING DAMAGE	ESTI-MATED Losses
	INTRASLAB	32 miles	M 7.1	369 Dead 6,000 Injured	38 Collapsed 3,782 Serious	\$2B
EPICENTER						
74 mi SE of Mexico City						
SEPT 7, 2017 AT 11:49 PM	TYPE	DEPTH	MAGNITUDE	CASUALTIES	BUILDING DAMAGE	ESTI-MATED Losses
	SUBDUCTION	57 miles	M 8.1	100 Dead 300+ Injured	110,000+ Serious	\$356M
EPICENTER						
471 mi SE of Mexico City						
1985 EARTHQUAKE ³						
SEPT 19, 1985 AT 7:17 AM	TYPE	DEPTH	MAGNITUDE	CASUALTIES	BUILDING DAMAGE	ESTI-MATED Losses
	SUBDUCTION	17 miles	M 8.0	9,500 Dead 30,000+ Injured	412 Collapsed 3,124 Serious	\$3B ('85)
EPICENTER						
394 mi SW of Mexico City						

2017 NOTES: As of Nov 12, Houses Rebuilt: Oaxaca - 3,594; Chiapas - 1,255

1985 NOTES³: About 60% of the buildings were destroyed at Ciudad Guzman, Jalisco. Damage also occurred in the states of Colima, Guerrero, Mexico, Michoacan, Morelos, parts of Veracruz, and in other areas of Jalisco. Buildings of 5 to 7 stories matched the two-second natural period of the earthquake. Five common patterns of failure for the severely damaged buildings: **42%** were corner building failures, **40%** were a collapse of intermediate floors, **38%** were a collapse of upper floors, **15%** were due to pounding, **13%** were foundation failures

Seismology & Geology

Central and South Mexico have a long history of earthquakes (Fig. 7). Along Mexico's southwest coast, the Cocos Tectonic Plate is subducting beneath the North American Tectonic Plate. In the past, this has caused megathrust subduction zone earthquakes along the coast and intraslab and deep earthquakes in the interior (Fig. 8). These subducting plates are also the cause of central Mexico's volcanoes.

Mexico City rests among these volcanoes on an ancient lakebed in a high mountain valley (elev. 7,400 feet). Inhabitants drained the water level in the lake over many years, leaving soft saturated soils that present unique challenges for buildings and infrastructure (Figs. 9 to 12). One of these challenges is the amplification of seismic waves in the central areas of the City. The soil amplification is evident in the CIRES spectral accelerations (Fig. 11) for the Mariscal Tito station⁸ at the hard rock and the Alameda Central station⁸ at the softer clays within the ancient lakebed. The localized damage can be attributed to basin effects and directionality

effects; the basin can trap the seismic energy and cause amplified accelerations. These local soil effects impact the seismic design of buildings in Mexico City.

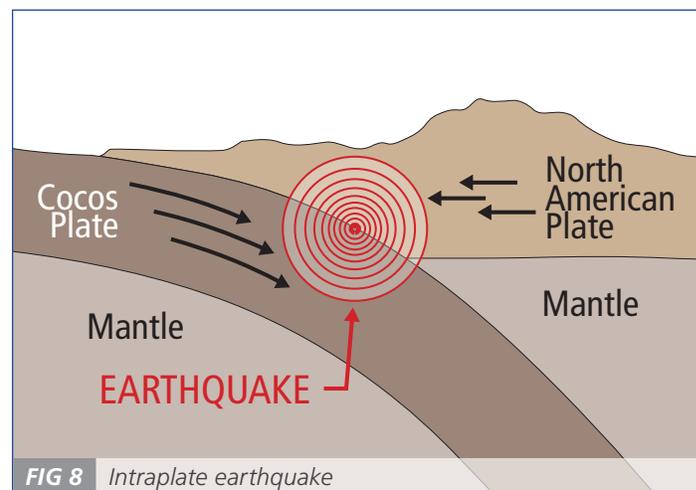


FIG 8 Intraplate earthquake

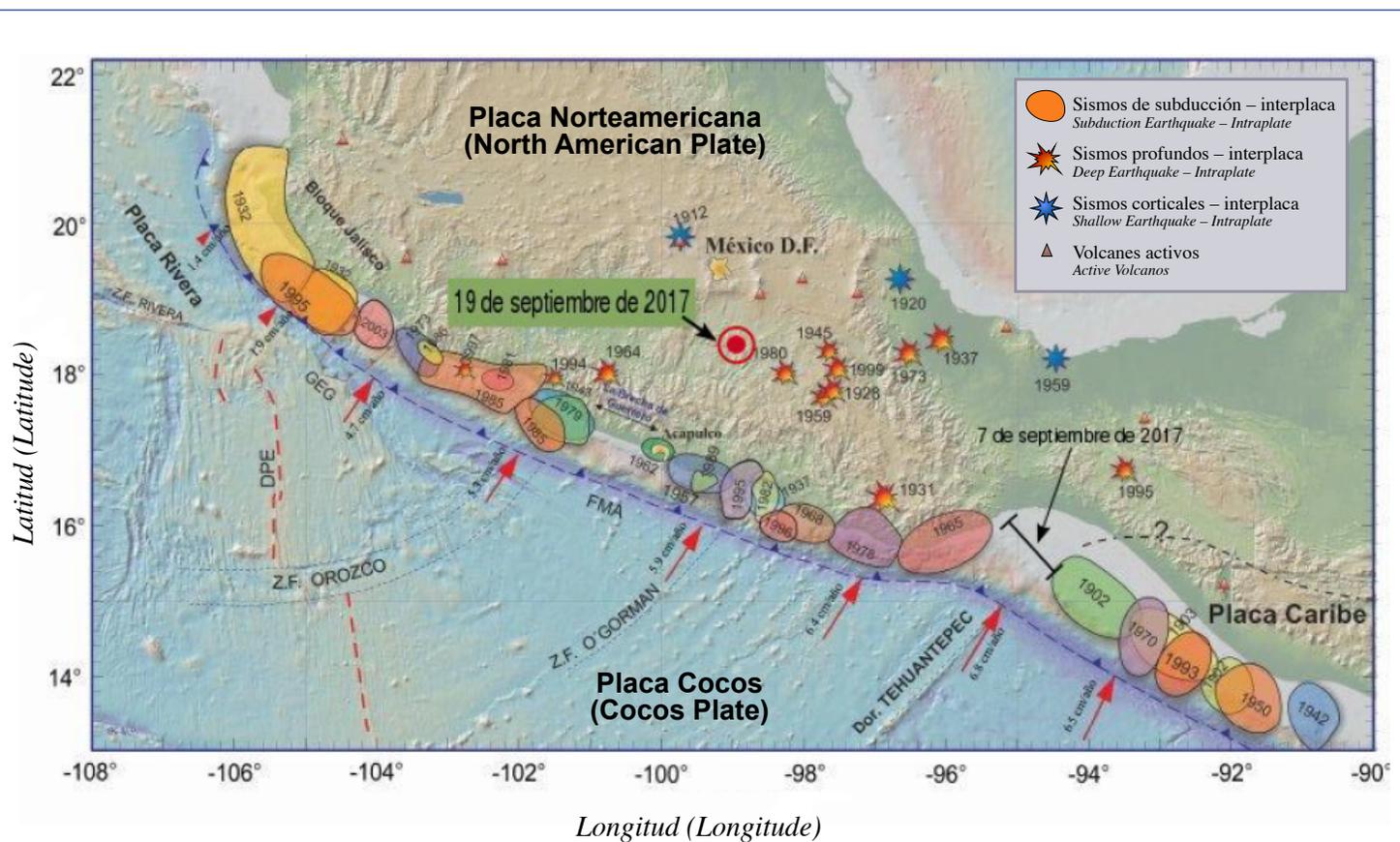
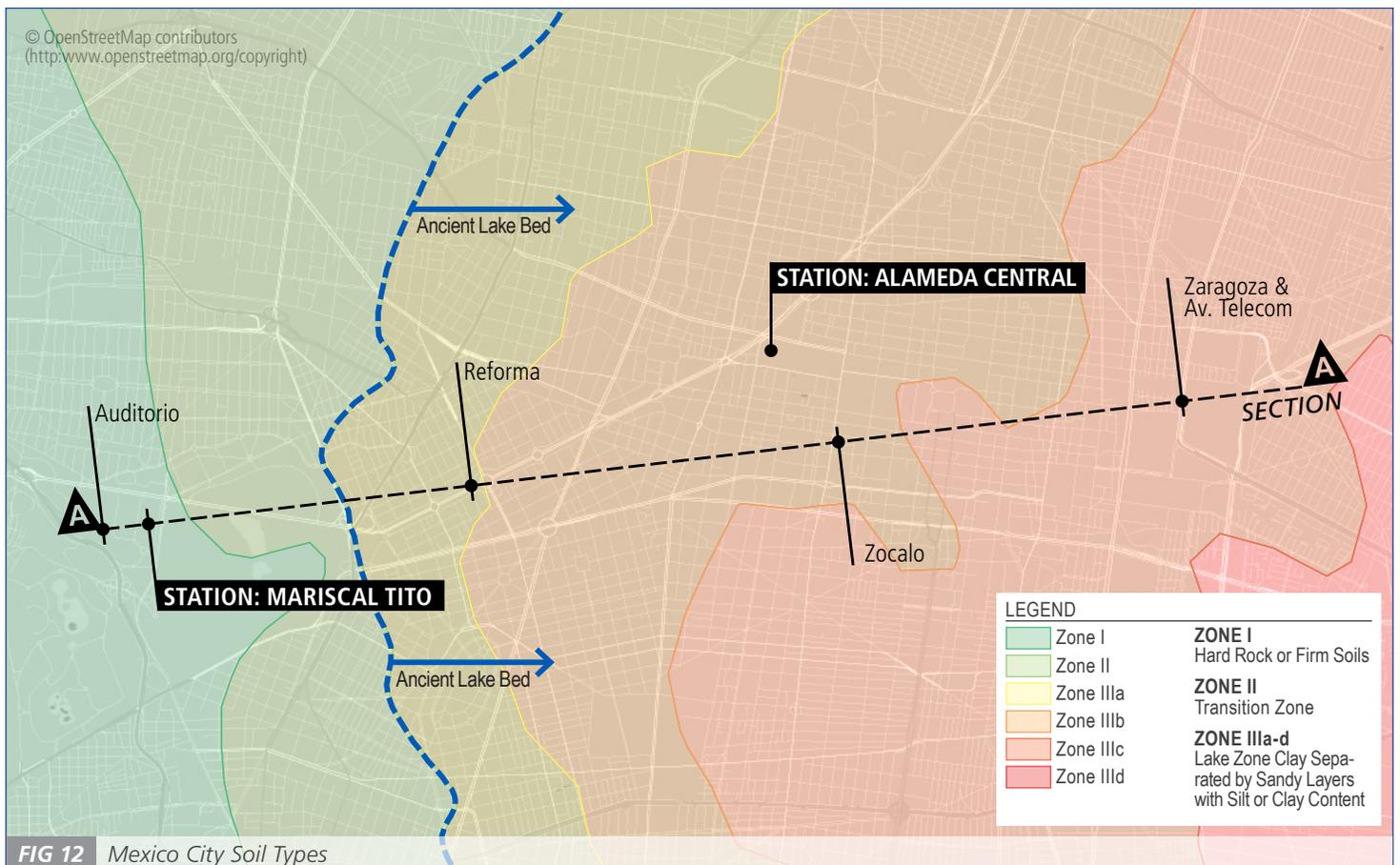
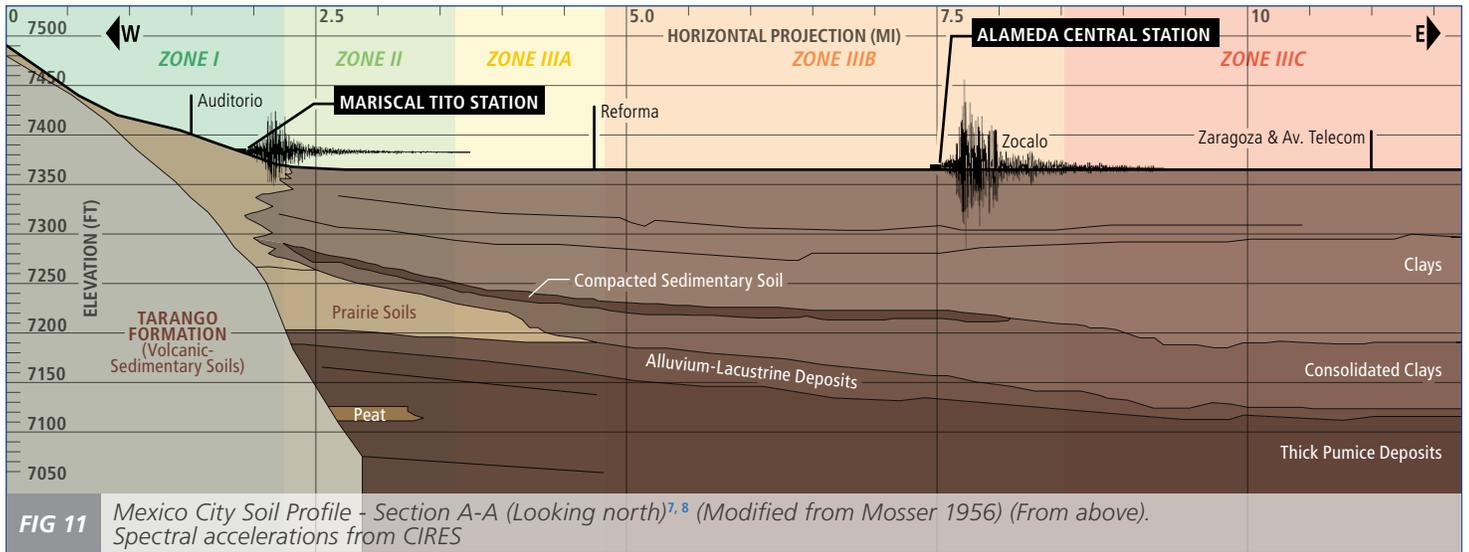
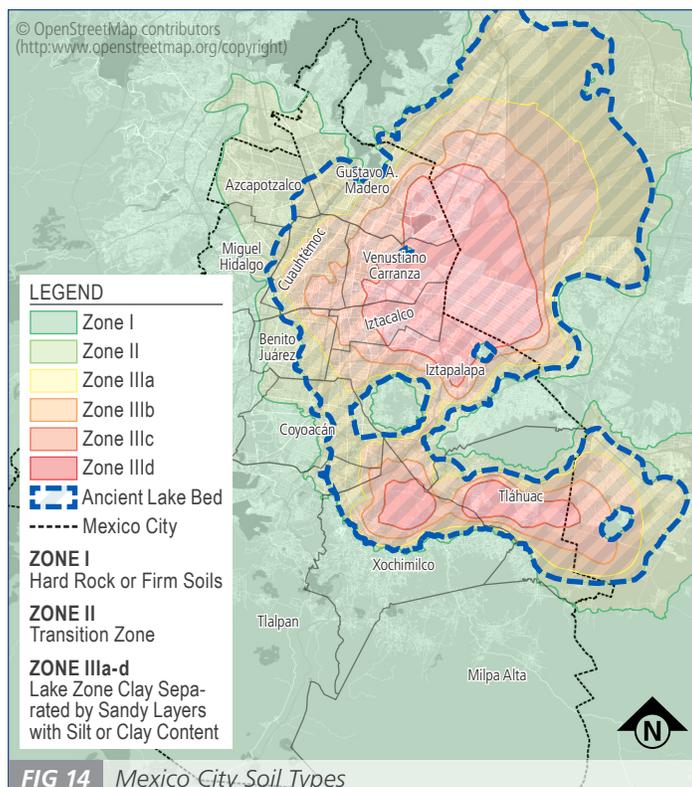
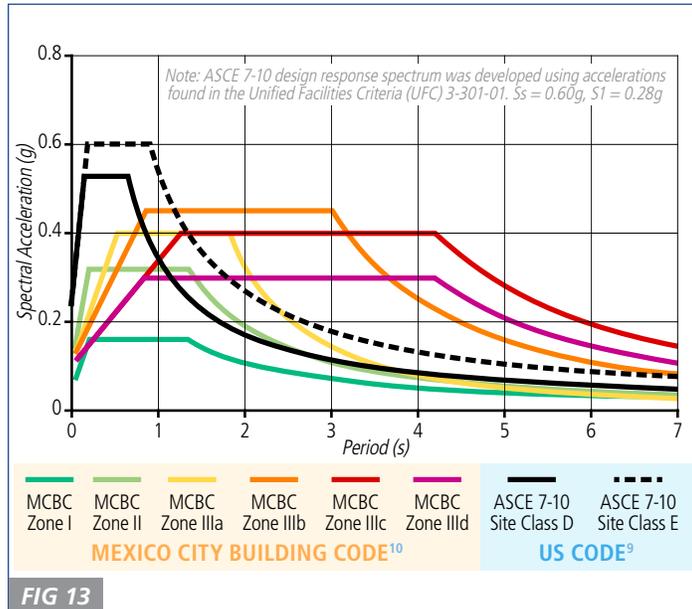


FIG 7 Locations of the most important earthquakes that have occurred in Mexico since 1902.⁵



Seismic Design Comparison

In seismic design of buildings, similar features can be found in the US and Mexico's building code. Mexico's seismic design code considers different zones used in seismic design (Figs. 13 & 14) similar to how U.S. codes use site classifications and seismic design categories. The lake transition zone (majority of building collapses) is identified as Zone IIIa. Mexico's seismic design is intended to prevent major structural failures or loss



of life for the design seismic loads. However, minor structural damage and potential damage to nonstructural systems may occur which could affect building operation and occupancy as observed during the reconnaissance. Unlike the US code, performance level and the return period of the design earthquake is not explicitly stated in the Mexico code. A comparison of the design spectra is shown on Figure 13.

In rural and historic areas, separation between adjacent buildings appeared minimal. Potential falling hazards and damage which may have been due to building pounding or insufficient building separation was observed in damaged buildings (Fig. 15). The minimum building separation requirement of U.S. codes is the square root of the sum of the squares (SRSS) of the inelastic displacement of adjacent buildings. Mexico's building code requires a minimum setback distance of the lesser of 50 mm or a distance equal to the design horizontal displacement increased by a percentage of the floor height. Adjacent buildings should be separated by the sum of the setback distance for both buildings.



Emergency Response



FIG 16 US&R team at collapsed building

The M7.1 earthquake on September 19, 2017, caused 38 buildings to collapse in Mexico City and left 3,782 damaged and red tagged buildings. According to the Secretariat of Civil Protection in Mexico City (Civil Protection), a red tag means that the building is high risk and no one is allowed access, a yellow tag means that the building has serious damage and access is restricted, and a green tag means the building is low risk and there are no restrictions. Civil Protection's mission is to safeguard the life, assets, and environment of the citizens of Mexico City and to mitigate the destructive effects of natural disasters to the structure of vital services and systems of Mexico City. Civil Protection was in charge of organizing and performing Post Earthquake Reconnaissance Rapid Evaluations. Members of the Reid Middleton team volunteered to perform Rapid Evaluations in the Condesa neighborhood on Monday, September 25.



FIG 17 Jojutla - Unloading of water supply truck

According to an article in *La Jornada*, a Mexican newspaper, Mexico City has only 100 structural engineering experts. Therefore, employees from Civil Protection were grateful our team volunteered to perform building evaluations. In addition, the team volunteered with Casa de Arquitectos (AIA equivalent) to perform residential building evaluations to single-family homes in Iztapalapa.

Not only did the team volunteer to perform building evaluations, David Swanson (a member of FEMA's Urban Search & Rescue (US&R) Washington Task Force (WA-TF-1)) was able to provide structural engineering guidance at the search and rescue efforts at a collapsed office building in Condesa, Alvaro Obrégón 284/286 (Figs. 16 & 18).

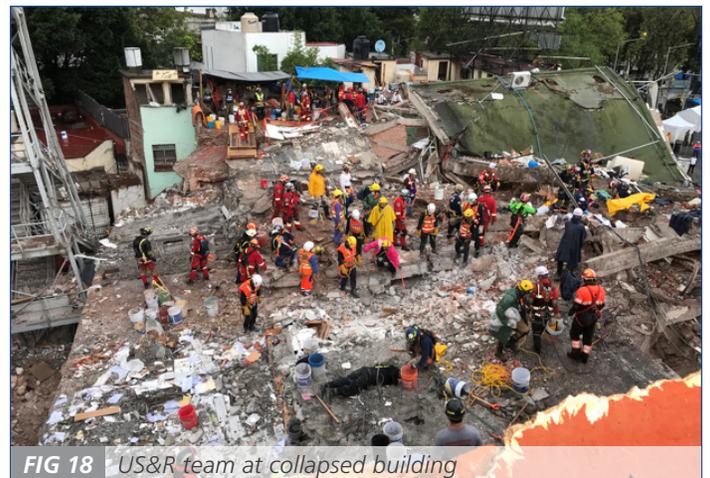


FIG 18 US&R team at collapsed building

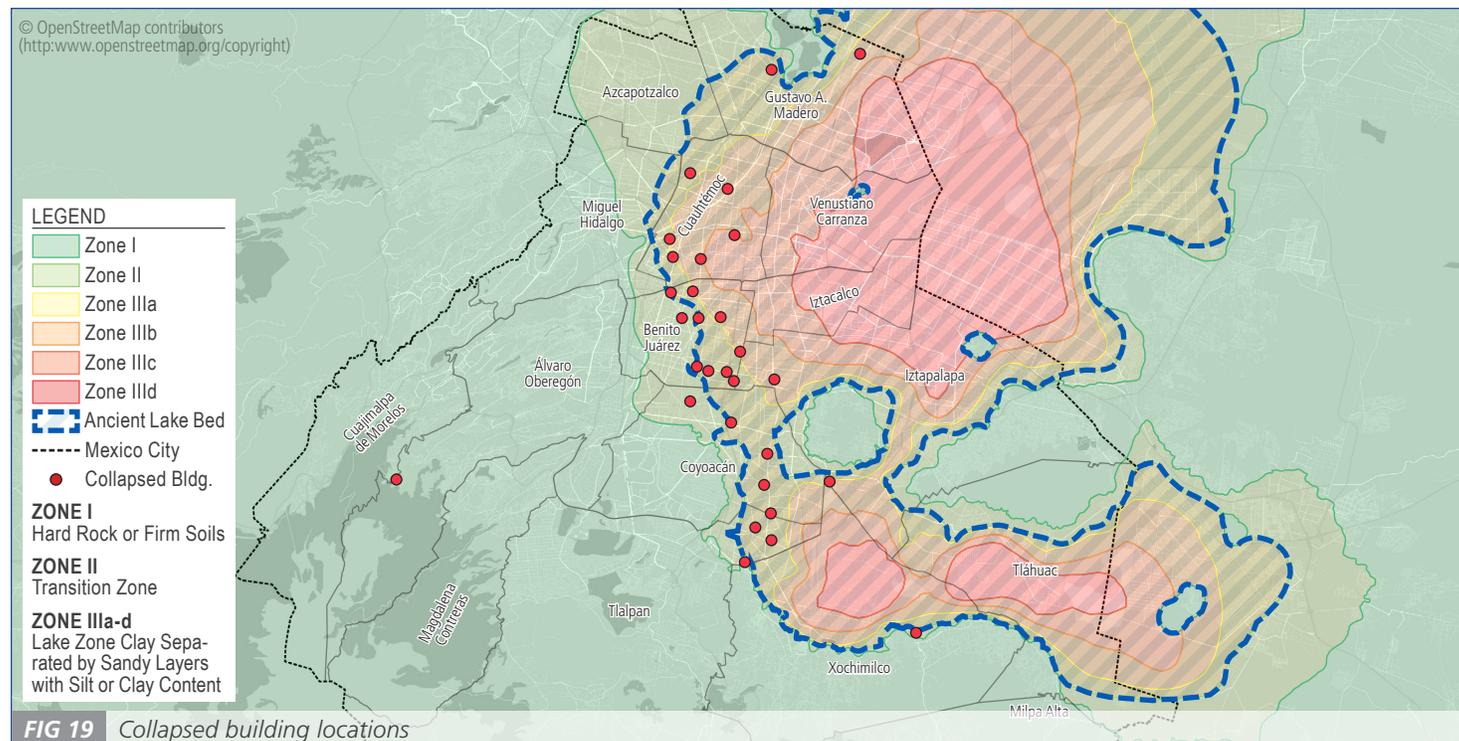
COMMUNITY RESPONSE

Some of the most impressive and profound observations were that of local communities organizing responses in incredibly impressive, selfless, organic, and unified ways. For example, urban search and rescue efforts at collapsed buildings that were led entirely by volunteers from México and abroad, a miner who left his hometown and put his life in significant danger to assist with rescue efforts, and Abuelas "grandmas" making food in tents nearby for volunteers.

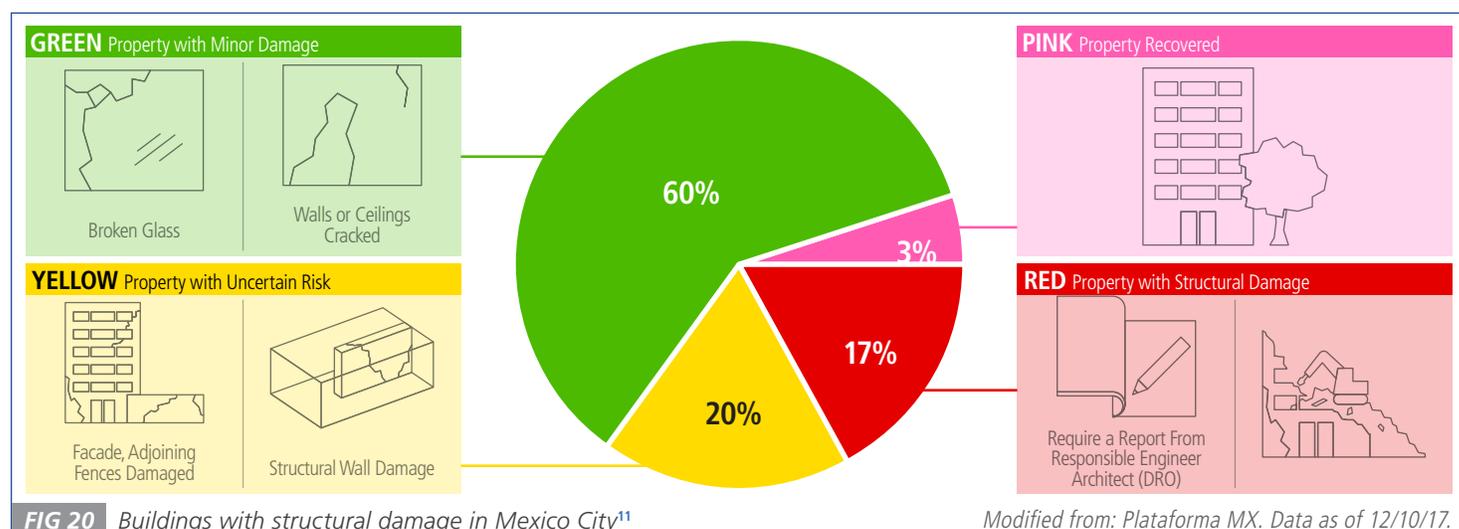
In Jojutla, we met a team of students who came from Mexico City to assist in response efforts. They found themselves leading the grassroots effort of receiving and distributing donated resources, organizing demolitions and repairs, and serving as a local focal point for the devastated community (Fig. 17). These are 19-year-old students. We had the opportunity to collaborate with several students at the fulcrum of the emergency operations center within the Colegio de Ingenieros Civiles in Mexico City, where the building evaluations are organized, documented, and distributed.

Building Damage – Mexico City

The M7.1 earthquake on September 19, 2017 caused structural damage to building throughout Mexico City. According to data from Protection Civil, 38 buildings collapsed in Mexico City as shown in *Figure 19*. The collapsed buildings were located in the lake zone where there are stiffer clay soils.



The earthquake caused structural damage to buildings throughout Mexico City. According to data from Protection Civil, 38 buildings collapsed in Mexico City as shown in *Figure 19*. The collapsed buildings were located in the lake zone where there are stiffer clay soils. Miguel Ángel Mancera, the governor of Mexico City, presented the CDMX Platform digital database, which contains the location of each building that has been reviewed with the determination of the type of damage caused by the earthquake. The statistics show that 22,367 buildings were reviewed (1,015 – Pink; 13,393 – Green; 4,176 –Yellow, 3,782 –Red, as of 12/10/17.)¹¹ The Institute for Building Safety reviews properties with structural damage (red) and determines the need for demolition. If demolition is deemed necessary, the order then needs to be approved by the Civil Protection Emergency Committee of Mexico City (Protección Civil).



There were many buildings with damage observed throughout Mexico City. The damaged structures included confined masonry and non-ductile concrete buildings

NON-DUCTILE COLUMN DAMAGE



FIG 21



FIG 22

DAMAGED URBAN BUILDING IN BENITO JUAREZ - 5-story structure that had columns at the first floor, which appeared to be sheared through the middle of the span. This would indicate that the building may be on the brink of collapse. A soft-story irregularity, generally where a floor is considerably less stiff than the ones above, is likely the cause.

FOUNDATION DAMAGE & NON-DUCTILE CONCRETE COLUMN COLLAPSE



FIG 23

PARTIALLY COLLAPSED BUILDING - The 5-story residential and departmental building suffered a partial collapse. The truss supported roof, distinguished by solar panels, tanks, and satellite dishes, still sheltered the area of the collapse. After the earthquake, an adjacent bridge was shut down to heavy vehicles to prevent further damage to the building through vibration.

NON-DUCTILE CONCRETE COLLAPSE



COLLAPSED BUILDING IN BENITO JUAREZ - The 4-story residential building appeared to have incurred multiple failures of the infill masonry out of plane. In addition, the first floor or garage level completely collapsed.

SETTLEMENT DAMAGE



IZTAPALAPA - Majority of structures observed during volunteer safety assessments were single-family dwelling units, mostly built in the 1970's and typically consisted of confined masonry construction. The types of earthquake damage noticed were, for the most part, wall cracks likely due to ground settlement combined with earthquake loading. Building leaning was also observed from ground settlement which measured about 1 foot. Measurements suggested that it was leaning about 1 to 2 degrees out of plumb.

FIG 26

NON-DUCTILE CONCRETE COLLAPSE



FIG 27

COLLAPSED BUILDING IN CONDESA, CUAUHTÉMOC – Álvaro Obregón 284 & 286 - 5 & 7 story buildings, respectively, were office buildings occupied at the time of the earthquake.

NON-DUCTILE CONCRETE COLUMN DAMAGE & MASONRY INFILL DAMAGE



FIG 28



FIG 29

DAMAGED MIXED USE BUILDING IN CONDESA, CUAUHTÉMOC – 5 story & underground parking residential/mixed use building experienced much non-structural damage.

MASONRY INFILL WALL DAMAGE

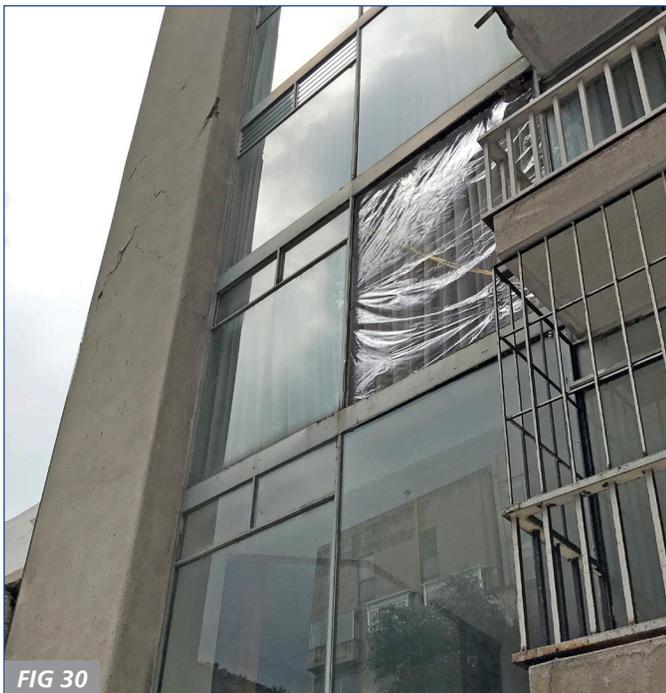


FIG 30



FIG 31

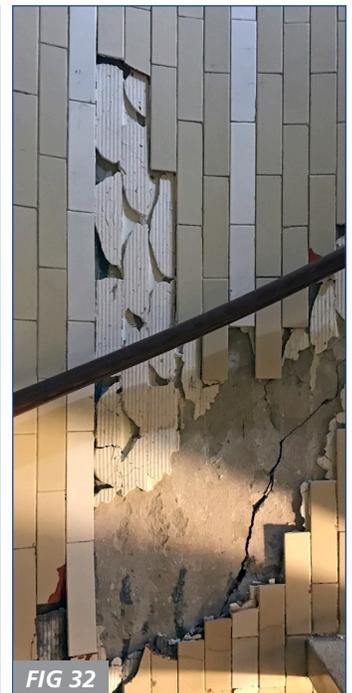


FIG 32

DAMAGED RESIDENTIAL BUILDING IN CONDESA, CUAUHTÉMOC – The 6 story residential building had damage to masonry infill walls. In addition, there was damage to the stairwell.

UNDAMAGED BUILDINGS



FIG 33

DOWNTOWN MEXICO CITY - The 1956 Torre Latinoamericana Tower, which was the first major skyscraper successfully built in a high-seismic area and had survived the 1985 earthquake undamaged, did not appear to have sustained major damage.¹²



FIG 34

HISTORIC CENTER OF MEXICO CITY - The Cathedral Metropolitana, which is the oldest and largest cathedral in Latin America, survived the 1985 earthquake and was retrofitted. The cathedral still stood and did not appear to have suffered major damage.¹³



FIG 35

HISTORIC CENTER OF MEXICO CITY - It was noted that very few of the buildings in the area of the Historic Center of Mexico City had observable exterior structural damage. All of the structures were being used as their typical occupancy type, and it remained fully operational.

Building Damage – Puebla

Puebla's quaint city center, is mostly comprised of 1- to 2-story buildings constructed of either unreinforced masonry (URM) or confined masonry (concrete frame with masonry infill walls). Minimal damage was observed in Puebla considering the significant seismic vulnerability of the buildings and proximity to the epicenter.



PARAPET DAMAGE - Historic City Center parapet damage to 2-story buildings. This is an example of minimal damaged observed in vulnerable buildings.

NO DAMAGE - Historic cathedral did not show any structural damage



HISTORIC CENTER OF PUEBLA - This 2-story building experienced a commonly observed phenomena in dense, adjoined building construction. One of the few severely damaged buildings in Puebla

Building Damage – Jojutla, Morelos

The buildings in Jojutla were severely damaged. A local resident said that approximately 50% of the buildings in the town had been heavily damaged or collapsed during the earthquake. Most of the structures in Jojutla were 1- to 2-story confined masonry, unreinforced masonry, or adobe buildings. These types of structures are particularly vulnerable to earthquake damage because of their lack of sufficient strength or ductility. There was significant evidence of how the earthquake affected the local people. Many people were without permanent shelter and the government and private organizations were providing food and aid to people. Jojutla received disproportionately more damage than surrounding towns. One theory is that the disproportionate damage could have been caused by the soil conditions, or the focusing of the seismic waves due to the surrounding geology and topography.



FIG 39

RACKING & NON-DUCTILE COLUMN DAMAGE - Reinforced concrete structure that experienced significant drift - potential soft story



FIG 40

REBAR PILE FOR SCRAPPING - Ongoing demolition and cleanup at site of collapsed buildings



FIG 41

CONFINED MASONRY DAMAGE - Significant damage to confined masonry infill

Lifeline Performance Observations

In addition to studying building and structures damage, another primary reconnaissance objective was to study the performance of lifeline systems and critical community functions. These systems include utility infrastructure (water, wastewater, electrical, communications, etc.), transportation systems/networks, and healthcare and education infrastructure.

WATER SYSTEM: Providing reliable water service and maintaining water supply resilience was an on-going challenge for Mexico City (CDMX) prior to the earthquake. This is partially due to the complexity of the city's geology, with some areas "sinking" 30cm (12 inches) a year. In many areas of the city, water service is unreliable.



FIG 42



FIG 43 Drums of potable water

As a result of the event, several transmission pipelines were damaged, and many communities did not have access to water service a week after the event. Often, these communities were in less affluent and less influential areas of CDMX. Municipalities and water service providers distributed large drums of potable water throughout communities and returned on regular cycles to refill the drums. The drums were strategically placed within walking distance for most community residents (Fig. 43).

There was observable damage to the primary water distribution system and to the aqueducts in the Tláhuac and Xochimilco regions of CDMX. The primary distribution network had about 22 breaks, according to Conagua. And seven hundred thousand people were affected by the 26 breaks in 14 miles of the Mixquic-Tláhuac aqueduct, which supplies water to eastern Iztapalapa and a part of Tláhuac, as reported by the National Water Commission (Conagua), the Mexico City Water Administration (Sacmex), and the Water Commission for the State of Mexico (Caem).¹⁴ Conagua also reported 20 breaks in the Chalco-Xochimilco and Xochimilco aqueducts.¹⁴



FIG 44

WATER DISTRIBUTION SYSTEMS – Emergency repairs were observed being performed on a 48" diameter main water service line for Mexico City. In addition, as shown in the photo, damage to the adjacent municipal network was observed and being repaired in order to allow for the service line repair. This resulted in frustrated community members based on the expectations that local water service would be restored

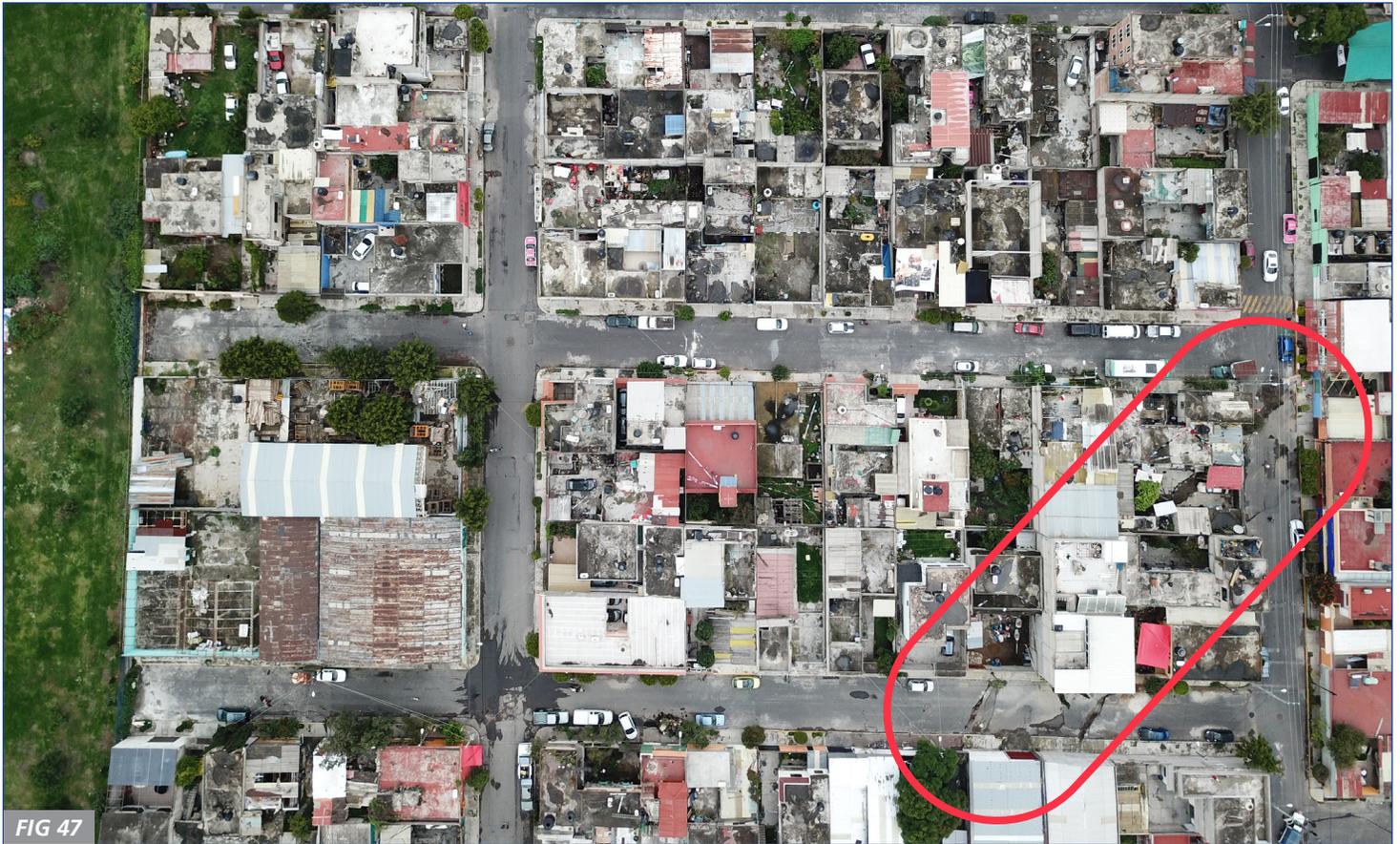


FIG 45

WATER DISTRIBUTION SYSTEMS – Repairs were ongoing to foundation damage at water tank. Steel columns were shored and tank was emptied while reinforced concrete foundations were poured

**FIG 46**

WATER DISTRIBUTION SYSTEMS – Steel water distribution tank where bracing rods were observed to be loose from inelastic deformations during the seismic event



WATER DISTRIBUTION SYSTEMS – Tlahúac water system damage, ongoing repairs to main aqueduct

WASTEWATER SYSTEM: The system experienced some damage, including to treatment plants and transmission lines. The wastewater system was nominally operating at pre-event levels immediately after the event.

POWER SUPPLY SYSTEM: Although first-hand reports noted some damage to several substations, the power was mostly functional after the event. However, damaged or collapsed buildings caused localized interruption to electricity in many areas.

TELECOM SYSTEM: The telecom system in CDMX remained mostly functional after the event. More-rural areas, such as Jojutla, were without telecom services until local telecom companies voluntarily installed temporary towers three to four days after the earthquake.

TRANSPORTATION SYSTEM: There were reports that five of the city's 13 metro lines stopped service after the earthquake due to electricity failure, but they quickly restarted. In fact, public transportation systems were operating for free or reduced fares immediately after the event. Otherwise, there was not significant damage or interruption to the transportation system in CDMX after the event aside from rerouting traffic around damaged buildings. Outside of CDMX, there was some interruption to the transportation system due to bridge damage and geotechnical failures, including damage to roads and bridges in the nearby state of Morelos. Also, the MEX airport closed for approximately three hours immediately after the earthquake.



FIG 49 Chlorine tank essential for hospital housekeeping operations at Hospital General Dr. Ernesto Meana San Roman

HEALTHCARE SYSTEM: Several hospitals sustained nonstructural damage, loss of water service (ostensibly), and minor structural damage. Local newspapers reported that the operations of 600+ healthcare facilities were affected on some level, including clinics, hospitals, and medical office buildings. However, there were no reports of hospitals that suffered extreme structural damage or collapse.



FIG 50 Hospital General Dr. Ernesto Meana San Roman in Jojutla, Morelos suffered structural damage to half of the building but the other half remained operational



FIG 51 Damaged Primary School in Jojutla. The unreinforced masonry infill walls were damaged

EDUCATION SYSTEM: We visited several schools that were undamaged, but we also observed several schools that suffered severe damage or collapse. Local newspapers reported that nearly 1,000 schools suffered some form of damage, seven of which will require total reconstruction, like the one shown here.



FIG 52 Damaged Primary School in Jojutla. Total failure due to diagonal tension in unreinforced masonry wall

General Reconnaissance Observations

The following is our “top 13” list of technical observations, social observations and “lessons learned” from this particularly unique event. Of course, this is not a comprehensive list as there are countless additional lessons to be learned for communities in seismically active regions around the world. While Central Mexico has some unique geology and seismicity, many of these observations are not unique to Central Mexico. Rather, they reinforce previous lessons learned and provide a powerful and poignant reminder that we must be proactive in acting on lessons learned in order to increase the resilience of our own communities.

TECHNICAL-ORIENTED OBSERVATIONS

1. **LAKEBED SOIL AMPLIFICATION EFFECTS SIGNIFICANT** – A defining characteristic of this event is the unique condition of localized soil amplification in specific areas of Mexico City constructed on a drained lakebed. Specifically, the majority of the building damage and collapses occurred along the western transition zone of the lakebed boundary rather than in the softer lakebed center, as one may intuitively expect. Although soft soil amplification is generally expected and considered in the design code, the clarity of this trend is striking. There is a lot more to learn from this event regarding the characteristics of soft soil amplification, basin effects, including transition zones seismic wave focusing, and directionality behaviors.
2. **DAMAGE VERY LOCALIZED** – As described throughout this report, the damage that we observed was concentrated, both regionally and locally. For example, the town of Puebla had relatively minimal damage, while the town of Jojutla (with equivalent proximity to the earthquake source) was devastated. However, even within the town of Jojutla, as an example, there were city blocks that were mostly destroyed while adjacent orthogonal, or intersecting, city blocks remained largely undamaged. Similarly, within Mexico City, the damage was extremely localized; there were neighborhoods that had somewhat uniform, ubiquitous damage while others with similar vulnerable infrastructure appeared unaffected.
3. **BUILDING IRREGULARITIES** – The buildings that suffered significant damage or collapse tended to have either vertical, plan, or torsional irregularities. Additionally, buildings on the corner of a continuously connected block often suffered damage from a “Newton’s Cradle effect”. These behaviors can be overcome with good design techniques, but these conditions exacerbate structural vulnerabilities compared to more regular building configurations.
4. **VULNERABLE BUILDINGS** – As expected, unreinforced masonry (URM) buildings performed poorly when subjected to ground motions. Comparatively, confined masonry (CM) buildings have more durability and ductility, although still a vulnerable building archetype. Expectedly, well-designed, ductile reinforced concrete (RC) buildings tend to fare better than both URM and CM buildings. However, reinforced concrete also allows for larger, more-irregular construction. Therefore, when not reinforced with ductile practices, reinforced concrete buildings proved to be equally vulnerable and have higher consequences of damage due to their size and configuration. Many of the severely damaged/collapsed buildings were non-ductile concrete structures.
5. **BUILDING AMPLIFICATIONS** – Similar to the 1985 event, buildings of a specific height and natural frequency range were subjected to higher motions than taller and shorter buildings. As a result, many of the damaged/collapsed buildings were in the mid-height, 4 to 8 story range.
6. **AEC INDUSTRY** – The system oversight and quality control in the architectural-engineering-construction (AEC) industry is critical to ensuring earthquake performance. This includes educating and licensing engineers and contractors, permitting approval for construction, and independent inspection oversight during construction. When there is a weak link in this chain of oversight and quality control, the potential for failure exists, as was illustrated by damaged/collapsed buildings with unpermitted additional floors or lacking effective quality control practices for effective quality control practices for construction.

SOCIAL/RESILIENCE-ORIENTED OBSERVATIONS

7. **EARTHQUAKE EARLY WARNING (EEW) TECHNOLOGY** – Although this particular event didn’t maximize the benefits of earthquake early warning (EEW) technology due to the proximity of the particular earthquake source, it provided a real-world test of this earthquake preparedness tool and demonstrated its potential. With sufficient training/messaging, this technology has the potential to save countless lives in the long-distance event for which it’s designed.
8. **RAPID POST-EVENT DAMAGE ASSESSMENTS MATTER** – Numerous disaster response workers and volunteers participated in post-earthquake building safety evaluations (similar to ATC-20 system in the United States). Tens of thousands of these evaluations were performed through numerous collaborating governmental and non-governmental organizations. The majority of these evaluations produced green

tags, allowing people to get back into their homes and workplaces, promoting a restoration of societal functions and a more rapid recovery. It is critical that all regions in seismic zones develop well-defined systems to train, credential, deputize, and deploy armies of post-earthquake damage evaluators for community resilience.

9. CRITICAL FACILITIES WITH NONSTRUCTURAL DAMAGE – As has been observed in previous events around the world, several critical facilities (particularly hospitals) experienced good structural performance but had to close due to the poor performance of nonstructural systems. In order to meet the immediate occupancy performance objectives, both the structural and nonstructural systems have to be designed and constructed to achieve high seismic performance.

10. WATER SYSTEM PERFORMANCE – Due to its lakebed context, CDMX has several challenges to address in respect to its water distribution system, including significant settlement observed in several areas of the city. Water service is unreliable in some areas of the city, irrespective of an earthquake. The earthquake exacerbated these issues and aggravated the water systems vulnerabilities. As a result, there were substantial regions of the city without water two weeks (and later) after the event. However, this vulnerability is not unique to CDMX. Lifeline systems in seismic zones around the world should evaluate their system’s vulnerabilities and take proactive measures to increase their resilience in order to provide critical post-earthquake services.

11. CONTINUITY & RECOVERY IMPACTS – in many areas of the city, residents were displaced for indefinite durations. Critical community functions (including schools and hospitals) were closed. Business was interrupted directly by impacts to the buildings they occupy or indirectly by nearby affected buildings, roadways, or lifeline services. As a result, it is uncertain when and how these communities will recover or even if residents should return to invest in the same community. In order to improve resilience, a

broader investment in both infrastructure and critical community functions should be considered.

12. 1985 LESSONS LEARNED – Mexico City experienced a devastating event 32 years to the day before this event. We were told anecdotally that after the 1985 event, life was essentially suspended for months; no one was in the streets. Days after this event, in many parts of Mexico City, it was hard to tell that there was an earthquake. This isn’t by accident. It is the byproduct of purposeful decisions made after paying attention to the lessons learned from 1985. CDMX developed better codes and standards, implemented technologies (e.g. seismic instrumentation and early-warning systems), invested in infrastructure, and educated themselves on how to become more resilient. As a result, the differences between 1985 and 2017 are substantial.

13. ORGANIC COMMUNITY ORGANIZING – Some of the most impressive and profound observations were that of local communities organizing responses in incredibly impressive, selfless, organic, and unified ways. This includes urban search and rescue efforts at collapsed buildings that were led entirely by volunteers from México and abroad. For example, millennials who came from CDMX to help out with post-disaster recovery efforts in Jojutla and students at the fulcrum of the emergency operations center within the Colegio de Ingenieros Civiles. Amidst some of the worst suffering, snippets of incredible beauty emerged.

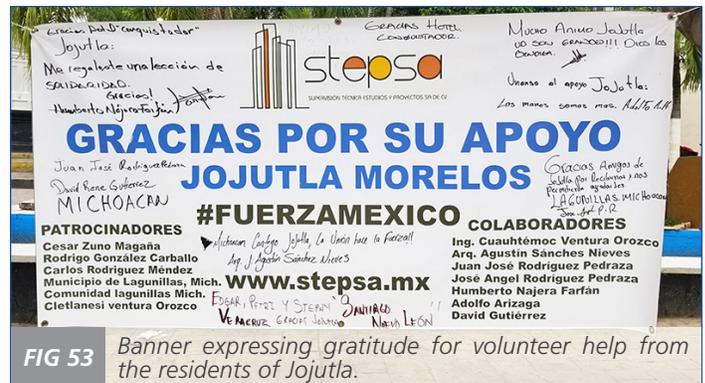


FIG 53 Banner expressing gratitude for volunteer help from the residents of Jojutla.



FIG 54 Team in Jojutla, left to right: Darin Aveyard, Mark Pierepiekarz, Mariana, Arturo Gonzalez, Erik Bishop, Luis Star, Erica Fischer, Kenny O’Neill

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