MEXICO CITY RECOVERY UPDATE:
SEVEN MONTHS AFTER THE M7.1 CENTRAL MEXICO EARTHQUAKE

MRP Engineering Newsletter **July 2018**

This newsletter summarizes MRP Engineering's observations of ongoing post-earthquake reconstruction efforts in parts of Mexico City. The September 19, 2017, M7.1 Puebla-Morelos earthquake was the most damaging event for Mexico City since the 1985 M8 Michoacan earthquake that devastated parts of the city. Since 1985, the region has taken proactive steps to lessen potential impacts from future earthquakes. Building standards for new construction were revised. An earthquake early warning system was developed to provide advance notice to Mexico City residents. Mexico City residents have benefited from this alert system on several occasions in recent years. Periodic post-earthquake response drills are regularly conducted in the region. Although seismic upgrades of some vulnerable structures were also completed, much of the damage in 2017 occurred to pre-1985 concrete frame structures still in use. Over 4,000 of such structures were impacted, including apartment buildings, offices, schools, and hospitals. Families were displaced since many residential structures were no longer habitable. More than 3,500 businesses were directly impacted. As of April 2018, post-earthquake repairs of many damaged structures continue. This lengthy rebuilding process in Mexico City offers relevant lessons to other communities and organizations located in areas prone to earthquakes.

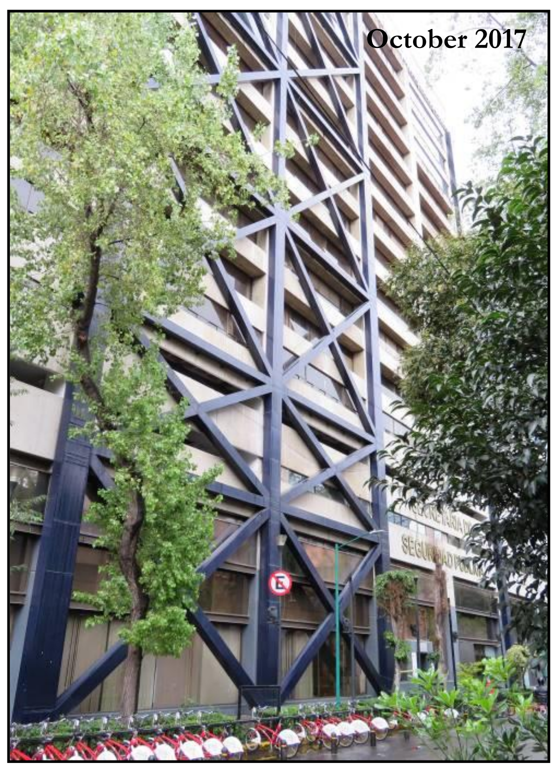
Mexico City Plaza Villa Madrid—The two structures in the background illustrate post-earthquake status quo. The shrouded high-rise structure (left) is still undergoing lengthy repairs. The building on the right with steel braced frames is fully functional.

Mexico City's "Achilles heel" is its location in a valley containing soft clay soils that once formed the bottom of Lake Texacoco. During an earthquake, the ground shaking can be amplified by these deposits resulting in very strong shaking even from relatively distant earthquakes. Particularly vulnerable are pre-1985 reinforced concrete frame structures lacking in steel reinforcement to prevent brittle fracture of beams or columns. These structures commonly include unreinforced masonry infill walls that can alter a building's behavior and contribute to further damage. Common causes of damage (or collapse) included:

- Pounding (impact) between side-by-side buildings
- Extensive ground floor openings resulting in "weak" or "soft story"
- Twisting (torsion) due to irregular layout of building walls
- Flat-slab floor construction (floors without beams)
- Concrete framing members lacking tightly spaced steel rebar ties to prevent brittle fractures
- Settling of building foundations

Example reinforced concrete frame apartment building in La Condesa undergoing post-earthquake repairs and retrofit with new steel plates over existing concrete columns.

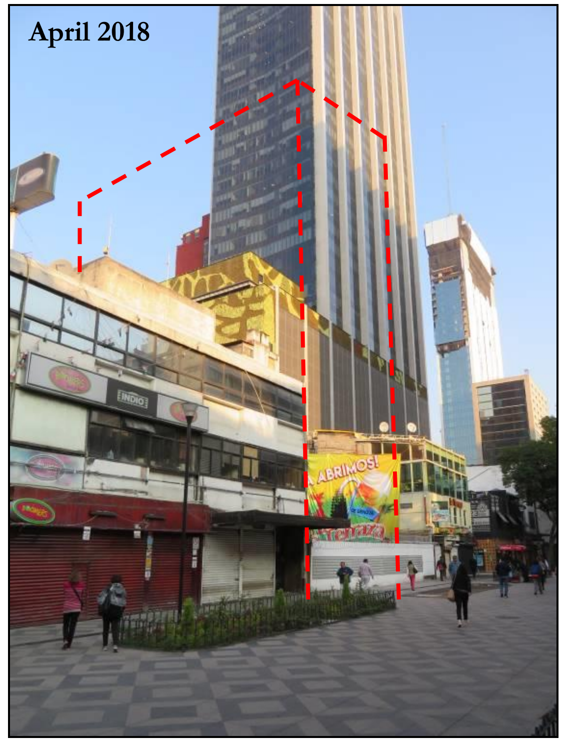
Repairs of damaged concrete structures can result in many months of loss-of-use (see adjacent photo). This represents a hardship to the displaced residents or businesses. Several buildings were demolished. Additionally, occupants of neighboring buildings are impacted by the construction operations. Seismic upgrades of such structures were effective in preventing extensive damage in the 2017 earthquake. Steel bracing represents one solution, as shown in the adjacent photo. External bracing systems tend to be less costly relative to building interior upgrades. We observed several similarly retrofitted buildings that were functional in October 2017. Other common retrofits included pile foundations to address soil settlement. Anchorage of critical in-building equipment facilitated more rapid recovery of operations. Unfortunately, relatively few buildings had been seismically retrofitted by 2017, since Mexico City did not have a policy requiring seismic retrofits of vulnerable structures. The case of Mexico City is relevant for other communities worldwide with existing building stock that includes many un-retrofitted vulnerable structures still in use.



Example of a seismic upgrade of an existing reinforced concrete frame building with steel braced frames.

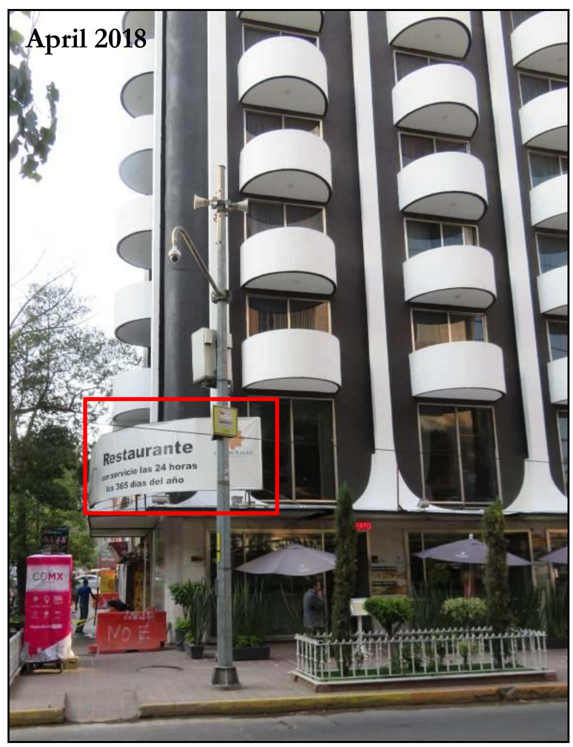
The following photographs illustrate structural performance and current status of selected buildings in central Mexico City following the September 19, 2017, earthquake.

MEXICO CITY—REFORMA AREA



This damaged 12-story building with reinforced concrete bracing was demolished. Adjacent restaurants and businesses were impacted by street closures and demolition activities.

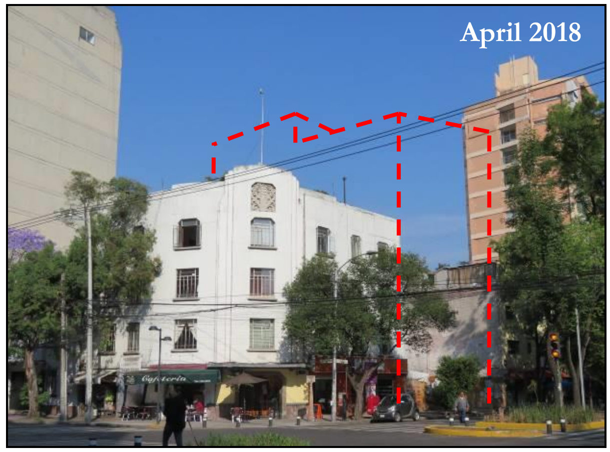
Example new construction infilling a vacated lot. New framing includes heavily reinforced concrete columns.



Restaurants and other businesses adjacent to damaged buildings advertise as "always open (24/365) for business".

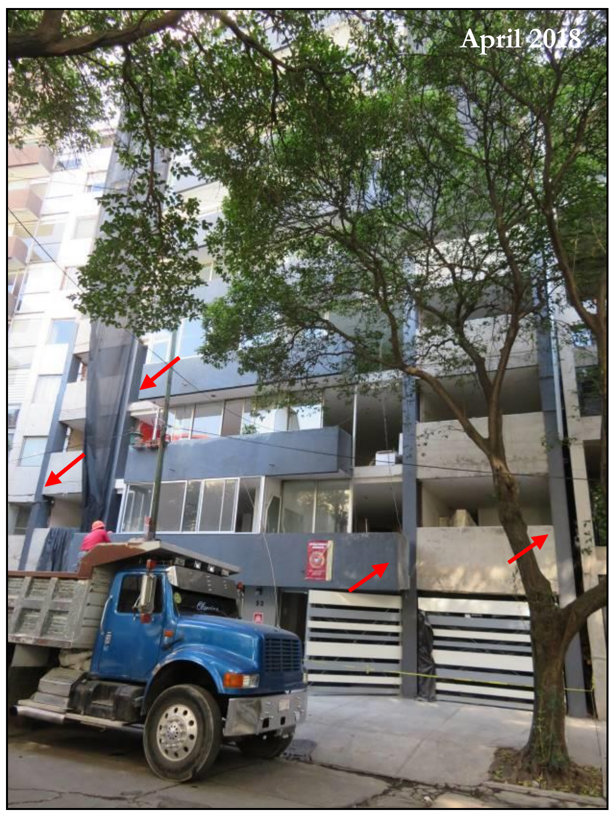
LA CONDESA

This park-like residential area near the city center was particularly affected by the earthquake. We observed a range of cases: demolished buildings, repairs in progress, and vacant damaged buildings. The following photographs illustrate the current status of some damaged buildings.



Example of a pre-1985 reinforced concrete frame building failure. Typical issues included: impact with adjacent structures, inadequate reinforcement of concrete members, and twisting of irregularly shaped structures.

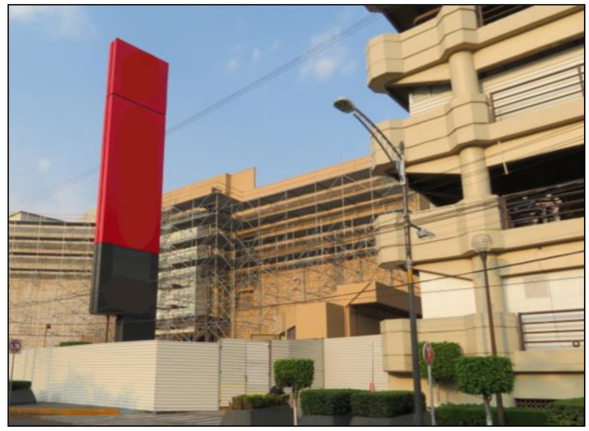
Vacant damaged apartment building in La Condesa. Note concrete frame and brick infill wall construction with extensive ground-level openings.



An apartment building undergoing damage repairs and column upgrades (steel plate jackets).

SUBURBAN MEXICO CITY

Southern suburban areas of Ixtapalapa, Coyoacan, and Tlalpan include modern shopping and commercial centers with low- to mid-rise residential developments. Soil amplification of ground shaking at some locations resulted in horizontal forces 2.5-times the design forces for mid-rise buildings. In Ixtapalapa, over 12,500 homes were damaged, with 4,500 likely to be demolished. The Coapa neighborhood (Coyoacan and Tlalpan) damage to multi-family apartment buildings, schools, healthcare facilities, utilities, and commercial structures was particularly extensive. Reconstruction progress appears relatively slow in some areas. The following images compare progress from October 2017 to April 2018.



Earthquake damage repairs still in progress at the Coapa regional shopping mall.

A regional mall in Coapa experienced extensive damage to pedestrian bridges, nonstructural systems, and façades. The complex is currently undergoing an extensive and lengthy renovation as a result of earthquake damage.

Coapa multi-family residential structures commonly include concrete framing with lightly reinforced masonry walls. Damage to walls and adjacent concrete framing was commonly observed. Many such damaged structures still remain vacant resulting in prolonged hardships for the displaced families.

CONCLUSIONS

Seven months after the earthquake, lengthy recovery and reconstruction continues in some Mexico City neighborhoods. Heeding lessons from this earthquake, Mexico City is making efforts to become a more earthquake-resilient region in the future. Initiatives underway include: early earthquake warning system improvements, standards for seismic rehabilitation for existing vulnerable buildings, and updates to building codes for new construction. The case study of Mexico City offers the following lessons for other worldwide regions prone to earthquakes:

- Well maintained early warning systems save lives and limit impacts on critical facilities.
- Site soils affect the severity of ground shaking and resulting impacts. Regional geological setting (presences of deep basins) can also increase the intensity of shaking.
- Passive retrofit policies for existing vulnerable structures are not effective enough. Implementation of mandatory upgrade policies (with related funding assistance) is vital for community resilience.

Critical facilities: *Earthquake repairs and upgrades (column strengthening) continue at a telecom central office in Coapa.*

Proactive risk assessments performed by structural engineers can identify potential vulnerabilities and practical solutions to limit the impact of future earthquakes.

Schools: *A damaged classroom building still stands vacant at a private college in Coapa.*

Vulnerable structures: *A damaged unreinforced masonry (URM) building (adjacent to a high-rise apartment building) remains unattended.*

MRP ENGINEERING

MRP Engineering is a structural engineering firm specializing in earthquake engineering. Our technical staff actively contributes to the advancement of earthquake engineering standards and routinely investigates performance of structures and systems in actual earthquake events. We assist clients with structural engineering-based risk reduction solutions. Contact us at info@mrpengineering.com.