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メキシコ中部地震調査速報

Flash Report on the Damage of Mexico City and Puebla Related to the 2017 Puebla-Morelos Earthquake

NIED 国立研究開発法人 防災科学技術研究所

National Research Institute for Earth Science and Disaster Resilience, Japan

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表紙写真 ・・・ 右上：ケツァルコアトルと言われる羽蛇として表される伝説のアステカ族の神、降り立った地点がメキシコシティ中心部と言われている(メキシコ国立人類学博博物館にて撮影).
背景：地震に耐えたラテンアメリカタワーの 3 文化広場(北側)方面を撮影.

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発行者 防 災 科 学 技 術 研 究 所
〒 305-0006
茨 城 県 つ く ば 市 天 王 台 3 － 1
電話 (029)863-7635
http://www.bosai.go.jp/

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Flash Report on the Damage of Mexico City and Puebla Related to the 2017 Puebla-Morelos Earthquake

Tsuneo OHSUMI* and Yuji DOHI*

**Integrated Research on Disaster Risk Reduction Division,*
National Research Institute for Earth Science and Disaster Resilience, Japan
t_ohsumi@bosai.go.jp, dohi@bosai.go.jp

Abstract

An earthquake with a moment magnitude (*Mw*) of 7.1 occurred at 13:14 CDT (18:14 UTC) on September 19, 2017, in the city of Puebla in Mexico. A damage survey was conducted in the affected area from November 18 to 21 by a team from the National Research Institute for Earth Science and Disaster Resilience. This paper outlines the findings of the survey in terms of the various aspects of the earthquake that affected Mexico City and surrounding areas. It was observed that the main damage was to masonry reinforced concrete buildings and the most heavily damaged structures correspond to areas underlain by soft soils 10–20 m in thickness. Comparison of estimated acceleration distribution for periods of 1 s corresponds to 8–12 story buildings, and these period areas correspond to heavily damaged structures. In the city of Atlixco, most of the damage was to church buildings.

Key words : 2017 Puebla-Morelos Earthquake, Mexico City, Puebla, Earthquake disaster, Disaster resilience technology

1. Introduction

An earthquake with a moment magnitude (*Mw*) of 7.1 occurred at 13:14 CDT (18:14 UTC) on September 19, 2017, in the city of Puebla, Mexico. The epicenter was in central Mexico (18.58° N 98.40° W) at a depth of 51 km (USGS: U.S. Geological Survey). The earthquake was officially named the 2017 Puebla earthquake because the epicenter was located beneath the city of Puebla, and the shallow depth resulted in it being highly destructive.

Statistics provided by The National Coordinator of Civil Protection of the Ministry of the Interior indicate that 369 casualties were recorded on October 5. Mexico City had the highest number of deaths (228), while 73 deaths were recorded in Morelos. A total of 45 deaths were recorded in Puebla, 13 in the State of Mexico, 6 in Guerrero and 1 in Oaxaca.

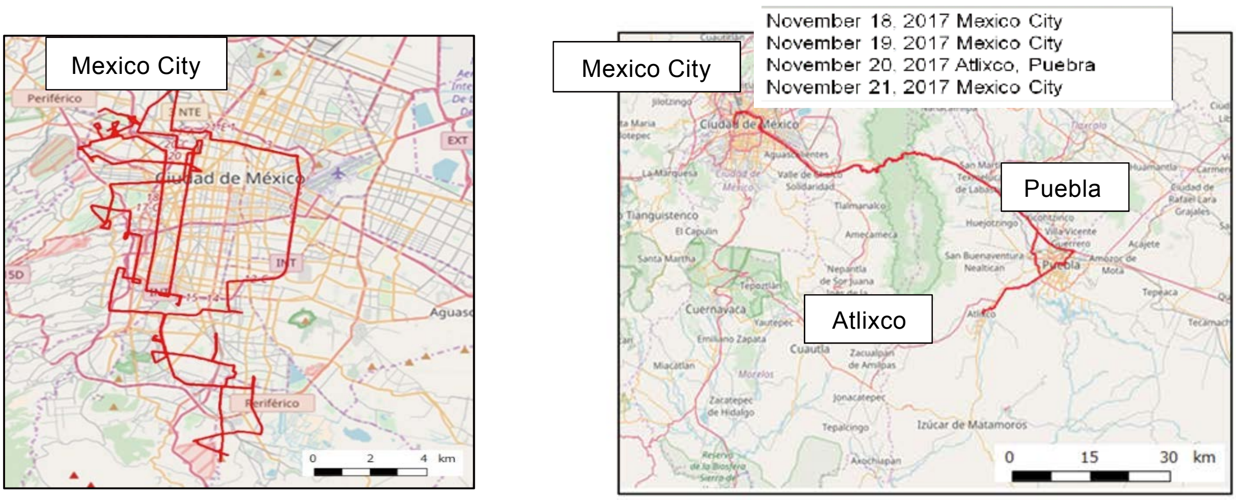


Fig. 1 Maps of Mexico City and surrounds showing the survey routes followed (red lines) (OpenStreetMap https://www.openstreetmap.org/).

* 3-1 Tennodai, Tsukuba, Ibaraki, 305-0006, Japan

2. Tectonics Setting and Historical Earthquakes in Mexico

2.1 Tectonic Setting

Based on data from the trans-Mexico temporary broadband seismic network centered on Mexico City, Pérez-Campos, X., *et al.* (2008)[1] indicate that the Cocos Plate subducts horizontally beneath central Mexico and tectonically underplates the base of the crust for a distance of 250 km from the trench. The Cocos Plate is decoupled from the crust by a very thin low viscosity zone. **Fig. 2.1** shows a 3D image of the composite model derived from the Mexico Subduction Experiments (MASE) seismic array.

2.2 Tectonic Interpretation of the 2017 Puebla-Morelos Earthquake on September 19, 2017

In a section perpendicular to the Mesoamerican trench (**Fig. 2.2**) it can be seen that the hypocenter of the earthquake occurred just below the continental plate, within the Cocos Plate. The hypocenter is represented by a red star and the black points correspond to hypocenters of other earthquakes, for the period 2000–2016. The dashed orange line indicates the approximate depth of the continental crust and the gray dashed lines correspond to the geometry of the Cocos Plate beneath the North American Plate[2].

2.3 Historical earthquakes that have occurred of Mexican

Fig. 2.3 shows the most important earthquakes that have occurred in Mexico since 1902. Other earthquakes that are of less importance for assessing the seismic hazard are those located within the oceanic fracture zones. These earthquakes have not caused appreciable damage because of their location beneath the seabed, far from coastal areas. The yellow star indicates the epicenter of the earthquake of September 19, 2017. The various colored ellipses correspond to areas of inter-plate rupture earthquakes in Mexico. The red (deep earthquakes) and blue stars (shallow earthquakes) are the epicenters of intraplate earthquakes[3].

Located in the subduction zone of the Cocos Plate on the east coast of the Pacific Ocean, the Mexican Pacific coastal area is one of the most earthquake- and tsunami-prone regions in the world. However, the offshore Guerrero State is a seismically unaffected area, and has been referred to as the “Guerrero earthquake seismic gap area” since 1911. No major earthquake of *Mw* 7 or more has occurred in this region since 1911 (Itou, 2016)[4].

Fig. 2.4 shows the seismicity of the Puebla-Morelos earthquake in Mexico. According to the USGS[5], the area west of the Gulf of California is moving northwestward with the Pacific Plate at about 50 mm per year. Here, the Pacific and North American Plates form a strike-slip fault boundary which is the southern extension of the San Andreas Fault. In the past, the relative plate motion pulled Baja California away from the coast, forming the Gulf of California, and is the cause of current earthquakes in the Gulf of California.

Fig. 2.5 shows a comparison of earthquake seismicity (*Mw* 7 or greater) for Mexico since 1907. There are 29 earthquakes greater than 7 degrees of magnitude in the last two centuries. Some of them have been devastating. On September 19, 1985, the earthquake of *Mw* 8.1, caused 8 thousand casualties and collapsed hundreds of buildings in this city.

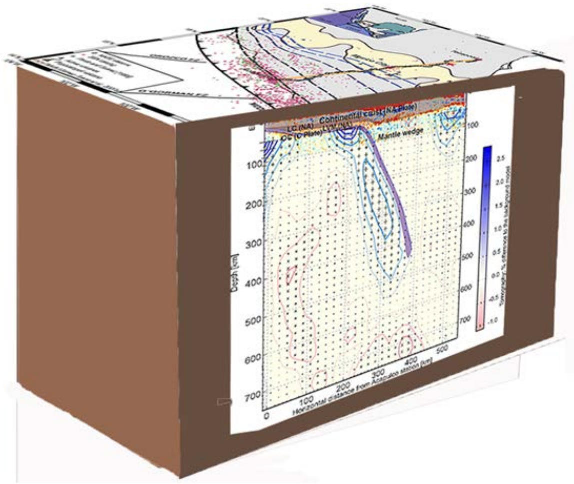


Fig. 2.1 3D images of a composite model derived from the Mexico Subduction Experiments (MASE) seismic array (*after* Pérez-Campos, X., *et al.* (2008)) [1].

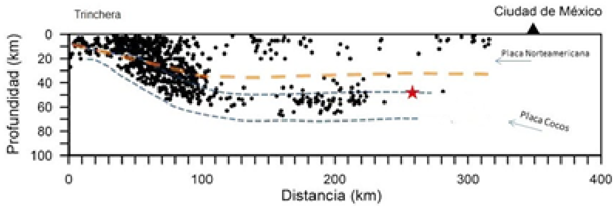


Fig. 2.2 Epicentral section perpendicular to the Mesoamerican trench. The hypocenter of the September 19, 2017 Puebla-Morelos earthquake is represented by a red star. Black dots indicate the hypocenters of other seismic events in the region[2].

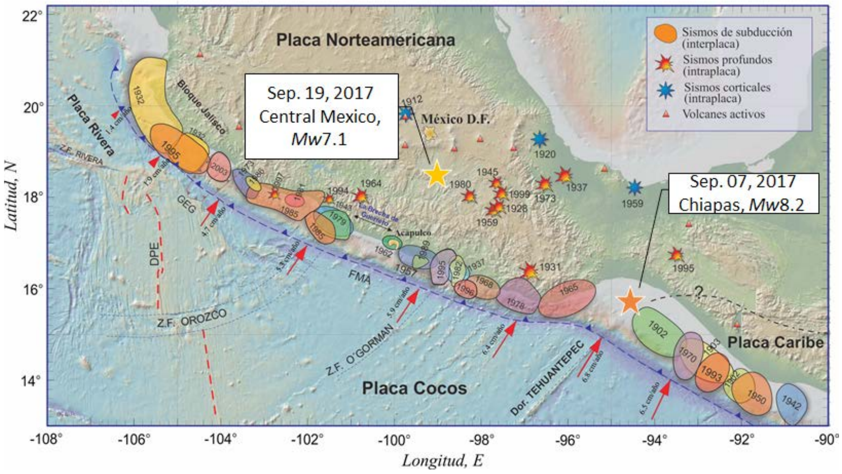


Fig. 2.3 Map showing the distribution and dates of the most important earthquakes in Mexico since 1902. The epicenter of the 2017 Puebla-Morelos earthquake is shown by the large yellow star[3].

Fig. 2.4 Seismic magnitude map (1900–2015) of Mexico showing the position of the 2017 Puebla-Morelos earthquake[5].

Fig. 2.5 Histograms comparing earthquake magnitudes (*Mw* 7.0–8.2) in Mexico during the last 110 years (courtesy of EL FINANCIERO, September 26, 2017). (Courtesy of EL FINANCIERO, September 26, 2017)

2.4 Comparison of the *Mw* 8.2 Chiapas and *Mw* 7.1 Puebla-Morelos earthquakes

Mw 8.2 Chiapas earthquake: a

In offshore Chiapas, Mexico, an *Mw* 8.2 earthquake occurred in September 8, 2017 as the result of normal faulting at an intermediate depth. According to the USGS, focal mechanism solutions for the earthquake indicate that slip occurred on either a fault dipping very shallowly towards the southwest, or on a steeply dipping fault striking NW–SE. This focal mechanism is not a pure “eyeball” in appearance.

The Cocos Plate converges obliquely in a northeasterly direction with North America at a rate of approximately 76 mm/yr. The Cocos Plate begins its subduction beneath Central America at the Middle America Trench, just over 100 km to the southwest of the Chiapas earthquake.

Mw 7.1 Puebla-Morelos earthquake: b

In Central Mexico, an *Mw* 7.1 earthquake occurred on September 19, 2017 as a result of normal faulting at a depth of approximately 50 km. According to the USGS, focal mechanism solutions indicate that the earthquake occurred on a moderately dipping fault, striking either to the southeast or to the northwest. This focal mechanism is purely “eyeball” in appearance. The focus was near, but not directly on, the plate boundary between the Cocos and North America Plates in the region. The Cocos Plate begins its subduction beneath Central America at the Middle America Trench, about 300 km to the southwest of the position of the earthquake. The location, depth and normal-faulting mechanism of this earthquake indicate that it was an intraplate event, within the subducting Cocos Plate, rather than on the shallower megathrust plate boundary. **Fig. 2.6** shows rupture areas, slip distributions and focal mechanisms for the Chiapas and Puebla-Morelos events.

3. Strong Motions

3.1 Intensity map

Fig. 3.1 shows a seismic intensity map for Mexico during the 2017 Puebla-Morelos earthquake. According to the UNAM (Universidad Nacional Autonoma de Mexico) report[6], the amplitude of seismic waves with close periods of 2 s are up to 50 times greater in the lake zone (soft zone) such as Colonias Roma, Condesa, Centro and Doctores than in firm soil, such as Mexico City. However, the waves are also amplified in the firm ground in the peripheral areas such as Mexico City, and the amplitude in lake areas can be 300–500 times greater. In some lake zone areas the maximum accelerations produced by the *Mw* 7.1 earthquake in soil were lower than those registered in 1985.

(*a*) Chiapas earthquake (*b*) Puebla-Morelos earthquake

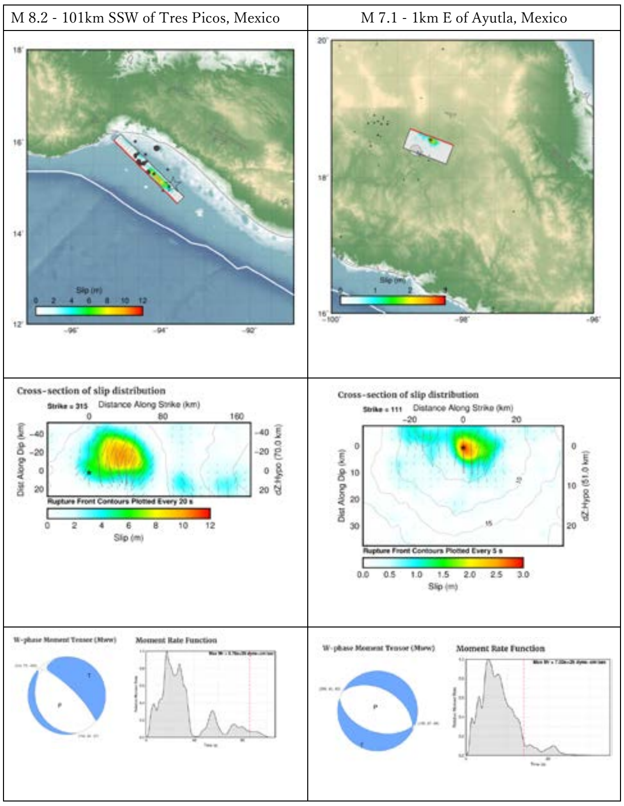


Fig. 2.6 Rupture areas, slip distributions and focal mechanisms of the (*a*) Chiapas earthquake and (*b*) Puebla-Morelos earthquake (*after* USGS)

3.2 Comparison of the 1985 and 2017 earthquakes

Fig. 3.2 shows a comparison of the Fourier spectra of different heights at sites CU (rocky ground) and SCT (soft ground) for the 1985 earthquake (blue) and the 2017 earthquake (red). According to UNUM report6), peak Ground Acceleration (PGA) in 1985 was 160 Gal, while in 2017 PGA was 91 Gal. Peak Ground Acceleration (PGA) is a measure of the severity of ground shaking. However, accelerations in the soil during the 2017 earthquake were most likely greater than those recorded in 1985 because of the complex movement pattern and high spatial variability.

In 1985, the ground response was amplified up to 7–8 times at building sites located on the lake bed in contrast to those located on hard rock in Mexico City. During the 1985 earthquake, PGA at the soft soil site (SCT) was significantly higher than at the rocky site (CU).

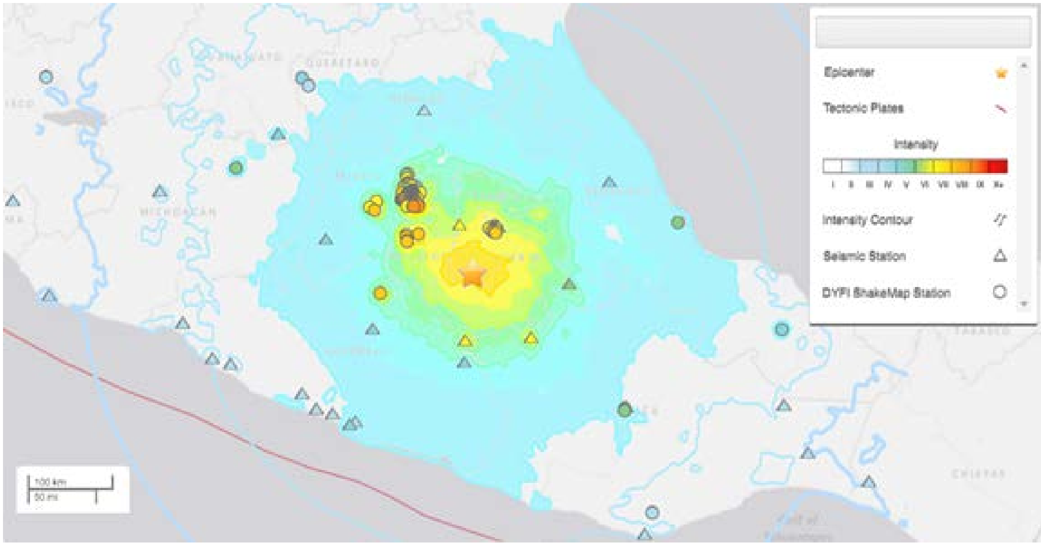


Fig. 3.1 Seismic intensity map of Mexico during the 2017 Puebla-Morelos earthquake (source USGS)[5].

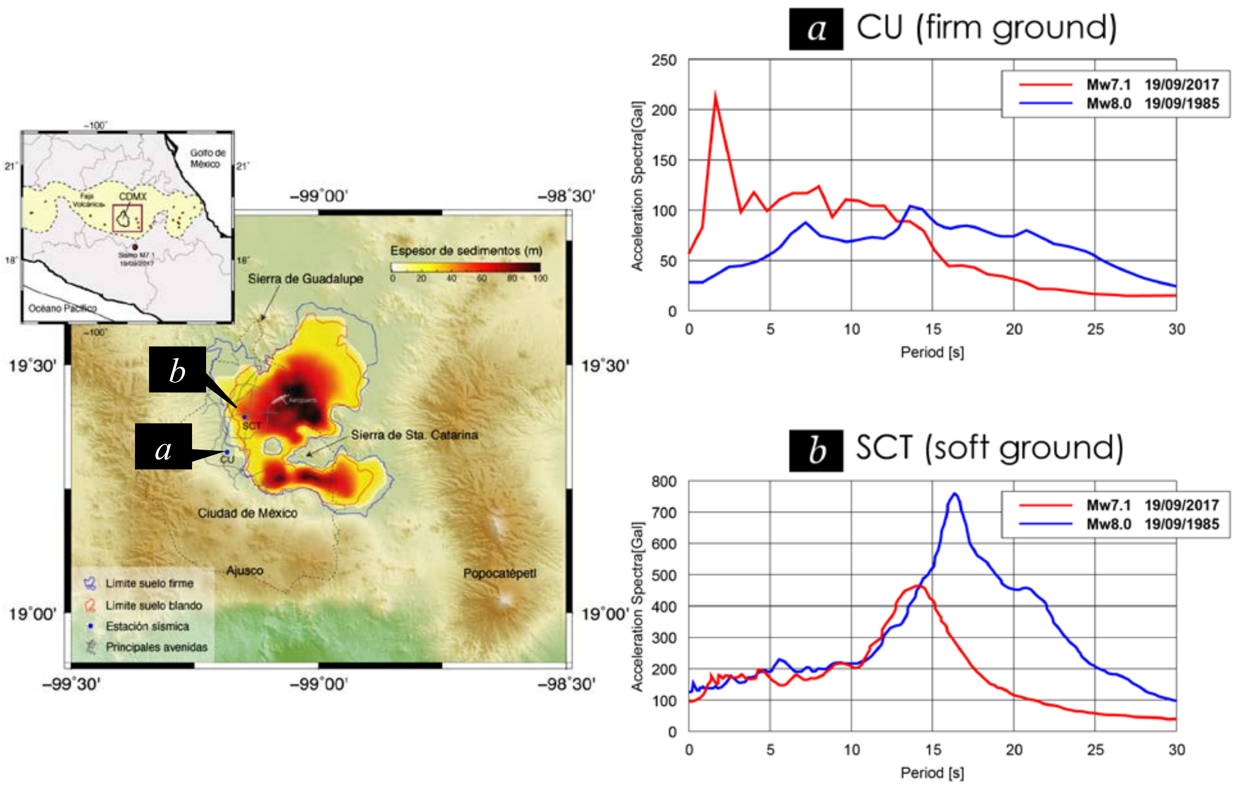


Fig. 3.2 Comparison of the Fourier spectra of different heights at sites (*a*) CU (firm ground) and (*b*) SCT (soft ground) for the 1985 earthquake (blue) and 2017 earthquake (red)[6].

3.3 Estimated acceleration

Fig. 3.3 shows acceleration estimated distributions estimated by the Institute of Engineering of the UNAM[2]. The estimated accelerations were calculated in the roof's level of buildings with different numbers of stories in Mexico City. Comparison of the acceleration distributions are: 0.06 s period for one-story buildings, 0.3 s period for 2–3 story buildings, 1 s period for 8–12 story buildings and 2 s period for 16–20 story buildings.

3.4 Comparison of seriously damaged structures from the 1985 and 2017 earthquakes

Fig. 3.4 shows a comparison between seriously damaged structures from the 2017 earthquake (red) and the 1985 earthquake (blue). The thickness of soft soils is also shown; the base map derived from Martinez Gonzalez, Jose (2015)[7]. The seriously damaged structures in 2017 were concentrated in areas with 10–20 m soil thickness, while seriously damaged structures from 1985 were concentrated in areas with 30–40 m soil thickness.

Fig. 3.5 shows a comparison between seriously damaged structures from the 2017 earthquake (red) and the 1985 earthquake (blue). Periods were measured using microtremor measurements, with the base map derived from Reinoso, E. and Lermo, J. (1991)[8]. The seriously damaged structures in 2017 were concentrated 1–2 s areas, while seriously damaged structures in 1985 were concentrated in 3–4 s areas.

Fig. 3.6 shows a comparison between seriously damaged structures from the 2017 earthquake (red) and 1985 earthquake (blue) with seismic zonation map. The base map was derived from the 1995 version, which contains three zones[9] (I, II and III). The structures seriously damaged in 2017 were concentrated in the IIIa zone, while those seriously

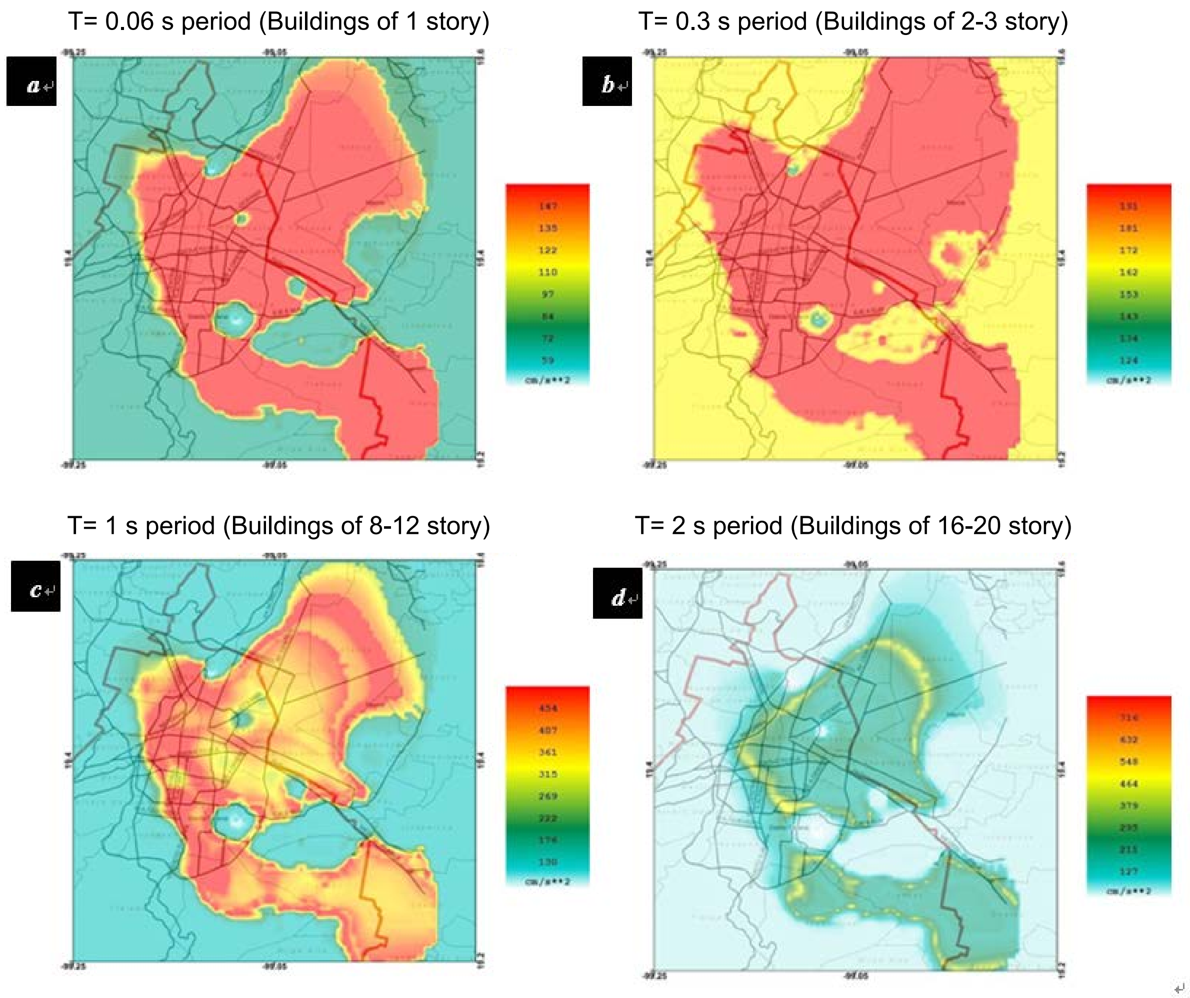


Fig. 3.3 Estimated acceleration distribution[2].

a: Acceleration distribution for 0.06 s period (Buildings of 1story)
b: Acceleration distribution for 0.3 s period (Buildings of 2-3 story)
c: Acceleration distribution for 1 s period (Buildings of 8-12 story)
d: Acceleration distribution for 2 s period (Buildings of 16-20 story)

damaged in 1985 were concentrated in zones IIIb and IIIc. In Mexico City, the proposed norm of 2003 has six zones, with Zone III further divided into four subzones (I, II, IIIa, IIIb, IIIc and IIId). The designations are as follows: Zone I: Hard Ground, Zone II: Transition and Zone III: Soft Soil (divided into four subzones).

Fig. 3.7 shows transfer functions obtained from 10 m, 20 m and 40 m within the simplified soil profiles and sedimentary layers from one-dimensional analysis of the dominant frequency. The *Vs* values of the ground were set from Facciolia and Flores (1975)[10] to FAS, which is normally consolidated clay, and DP, which is a sand layer including gravel.

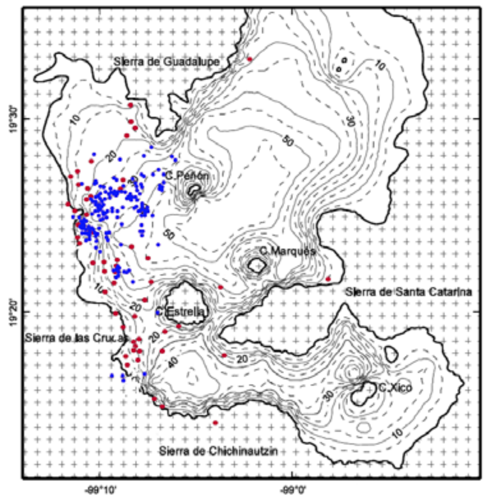


Fig. 3.4 Map showing the thickness soft soils and damaged structures (blue dots: 1985 earthquake, red dots: 2017 earthquake) (base map from Martinez Gonzalez, Jose, 2015)[7].

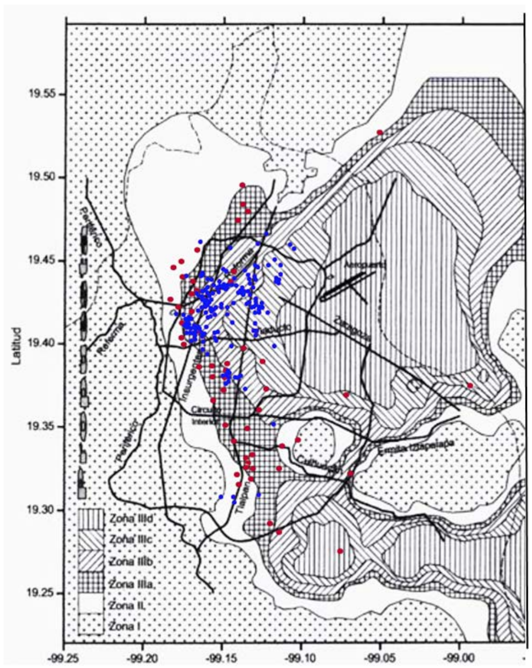


Fig. 3.6 Seismic zonation map showing damaged structures (blue dots: 1985 earthquake, red dots: 2017 earthquake). Note that the base map is the 1995 version with three zones (I, II and III)[9].

In the 10 m case, the dominant period of transfer functions is 0.645 s (1.6 Hz) and the amplification of ground motion is 5.3. In the 20 m case, the dominant period of transfer functions is 1.1 s (0.95 Hz) and the amplification is 4.3. In the 40 m case, the dominant period of transfer functions is 2.0 s (0.5 Hz) and the amplification is 3.9. In the 1985 earthquake, which had long-period components of earthquake motion, caused high amplification in soft soils. However, in the 10 m case, which is shallow and segmented, the higher contrast *Vs* value of segmented layers and the basement contributed to increasing the amplification of ground motion in the 2017 earthquake, which had short-period components of earthquake motion.

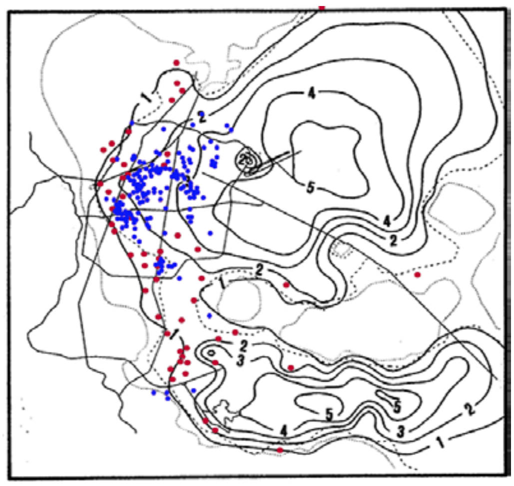


Fig. 3.5 Comparison between seriously damaged structures from the 2017 earthquake (red) and the 1985 earthquake (blue). Periods were measured using microtremor measurements, with the base map derived from Reinoso, E. and Lermo, J. (1991)[8].

Serious damaged structures
- in 2017
- in 1985

Source from UNAM

Zone I : Hard Ground
Zone II : Transition
Zone III : Soft Soil (divided into four subzones)

Peak Ground Accelerations (Horizontal and Vertical). Horizontal peak ground accelerations a_0 (as related to gravity) are defined for each zone or subzone:

Zone	a_0
I	0.04
II	0.08
IIIa	0.10
IIIb	0.11
IIc	0.10
IIId	0.10

Fig. 3.8 shows seriously damaged structures from the 2017 earthquake with acceleration distribution for the 1.0 s period estimated from the roofs of buildings. **Fig. 3.9** shows seriously damaged structures from the 1985 earthquake with acceleration distribution for the 2.0 s period estimated from the roofs of buildings. Each damaged structure distribution can be explained as the resonance of a building, which is related to the soil layers and their properties by ground motion characteristics.

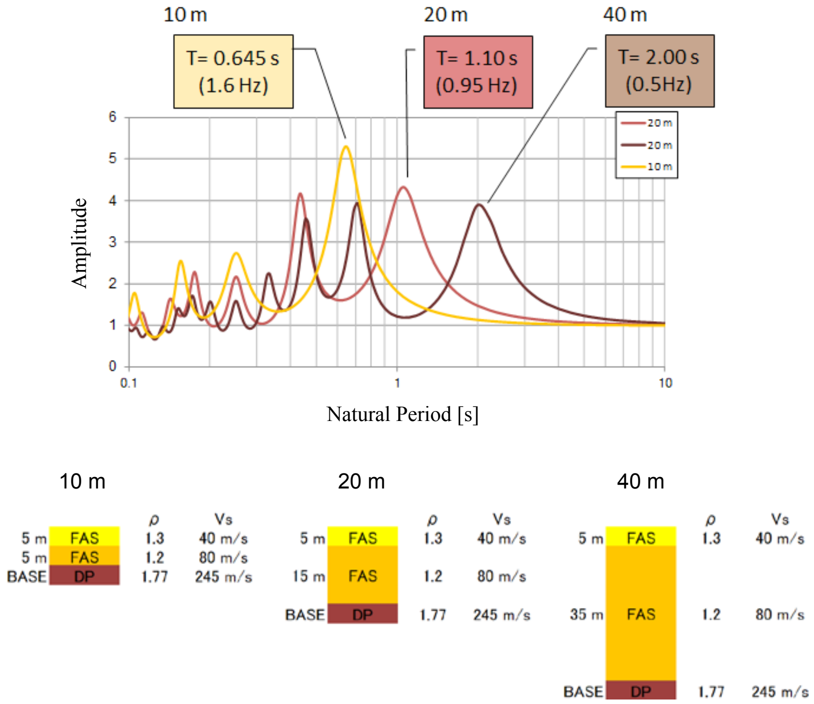


Fig. 3.7 Transfer functions were obtained from 10 m, 20 m and 40 m in the simplified soil profiles.

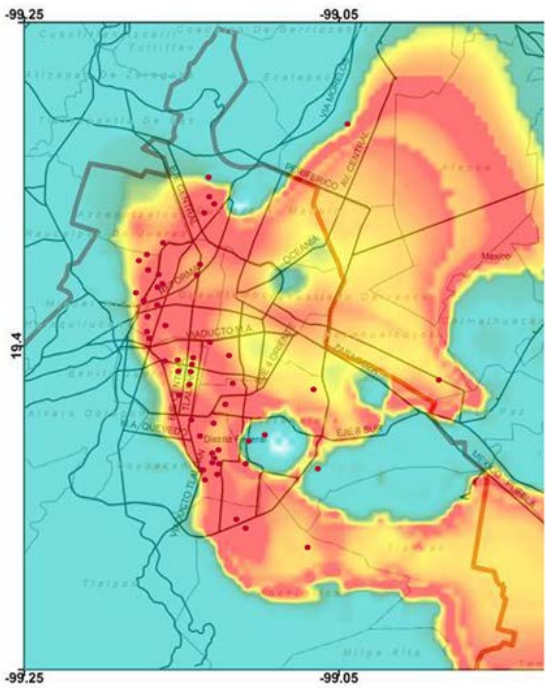


Fig. 3.8 Map showing the distribution of seriously damaged structures from the 2017 earthquake with acceleration distributions for the 1.0 s period estimated from the roofs of buildings [2)].

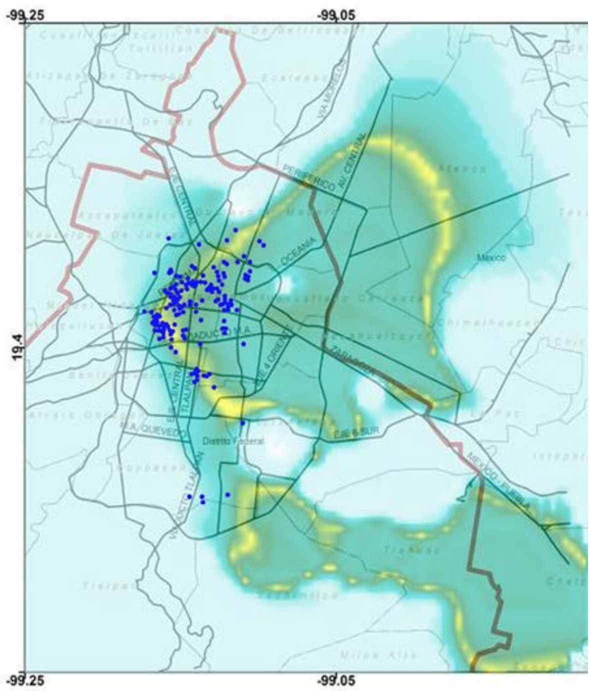


Fig. 3.9 Map showing the distribution of seriously damaged structures from the 1985 earthquake with acceleration distributions for the 2.0 s period estimated from the roofs of buildings [2)].

4. Survey Areas in This Study

4.1 Mexico City (CDMX)

Buildings designated for demolition

In Mexico, seismic diagnosis of buildings is undertaken by government. Based on the judgment following the 2017 earthquake, it was decided that 13 buildings would be demolished.

After obtaining approval from the Emergency Committee, the demolition work started on October 10, 2017 in the CDMX. There are 13 buildings already confirmed for demolition, since it was specified that in the first three cases, the state will use surveyors and an engineering team to determine the demolition method. These 13 buildings were selected as survey points in this study as shown in **Figs. 4.1** and **4.2**).

Fig. 4.3 shows the demolition level structures with the acceleration distribution for the 1.0 s period estimated from the roofs of buildings. All structures are within the 1.0 s acceleration period area.

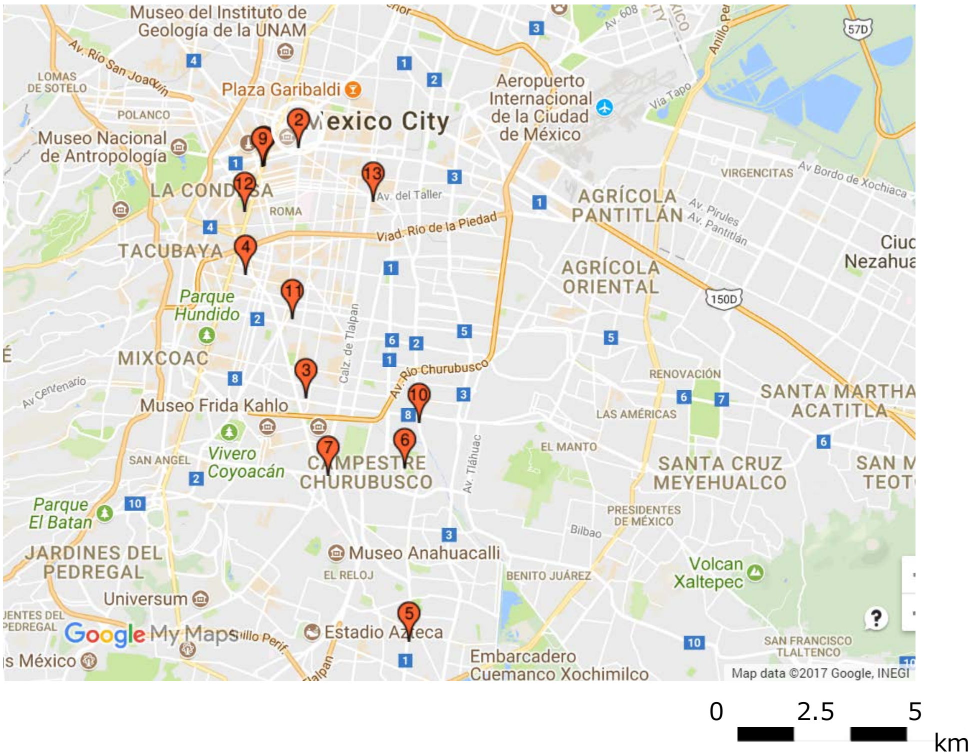


Fig. 4.1 Map showing the 13 buildings designated for demolition (Google Maps®).

❶Génova 33, colonia Juárez, delegación Cuauhtémoc	9 story of building.
❷Versalles 37, colonia Juárez, delegación Cuauhtémoc	10 story of building.
❸Tokio 517, colonia Portales norte, delegación Benito Juárez	5 story of building.
❹Patricio Sanz 37, colonia del Valle, delegación Benito Juárez	7 story of building.
❺Canal de Miramontes 3010, colonia Girasoles, delegación Coyoacán	6 story of building.
❻Paseos del río 10, colonia Paseos de Taxqueña, delegación Coyoacán	6 story of building.
❼Escocia 29, torre 2, colonia Parque San Andrés, delegación Coyoacán	5 story of building.
❽Escocia 33, colonia Parque San Andrés, delegación Coyoacán	4 story of building.
❾Hamburgo 112, colonia Juárez, delegación Cuauhtémoc	8 story of building.
❿Calzada de la Viga 1756, colonia Héroes de Churubusco, sección primera, delegación Iztapalapa	8 story of building.
⓫ Concepción Béistegui 1503, colonia Narvarte, delegación Benito Juárez	5 story of building.
⓬ Sonora 149, colonia Roma norte, delegación Cuauhtémoc	7 story of building.
⓭ San Antonio Abad 122, colonia Tránsito, delegación Cuauhtémoc	9 story of building.

Fig. 4.2 (*a*) Photographs of 8 of the 13 buildings designated for demolition (❶-❽) (photo taken by T. Ohsumi and Y. Dohi on November 19, 2017).

Fig. 4.2 (b) Photographs of 5 of the 13 buildings designated for demolition (❾- ⓭)
(photo taken by T. Ohsumi and Y. Dohi on November 19, 2017).

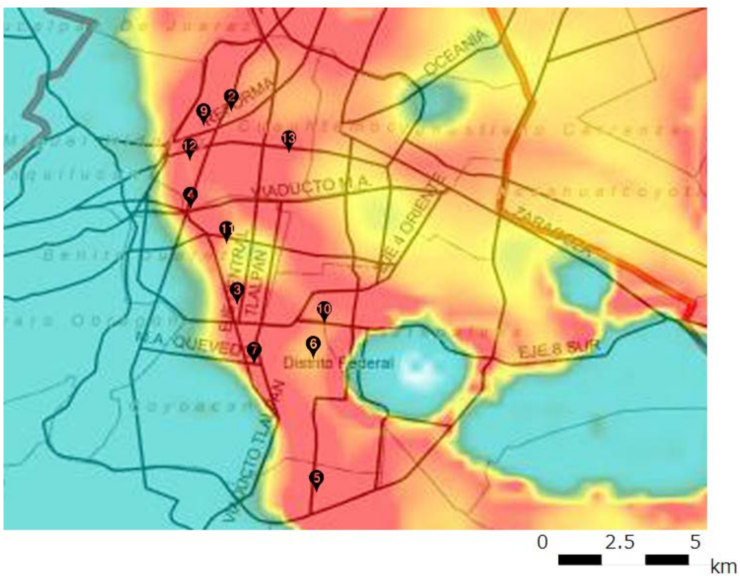


Fig. 4.3 Map showing the distribution of the 13 structures designated for demolition level within the 1.0 s acceleration period area [2)].

Tlatelolco Complex area

The Tlatelolco Complex area was heavily damaged in the 1985 earthquake (**Fig. 4.4**). For example, the 14-story RC Nevo Lion building in the Tlatelolco Complex, which included a north side and southern wing connected by an Expansion Joint, suffered a collapse of the two north side buildings that resulted in many casualties. After the 1985 earthquake, the Nevo Lion was renovated with new wings and walls with JICA (Japan International Cooperation Agency) support (**Fig. 4.7**).

We visited the Tlatelolco Complex area (**Fig. 4.5**) to verify this renovation. **Fig. 4.6** shows photos of the Tlatelolco Complex area, in which it is evident that ground surface deformation appeared after the 2017 earthquake. However, structures designed and built with earthquake-resistance showed no discernible damage after the 2017 earthquake based on external inspection. **Fig. 4.8** shows the lack of externally visible damage evident in the renovated Tlatelolco Complex after the 2017 earthquake. **Fig. 4.4** is included in memory of the victims of the 1985 Mexico City earthquake, and to acknowledge the courage and unity of the citizens of Mexico City (courtesy of EL FINANCIERO, 2015) [11].

Fig. 4.4 In memory of the victims of the earthquakes of 1985 and the courage and the union of the citizenship (2015) (courtesy of EL FINANCIERO)[11].

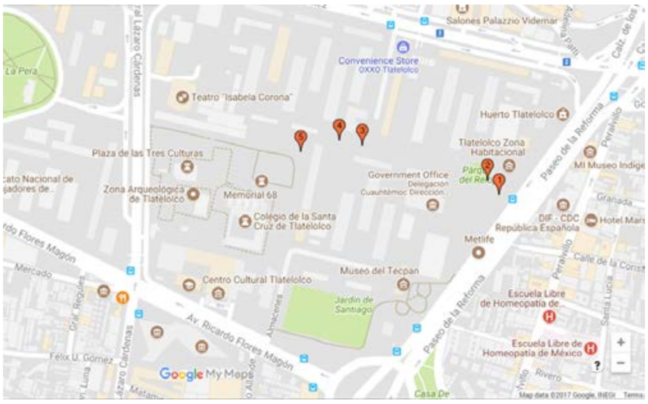


Fig 4.5 Map of the Tlatelolco Complex area in Mexico City (Google Maps®).

Fig. 4.6 Photographs of the Tlatelolco Complex area. (photo taken by T. Ohsumi on November 19, 2017).

Fig. 4.7 Photographs of the renovated Tlatelolco Complex, after the 1985 earthquake (courtesy of Prof. Nakano with Tokyo Univ.).

Fig. 4.8 Photograph of the undamaged Tlatelolco Complex from outside inspection, after the 2017 earthquake. (photo taken by T. Ohsumi on November 21, 2017).

Damaged RC housings

Two adjacent housing blocks were built in the same period in 1970, as shown in **Fig. 4.9**, and both buildings will be demolished. However, the building on the right was heavily damaged and the parking lot on the first floor collapsed. The housing block on the left was inspected, and found to have higher quality concrete than the right block. Also, the building column construction used hoops/stirrups at a 45 cm pitch, while the hoops/stirrups were of very poor quality in the housing block on the right.

Fig. 4.10 shows the photograph of complete structural failure in the Residencial SanJosé, Zapta 56 (EL FINANCIERO)[12]. **Fig. 4.11** shows the photograph of building damage to the Residencial SanJosé, Zapta from over bridge. **Fig. 4.11** shows the photograph of building damage to the Residencial San José, Zapta from over bridge. The adjacent right building was no damage from outside inspection.

According to the architect at UNAM, the following issues have been raised concerning damaged RC buildings[13]:

- The submitted technical drawings and the buildings do not match.
- It is stated in the drawings submitted that the buildings can withstand seismic intensity 6, but the buildings will actually collapse at seismic intensity 5.
- The point of the beam is not fixed and the ceiling and the building are not fixed.
- Electric wiring should be ducted, but in the building it is exposed.
- Documents submitted with the building application were not accompanied by a statement of calculation. It is a description only of the origin of the rebar.
- A structural statement is not shown.
- There is no mention of the name of the person in charge.

Fig. 4.9 Comparison of damage to two housing blocks. Note the heavily damaged housing on the right with poor quality hoops/stirrups (photo taken by T. Ohsumi on November 19, 2017).

Fig. 4.10 Photograph of complete structural failure in the Residencial SanJosé, Zapta 56 (EL FINANCIERO)[12].

Fig. 4.11 Photograph of building damage to the Residencial SanJosé, Zapta from over bridge (photo taken by T. Ohsumi on November 19, 2017).

Fig. 4.12 Typical housing in Mexico City. (photo taken by T. Ohsumi on November 21, 2017)

Fig. 4.13 Photograph showing the collapse of the basement space in which cars were crushed. (photo taken by T. Ohsumi on November 19, 2017)

Was the piloty structure damaged?

According to National Population Council, the estimated population for the metropolitan section of Mexico City in 2009 was approximately 8.84 million people. According to the most recent definition agreed upon by the federal and state governments, the Greater Mexico City population is 21.3 million people, making it the largest metropolitan area in the Western Hemisphere, the tenth-largest agglomeration, and the largest Spanish-speaking city in the world. Most housing developments are constructed with a dense overlapping structure (**Fig. 4.12**), and the first floor has a piloty space. The piloty structure of this space is typically weakly built, and they have collapsed in many housing (**Fig. 4.13**).

Steel braces and concrete columns

In Mexico City, braces are installed on buildings to decrease the risk of blocks falling off, or bricks in the wall falling out of the plane of the building. Thus, a gable wall between the brace is used to sustain this resilience method (**Fig. 4.14**). Buildings reinforced with steel braces are shown in **Fig. 4.15** and typical diagonal reinforced concrete bracing with masonry infill is shown in **Fig. 4.16**.

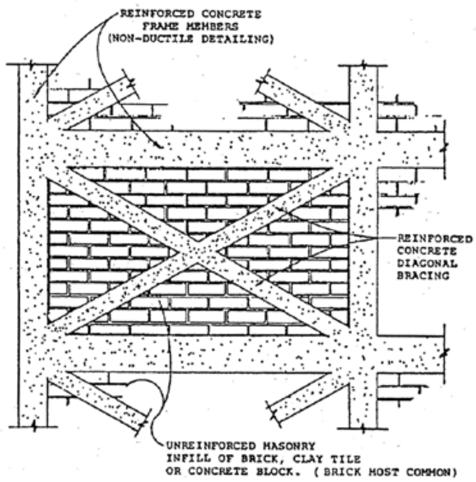


Fig. 4.14 Typical diagonal reinforced concrete bracing with masonry infill used in Mexico City [14].

Fig. 4.15 Photographs of buildings reinforced with steel braces. (photo taken by T. Ohsumi on November 18-19, 2017)

Fig. 4.16 Masonry building which was reinforced with concrete columns.

Latin American Tower

The Latin American tower was inaugurated on April 30, 1956. It was designed by Adolpho Zeevaert, in consultation with N. Newmark and Leonardo Zeevaert. The Latin American Tower is a source of pride for the inhabitants of the Mexico City metropol, as it broke several engineering records during its construction using Mexican technology. The structure survived the 1957, 1978, 1979, 1985 and also the September 2017 earthquakes with only minor nonstructural damage. A memorial plate was installed in the Latin American Tower (**Fig. 4.17**) and it describes how the Tower has been able to sustain multiple episodes of strong seismic forces. **Figs. 4.18** and **4.19** show the seismometer and deformation meter of the tower, respectively. Deformation is registered as the proportion of movement within a range of permissible values in the tower. **Fig. 4.20** highlights the primary structural features and advanced technology of the Latin American Tower.

Fig. 4.17 Memorial plate in the Latin American Tower. (photo taken by T. Ohsumi on November 21, 2017)

Fig. 4.18 Seismometer in the Latin American tower. (photo taken by T. Ohsumi on November 21, 2017)

Fig. 4.19 Deformation meter in the Latin American Tower. (photo taken by T. Ohsumi on November 21, 2017)

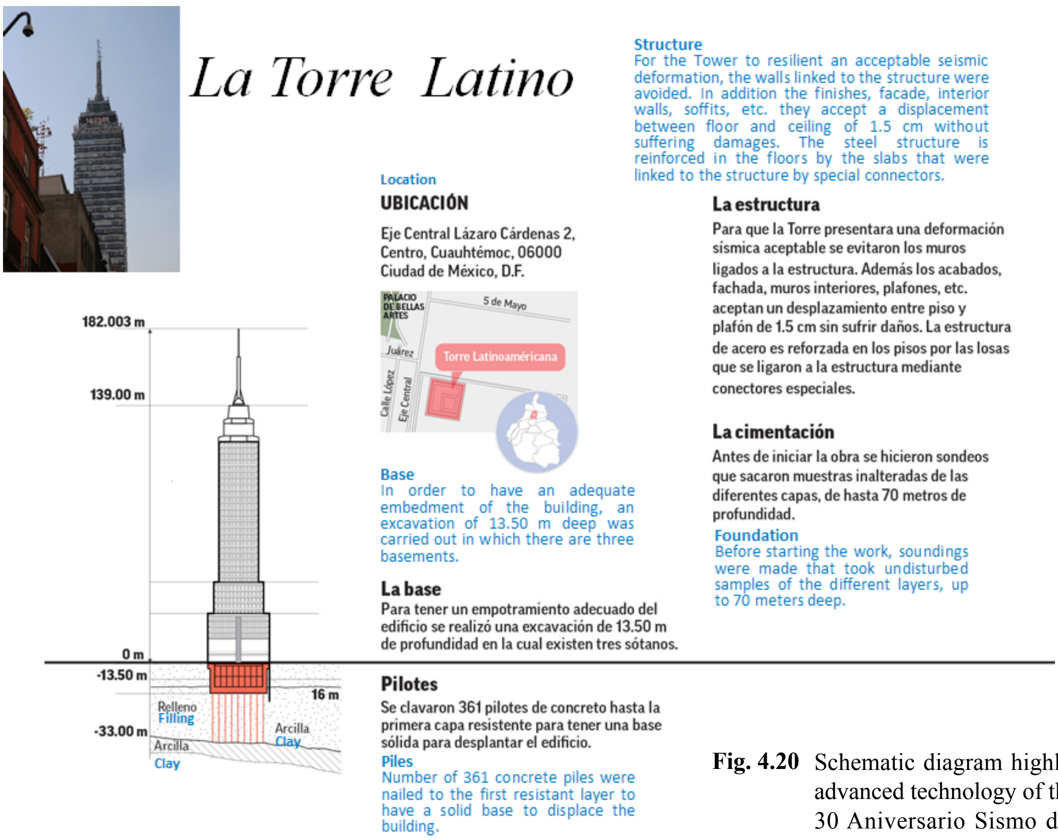


Fig. 4.20 Schematic diagram highlighting the structure and advanced technology of the Latin American Tower. 30 Aniversario Sismo del 85: La Gran Urbe no Deja de Moverse, EL FINANCIERO [15].

Torre Mayor

The Torre Mayor is one of the most modern and seismically safe buildings in the world. The base of the structure extends to a depth of 40 m or more and the first 10 floors of the building are constructed with concrete columns in a steel frame. The diamond-shaped design includes shock absorbers that absorb seismic forces across both sides of the building columns, thus dissipating the energy, as shown in **Fig. 4.21**.

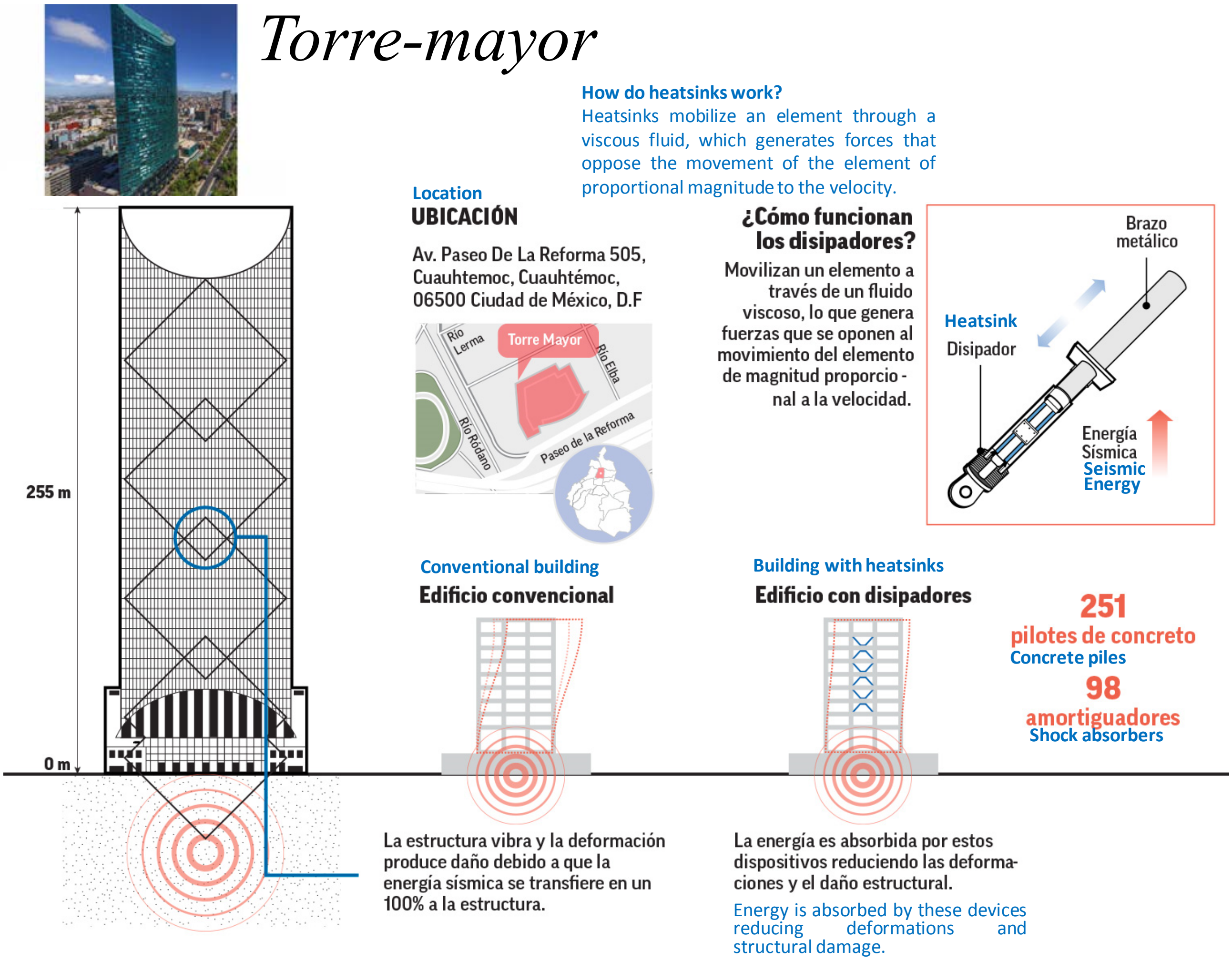


Fig. 4.21 Schematic diagram illustrating the advanced technology used in the Torre Mayor in Mexico City. 30 Aniversario Sismo del 85: La Gran Urbe no Deja de Moverse, EL FINANCIERO [15].

4.2 Puebra

Atlixco

Atlixco is a city and municipality in the Mexican state of Puebla, located at 18.900648° N and 98.445572° W about 90 km southeast of Mexico City and 39.3 km north of the 2017 earthquake epicenter (18.550° N, 98.489° W) (**Fig. 4.22**).

The earthquake damaged areas beyond Atlixco, including the five local governments of Huaquechula, Atzitzihuacán, Santa Isabel Cholula, Tepeojuma and Tianguismanalco. Damage was mostly structural, and church buildings were especially affected (**Fig. 4.23**).

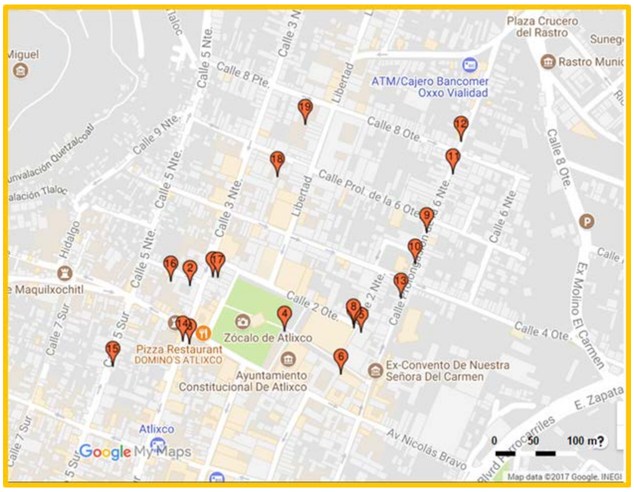


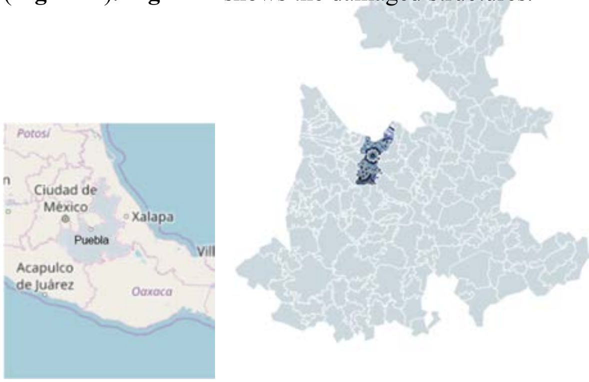
Fig. 4.22 Locality map of the Atlixco area in Mexico (Google Maps®).

Fig. 4.23 (*a*) Various damaged buildings in the Atlixco area (❶-❻).
(photo taken by Y. Dohi and T. Ohsumi on November 20, 2017)

Fig. 4.23 (*b*) Various damaged buildings in the Atlixco area (❼- ⓬)
(photo taken by Y. Dohi and T. Ohsumi on November 20, 2017)

Puebra City

Puebla City is known as Puebla de los Angeles, and is located within the Puebla Municipality, the capital and largest city in the state of Puebla. Puebla City is famous for the ceramics (Las talaveras) it produces (**Fig. 4.24**). **Fig. 4.25** shows the damaged structures.



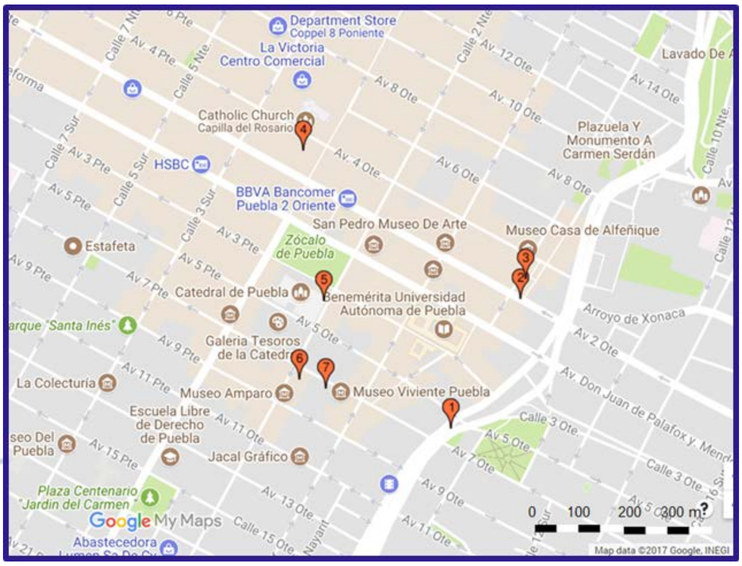


Fig 4.24 Locality and city map of Puebla City (Google Maps®).

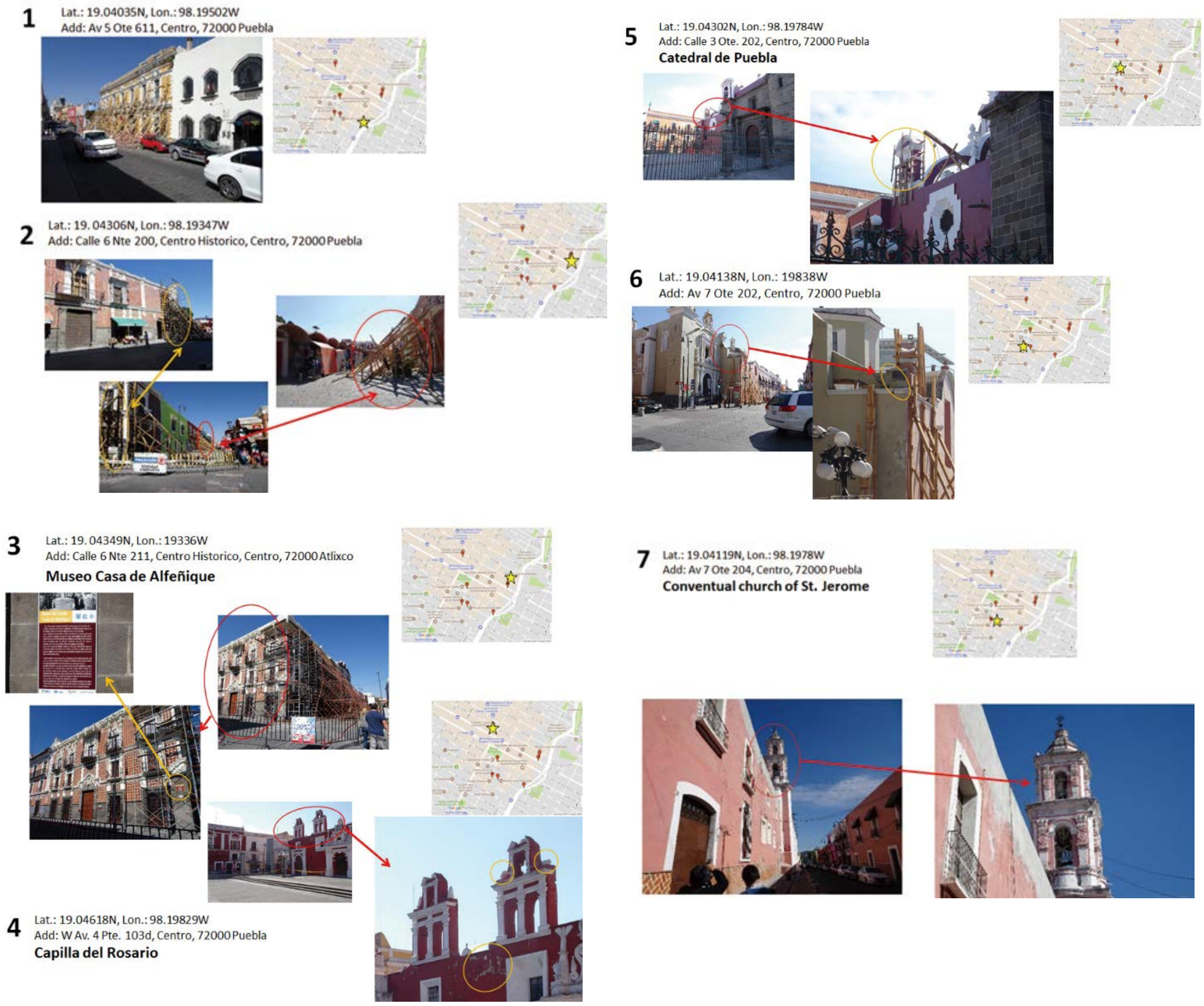


Fig. 4.25 Various damaged buildings in the Puebla City area (❶-❼).
(photo taken by Y. Dohi and T. Ohsumi on November 20, 2017)

5. Transmission of Horizontal Forces in an Earthquake

The elements within a building that are most affected during an earthquake are the structural elements because of the forces that are transmitted through them (**Fig. 5.1**).

What is a structural system?

It is important to note whether structures are composed of several elements, and have the function of supporting the loads that act on them seismically, by transmitting them into the ground, such as is shown in **Fig. 5.2**.

Type of Cracks

The engineer Yoshio Joel Salinas, general director of T22 Coordination and Architecture, indicated that after the earthquake it is necessary to detect the types of cracks evident in buildings in terms of their relative risk of further failure (**Fig. 5.3**).

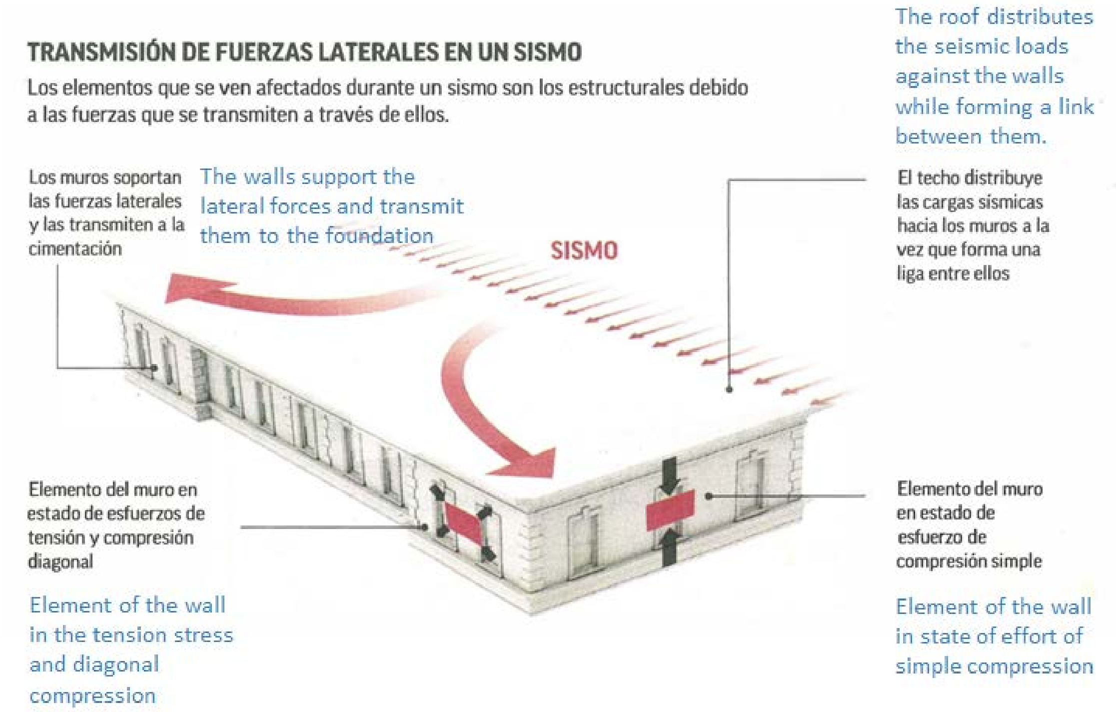


Fig. 5.1 Diagram illustrating the transmission of horizontal forces during an earthquake (courtesy of EL FINANCIERO, September 26, 2017).

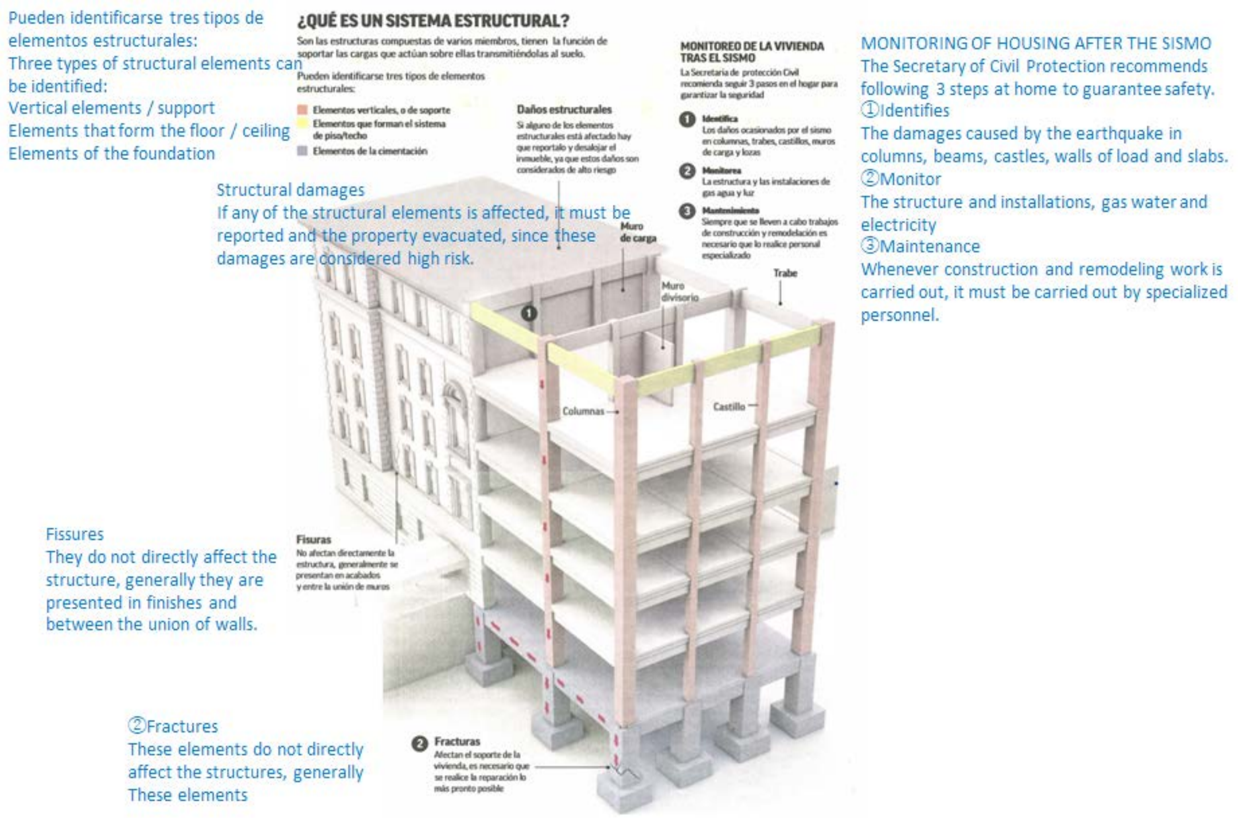


Fig. 5.2 Diagram illustrating the various structural elements in a building (e.g., fissures, fractures, columns) that need to be considered in terms of identifying, monitoring and repairing (courtesy of EL FINANCIERO, September 26, 2017).

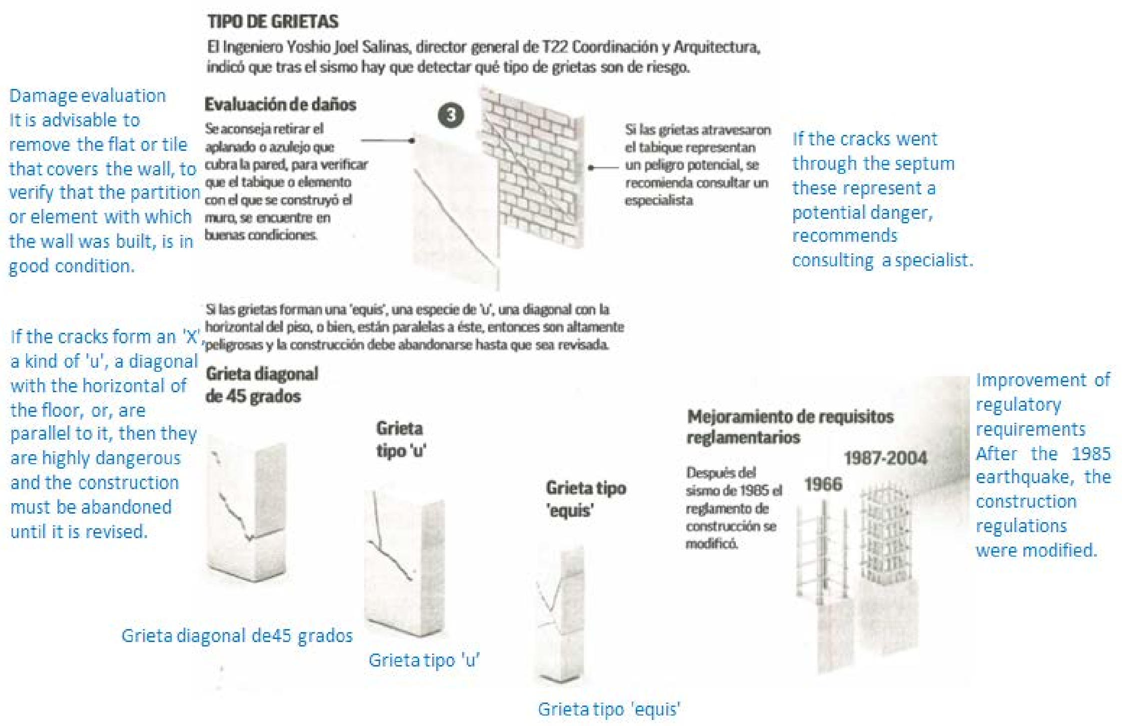


Fig. 5.3 Diagram showing the various type of cracks that can occur and should be monitored in a seismically damaged structure (courtesy of EL FINANCIERO, September 26, 2017).

6. Rescue Technology

6.1 Anything goes to find life: dogs and scanners

Scanning technology has progressed significantly since 1985, and is used by the Armed Forces (such as SEDENA in Mexico, Secretaría de la Defensa Nacional) to find people trapped under rubble.

SEDENA uses wall-mounted scanners to search for people in collapsed structures and works in the same way as radar. The equipment sends out a signal to a specific point, and returns and informs if there is no vibration. Any movement, even that of a finger, is recognizable by this device. The wall-mounted scanners have a range of up to 40 m, depending on the type of wall. It is able to determine the depth and location of buried individuals. All branches of SEDENA where collapses occurred have a team equipped with these scanners.

In addition, the "canine binomials" are important additions to the rescue efforts, and consist of a trained rescue dog and a handler. The relationship between the two, and with the individual being rescued, is one of trust and empathy. The dogs are able to detect even faint odors of buried individuals and their physical dimensions allow them to travel through smaller spaces than humans would be able to. Navy's staff is responsible for training the dogs for 12 to 14 months, and they are employed in rescue tasks for six to seven years. **Fig. 6.1** shows the scanning technologies, which are described in detail below.

● Uwb Detector

These detectors use radio technology at bandwidths >500 MHz (UWB) to probe beneath the surface of the debris for movement. The device detects even small movements of the chest caused by breathing. It locates victims by detecting movements up to 30 m away. The rescuers do require absolute silence during detection to accurately follow meaningful signals beneath debris.

● Canine Binomies

These are the partnered dog and trainer, both prepared to search for people under rubble. A Harness may be used if they require it, and glasses help protect the dog's eyes in case of smoke, dust or other substances. Boots are also used to help protect their legs.

Frida is a dog that belongs to the canine section of the Mexican Navy Secretariat, and she has managed to rescue 52 persons and has collaborated in rescue work in Honduras, Ecuador and Haiti.

● Thermal Equipment Reading

Thermal equipment is used to locate people beneath the rubble. The rescue of those who are buried in debris without injuries and who can move freely is relatively easy with this method. In the event that an individual is injured or trapped a tourniquet can be used and vital signs are checked, followed by their recovery.

There is no parameter with which to measure the resistance of a building to collapse. Regardless of being a child or an adult, there are cases of victims being without food, buried in rubble for six days before rescue.

● Wall Scanning

The wall scanning equipment allows users to observe an area from behind a wall. The scanner detects micro-shocks caused by breathing, heartbeat or physical gestures of people trapped.

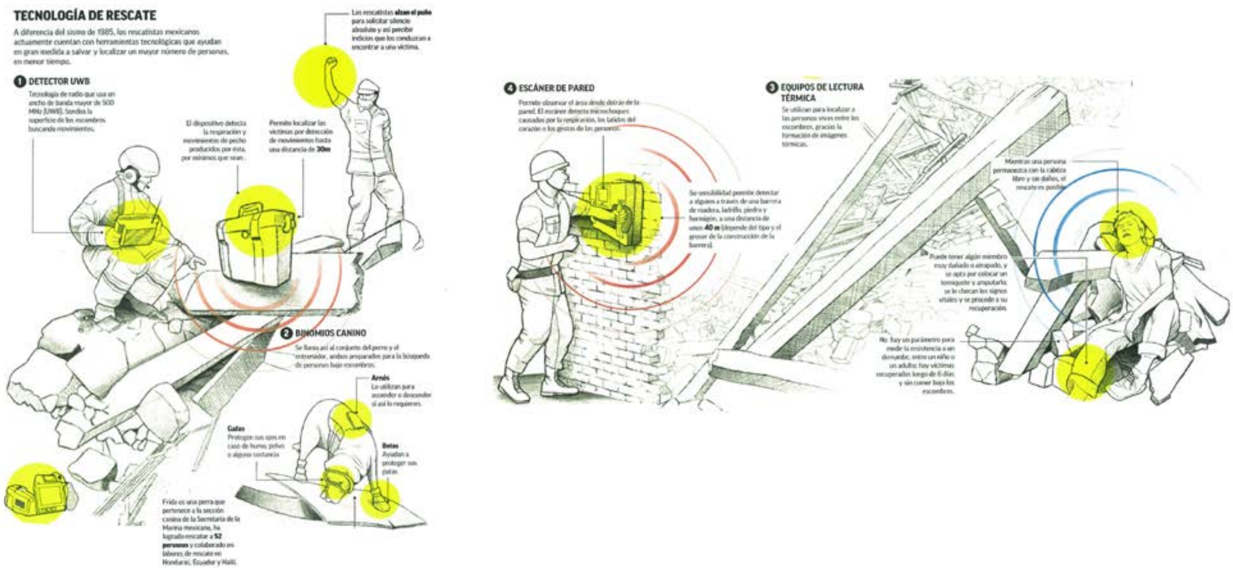


Fig. 6.1 Schematic diagram of the five main types of scanning technology used in post-earthquake rescue (courtesy of EL FINANCIERO, September 22, 2017).

6.2 Japan's Disaster Relief Team

At the request of the Mexican government, the Japanese government dispatched Japan's Disaster Relief Team on September 21, 2017. The team consisted of 72 people who conducted disaster relief at the three main areas affected by the earthquake in central Mexico City (**Fig. 6.2**). The team returned to Japan on September 28 (**Figs. 6.3** and **6.4**). The activities of Japan's Disaster Relief Team were featured in local Mexican newspapers (**Fig. 6.5**).

Fig. 6.2 Japan's Disaster Relief Team Working at Mexico Coty Aire port, September 21, 2017. (photo taken by Y. Ohsumi)

Fig. 6.3 Appreciative words in Mexico Coty Aire port, September 27, 2017. (photo taken by Y. Ohsumi)

Regresan a su país

TERREMOTO UN NUEVO 19 DE SEPTIEMBRE

Para japoneses es la hora de reconstruir, el rescate terminó

"Más allá de nuestra ayuda, la ayuda principal surge de los vecinos, de la gente que está ahí"

Toshihide Kawasaki
LÍDER DEL EQUIPO JAPONÉS

Les impacta el esfuerzo y la entrega de la sociedad civil al rescatar personas

ANABEL CLEMENTE
aclemente@elfinanciero.com.mx

El equipo de rescate de Japón, que llegó a México hace cuatro días, terminó su labor en la capital del país. Desde ayer se fueron los 72 brigadistas y los cuatro perros que apoyaron en el rescate de personas tras el terremoto del pasado 19 de septiembre.

En conferencia de prensa, en la Asociación México Japonesa, el líder del equipo, Toshihide Kawasaki, señaló que la fase de rescate terminó en la Ciudad de México y es momento de continuar con la de reconstrucción, por esa razón diversas brigadas internacionales, incluyendo la japonesa, comienzan a salir del país.

"Desde que sucede el temblor empieza a transcurrir un tiempo que tiene un periodo para hacer búsqueda y rescate, pero ese periodo termina y se tiene que entrar a la fase de reconstrucción y de rehabilitación… Es por eso que junto con el gobierno mexicano y los otros equipos de carácter internacional se va definiendo hasta qué momento es adecuado estar", apuntó.

El equipo japonés realizó actividades de búsqueda y rescate en tres de los lugares afectados: el conjunto habitacional en la calle Bretaña, las oficinas en la calle Álvaro Obregón y en el multifamiliar de Tlalpan, lugares donde recibieron "el profundo agradecimiento del gobierno y del pueblo mexicano".

"Estoy muy impactado por la entrega y el esfuerzo de los voluntarios, de la sociedad civil de rescatar a la gente que quedó atorada… más allá de nuestra ayuda, la ayuda principal surge de los vecinos, de la gente que está ahí", destacó.

Kawasaki dio a conocer que una vecina en el multifamiliar obsequió una carta a la delegación japonesa que decía: "Muchísimas gracias, Japón". Aseguró que en todos los sitios en los que estuvieron recibieron gran apoyo de la sociedad civil.

"Fue una estadía corta de 72 brigadistas y cuatro perros de rescate. Esperamos que nuestra presencia haya contribuido a sanar el sentimiento de daño que ha sufrido el pueblo mexicano", agregó el brigadista.

Explicó que una vez que termina el plazo de rescate, las autoridades buscarán las razones por las cuales se desplomaron los edificios, "podría ser que alguna de las causas sea que en los edificios más antiguos no se estaba cumpliendo con una norma de construcción, o que era muy débil".

AGRADECIMIENTO. El equipo japonés de rescate, cuyo líder es Toshihide Kawasaki, recibió muestras de agradecimiento del pueblo de México.

Fig. 6.5 Introduction of Japan's Disaster Relief Team to the area affected by the earthquake (courtesy of EL FINANCIERO, September 26, 2017).

Fig. 6.4 Japan's Disaster Relief Team returning to Narita Airport with the emergency rescue dogs, September 28, 2017. (photo taken by T. Ohsumi)

7. Telephone Questionnaire Survey

The EL FINANCIERO newspaper published the results of a telephonic questionnaire survey conducted six days after the 2017 earthquake. The survey was funded by EL FINANCIERO, and design and directed by Alejandro Moreno.

7.1 Methodology

The survey in Mexico City consisted of 500 interviews with adults (300 in-house and 200 by telephone) on September 22 and 23, 2017. EL FINANCIERO used a probabilistic sampling method based on 30 electoral sections of the housing survey, and a random selection of telephone numbers. In both cases the proportionality of voters was kept the same in each of the delegations. With a confidence level of 95 %, the total error margin of the survey was ± 4.4 %. The rejection rate for interviews was 40% in the housing survey and 52 % in the telephonic survey.

7.2 Solidarity and Voluntary Pride

The questions asked for this portion of the questionnaire are shown below:

1) How many persons felt a sense of human solidarity on September 19? (%)
2) How proud are you of the state of citizens of Mexico City where the emergency occurred? (%)
3) Do you believe that human solidarity lasts after the emergency/Do you think it will disappear? (%)
4) Are you proud to live in Mexico City? (%)

Fig. 7.1 shows the results of survey questions related to feelings of solidarity and volunteer pride in Mexico City

7.3 Evaluation before the emergency

The question asked for this portion of the questionnaire is shown below:

What do you think about the work of the following individuals/organizations before the emergency of September 19? (%)

Fig. 7.3 shows the results of the evaluation before the emergency.

7.4 Housing damage

The questions asked for this portion of the questionnaire are shown below:

1) Did you and your family suffer material damage in your home? (%)
2) Is the damage that your house incurred reparable? (%)
3) Do you have home insurance? (%)
4) Did your residence suffer any damage? (%)

Fig. 7.2 shows the survey results related to housing damage.

7.5 Volunteers

The questions asked for the volunteers of the questionnaire are shown below:

Did you/your family leave as a volunteer to provide help?

How did you get the information to help, for ...? (%)

? (%)

Fig. 7.4 shows the survey results related to volunteer work during the emergency.

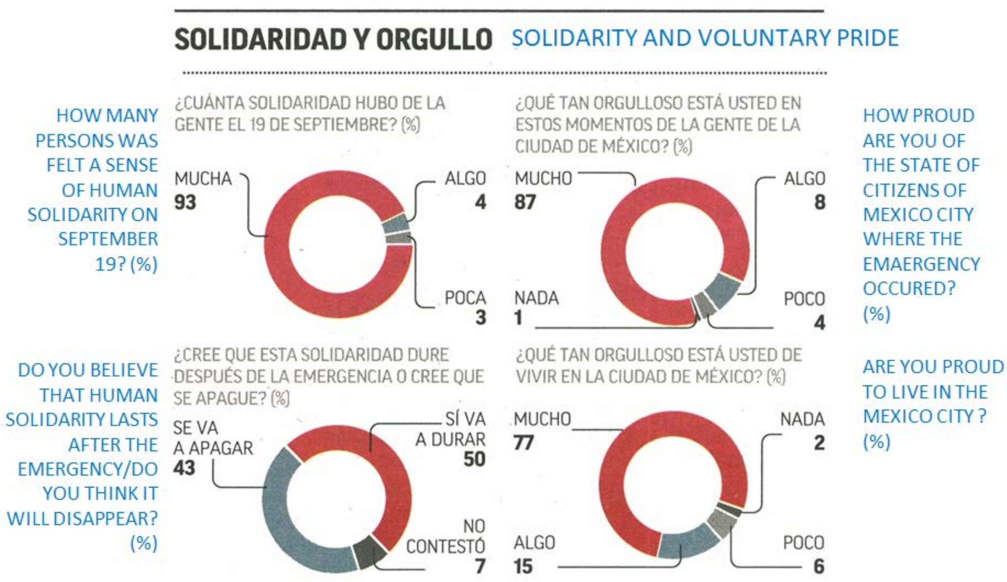


Fig. 7.1 Results of survey questions related to feelings of solidarity and volunteer pride in Mexico City (courtesy of EL FINANCIERO, September 25, 2017).

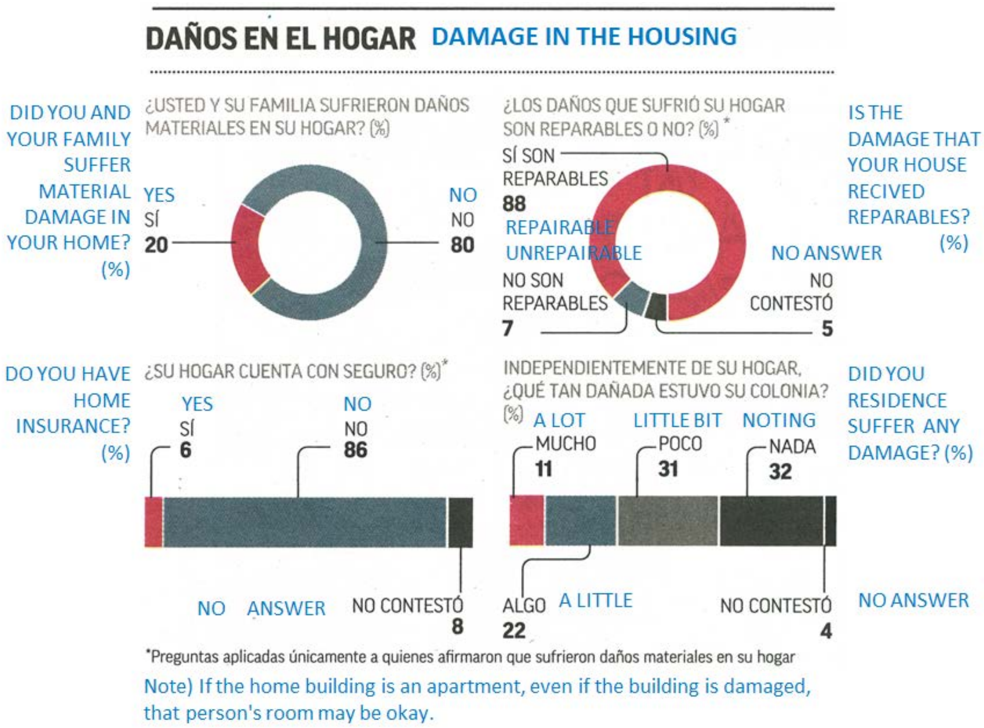


Fig. 7.2 Results of survey questions related to damage caused in housing (courtesy of EL FINANCIERO, September 25, 2017).

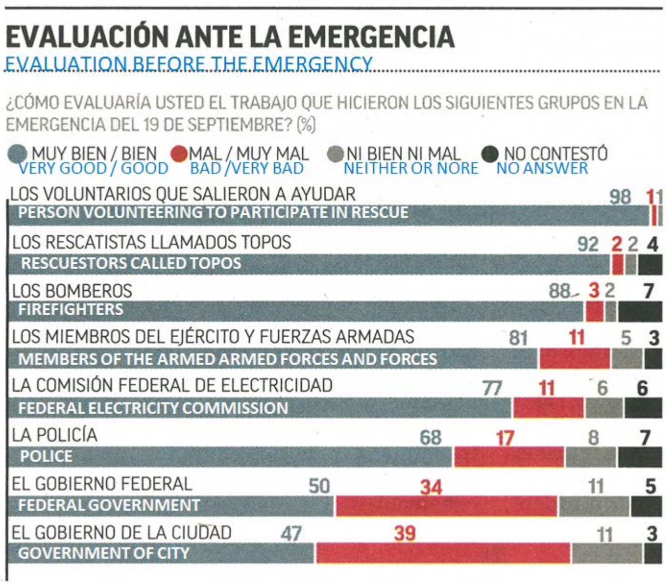


Fig. 7.3 Results of survey questions related to evaluation of emergency services before the emergency. (courtesy of EL FINANCIERO, September 25, 2017)

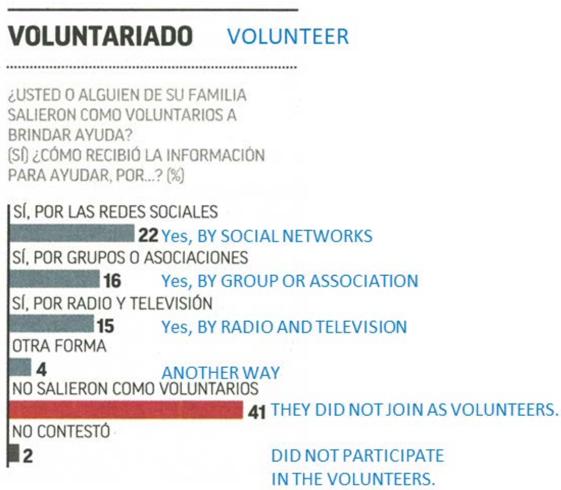


Fig. 7.4 Survey results related to volunteer work during the emergency. (courtesy of EL FINANCIERO, September 25, 2017)

7.6 Mental Damage

The questions asked for this portion of the questionnaire are shown below:

1) Was anyone in your family affected mentally? (%)
2) Was anyone in your family injured? (%)

Fig. 7.5 shows the survey results related to questions about mental damage.

7.7 Politics

The question asked for this portion of the questionnaire is shown below:

Are there political parties that had the suggestions for reconstruction after the earthquake? What did you think about the proposals? (%)

Fig. 7.6 shows the results of the survey question related to the political response to the emergency.

7.8 Insecurity

The question asked for this portion of the questionnaire is shown below:

What do you think about crime that occurred during the emergency of the earthquake? (%)

Fig. 7.7 shows the results of survey question related to insecurity and crime during the earthquake emergency.

8. Findings

Based on the study presented, and the survey results, the following conclusions can be drawn:

- Heavily damaged structures in the Mexico City area related to the 2017 earthquake are underlain by areas consisting of soft soils 10–20 m in thickness.
- Comparison of the estimated acceleration distribution for the 1 s period corresponds to 8–12 story buildings. These period areas correspond to areas of heavily damaged structures related to the 2017 earthquake.
- In the 10 m case, which is shallow and segmented, the higher contrast Vs value of segmented layers and the basement contributed to increased amplification of ground motion in the 2017 earthquake, which had short-period components of earthquake motion.
- In Mexico City, minor damage was evident in urban buildings with modified improvement of regulatory requirements in terms of construction that were in place after the 1985 earthquake. Conversely, buildings not subject to these regulatory requirements were more heavily damaged.
- In Atlixco (proximal to the earthquake epicenter) , there many 16 century structures, most structural damage was caused to historic churches.

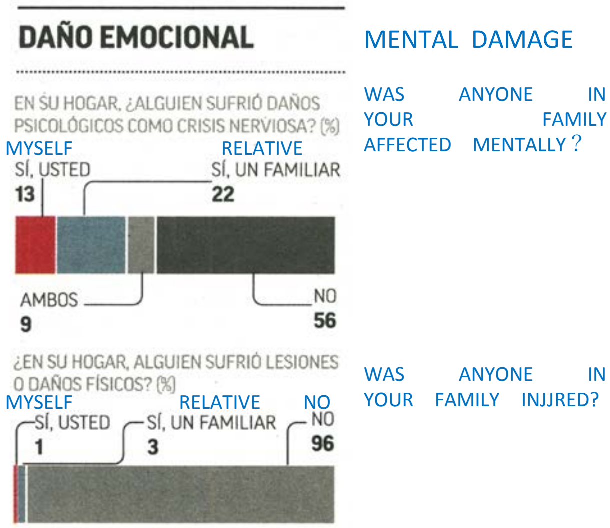


Fig. 7.5 Results of survey related to questions of mental damage caused by the earthquake (courtesy of EL FINANCIERO, September 25, 2017).

Fig. 7.6 Results of the survey related to the political response to the earthquake emergency (Courtesy of EL FINANCIERO, September 25, 2017).

Fig. 7.7 Survey results related to insecurity and crime during the emergency (courtesy of EL FINANCIERO, September 25, 2017).

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メキシコ中部地震調査速報

大角恒雄*・土肥裕史*

*防災科学技術研究所，社会防災システム研究部門

要　旨

防災科学技術研究所は 2017 年 9 月 19 日 13 時 14 分（現地時間），メキシコ中部プエブロ州を震源域とするマグニチュード（*Mw*）7.1 の地震が発生し，首都メキシコシティを中心とする広い領域で，主として RC 構造の建物が倒壊による多くの被害が発生した．本報告は，11 月 18 日から 22 日にかけてメキシコシティと震源近くのプエブロを中心にデータ収集を目的とし，調査団を派遣し，その調査速報である．この調査の目的は，深刻な被害を受けた建物は，10–20 m の厚さの堆積層の位置に相当し，1 秒間の推定加速度分布の位置に相当し，8 ～ 12 階の建物に対応する．震源近くのプエブロでは 16 世紀のスペイン統治時代の建物が残り，建物の損傷の大部分は教会の建物でその被害状況を報告する．

キーワード：メキシコ中部地震，メキシコシティ，プエブロ，地震災害，地震防災技術