Geociencias

sura

March 2018 No. 3

MEXICO:

A path to resilience

September 2017:
inside the two earthquakes

Brigades:
an example of preparedness, generosity, and knowledge

SURA's post-seismic method:
going beyond damages

CONTENT

Geociencias Sura Magazine | **Edition 3** | **March 2018**
Suramericana S.A., an Insurance, Trends and Risks company

A path towards **seismic resilience**

Natural phenomena are part of its dynamics and impact on the urban development of cities. For this reason, resilience is a huge challenge for seismic engineering worldwide, which is understood as the capacity of a society to control the level of damage and recover its functionality in the shortest possible time. Resilience results from the interactions between the forces of society, the environment, science, and technology. Society is increasingly interested in protecting life and property, business sustainability, and economic and social stability. Therefore, it focuses on better understanding the forces of nature and developing construction and rehabilitation techniques that can withstand them.

Thus, the achievement of this resilience capacity results from the integration of advances in seismic monitoring and instrumentation, knowledge of the seismic response of soils and buildings, together with the development of construction technologies.

The organization of Mexico into groups of brigades for the inspection of buildings in Mexico City is an outstanding achievement that shows that knowledge is only useful to the extent that it is put at the service of the common good. The brigade scheme shows not only the generosity of its members, but also the usefulness of their efforts to guide the decisions of the State. It can always be done better, but the result is a powerful initiative that was possible thanks to the generous dedication of a group of people motivated by a common cause, which has the great challenge of strengthening itself from the experiences of 2017.

SURA also tested its post-seismic plan in Mexico, which was developed several years ago because of its commitment to seismic resilience in Latin America. The excellent balance of this damage classification plan, vulnerability studies, and rehabilitation has been a very effective mechanism to support an engineering approach to our policyholders in Mexico affected by these earthquakes.

SURA has dedicated this special edition of the magazine Geociencias SURA, to show a positive view of the September 2017 earthquakes in Mexico. To highlight its contributions to seismic knowledge and the positive balance of all the research efforts put into practice since the great earthquake of 1985, which allow us to glimpse a promising path to increase the seismic resilience of the built environment. These lessons learned are the gateway to seeing risk as an opportunity. The important legacy and responsibility left by the earthquakes is to put their lessons into practice with responsibility and conviction that seismic resilience is an achievable challenge for our societies.

.

GONZALO ALBERTO PÉREZ ROJAS
CEO Suramericana S.A.

The earthquakes of September 7 and 19, 2017 in Mexico:
Was it a chain reaction or just a coincidence?

Mexico has recently reminded us of the latent seismic threat in most Latin American countries due to several earthquakes in September 2017. The most shocking thing is that one of these events was recorded just on the day that commemorated 32 years since the great earthquake of September 19, 1985.

SEP.19 1985

This earthquake had very important effects in Mexico City, marking a milestone in world seismic history, from which many research efforts were concentrated on the seismic response of the soil and its influence on the behavior of buildings.

Epicenter: Coasts of Michoacán

Time: 07:19 a. m. Local time

Depth: 28 km

Distance from Mexico City: 400 km

Magnitude **8.0** Source USGS

MICHOACÁN

Tectonic origin

Intraplate earthquake, occurred within the oceanic Cocos plate.

The great Michoacán earthquake of magnitude 8.0 (Mw), September 19, 1985, occurred in the central region of the Mexican Pacific coast, almost 400 km from Mexico City. This earthquake released 32 times more energy than the earthquake of September 19, 2017.

SEP.19 2017

When this earthquake occurred, it coincided with the commemoration of the 32nd anniversary of the great earthquake of 1985. Its effects were mainly felt in Mexico City, although there were also affected areas in the states of Mexico, Morelos, and Puebla.

Epicenter: Border between Puebla and Morelos

Time: 1:14 p. m. Local time

Depth: 48 km

Distance from Mexico City: 120 km

Magnitude **7.1** Source USGS

PUEBLA

Tectonic origin:

Intraplate earthquake, occurred within the oceanic Cocos plate.

The earthquake of September 19, 2017, showed important advances in Mexican earthquake engineering since 1985, and marked a new challenge towards resilience.

SEP.7 2017

The area of impact of the September 7 earthquake was concentrated in the states of Oaxaca and Chiapas.

According to records from Mexico's National Seismological Service, 482 aftershocks had been recorded 2 days after the earthquake.

Epicenter: 80 km off the coast of Chiapas

Time: 11:49 p. m. Local time

Depth: 47 km

Distance from Mexico City: 720 km

Magnitude **8.1** Source USGS

CHIAPAS

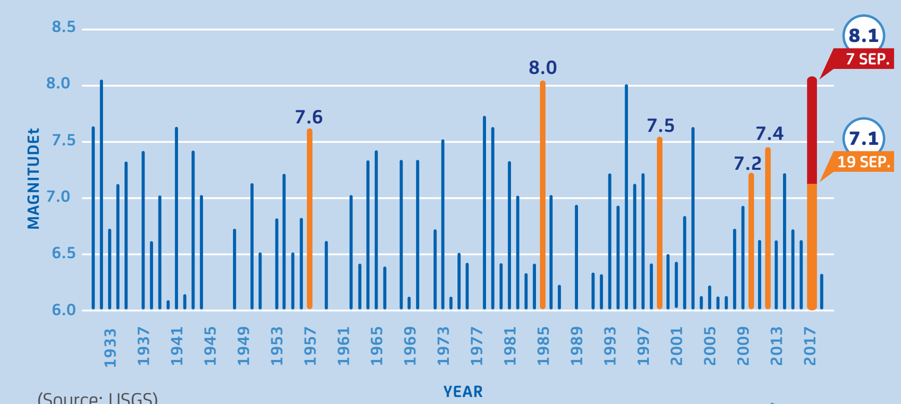
Tectonic origin:

Intraplate earthquake (oceanic Cocos plate)

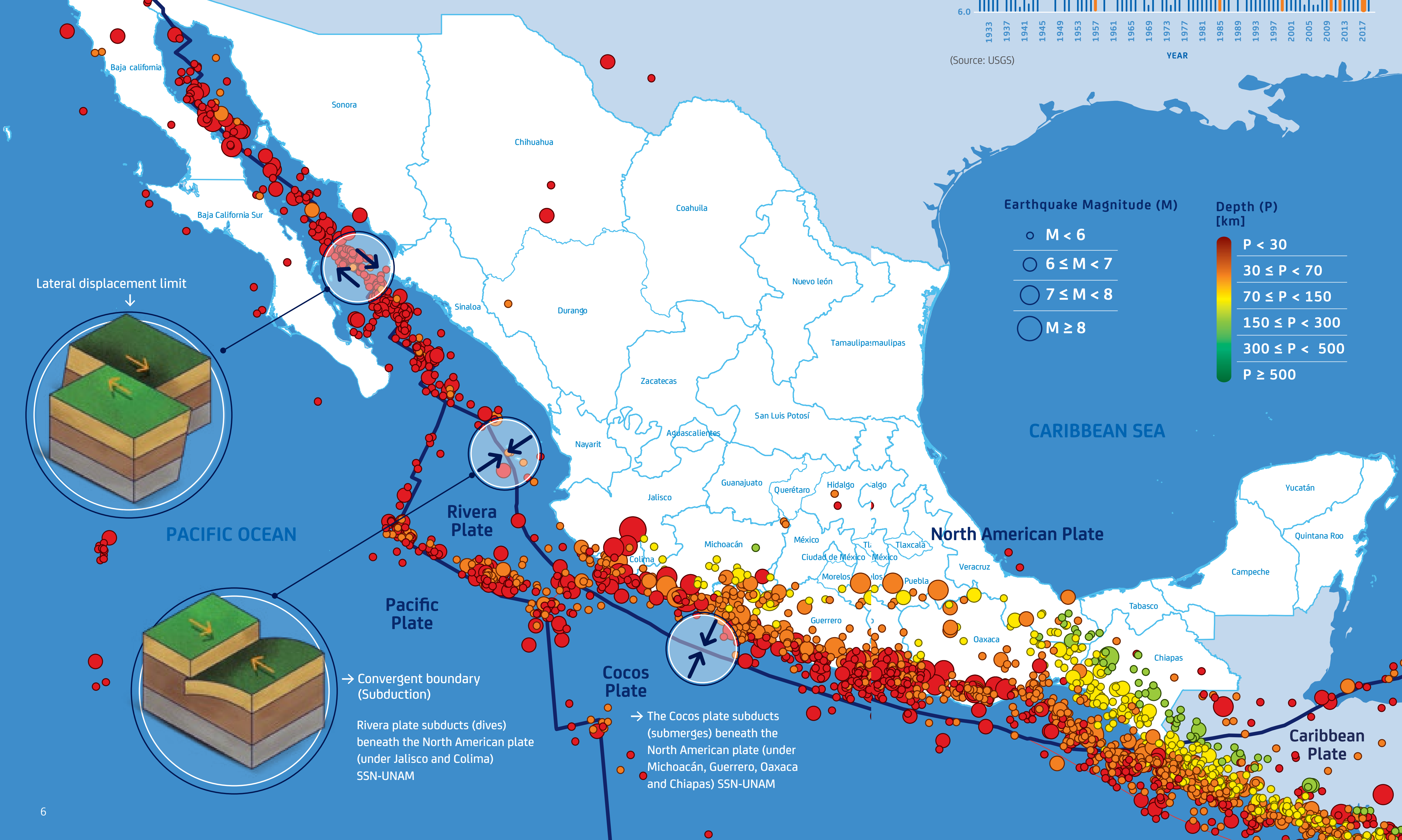
Tectonic environment and historical seismicity of Mexico

Mexico is located in an area of the American continent where five tectonic plates interact (Pacific, Rivera, Cocos, North American and Caribbean plates), which makes this region a major seismic hazard. As stated by the National Seismological Service of Mexico, although there is no current method or technology to predict earthquakes, the tectonic context of Mexico includes regions where large earthquakes have occurred and where they may occur in the future. This conviction has led this Latin American country to seek in the development of knowledge, a path towards seismic resilience.

Seismic events in Mexico



(Source: USGS)



OUTSTANDING EARTHQUAKES SINCE 1957

7.6

THE ANGEL EARTHQUAKE OF 1957

Date: **July 28**
Location: **Acapulco**
Magnitude: **7.6**
Depth: **38 km**

→ This earthquake motivated for the first time the incorporation of soil zoning in the seismic standard of Mexico City.

8.0

GREAT EARTHQUAKE OF 1985

Date: **September 19**
Location: **Coasts of Michoacán**
Magnitude: **8.0**
Depth: **28 km**

7.5

OAXACA EARTHQUAKE OF 1999

Date: **September 28**
Location: **Oaxaca**
Magnitude: **7.5**
Depth: **60 km**

7.2

2010 BAJA CALIFORNIA EARTHQUAKE (EL MAYOR-CUCAPAH)

Date: **April 4th**
Location: **23 km south of Mexicali**
Magnitude: **7.2**
Depth: **10 km**

7.4

OMETEPEC EARTHQUAKE, GUERRERO, 2012

Date: **March 20**
Location: **South of Ometepec, Guerrero**
Magnitude: **7.4**
Depth: **20 km**

8.1

CHIAPAS EARTHQUAKE SEP. 7, 2017

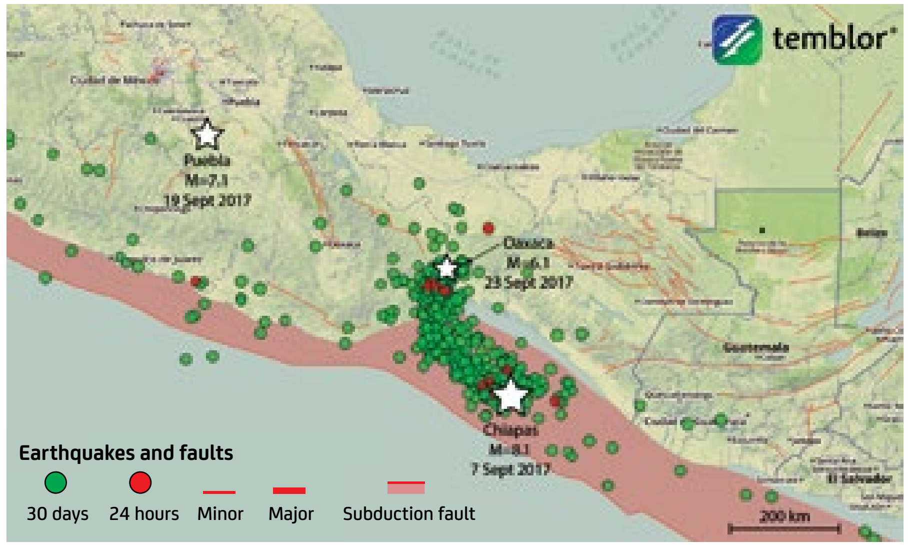
Date: **September 07**
Location: **80 km off the coast of Chiapas**
Magnitude: **8.1**
Depth: **47 km**

7.1

PUEBLA EARTHQUAKE OF SEP. 19, 2017

Date: **September 19**
Location: **Puebla-Morelos border.**
Magnitude: **7.1**
Depth: **48 km**

The two recent major earthquakes in Mexico are 600 km and 12 days apart

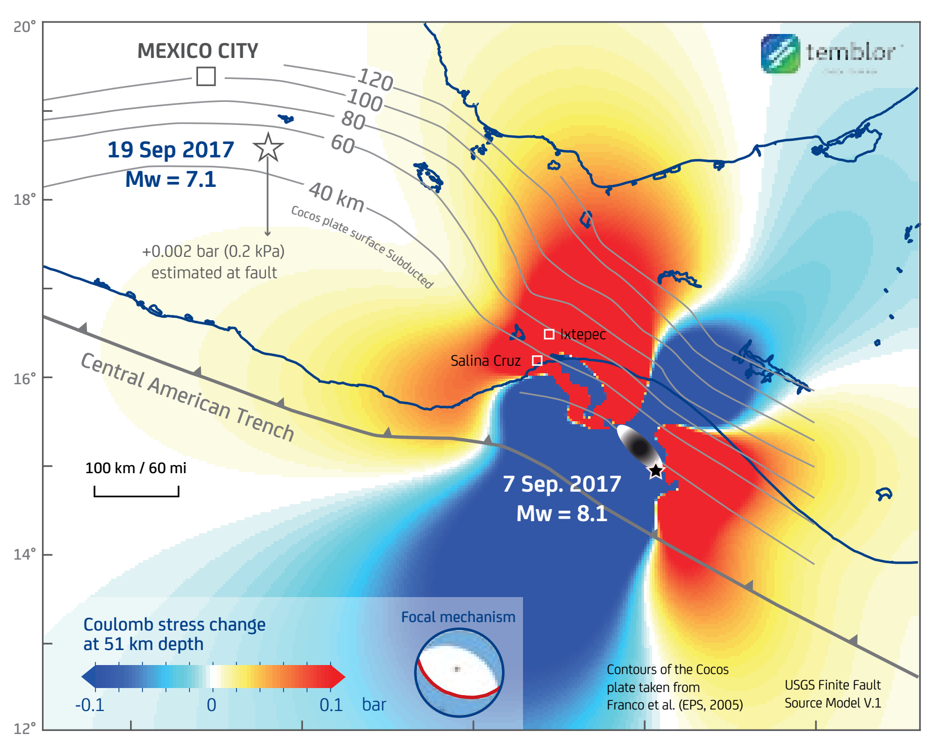


Are the 7S and 19S 2017 earthquakes related?

In September 2017, in a span of 12 days, Mexico was shaken by two major earthquakes. The sequence began on September 7 with a magnitude 8.1 (Mw) earthquake on the Pacific coast near the state of Chiapas. Twelve days later, on September 19, a 7.1 magnitude (Mw) earthquake struck Puebla, and caused the collapse of 44 buildings in Mexico City.

As stated by Ph.D. Ross Stein, professor of geophysics at Stanford University, USGS scientist emeritus and CEO of Temblor Inc: "A disturbing question arises following the occurrence of these two earthquakes: Are these events related to each other?".

The spatiotemporal proximity of these two events and the nature of their tectonic origin could lead to the assumption that there is indeed a chain reaction. To answer this interesting question, Ph.D. Ross Stein and the Temblor Inc. team studied the two earthquakes to estimate the possible relationship between them. Therefore, he evaluated the potential impact that the Chiapas earthquake could have had on the Puebla earthquake by means of a stress transfer analysis. The results of this analysis allowed the Temblor Inc. team to conclude that the 8.1 magnitude (Mw) earthquake recorded on September 7 in Chiapas did not generate stresses on the fault that gave rise to the earthquake recorded in Puebla 12 days later. As stated by Ph.D. Ross Stein in his publication on this analysis: "When calculating the stresses generated by the Mw = 8.1 earthquake in Chiapas on the fault that generated the Mw = 7.1 earthquake in Puebla, we find that the stresses experienced on the fault are so small that they are even smaller than those generated by rubbing the fingers of the hand.



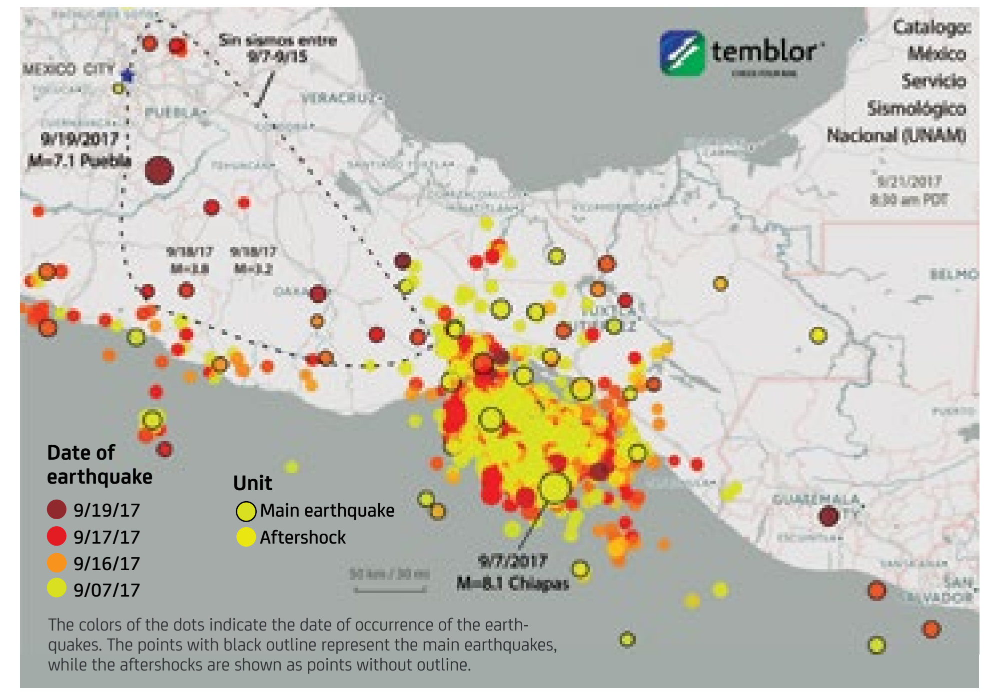
The increase in stress generated by the Chiapas earthquake (Mw = 8.1) corresponds to the strongest colors, while the lighter colors indicate a very low or even negligible incidence of the earthquake in those regions.

Could the recorded seismicity show any relationship between the 7S and 19S 2017 earthquakes?

The Temblor Inc. team analyzed the National Seismological Service (UNAM) catalog and found that the aftershocks of the Chiapas earthquake presents a pattern consistent with the estimated stress increment distribution (Coulomb analysis).

Another strong finding of Ph.D. Ross Stein is that when reviewing the distribution of the points where the aftershocks of the 7S earthquake in Chiapas (Mw = 8.1) originated, no aftershock was found near the region where the 19S earthquake in Puebla (Mw = 7.1) occurred. From this analysis it is concluded that the stresses transmitted by the 7S earthquake in Chiapas on the fault that gave rise to the 19S earthquake in Puebla are negligible, and, in this sense, there is no relationship between these two earthquakes.

Location of the earthquakes registered in Mexico between September 7 and 19.



What is the probability that these two events are independent?

According to the analysis carried out by the Temblor Inc. team, it is possible to infer that the Chiapas earthquake had no incidence on the occurrence of the Puebla earthquake, but what is the probability that these two events are independent, because the Puebla earthquake occurred only 11 days apart from the Chiapas earthquake, and that their epicenters were 600 km away from each other?

According to the calculations of Ph.D. Ross Stein and his team, this probability corresponds to 1 in 30,000: "You could say that a probability of 1 in 30,000 is too remote to think that the Chiapas and Puebla earthquakes are not related; but before considering that 1 in 30,000 is too small a number to consider both earthquakes as a coincidence, it is good to ask yourself this question: What is the probability that the Puebla earthquake (Mw = 7.1) occurred only 2 hours after the drill commemorating the 32nd anniversary of the 1985 earthquake in Mexico City, this definitely has to be a coincidence, right? This probability corresponds to 1 in 900,000 - almost one in a million!". Thus, in the words of Ph.D. Ross Stein, "Extreme coincidences can occur in our lifetimes and after seismological analysis, this is the best explanation we have".

SOURCES

David Jacobson
B.Sc. in Geological Sciences from Whitman College in Walla Walla, Washington, and M.Sc. in Geology from the University of Canterbury, Christchurch, New Zealand. He was involved in extensive research on liquefaction in and around Christchurch, while also conducting research on active faults, a central topic in his M.Sc. thesis. David received academic distinction and the Albert Ripley Leeds Award in geology from Whitman College. He currently works as a geographic information analyst at Temblor.net.

Ross S. Stein
CEO of Temblor.net, Professor of Geophysics at Stanford University, Scientist Emeritus of the United States Geological Survey (USGS), Chair of the Tectonophysics Section of the American Geophysical Union (AGU), and 2017-2018 International Speaker of the Geological Society of America (GSA). In 2012, Professor Stein received the Gilbert F. White Distinction, awarded by the AGU Natural Hazards section. In 2012 he delivered the TED talk "Defeating Earthquakes. He was awarded the Eugene M. Shoemaker Distinction by the USGS. In 2003, Professor Stein was distinguished as the second most cited author in seismic science during the preceding decade according to reports from the Science Citation Index, and was the tenth most cited author from 1900-2010. He frequently shares his experience and knowledge to the public through interviews, lectures and documentaries on IMAX and Discovery Channel. He is currently a member of the Resilient America panel of the United States National Academy of Sciences.

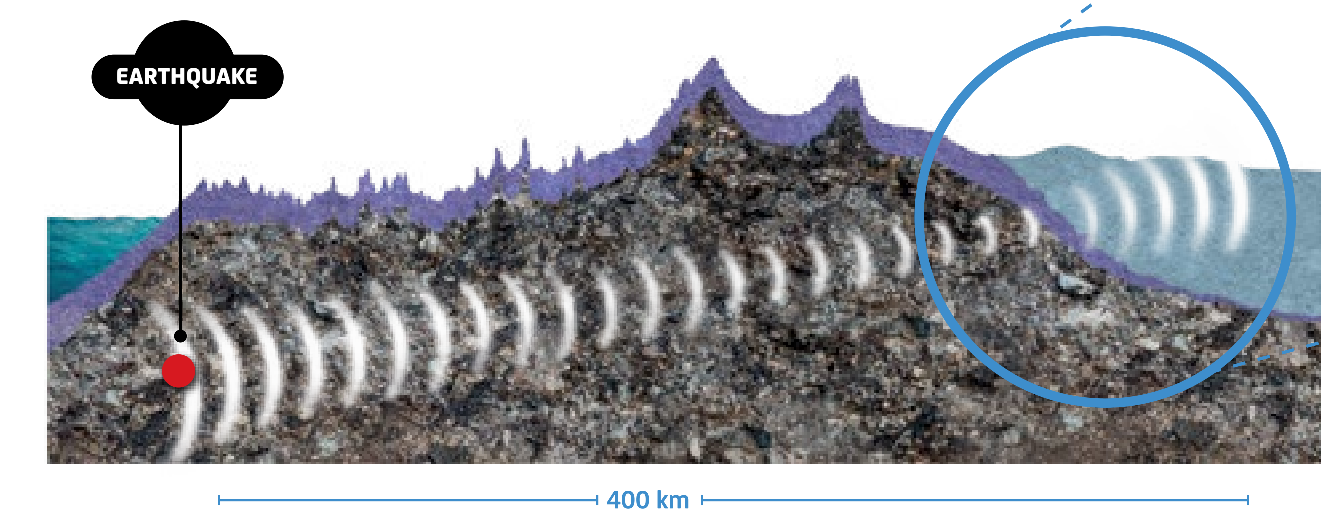
REFERENCES

- Stein, R., Jacobson, D and Toda, S. (2017). *The M=8.1 Chiapas, M=7.1 Puebla, and M=6.1 Oaxaca earthquakes: Chain reaction or coincidence?:* Temblor Inc. USA.
- UNAM (2017). *Reporte preliminar: Parámetros del movimiento del suelo sismo de Puebla-Morelos (Mw 7.1) 19 de septiembre de 2017.* Unidad de Instrumentación Sísmica – Coordinación de Ingeniería Sismológica, UNAM. México.
- Servicio Sismológico Nacional (2017). *Sismo del día 19 de septiembre de 2017, Puebla-Morelos (M 7.1).* Grupo de Trabajo del Servicio Sismológico Nacional, UNAM. México.
- Servicio Sismológico Nacional (2017). *Zone de subducción mexicana y su potencial para un sismo mayor.* Instituto de Geofísica, UNAM, México.

Impact of site effects on the seismic response of buildings

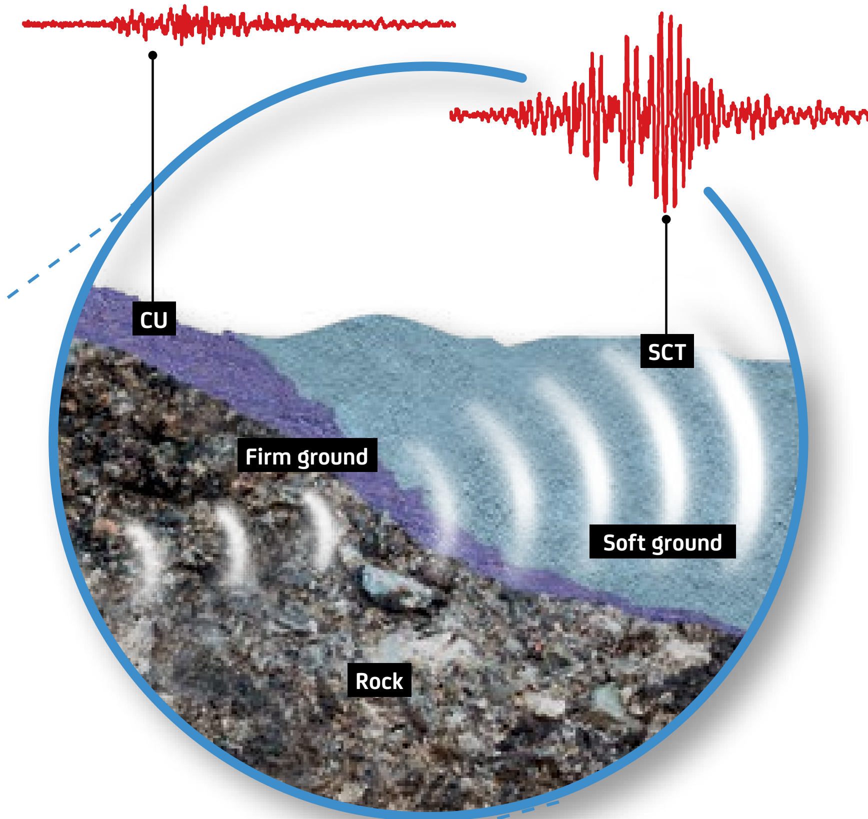
The effect of local geology and soil conditions on ground motions has been demonstrated in several earthquakes worldwide. Local site effects include the amplification associated with soil profile characteristics, which has the potential to modify the intensity, frequency content and duration of ground motions. This is why local site effects play an important role in seismic resistant design.

In recent global seismic history, seismic instrumentation has made it possible to quantitatively record the intensity of ground motions at different locations, which has provided elements for understanding site effects and incorporating them into seismic design standards.



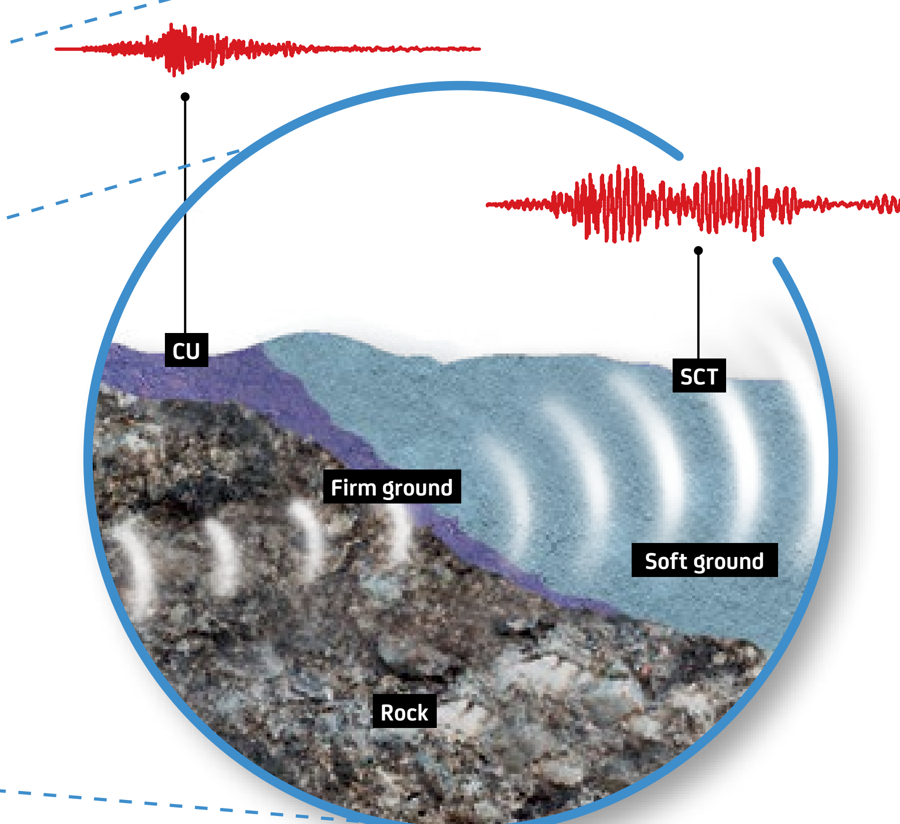
Schematic profile

Schematic profile



1985 EARTHQUAKE 8.0 Mw Source USGS

The great earthquake of 1985, whose rupture was generated almost 400 km from Mexico City, evidenced a strong relationship between soil conditions and the distribution of damage in that city. The earthquake records in some Mexico City sites marked a very important milestone for the investigation and understanding of the effects of soil in this city and in the world.



2017 EARTHQUAKE 7.1 Mw Source USGS

The 2017 19S earthquake originated 120 km from the Mexican capital. This earthquake confirmed the importance of ground effects and showed variations in intensities in different city areas. The differences in intensities and seismic response of buildings in this earthquake, with respect to what was recorded in 1985, are due to factors such as:

- It originated in an area much closer to Mexico City, which implied a shorter propagation distance for the seismic waves to reach the city.
- It released less energy than the 1985 earthquake (Mw = 7.1 and Mw = 8.0, respectively).

CU SCT
Two stations of Mexico City's accelerographic networks

What is so special about the soils of Mexico City?

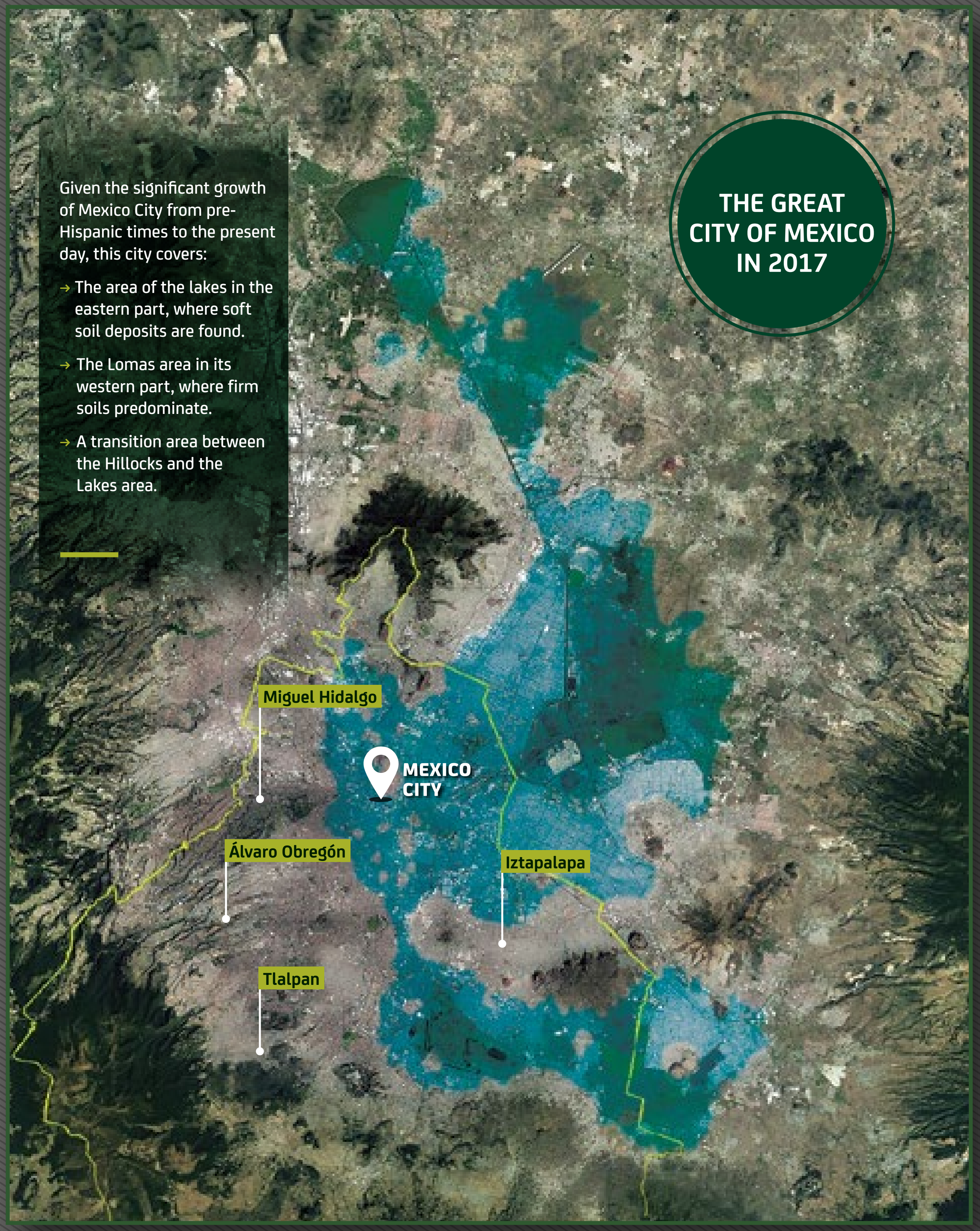
A 32.000 YEAR HISTORY

In pre-Hispanic times there was a lake system, formed by the Texcoco and Xochimilco-Chalco lakes, in the area where a large part of Mexico City is located today. In the areas where these lakes were located, there are deposits of soft sediments that generate the so-called “amplification effects” of seismic waves.

The seismic waves propagate from the rupture zone that originates the earthquake and when they reach the soft soil strata, they alter the characteristics of the waves significantly, amplifying the intensity of the movements that reach the buildings.

The **Texcoco and Xochimilco-Chalco** lakes were very rich in natural resources, which together with the mountains that surrounded them, provided abundant sources of resources to the nomadic groups, which since pre-Hispanic times have been located on their shores.

(García Martínez, B., 2007)



Given the significant growth of Mexico City from pre-Hispanic times to the present day, this city covers:

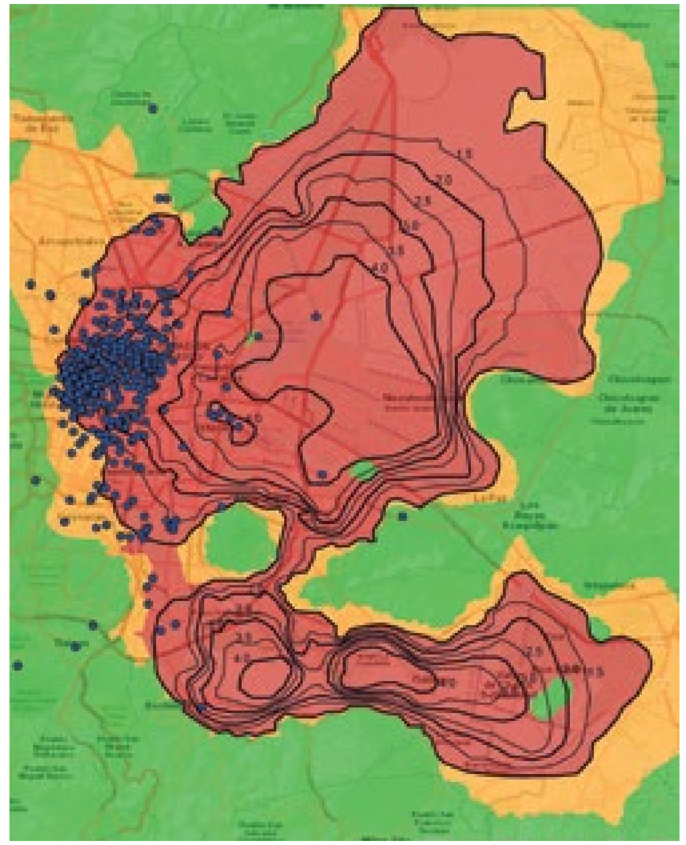
- The area of the lakes in the eastern part, where soft soil deposits are found.
- The Lomas area in its western part, where firm soils predominate.
- A transition area between the Hillocks and the Lakes area.

Relevant moments in the incorporation of soil effects in the Building Regulations for Mexico City

Mexico City's seismic history has made it possible to advance in the knowledge of soil effects and to apply it in its seismic design standards. The 1957 and 1985 earthquakes stand out for their contributions to this knowledge. The city's conviction of the need to install wide accelerograph networks (CIRES and UNAM) has made it possible to have records of ground motion, which have been essential in the study and understanding of the relationships between soil conditions and the intensities of the seismic response of the different sites.

These studies have allowed the development of increasingly detailed soil zonings, leading to what is now the System of Seismic Actions for Design (Sistema de Acciones Sísmicas de Diseño - SASID), which allows the estimation of soil response parameters at each site in Mexico City.

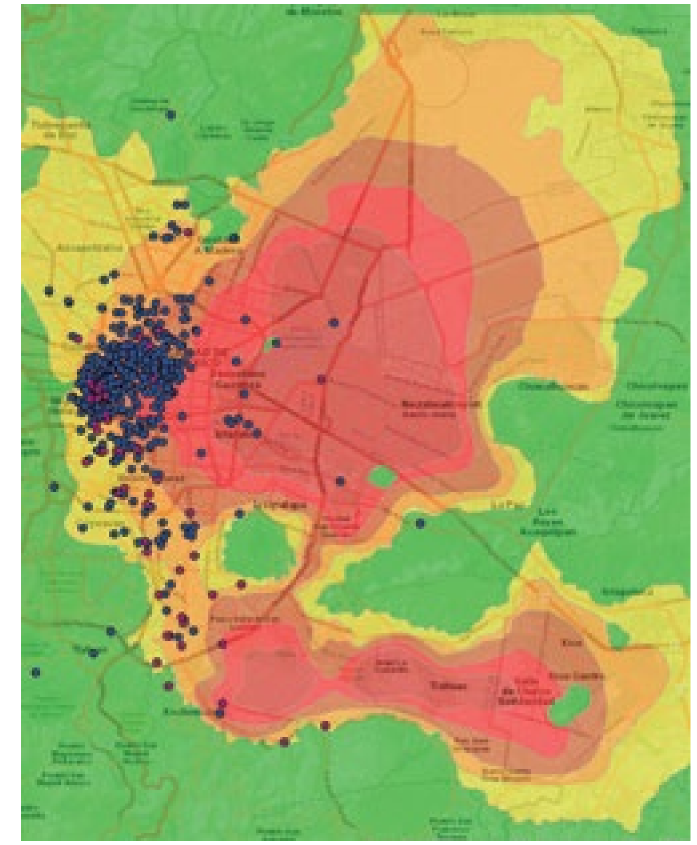
Damage map of the 1985 earthquake on seismic zoning of Mexico City in 1976



Source: Regulation 1987 - earthquake damage report 1985

- Zone I
- Zone II
- Zone III
- — Predominant soil periods (s)
- Buildings with major damage and collapse - Earthquake of September 19, 1985

Damage map of the September 19, 1985, and 2017 earthquakes on seismic zoning of Mexico City 2004



Sources: www.sismosmexico.org/mapas • Collaborative Map 2017 • Damage Report 1985

- Zone I
- Zone II
- Zone IIIa
- Zone IIIb
- Zone IIIc
- Zone IIId
- Buildings with major damage and collapse, earthquake of S19, 1985
- Buildings with major damage and collapse, earthquake of S19, 2017

1921

FIRST BUILDING REGULATIONS FOR THE FEDERAL DISTRICT

1957

1957 EARTHQUAKE (Mw 7.6)

It was the first event to show that Mexico City's soft soil deposits have the potential to amplify seismic movements.

1966

UPDATED REGULATION

Divides Mexico City into zones of high and low soil compressibility.

1976

UPDATED REGULATION

Divides Mexico City into three zones, according to soil conditions:
- Hill zone
- Transition zone
- Lake zone.

1985

MICHOACÁN EARTHQUAKE OF 1985 (Mw 8.0)

Source USGS

Major damage generated by this earthquake in Mexico City ratified the importance of soil effects in the seismic response of buildings and showed the need for a better characterization of soils.

1987

UPDATED REGULATION

- Incorporated for the first time isoperiods and iso-depth curves for soils.
- Increased the seismic coefficients for the design of the transition zone and the lake zone.

2004

UPDATED REGULATION

Complemented the seismic zoning of Mexico City, including a subdivision of zone III into four subzones (IIIa, IIIb, IIIc and IIId).

2017

EARTHQUAKE 19S OF 2017 (Mw 7.1)

- It registered significant intensities in Mexico City, in some areas they were higher than those registered in the 1985 earthquake.
- At the date of occurrence, the seismic standard update was practically ready to be published.

SASID SYSTEM

- This new system incorporates the definition of site-specific soil response parameters.

SOURCES

Francisco García Álvarez
Civil Engineer, M.Sc. in Engineering. President of the Mexican Society of Structural Engineering. He belongs to the Mexican Society of Earthquake Engineering, the College of Civil Engineers of Mexico and the Earthquake Engineering Research Institute, has published in conferences and technical journals and was the director of the Crisis Center that was mounted jointly SMIE-CICIM for inspection brigades after the earthquake of September 19, 2017.

Francisco García Jarque
Civil Engineer, M.Sc. in Engineering. He is a member of the Evaluation Committee of Professional Experts in Structural Safety of the College of Civil Engineers of Mexico and of the Committee of Corresponsible in Structural Safety of the Government of the Federal District. He is a member of the Structural Safety Advisory Committee of the Federal District Government and has participated in more than 4,000 structural projects. In 2010 he won the National Engineering Award for Professional Practice, granted by the College of Civil Engineers of Mexico; he was president of the Mexican Society of Structural Engineering from 1999 to 2000.

Gloria María Estrada Álvarez
Civil Engineer, specialist in Environmental Engineering, specialist and M.Sc. in Earthquake Resistant Engineering. Geosciences Manager of Suramericana. She has worked in the development and coordination of studies and research in seismic engineering, soil dynamics and seismic risk. He has published more than 20 technical articles in the area of seismic engineering.

Mario Rodríguez Rodríguez
Civil Engineer, M.Sc. and Ph.D. in Structures, full time researcher at the Institute of Engineering of UNAM. His research work conducted with Professor José Restrepo of UCSD, has been the basis of the new section 12.10 of the US standard ASCE/SEI 7-16 (2016) Minimum Design Loads for Buildings and Other Structures. He has been the author of the 2016-2017 modifications to the seismic design of diaphragms in buildings of the 2017 Mexico City Supplementary Technical Standard for Earthquakes; he is an Expert in Structural Safety and professor of the course on Seismic Design of Concrete Structures in the Graduate Engineering Program of the Faculty of Engineering of the UNAM; he has also taught refresher courses for engineers in structural safety in Mexico, Peru, Colombia and Chile. He participated in the damage assessment of the earthquakes of Chile 1985, Mexico 1985, Japan 1995 and 2010, Peru 2007, Mexicali 2010, Chile 2010, and Mexico City 2017. He is a voting member of the ACI 318 Main Committee of the American Concrete Institute International (ACI), which develops the ACI 318 Regulation for Structural Concrete, as well as several ACI technical committees. He is president of MR Ingenieros Consultores en Estructuras, founded in 2005.

REFERENCES

- Colegio de Ingenieros Civiles de México, A.C. (2017). *¿Qué ocurrió el 19 de septiembre?*. IC CICM, Vol. 580. Ciudad de México, México.
- Kramer, S. (1996) *Geotechnical Earthquake Engineering*. Prentice Hall. New Jersey, USA.
- García Martínez, B. (2007). *La Cuenca de México, Arqueología Mexicana*, núm. 86. Vol. XV
- Miranda, E. et al. (2017). *Preliminary Statistics of Collapsed Buildings in Mexico City in the September 19, 2017 Puebla-Morelos Earthquake*.

SURA's methodology for evaluation
of buildings Postseismic

SURA developed a Postseismic evaluation methodology applied only by specialists in structural engineering for the diagnosis, damage classification and definition of intervention solutions for buildings affected by earthquakes.

Origin
The earthquake of magnitude 6.2 (Mw) at a depth of 10 km in the city of Armenia (Colombia) on January 25, 1999, generated in the directors of SURA, particularly in its president, Gonzalo Alberto Perez, the need to develop a methodology of the company for the evaluation of Postseismic buildings. Although SURA's Postseismic care in the areas affected by the Armenia earthquake involved the participation of a group of structural engineers, there was no methodology that allowed homologation and unified criteria for the evaluation of the affected buildings. This earthquake was the inspiration for SURA's Postseismic evaluation methodology.

Vision and approach
The methodology focused on achieving unicity of procedures and evaluation criteria, oriented to the diagnosis and classification of objective damages, to support decisions of repair, rehabilitation or reconstruction of its clients' buildings, in accordance with the applicable seismic resistant construction regulations and the advances of the state of the art in structural engineering in the world.

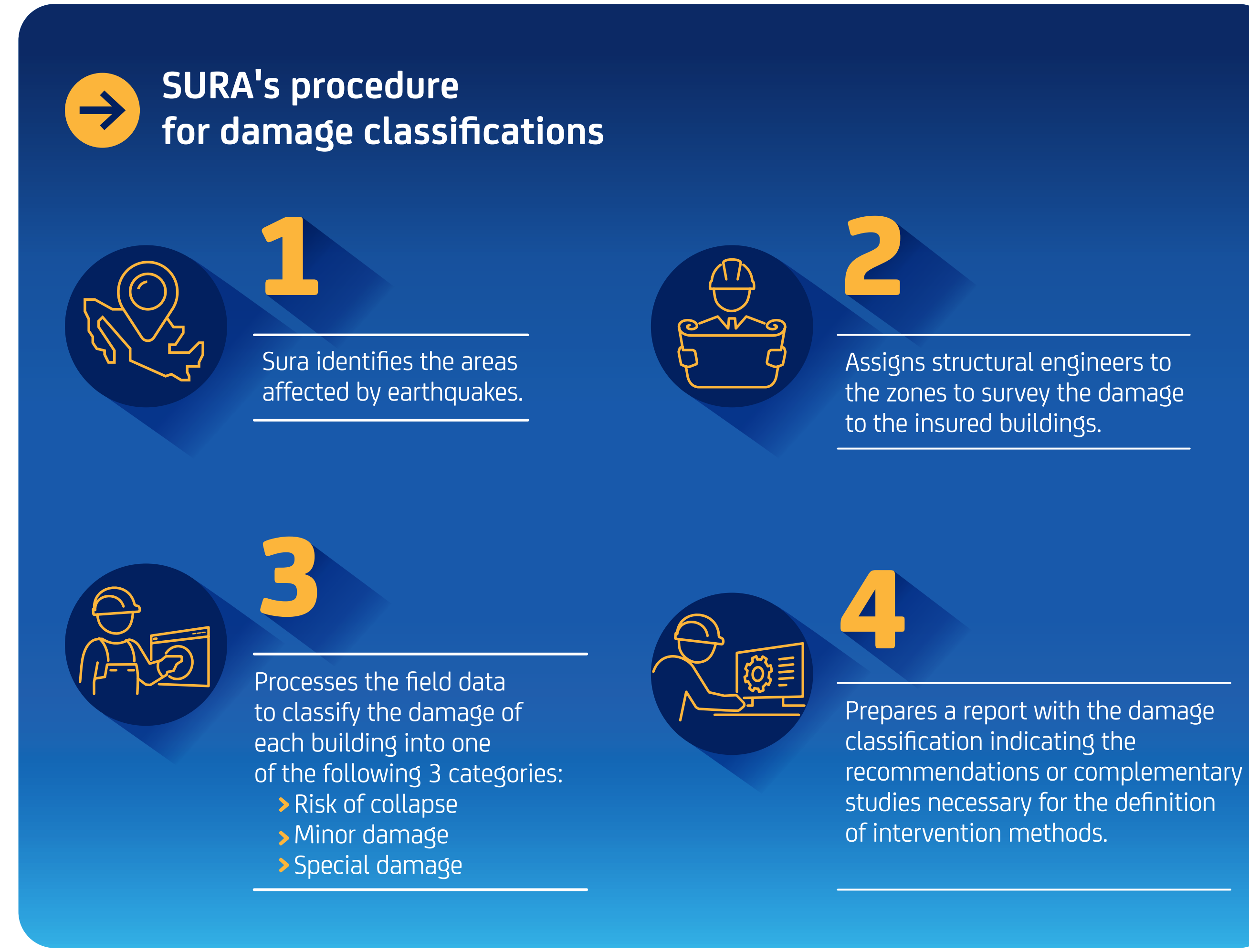
Development and implementation
Since its inception in 2005, the development of SURA's Postseismic evaluation methodology has been led by engineer Gloria María Estrada, SURA's current regional Geosciences Manager, with the participation of three external advisors from academia and the professional practice of structural engineering, engineers Juan Diego Jaramillo, Roberto Rochel and Álvaro Pérez. This team developed the first version of the methodology that was completed in 2008.

> *Suramericana has had a lot of vision in developing this methodology, since it is not only thinking about paying for damages, but also contributing to building more resilient and less vulnerable cities that are better prepared to face another earthquake".*
>
> Juana Llano, Vice President of Seguros SURAMERICANA S.A.S

Weeks after the 8.8 magnitude (Mw) earthquake in Chile on February 27, 2010, this group of professionals made a reconnaissance visit to the main affected areas to test the methodology in different types of buildings with different levels of damage.

In order to develop this methodology, different proposals and criteria existing in the world were studied, among which FEMA (Federal Emergency Management Agency of the United States), NEHRP (National Earthquake Hazard Research Program of the United States) and some specific publications of the AIS (Colombian Association of Earthquake Engineering) stand out. The great contribution of SURA's methodology to the existing approaches was to diagnose and classify damages based on quantitative data, which allows obtaining an objective vision based on engineering criteria.

Between 2012 and 2015, engineers Elizabeth Cardona, Victoria González and Juan David Rendón, who are now part of the SURA Geosciences team, joined the team. Additionally to the internal revisions done by the Geoscience team, this methodology has undergone review and feedback processes from external specialists, such as engineers Francisco Pérez, from the company Andes Ingeniería and Alejandro Pérez, from the company Proyectos y Diseños. This feedback has been sought to be at the forefront of advances in structural and seismic engineering.



SURA has trained external teams of structural engineering specialists to implement this methodology. In 2008, SURA had a group of 60 trained structural engineers in Colombia. Currently, the company has expanded this group and has specialists in Colombia, Chile, and Mexico. This expansion gives it a better response capacity.

> **About the procedure, Professor Juan Diego Jaramillo from EAFIT University comments: "SURA's Postseismic building evaluation methodology is a novel and pioneering work in which SURA should persevere".**

The most important test of this methodology took place in 2017, in SURA's evaluation plan after the earthquake of September 19, 2017, in Mexico. A group of more than 70 engineers who specialized in structures participated. From this experience, there are very valuable lessons learned. Still, the most important is the conviction of its importance to channel efforts towards the seismic resilience of our region, seeking to repair, rehabilitate and reconstruct buildings in accordance with the advances in engineering.

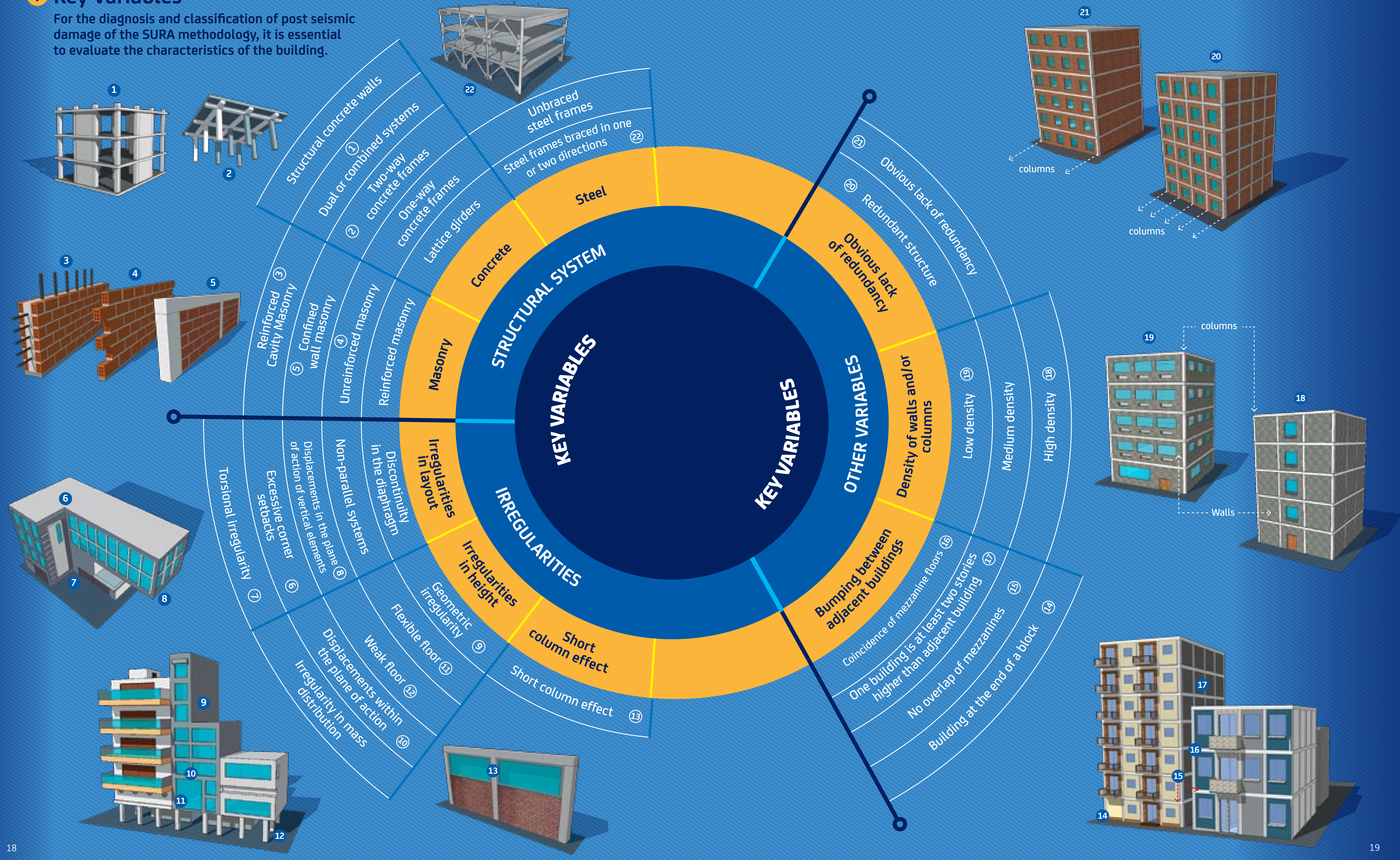
Tomás Isaza, current Insurance Manager of SURA Mexico, promoted and supported the development of SURA's methodology for the evaluation of Postseismic buildings since its inception in 2005 and after seeing its application in Mexico, he is convinced of its effectiveness in meeting the needs of clients affected by earthquakes.

What is SURA's methodology for evaluating post-seismic buildings?
Our structural engineering specialists accompany the client in two fundamental stages:

- Damage diagnosis and classification: A standard damage survey manual is followed based on inspection visits carried out exclusively by structural engineers. The results are analyzed by a centralized team of specialists, which generates the damage classification report for each building.
- Assignment of repair, rehabilitation or reconstruction methods, according to the damage.

Key Variables

For the diagnosis and classification of post seismic damage of the SURA methodology, it is essential to evaluate the characteristics of the building.



Damage classification procedure using SURA's Postseismic Evaluation Methodology

Stage 1

Diagnosis and classification of damage, including:

- Manual for filling out the field form, to achieve unified criteria.
- Form for the collection of information in the field by structural engineers to characterize the building and the postseismic damage in the affected areas.
- Analysis of forms filled out in the field by a centralized team of specialists.
- Program for the generation of diagnostic reports and damage classification, based on the processing of field forms.

The field information survey conducted in stage 1 involves the identification of the structural and non-structural elements of the buildings, as well as the assessment of the respective damages.

→ **Damage is classified into the following categories:**

CATEGORY 1
Risk of collapse

Buildings whose damage implies collapse or risk of collapse, requiring demolition and construction of a new building, following the applicable seismic design standards.

CATEGORY 2
Minor damage

Buildings with minor damage repairable by standard procedures.

CATEGORY 3
Special damage

Require complementary studies to define the most appropriate solution for postseismic intervention

Stage 2

At this stage, repair, rehabilitation or reconstruction methods are assigned, according to the level of damage

- Complementary studies by structural engineering firms with extensive knowledge and experience, to define the most appropriate intervention of the building.

→ **The deliverables of these studies vary according to the particular conditions of each building:**

- Recommendations and plans with repair procedures.
- Analysis of the structure, designs and plans for its rehabilitation or reinforcement.
- Recommendation for demolition and construction of a new building, in case the rehabilitation solution is not technically or economically feasible.

Connection with the mega-trend of urbanism

SURA's methodology for postseismic evaluation allows for an adequate treatment of affected buildings and in turn, leverages the development of knowledge that feeds back positively to earthquake risk management in Latin America. In this way, preventive studies and projects are promoted based on the knowledge acquired on how to achieve a better seismic performance of buildings, which is directly connected to the megatrend of urbanism. As part of this megatrend, all opportunities for earthquake damage reduction to build more resilient cities will be enhanced, because for people, companies and society in general, postseismic care will always be more costly than preseismic management. SURA, through this and other initiatives, wants to bring experience, knowledge and conviction to the region.

SOURCES

Álvaro Pérez Arango
Civil Engineer from Universidad Nacional de Colombia; M.Sc. in Structural Dynamics and Earthquake Engineering from the Technical Institute of Karlsruhe, Germany. In 2012 he was awarded the distinction of Professor Emeritus at the Universidad Nacional de Colombia. He currently serves as manager of the firm Álvaro Pérez Arango y CÍA. LTDA. specialized in structural design and studies of structural pathology, seismic vulnerability and rehabilitation projects of buildings.

Gloria María Estrada Álvarez
Civil Engineer, specialist in Environmental Engineering, specialist and M.Sc. in Earthquake Resistant Engineering. Geosciences Manager of Suramericana. She has worked in the development and coordination of studies and research in seismic engineering, soil dynamics and seismic risk. He has published more than 20 technical articles in the area of seismic engineering.

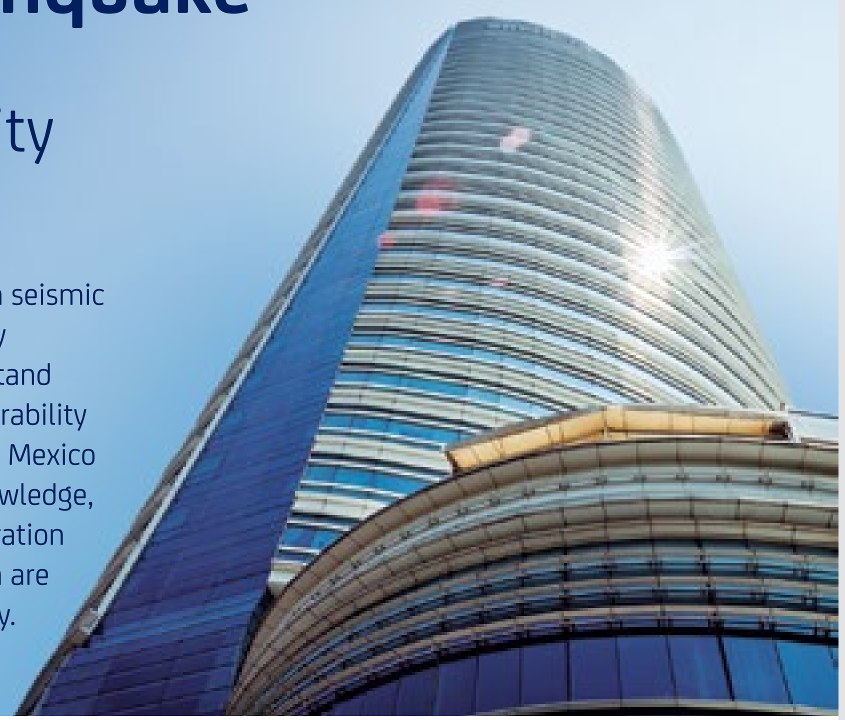
Juan Diego Jaramillo Fernández
Civil Engineer, M.Sc. in Earthquake Resistant Engineering and Dr. in Engineering. He has received academic recognitions among which stand out; Lorenzo Codazzi Award from the Colombian Society of Engineering (2000); Gerald A. Leonards Award from the Colombian Society of Engineering and Annual Research Award at EAFIT University (1998) for the project: Seismic Instrumentation and Microzoning of the city of Medellin. He has worked as a professor in the Department of Structures at Universidad EAFIT and has worked on numerous research projects, as well as publishing in scientific journals.

Roberto Rochel Awad
Civil Engineer M.Sc. in Structures; Professor Emeritus of Universidad EAFIT, Visiting Professor at Universidad del Norte, Universidad Nacional de Medellín, Universidad de Antioquia and Universidad Industrial de Santander.
Author of the books Diseño Sísmico de edificios and Diseño de concreto reforzado (Seismic Design of Buildings and Design of Reinforced Concrete). Former president of the Association of Structural Engineers of Antioquia. Has more than 200,000 m2 of reinforced concrete building design. Has performed pathology studies of educational, residential and airport facilities. Has performed postseismic evaluations in Colombia, Chile, Haiti and Mexico.

REFERENCES

- SURAMERICANA, (2010). *Lecciones para Colombia del sismo de Chile del 27 de febrero de 2010.* Suramericana S.A. Medellín, Colombia.
- SURAMERICANA, (2017). *Metodología para el diagnóstico, clasificación de daños y asignación de métodos de intervención, y supervisión técnica de rehabilitación y reconstrucción de edificaciones afectadas por sismo*. Suramericana S.A. Medellín, Colombia.
- SURAMERICANA, (2017). *Manual para el diligenciamiento del formulario de SURAMERICANA para el diagnóstico y clasificación de daños postsismo.* Suramericana S.A. Medellín, Colombia.

Effects of the earthquake
of September 19, 2017 on buildings in Mexico City



Mexico is a territory with a vast seismic history with seismic records dating back to 1500, in which high-intensity earthquakes such as those of 7S and 19S of 2017 stand out. Considering that the reduction of seismic vulnerability is key for the sustainable development of a country, Mexico has concentrated efforts in the development of knowledge, the evolution of building regulations and the preparation of suitable professionals for their application, which are essential elements to increase its resilience capacity.

Throughout history, the lessons learned from earthquakes in Mexico have encouraged the development of research generating changes in the Seismic Resistance Standards. These changes entailed the incorporation of requirements at all stages of the projects, such as detailed studies of the soil characteristics and its local effects on buildings, greater knowledge in terms of methods of analysis and structural design, use of seismic resistant materials and greater controls during the construction process.

As a result of the evolution of the Seismic Resistance Standards in Mexico, there is a positive balance of the last earthquake of September 19, 2017. Only a small percentage of the buildings constructed in Mexico City collapsed or suffered significant damage, demonstrating that the changes generated in the same have been key to achieving a reduction in seismic vulnerability.

Evolution of the Building Regulations for Mexico City, a path towards resilience

- **1921** — FIRST BUILDING REGULATIONS FOR THE FEDERAL DISTRICT
- There were no seismic design regulations. Buildings designed only to support vertical loads and loads related to the use of the building
- **1942** — UPDATE REGULATION
- **1957** — ANGEL EARTHQUAKE (Mw 7.6). Publication of emergency standards that begin to consider detailed seismic design requirements
- **1966** — UPDATE REGULATION
- **1976** — UPDATE REGULATION. The Complementary Technical Standards are incorporated:
  - Earthquake and Wind Design
  - Design and Construction of:
  - Foundations
  - Steel Structures
  - Concrete Structures
  - Timber Structures
  - Masonry Structures
- MICHOACÁN EARTHQUAKE (Mw 8.0) SOURCE USGS
- **1985**
  - The National Reconstruction Program is created
  - Emergency Standards for Repair, Rehabilitation and New Construction Projects are issued
- **1987** — UPDATE REGULATION
  - Seismic design adjustments
  - Greater rigor in the design of vital buildings
  - Definition of the figures: Director Responsible for Construction (DRO) and Structural Safety Coordinator (CSE)
- **1993** — UPDATE REGULATION
- **1995** — Complementary Technical Standards
  - Design and construction of wood structures
  - Design and construction of metallic structures
- **2004** — UPDATE REGULATION
- **2017** — UPDATE REGULATION. EARTHQUAKE 19S (Mw 7.1)
  - New Complementary Technical Standards
  - Seismic Rehabilitation of concrete buildings damaged by the earthquake of September 19, 2017
  - Review of Structural Safety of Buildings (NTC-RSEE)

Management of buildings affected by earthquakes

Damage magnitude and severity depends on several factors, such as the characteristics of the supporting soil, quality of the structural design, structural typology, construction materials, and presence of irregularities, among others. The presence of damage in a building implies a detailed review of it, to determine if it can be repaired, rehabilitated or if, due to the level of damage, it is convenient to demolish it and build it again.

Classification of damage to structural and non-structural elements of buildings

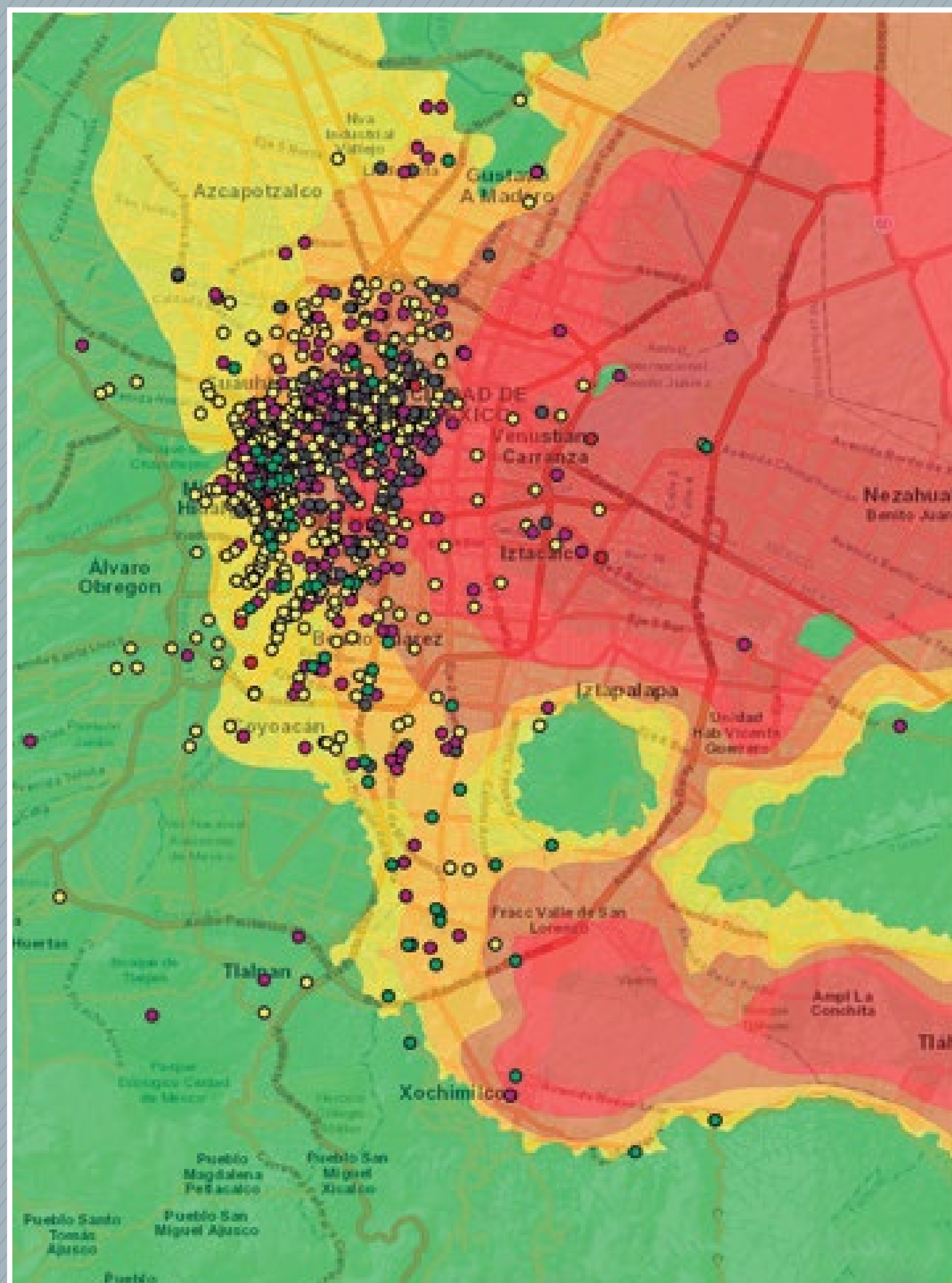
MINOR DAMAGE → **Repair**: Restoration of the original characteristics of the building so that it can operate again
- Structural Elements: Slight and isolated cracks visible to the naked eye in reinforced concrete elements, which do not compromise the stability of the building. They are repairable under conventional methods.
- Non-Structural Elements: Slight and isolated cracks visible to the naked eye in non-structural masonry walls or dividing elements. They are easily repairable.

SPECIAL DAMAGE → **Repair / Rehabilitation**: Optimization of the seismic performance of a building in compliance with current regulations
- Structural Elements: Moderate cracks and fissures affect the structural capacity of the building and may compromise its stability. Structural safety studies and repair/rehabilitation project are required.
- Non-Structural Elements: Widespread cracks in the dividing or non-structural walls of the building, which may involve the partial or total rupture of the masonry pieces.

COLLAPSE → **Demolition**: Destruction of a building and construction of a new one, in compliance with current regulations
- Structural Elements: Unstable structure resulting from deformations or damage to destroyed or severely cracked or crushed structural elements. Buildings whose repair is not technically or economically feasible.

Building damage distribution reported by official sources, 1985 and 2017 earthquakes of September 19, 1985 and 2017

The distribution of collapses of 19S 2017 reported in the brigades' collaborative map indicates that these were concentrated in buildings of less than 10 stories, built before 1985, with flat slab typologies, masonry and reinforced concrete frames. Compared to the 1985 earthquake of September 19, 1985, 45% of the collapses and severe damage occurred in concrete frame buildings and flat slab systems between 6 and 10 stories.



SEISMIC ZONING

- Zone I
- Zone II
- Zone IIIa
- Zone IIIb
- Zone IIIc
- Zone IIId

AFFECTATIONS OF THE EARTHQUAKE OF 19S, 2017

- Collapse
- Major damage

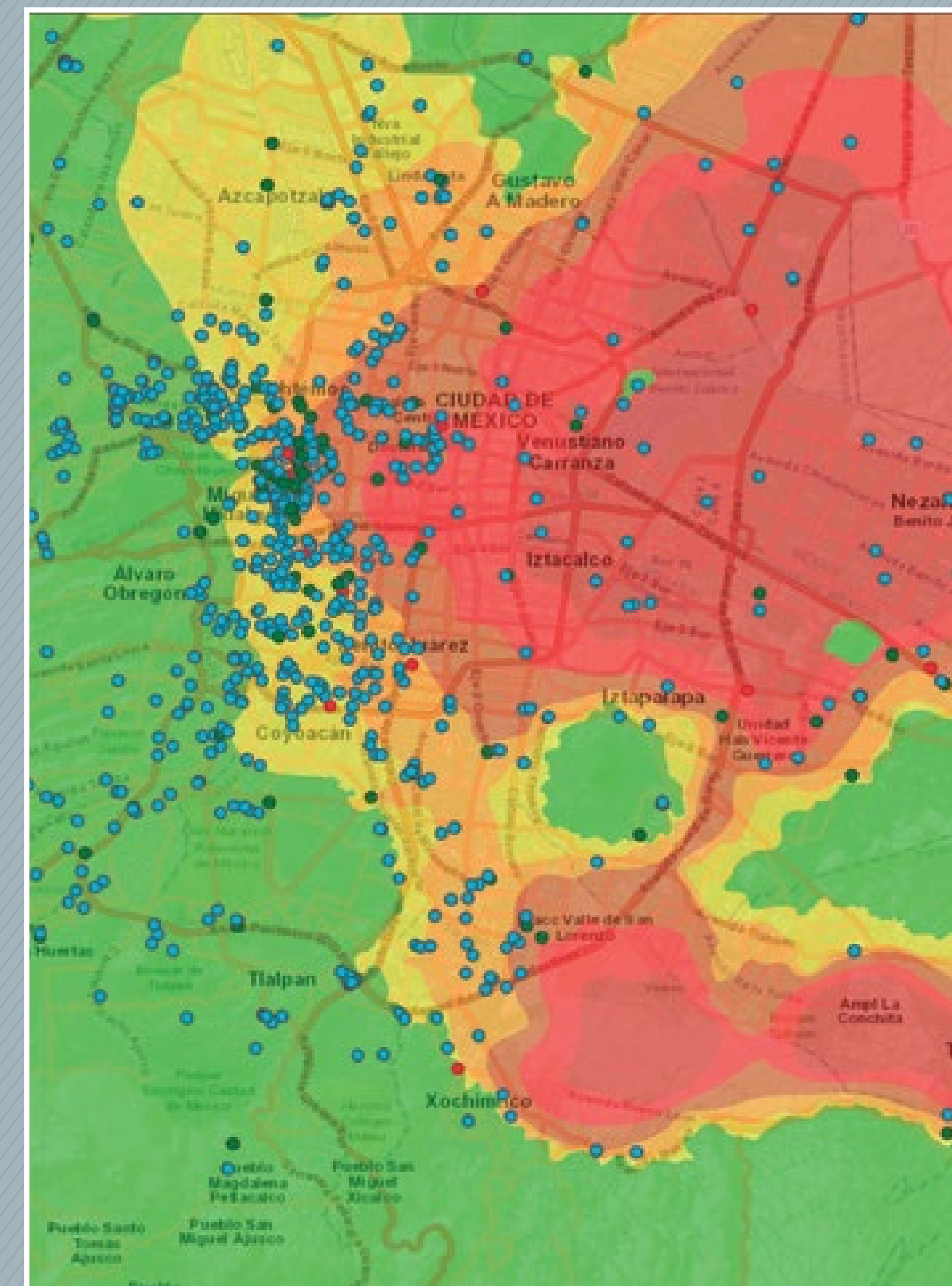
AFFECTATIONS OF THE EARTHQUAKE OF 19S, 1985

- Collapse
- Major damage
- Minor damage

Sources: www.sismosmexico.org/mapas • Collaborative Map 2017 • Damage report 1985

Distribution of damages in buildings inspected by Sura, earthquake of 19S 2017

From the group of buildings inspected by SURA, 192 were classified with special damage or risk of collapse, of which 65% are concentrated in masonry systems, reinforced concrete frames (filled with non-structural walls) and flat slab systems of less than 10 levels. In addition, from this group of buildings it was found that the irregular configuration of the structures, such as corner locations and weak floors, has a marked influence on the generation of earthquake damage.



SEISMIC ZONING

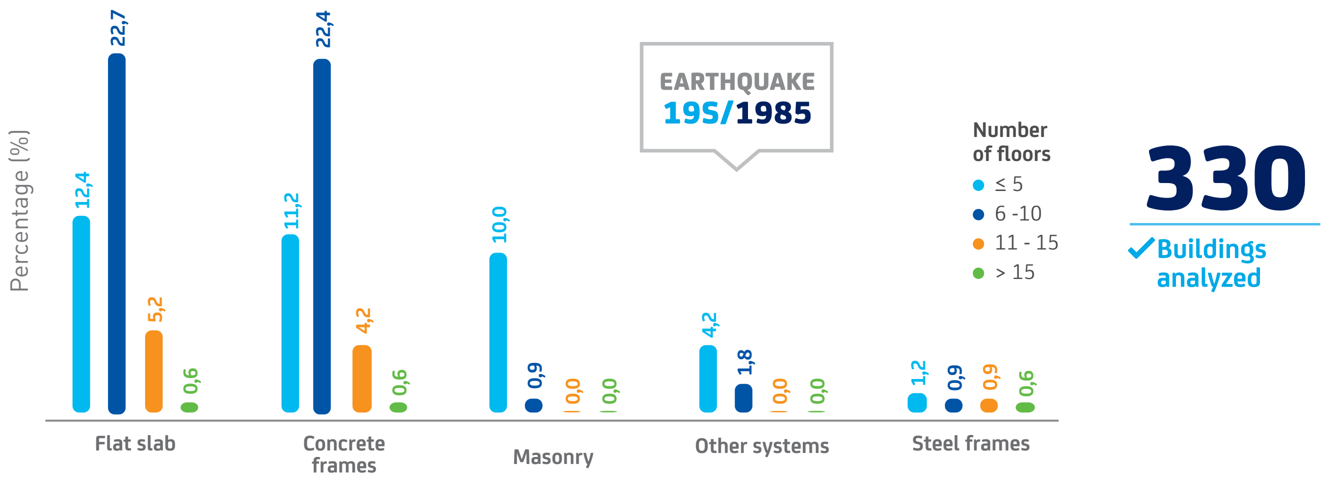
- Zone I
- Zone II
- Zone IIIa
- Zone IIIb
- Zone IIIc
- Zone IIId

BUILDINGS INSPECTED BY SURA, EARTHQUAKE OF 19S, 2017

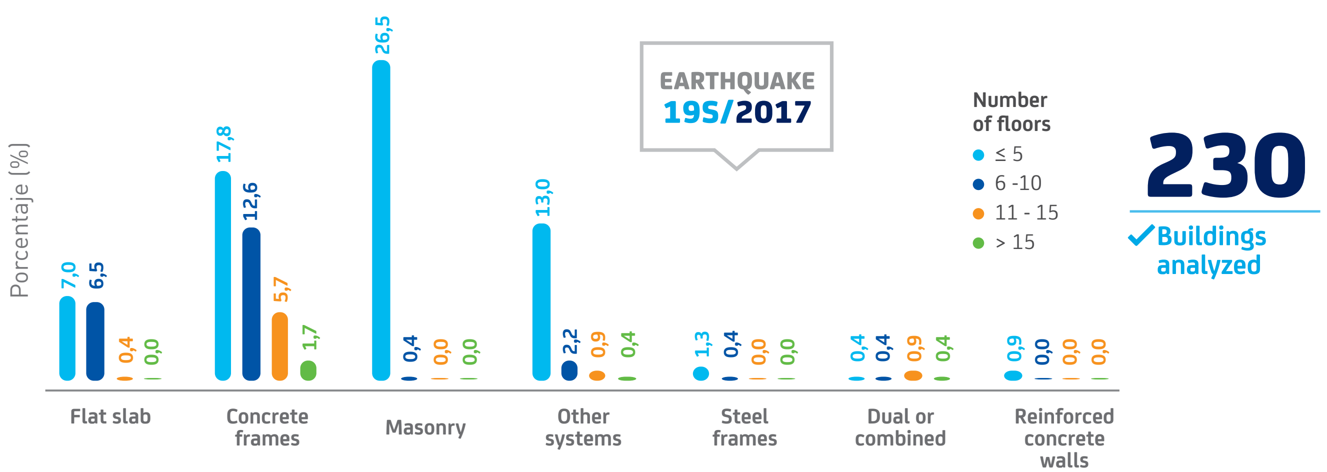
- Collapse Risk
- Special damage
- Minor damage

Source: SURA

Buildings with major damage and collapse, by structural typology and number of stories

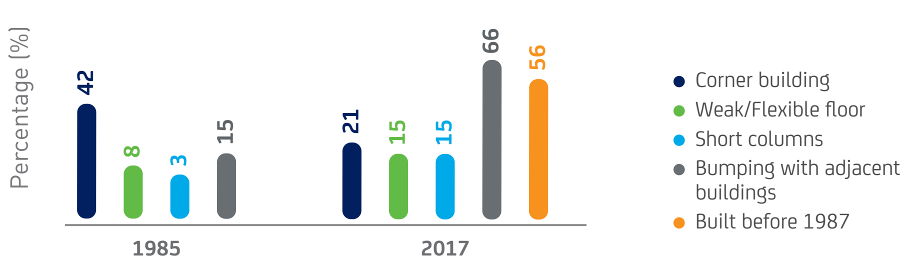


Source: Meli R, et al., (1986)



Source: www.sismosmexico.org/mapas - Inspections performed by SURA
(This analysis combines inspections performed by brigades and SURA)

Structural characteristics of buildings with major damage and collapse caused by the 1985 and 2017 earthquakes of September 19, 1985 and 2017



330
Buildings analyzed
19S/1985

192
Buildings analyzed
19S/2017

→ The same building may have none, one or several of these characteristics

Sources: buildings analyzed in the earthquake of 19S, 1985: Meli R, et al, (1986) Buildings analyzed in the earthquake of 19S, 2017: (Inspections performed by SURA).

Structural typologies included in the analysis of the 1985 and 2017 earthquakes of 19S

SURA is currently supporting the development of structural evaluation studies and repair/rehabilitation projects for approximately 40 buildings in Mexico City, the States of Mexico, Puebla and Morelos.

Repair/rehabilitation management

The most commonly used rehabilitation techniques for the reinforcement of medium-rise buildings damaged by the 1985 earthquake were the encasement of reinforced concrete columns and beams. For taller buildings, the predominant technique was the addition of reinforced concrete walls and metal bracing.

Currently, there is a great development of new technologies used in different parts of the world, seeking to improve the seismic performance of buildings.

A positive balance

The 19S earthquake of 2017 shows that the damage to buildings depends to a large extent on the structural system and the area where the building is located. Suppose a detailed analysis is carried out that considers which structures behaved adequately in Mexico City, both in the 1985 earthquake and the 19S earthquake of 2017. In that case, it could be easily concluded that dual and combined systems were some typologies that had a better seismic performance.

The worldwide effort to achieve greater resilience has focused on the use of new technologies both for the design of new buildings and for the implementation of rehabilitation alternatives. For example, energy dissipation and seismic isolation systems, which imply an increase in initial investment costs but a significant reduction in structural damage and losses associated with business interruption. This results in a lower total cost distributed over the expected useful life of the building.

According to the opinion of M.Sc. Francisco García Álvarez, the earthquake of 19S of 2017 had different characteristics to the earthquake occurred in 1985, where the great distance between the epicenter and Mexico City (400 km), for the latter, caused the high frequency contents of the earthquake to disappear, leaving only the low frequencies that excited structures between 8 and 15 levels; while in the 2017 earthquake, with an epicenter closer to the city (approximately 120 km), the high frequencies were filtered out and therefore affected buildings of lower height, with the disadvantage that these are the most predominant.

The number of buildings affected by the earthquake of September 19, 2017 is low for a megacity such as Mexico City. The path towards seismic resilience marks a challenge that seeks to substantially reduce the vulnerability of the built environment, which implies interconnections with the mechanisms of communication to society.

Structural systems with better performance during the 19S earthquake of 2017

- Low masonry structures with continuity of walls from the foundation to the roof.
- Due to their modern design and height, steel structures have a very different way of vibrating than the predominant ground vibration.
- Structures with parking lots outside the building, eliminating the possibility of a weak floor in the structure.
- Buildings constructed after 1985.
- Dual or combined systems. Rigid structures whose displacements are smaller than those of concrete frames.
- Reinforced concrete wall structures.

SOURCES

Elizabeth Cardona Rendón
Civil Engineer and specialist in Earthquake Resistant Engineering from Universidad EAFIT. She has worked at Suramericana since 2008 and since then she has worked in different areas. She is currently the Director of Business Applications in the Geosciences area.

Francisco García Álvarez
Civil Engineer, M.Sc. in Engineering. President of the Mexican Society of Structural Engineering. He belongs to the Mexican Society of Earthquake Engineering, the College of Civil Engineers of Mexico and the Earthquake Engineering Research Institute, has published in conferences and technical journals and was the director of the Crisis Center that was mounted jointly SMIE-CICIM for inspection brigades after the earthquake of September 19, 2017.

Francisco García Jarque
Civil Engineer, M.Sc. in Engineering. He is a member of the Evaluation Committee of Professional Experts in Structural Safety of the College of Civil Engineers of Mexico and of the Committee of Corresponsible in Structural Safety of the Government of the Federal District. He is a member of the Structural Safety Advisory Committee of the Federal District Government and has participated in more than 4,000 structural projects. In 2010 he won the National Engineering Award for Professional Practice, granted by the College of Civil Engineers of Mexico; he was president of the Mexican Society of Structural Engineering from 1999 to 2000.

Gloria María Estrada Álvarez
Civil Engineer, specialist in Environmental Engineering, specialist and M.Sc. in Earthquake Resistant Engineering. Geosciences Manager of Suramericana. She has worked in the development and coordination of studies and research in seismic engineering, soil dynamics and seismic risk. He has published more than 20 technical articles in the area of seismic engineering.

Juan David Rendón Bedoya
Civil Engineer and specialist in Structures from Universidad Nacional de Colombia. He has worked for consulting firms in the development of projects of analysis and design of buildings and lattice structures for power substations and transmission lines. He is currently working as a structural specialist in the area of Geosciences.

Mario Rodríguez Rodríguez
Civil Engineer, M.Sc. and Ph.D. in Structures, full time researcher at the Institute of Engineering of UNAM. His research work conducted with Professor José Restrepo of UCSD, has been the basis of the new section 12.10 of the US standard ASCE/SEI 7-16 (2016) Minimum Design Loads for Buildings and Other Structures. He has been the author of the 2016-2017 modifications to the seismic design of diaphragms in buildings of the 2017 Mexico City Supplementary Technical Standard for Earthquakes; he is an Expert in Structural Safety and professor of the course on Seismic Design of Concrete Structures in the Graduate Engineering Program of the Faculty of Engineering of the UNAM; he has also taught refresher courses for engineers in structural safety in Mexico, Peru, Colombia and Chile. He participated in the damage assessment of the earthquakes of Chile 1985, Mexico 1985, Japan 1995 and 2010, Peru 2007, Mexicali 2010, Chile 2010, and Mexico City 2017. He is a voting member of the ACI 318 Main Committee of the American Concrete Institute International (ACI), which develops the ACI 318 Regulation for Structural Concrete, as well as several ACI technical committees. He is president of MR Ingenieros Consultores en Estructuras, founded in 2005.

Victoria Luz González Pérez
Civil Engineer from Universidad de Medellin, specialist and M.Sc. in Earthquake Resistant Engineering from Universidad EAFIT. She worked as director of structural design in a consulting firm for 12 years. She is currently working as a structural specialist in the area of Geosciences.

REFERENCES

- Aguilar, J. et al., (1989). *The Mexico Earthquake of September 19, 1985 – Statistics of Damage and of Retrofitting Techniques in Reinforced Concrete Buildings Affected by the 1985 Earthquake.* Earthquake Spectra, Volume 5, No. 1, pages 145-151, Earthquake Engineering Research Institute.
- Colegio de Ingenieros Civiles de México, A.C. (2017). *¿Qué ocurrió el 19 de septiembre?* IC CICM, Vol. 580. Ciudad de México, México.
- Colegio de Ingenieros Civiles de México, A.C. (2017). *Diseño sísmico basado en resiliencia, una necesidad nacional.* IC CICM, Vol. 581. Ciudad de México, México.
- Meli R, et al., (1986). *Evaluación de los efectos de los sismos de septiembre de 1985 en los edificios de la Ciudad de México, Parte I, Evaluación de daños,* Volumen 2-1, Instituto de Ingeniería, UNAM.
- Meli R, et al., (1986). *Evaluación de los efectos de los sismos de septiembre de 1985 en los edificios de la Ciudad de México, Parte II, Evaluación detallada de edificios típicos,* Volumen 2-1, Instituto de Ingeniería, UNAM.
- Miranda, E. et al., (2017). *Preliminary Statistics of Collapsed Buildings in Mexico City in the September 19, 2017 Puebla-Morelos Earthquake.* John A. Blume Earthquake Engineering Center. Department of Civil and Environmental Engineering. Stanford University. California, USA.
- Quiroga C. et al., (2004). *Evaluación de los daños del sismo del 19 de septiembre de 1985 a la luz de nuevos datos y estudios y con ayuda de sistemas de información geográfica,* XIV Congreso Nacional de Ingeniería Estructural, Acapulco, Gro., 2004, Sociedad Mexicana de Ingeniería Estructural.
- Rodríguez, M. (2017). I*nterpretación de los daños y colapsos en edificaciones observados en la Ciudad de México en el terremoto del 19 de septiembre de 2017.* Instituto de Ingeniería UNAM. Ciudad de México
- Vázquez, A. (1997). *La evolución de la construcción en México, como consecuencia del sismo de 1985.* Academia Mexicana de Ingeniería.

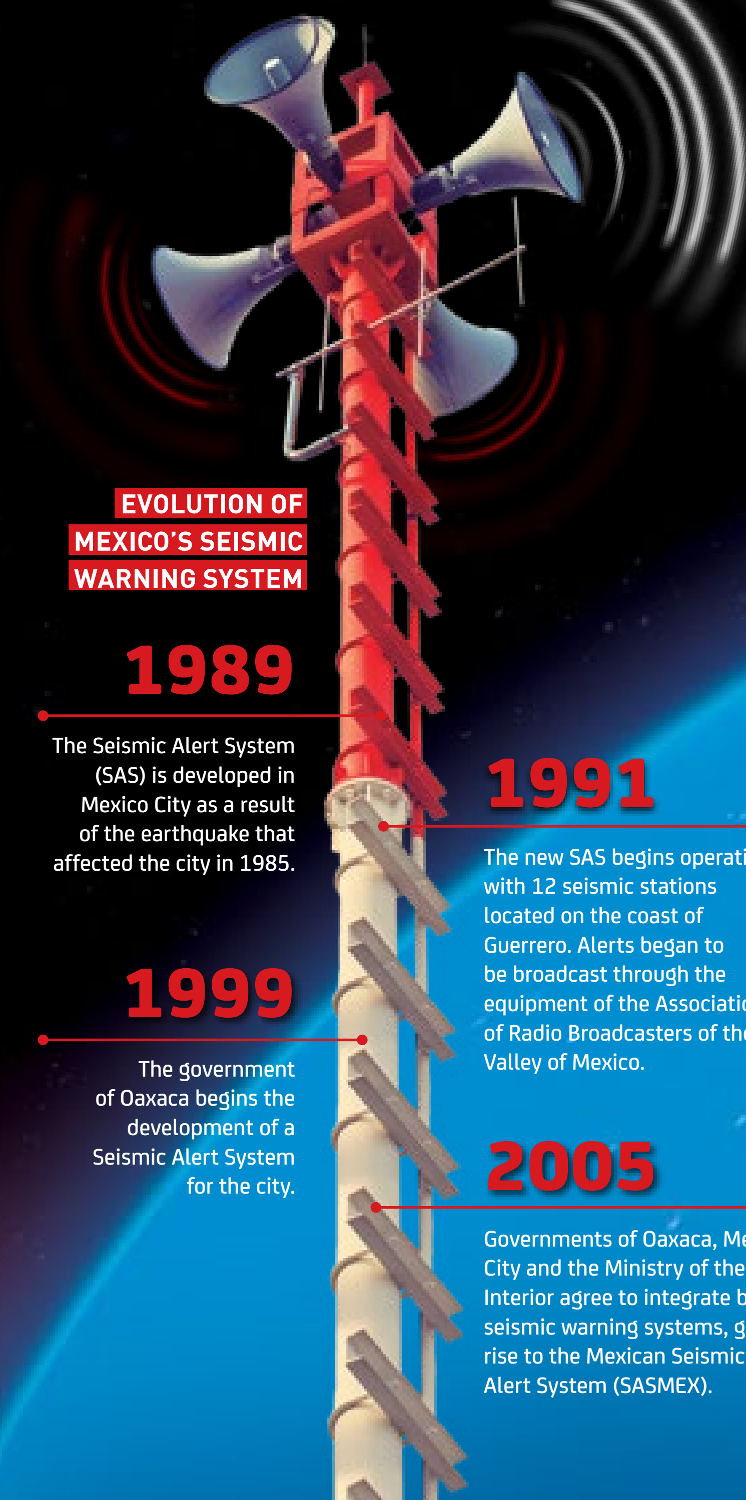
Technology and engineering for the management of earthquakes

Mexico's technological advances and the possibilities of recording earthquakes are noteworthy, since they have allowed them to generate early warnings, and the opportunity to study, monitor and know these natural phenomena in greater detail.

Mexico's seismic warning system

Seismic monitoring technology enhances the knowledge of seismic wave transmission phenomena and the effects of seismic response of soils, to seek analysis and design mechanisms that improve the seismic performance of buildings. Mexico currently has a dense network of instruments to record earthquakes, which, combined with the installation of radio sensors, make up the Mexican Seismic Alert System (SASMEX), to warn the population of the occurrence of distant earthquakes. This innovative system is advancing more and more in its coverage, and its great challenge is to ensure that the population interprets its signals better and better, so that it follows the appropriate protocols to protect life.

The Center for Instrumentation and Seismic Registration A.C. (CIRES, A.C.), headed by its director, engineer Juan Manuel Espinosa Aranda, is aware that the current seismic warning system works well, but can be improved in many aspects, even more so when technological developments are continuously seen on all fronts that can enhance the current network, so as to achieve a more inclusive system, incorporating other types of signals so that, for example, people with hearing or visual impairments can warn them, and a more robust system, in which the existing sensor network is expanded.



EVOLUTION OF MEXICO'S SEISMIC WARNING SYSTEM

1989

The Seismic Alert System (SAS) is developed in Mexico City as a result of the earthquake that affected the city in 1985.

1991

The new SAS begins operating with 12 seismic stations located on the coast of Guerrero. Alerts began to be broadcast through the equipment of the Association of Radio Broadcasters of the Valley of Mexico.

1999

The government of Oaxaca begins the development of a Seismic Alert System for the city.

2005

Governments of Oaxaca, Mexico City and the Ministry of the Interior agree to integrate both seismic warning systems, giving rise to the Mexican Seismic Alert System (SASMEX).

OPERATION OF THE SEISMIC ALERT SYSTEM

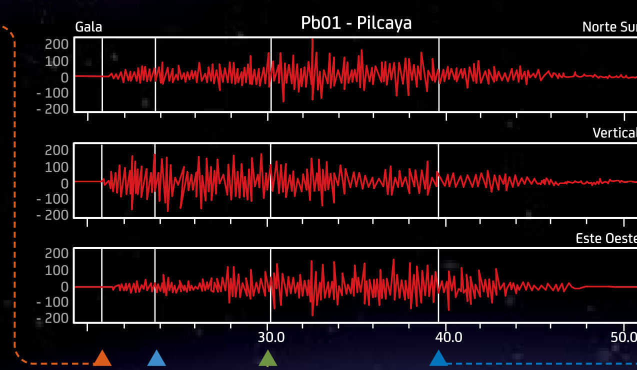
The operation of the Mexican Seismic Alert System is based on the capture and transmission of the earthquake phases by means of the network sensors, which estimate the energy of the earthquake through three algorithms, and subsequently transmit the result obtained to the SASMEX central stations by means of radio waves, which propagate faster than seismic waves.

1 P-WAVE DETECTION

Once the sensor registers the P-waves of the earthquake, the algorithms that transmit the alert signals to the SASMEX Control Center begin to run.

2 3S ESTIMATOR

After 3 seconds from the detection of the earthquake P-waves, the first of the algorithms is executed, which sends the signal to the Control Center.



4 2SP ESTIMATOR

The third algorithm monitors seismic wave conditions from the time P-wave motion is detected until a significant S-wave phase.

3 S-WAVE DETECTION

At the instant when the sensor registers the S-waves of the earthquake, the second algorithm is executed, in which the signal of the frequency and energy content of the P-waves registered up to that instant is sent.

Thanks to the fact that **radio waves** travel much faster than seismic waves, it is possible to issue distant earthquake warnings for Mexico City up to

100 SECONDS in advance.

Thanks to the fact that radio waves travel much faster than seismic waves, it is possible to issue distant earthquake warnings for Mexico City with up to

97 seismic sensors

distributed in the states of **Oaxaca, Guerrero, Puebla, and the southern states of Michoacán, Colima and Jalisco.**

MANAGEMENT OF THE BRIGADES of Civil Engineers in Mexico City - Earthquake of September 19, 2017

Once the earthquake happened, the Colegio de Ingenieros Civiles de México A.C., the Sociedad Mexicana de Ingeniería Estructural, the Academia de Ingeniería and the Instituto de Ingeniería de la UNAM, activated the brigades to review the structures affected by the earthquake. They summoned Professional Structural Safety Experts (PPSE), Structural Safety Corresponsible (CSE), civil engineers with experience in structures, university students of civil engineering and postgraduates.

They divided Mexico City into 45 critical areas, each one in charge of a specialized structural engineer recognized in the country with more than 15 years of experience. This engineer, in turn was in charge of a group of 2 or 3 civil engineers with more than 10 years of experience and between 10 to 15 engineers with less than 5 years of experience or civil engineering students. Each brigade classified the building into one of the following categories:

- No structural damage
- Slight or moderate damage to NON-structural elements
- Damage to structural elements.

FRANCISCO GARCÍA ÁLVAREZ, was the coordinator of 35 brigades for the attention of the 19S earthquake.

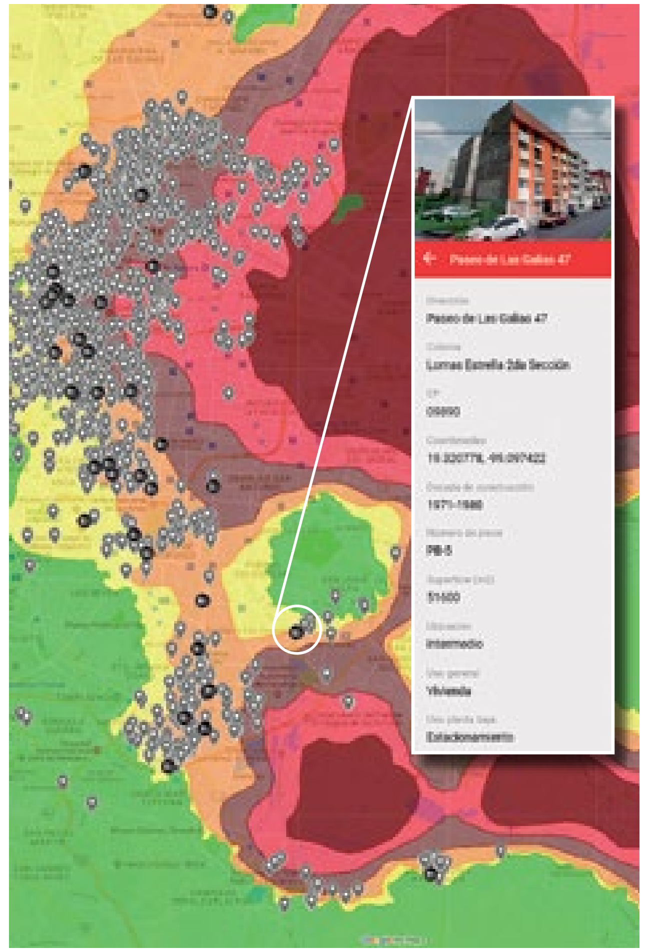
35 BRIGADES

MORE THAN 600 engineers and engineering students participated in the brigades (SMIE - CICM).

ALLIED ENTITIES

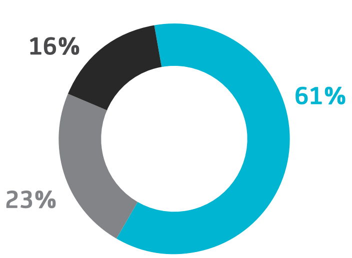
SMIE	Sociedad Mexicana de Ingeniería Estructural (Mexican Society of Structural Engineering)
CICM	Colegio de Ingenieros Civiles de México A.C. (College of Civil Engineers of Mexico)
UNAM	Universidad Nacional Autónoma de México (National Autonomous University of Mexico)
SMIG	Sociedad Mexicana de Ingeniería Geotécnica (Mexican Society for Geotechnical Engineering)
UAM	Universidad Autónoma Metropolitana (Autonomous Metropolitan University)

Collaborative map with information collected by the brigades of civil engineers in Mexico City



Map focused on technical specialists
www.sismosmexico.org/mapas

Damage classification - Buildings inspected by the brigades



Low risk · High risk · Unable to determine

CLASIFICATION	BUILDINGS
Low risk	1,210
High risk	460
Unable to determine	327
TOTAL	1,997

Preliminary summary of damages of the buildings inspected by the brigades of the earthquake of 19/09/2017. (https://www.sismosmexico.org/informes)

sura 'S MANAGEMENT with STRUCTURAL engineers in Mexico City

PHASE 1

Damage classification

In this phase, the inspection of the insured buildings that reported some type of damage was carried out by structural engineers, who filled out the form designed by SURA. The information gathered in the field was used to classify the damage into three categories:

- Minor damages
- Special damages
- Risk of collapse

12 Engineers FIRMS

9 independent structural ENGINEERS

67 STRUCTURAL ENGINEERS from México, Colombia and Chile

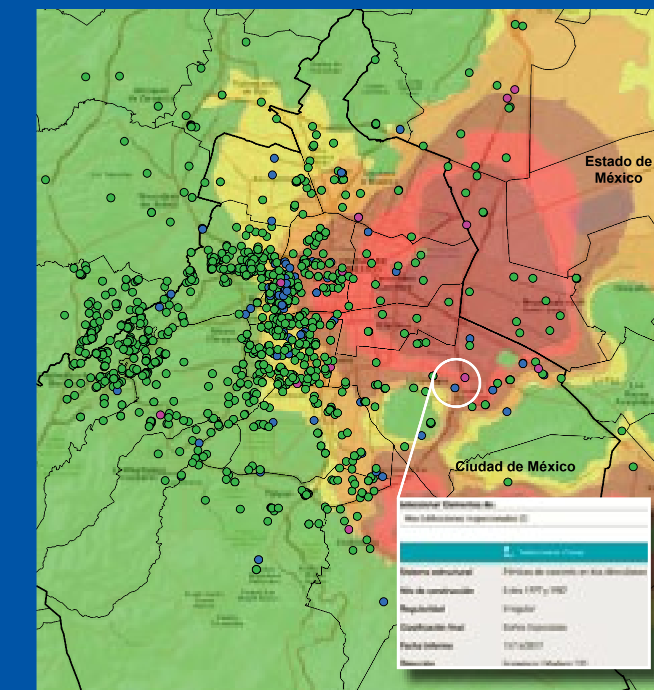
PHASE 2

Structural safety and rehabilitation studies

A more detailed analysis is performed at this stage, including modeling the building, to determine the necessary works to be carried out, according to current regulations. At this stage, the building is reviewed in accordance with Mexico City's rehabilitation standards or, failing that, those of the State that apply according to the site where the building is located.

The engineering companies supporting this stage are internationally recognized and have extensive experience in structural safety studies (seismic vulnerability) and rehabilitation of buildings affected by earthquakes.

SURA map with information collected by structural engineers in Mexico City



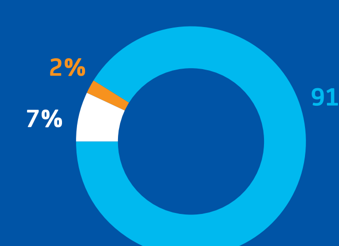
Buildings inspected by Sura
Risk of collapse · Special damages · Minor damages

Seismic Zoning of Mexico City
Zone I · Zone II · Zone IIIa · Zone IIIb · Zone IIIc · Zone IIId

Map with damage classification of buildings inspected by SURA - Taken from the tool GeoSURA

SURA also conducted inspections outside Mexico City in the States of: Morelos, Puebla, Mexico, and Tlaxcala.

Damage classification - Buildings inspected by SURA



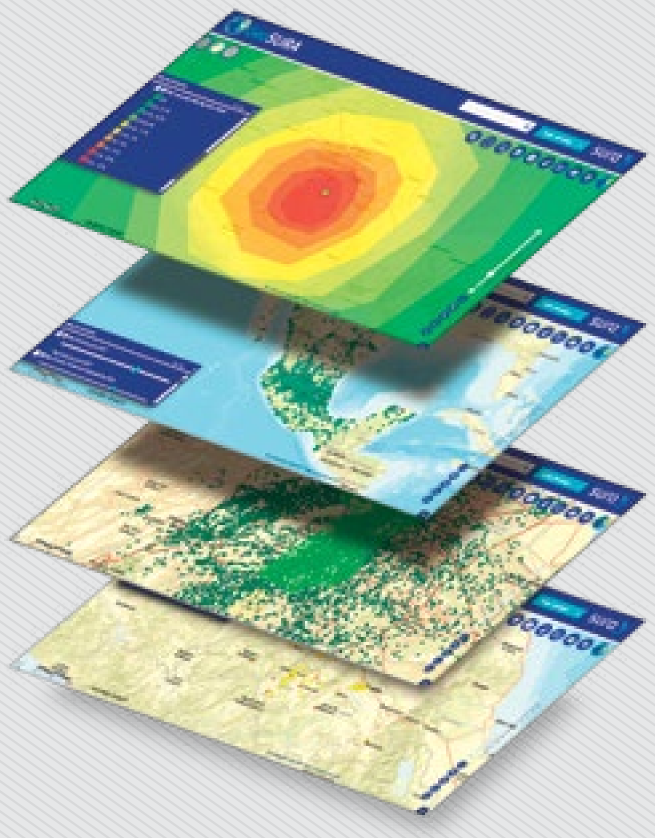
Minor damages · Special damages · Risk of collapse

CLASIFICATION	BUILDINGS
Minor damages	2,002
Special damages	157
Risk of collapse	35
TOTAL	2,194

Inspections carried out on insured buildings that submitted a claim.

Earthquake attention protocol

Sura's Geosciences area constantly monitors the information issued by national seismological services, including the United States Geological Survey (USGS), related to the latest earthquakes and their main characteristics such as magnitude, epicenter, depth, and intensity.



1. Information reported for each event by seismological services and other official sources is uploaded to the GeoSURA platform.
2. Thanks to the geolocation of Sura's portfolio, it is possible to carry out a geospatial cross-referencing of the clients' properties with the maps of seismic intensities reported by the seismological services, and, in this way, estimate the main areas affected by the earthquake.
3. Sura activates the postseismic evaluation plan and defines the number of structural engineers needed inspect the buildings located in the affected areas.
4. Using the information gathered in the inspections, a damage classification is made.

Sura's team supports clients according to the damage classification resulting from the structural engineering analysis.

In parallel to the damage classification of the inspected buildings, it was possible to identify the main variables associated with the vulnerability of each structure.

Thanks to the functionalities of the GeoSURA platform, it was possible to spatially cross-reference the available information to identify the most affected zones.

GeoSURA, platform for seismic event management

SURA's corporate geographic information platform - GeoSURA, facilitated the identification of the event, the affected areas and the policyholders that would potentially have some level of damage.

GeoSURA expedited the elaboration of maps and the follow-up of the inspections carried out, as well as the spatial visualization of the classification of damages and analysis of the information at different levels of detail.

Visualizing and graphically analyzing the information allowed us to make decisions for the management of the event.

GeoSURA is increasingly consolidating its position as an interactive platform that integrates information and facilitates the company's management at the service of people.

PHASE 1 PARTICIPANTS

- Desimone Consulting Engineers South America S.A.S.
- Doing estudio de Ingeniería S.A.S.
- Estrucmed Ingeniería Especializada S.A.S
- Estructuras, Interventorías y Proyectos LTDA.
- Ingetec S.A. Ingenieros Consultores
- Ingenio Construcciones y Consultorías S.A.S.
- Integral Ingenieros Consultores
- Loto Ingeniería Estructural
- Muñoz Castañeda Ing. Civil S.A.S.
- Proyectos y Diseños S.A.S.
- Rene lagos Engineers - RLE
- Triángulo Ingeniería S.A.S.
- Ing. Andrés Felipe Hernández
- Ing. Alejandro del Rincón
- Ing. Arabella Zapata
- Ing. Israel Iván León García
- Ing. Juan Camilo Hinestroza
- Ing. Juan Carlos Botero
- Ing. Kenny Rafael Vielman
- Ing. Roberto Rochel Awad
- Ing. Salvador Barrientos

PHASE 2 PARTICIPANTS

- Advanced Analysis and Design LLC
- García Jarque Ingenieros
- Rene lagos Engineers - RLE
- RIZZO International, Inc.
- Thornton Tomasetti
- Ing. Mario Rodríguez Rodríguez
- Ing. Roberto Rochel Awad

SOURCES

Ana María Cortés Zapata
Mathematical Engineer and aspiring M.Sc. in Applied Mathematics from Universidad EAFIT. Since 2014 she works as a professional in mathematical modeling in the area of Geosciences supporting in issues related to seismic risk modeling.

Esteban Herrera Estrada
Civil Engineer from the Universidad de Medellín. Analyst in the area of Geosciences, currently, he supports the GeoSURA corporate geographic information project and GIS related issues.

Francisco García Álvarez
Civil Engineer, M.Sc. in Engineering. President of the Mexican Society of Structural Engineering. He belongs to the Mexican Society of Earthquake Engineering, the College of Civil Engineers of Mexico and the Earthquake Engineering Research Institute, has published in conferences and technical journals and was the director of the Crisis Center that was mounted jointly SMIE-CICIM for inspection brigades after the earthquake of September 19, 2017.

Jorge Santiago Victoria Domínguez
Civil engineer from Universidad Nacional. He has worked with geographic information systems in the company and is currently part of the GeoSURA corporate geographic information project and supports GIS related issues.

Juan Pablo Restrepo Saldarriaga
Civil Engineer and specialist in Hydraulic Resources. He has worked as a consultant in hydrological studies for the design and sizing of hydroelectric power plants, and currently works in the area of Geosciences, conducting hydrological and hydraulic studies.

Victor Hugo Ángel Marulanda
Systems and IT Engineer and specialist in project management. He has been working at Suramericana since 2010, and since then he has worked in different departments of the company. He is currently the Director of Geographic Information Systems in the Geosciences department.

REFERENCES

- *Metodología Postsismo de SURAMERICANA.*
- *Reunión colaborativa entre García Jarque Ingenieros y SURA.*
- *Revista IC – Ingeniería Civil del Colegio de Ingenieros de México A.C. N° 580 de octubre de 2017 y 581 de noviembre - diciembre de 2017.*
- *Noticolegio, Órgano informativo interno del Colegio de Ingenieros Civiles de México A.C. N°514 de octubre de 2017 y 515 de noviembre de 2017.*

ONLINE RESOURCES

- https://www.sismosmexico.org/
- http://emergency.copernicus.eu/mapping/list-of-components/EMSR244
- http://www.atlasnacionalderiesgos.gob.mx
- http://www.cires.org.mx/cires_es.php
- http://aplicaciones.iingen.unam.mx/AcelerogramasRSM/RedAcelerografica.aspx
- http://www.ssn.unam.mx/acerca-de/estaciones/

Lessons learned:
the road to an earthquake-resilient world

Resilience is a huge challenge for earthquake engineering worldwide. The learnings from the 7S and 19S 2017 earthquakes in Mexico show very positive elements toward achieving this remarkable goal.

Each earthquake teaches us lessons to achieve this important objective. There are many global efforts, such as the Sendai framework (2015-2030), committed to disaster risk reduction to achieve the society's resilience, which responds to the megatrend of urbanism. Its fundamental approach is to ensure that the design, construction and postseismic recovery, rehabilitation and reconstruction processes consider the expected seismic performance of structures, to protect life, property, business sustainability, governmental, economic, and social stability of countries.

Earthquake effects have allowed the development of technologies for their attention. Some of them aimed at saving lives and uniting society in the recovery process of the affected areas and people. However, this attention must also be oriented to ensure that postseismic buildings' reconstruction, rehabilitation, reinforcement, and repair processes become an opportunity to achieve more resilient cities.

A road traveled in Mexico since 1985

The 1985 earthquake of September 19, 1985 marked a milestone, not only in the seismic history of Mexico, but also in the development of seismic engineering. The lessons learned from this great earthquake were of remarkable relevance for Mexico and the world, because they showed the preponderant role of the seismic response of soil profiles in ground movements and their effects on the performance of buildings indisputably. A large number of studies and investigations were developed based on this great earthquake, and from that day until today, the conviction of the fundamental role of soil characterization in seismic design codes has grown in the world.

The 2017 19S earthquake confirmed the findings of the 1985 19S, and showed the validity and relevance of soil response zoning in Mexico City, established in its seismic regulations. In the 2017 19S earthquake, collapsed buildings were predominantly concentrated in soft clay deposits 25 to 40 m thick, which have fundamental periods of vibration between 1.0 and 1.5 s, and are mostly classified in zone IIIa soils and a much smaller proportion in zone IIIb. Variations between the location and height of the buildings, where collapses and major damages were concentrated in the 1985 and 2017 19S earthquakes, are due to differences in the frequency content and distance between the seismic source and the site of these two events. The 1985 19S earthquake occurred almost 400 km from Mexico City, while the 2017 19S earthquake occurred 120 km away, which shows the countless importance of the consideration of the possible seismic sources with incidence in this city, coupled with the types of soil that in each case can intensify the seismic response.

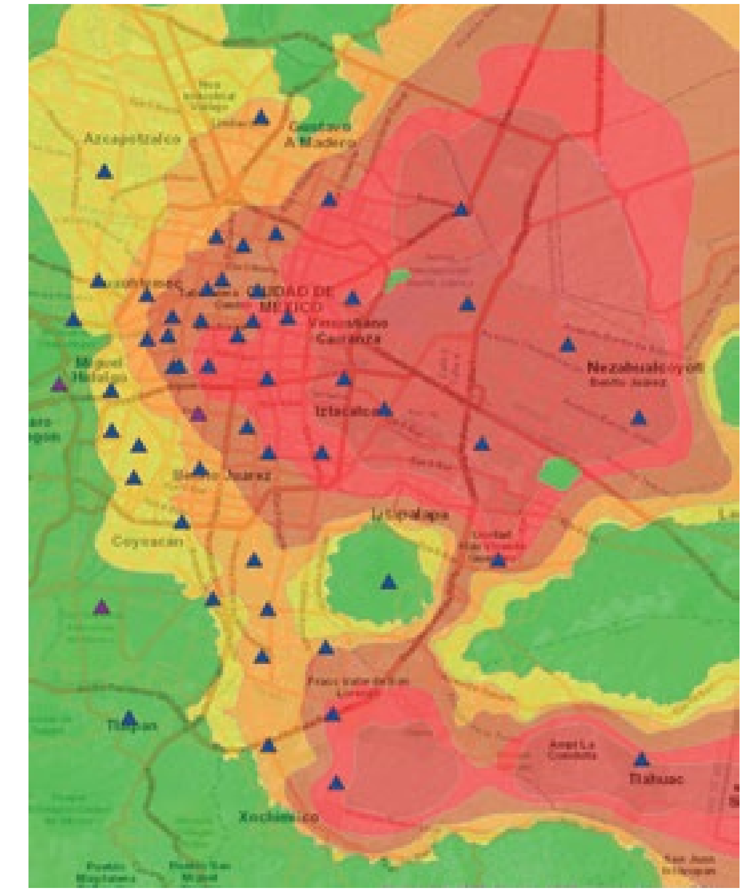
However, the importance of structural systems in the seismic behavior of buildings cannot be ignored. The 19S earthquakes of 1985 and 2017 show important learnings from structures with severe damage and collapse, concentrated in flat slab systems and reinforced concrete frames (with unreinforced masonry infills). All this information is key in repair decisions, reinforcement designs and construction of new buildings after the September 2017 earthquakes.

THE 7S AND 19S EARTHQUAKES OF 2017

In 12 days, during the month of September 2017, Mexico was shaken by two strong earthquakes. The first, with a magnitude of 8.1 (Mw) at a depth of 47 km, occurred in the state of Chiapas on September 7. The second, with a magnitude of 7.1 (Mw) at a depth of 48 km, was generated in the border between Puebla and Morelos, on September 19. The date of this earthquake of September 19 is an incredible coincidence, because it occurred precisely on the commemoration of the 32nd anniversary of the great earthquake of September 19, 1985.

Many lessons remain from these two earthquakes of September 2017. They reflect very positive results of effort and study in Mexico, which show progress on the path towards the search for seismic resilience that this country undertook with huge force, after the great earthquake of 1985.

Seismic Zoning of Mexico City for seismic design purposes - NTC 2004



Preparation, generosity, and knowledge

In response to the 7S earthquake of magnitude 8.1 (Mw), the XXXVI Board of Directors of the College of Civil Engineers of Mexico called for volunteer engineers to travel to Oaxaca and Chiapas to assess the damage and collaborate with federal and local authorities. The organization of Mexico in a group of brigades for the inspection of buildings in Mexico City is a remarkable achievement that this Latin American country shows to the world. The brigade scheme shows the generosity of its members, a group of more than 600 volunteer engineers and civil engineering students, and the usefulness of their efforts in guiding the State's decisions. Within these brigades, the commissions of structural engineers played a preponderant role due to their knowledge and experience in technically assessing the level of damage to the buildings. As the number of structural engineers is low in relation to the total number of brigade members, this plan for visual inspection of buildings implemented a first format of rapid evaluation of buildings that allowed filtering the most critical cases, in order to define the portion of buildings that required a second inspection visit with a more detailed form. The participation of engineer Francisco García Álvarez, president of the Mexican Society of Structural Engineering (SMIE), as leader of 35 brigades, reflects the outstanding commitment of the country's engineering to postseismic care. Thus, the participation of the groups of structural engineers was made possible by the leadership of the College of Civil Engineers of Mexico (CICM) and the commitment of the Mexican Society of Structural Engineering (SMIE) and the universities, as is the outstanding case of the UNAM. There is always room for improvement, but the result is a powerful initiative that was possible thanks to the generous dedication of a group of people motivated by a common interest, which has the great challenge of strengthening itself, standardizing formats and criteria, and achieving systematic and efficient support from structural engineers.

Technology at the disposal of the people

Information on the progress made by the brigades in Mexico City has been available to the general public since the earthquake occurred on www.sismosmexico.org. Likewise, the Mexican government launched a campaign at www.gob.mx/sismo/ to help identify structural damage to buildings, which allows them to define aid priorities.

The Seismic Alert System of Mexico City (SASMEX) is a novel system that exists in few cities in the world. It has useful current applications for earthquakes far from the city, such as the 1985 earthquake of September 19, 1985. This system can also be used for applications of earthquakes closer to the city, as the network of its instruments grows. For the population of Mexico City, it is essential to know better and better the operation and utilities of this seismic warning system, to properly interpret the signals and follow the correct protocols.

Lessons learned on the structural performance of buildings

Articles published by Ph.D. Mario Rodriguez, researcher at the Autonomous University of Mexico UNAM and the John A. Blume Earthquake Engineering Center at Stanford University, show statistics from the 19S earthquake of 2017, which allow identifying predominant characteristics of the buildings that collapsed and presented severe damage associated with this event.

Based on these findings from the buildings that collapsed by the earthquake of 19S of 2017, the John A. Blume Center for Earthquake Engineering at Stanford University, highlights the importance of generating regulatory mechanisms for the review and seismic rehabilitation of buildings constructed before 1985, located in the areas of the old lake of Mexico City.

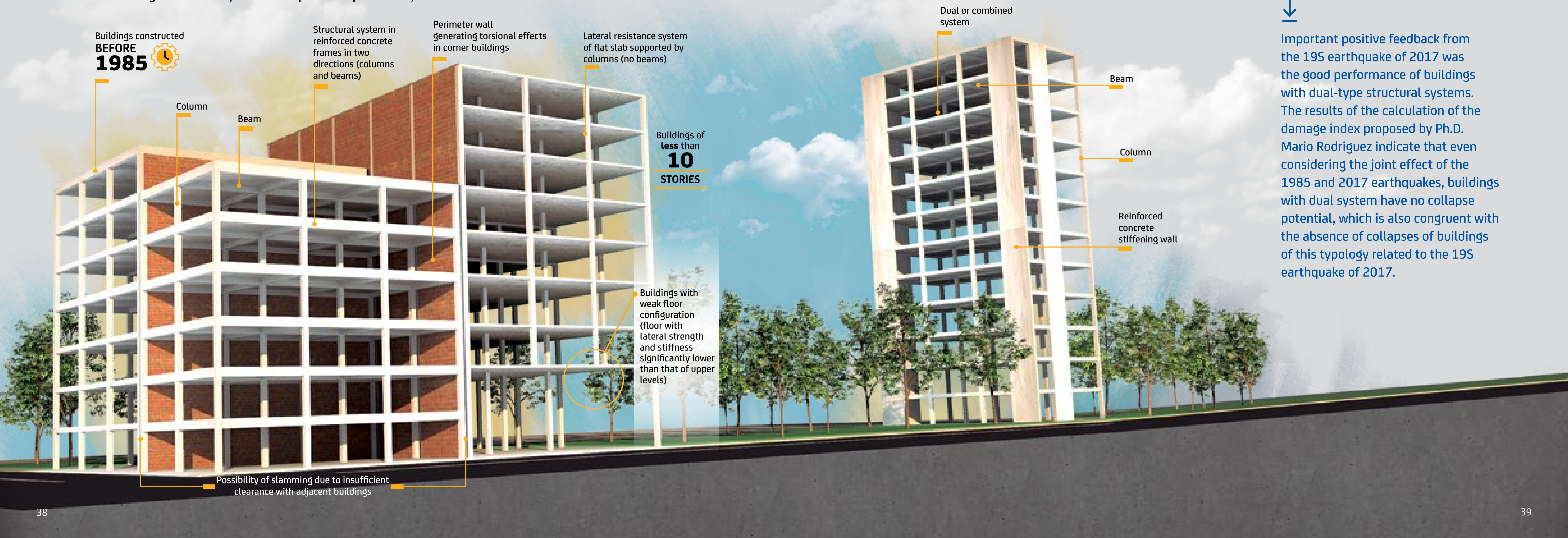
Furthermore, the concentration of collapses in buildings constructed before 1985 also shows a positive balance of the evolution of the Mexican seismic standard, which has sought to reflect in its requirements the lessons learned from the great earthquake of 1985.

Lessons learned from SURA's postseismic plan in Mexico

Commitment to repair, strengthen and rebuild to achieve buildings with better seismic performance for the future, where possible, is SURA's commitment to seismic resilience in Latin America. SURA's management after the September 2017 earthquakes in Mexico confirms the relevance of this conviction.

SURA's postseismic evaluation methodology was implemented in Mexico with several groups of structural engineers from Mexico, Chile and Colombia. From September 25 to December 21, 2017, SURA had permanent groups of around 23 structural engineering specialists to implement the inspection plan of more than 2,000 buildings in Mexico City and the States of Mexico, Morelos, Puebla, among others. Gloria María Estrada Álvarez, Geosciences Manager of SURAMERICANA S.A., believes that "the good balance of this postseismic plan in Mexico is that it has been a very effective mechanism to support our policyholders in Mexico affected by these earthquakes with an engineering approach. We have many logistical elements to improve, but the result has been a group of more than 150 people from SURA Mexico, the Geosciences team of SURAMERICANA S.A., and a group of professionals from structural engineering firms in Chile, Mexico, and Colombia. This group is trained in SURA's postseismic methodology, all committed to a common cause, inspecting and preparing forms of buildings with some type of damage, for the diagnosis and classification of damage to guide the processes of repair, rehabilitation and reconstruction. In the complementary studies stage for the group of buildings that require additional evaluations to define the most appropriate repair or rehabilitation techniques in each case. SURA has had the support of a group of international structural engineering firms with boundless postseismic experience and a Mexican firm of countless prestige in the field of structural engineering. At SURA we are convinced that private enterprise, and especially the insurance sector, has the responsibility to contribute to society, generating mechanisms that motivate to avoid repairing, rehabilitating or reconstructing vulnerability"

Predominant characteristics of the buildings that collapsed and suffered severe damage in Mexico City in the earthquake of September 19, 2017



Important positive feedback from the 19S earthquake of 2017 was the good performance of buildings with dual-type structural systems. The results of the calculation of the damage index proposed by Ph.D. Mario Rodriguez indicate that even considering the joint effect of the 1985 and 2017 earthquakes, buildings with dual system have no collapse potential, which is also congruent with the absence of collapses of buildings of this typology related to the 19S earthquake of 2017.

The collaborative schemes with SURA that were implemented in Mexico are the first initiatives with academia and professional associations. The UNAM, the Mexican Society of Structural Engineering (SMIE), and a group of structural engineering firms and structural engineers show a fruitful short and medium-term future to advance in the development of knowledge and management of seismic risk in Mexico.

A topic to work on in SURA's postseismic plan is to achieve a better collaboration scheme with the efforts of the Government and other institutions in the country. For SURA, it is clear that when a disaster of any kind occurs, it is a challenge for society as a whole, where joint public-private efforts should always be oriented to the common.

Considerations on seismic-resistant construction standards in Mexico

Since 1985, the evolution of seismic standards in Mexico has revealed positive aspects of the seismic performance of buildings in the country, which show the results of the lessons learned in practice. As expressed by Ph.D. Mario Rodriguez, after the 1985 earthquake, the seismic regulations in Mexico City changed with respect to those existing at that time, requiring more resistance and lateral stiffness in buildings, which is an additional factor to interpret the better behavior of buildings in the 19S earthquake of 2017 concerning that observed in buildings in the 19S earthquake of 1985.

The updated seismic standard for Mexico City includes details of the estimated soil response for site-specific seismic design purposes, for which designers access the System of Seismic Actions for Design (SASID), as explained by engineer Francisco García Álvarez, current president of the Mexican Society of Structural Engineering (SMIE). The provisions published in December 2017, which modify Mexico City's Building Regulations, include standards for the seismic rehabilitation of concrete buildings damaged by the September 19, 2017 earthquake.

Considering the cases of buildings that suffered collapse or major damage in the earthquake of 19S of 2017, and that had not had considerable damage in the earthquake of 19S of 1985, Ph.D. Mario Rodriguez, suggests that for a better interpretation of the vulnerability of structures, the effect of accumulated damage should be considered when structures experience more than one strong earthquake during their useful life. Ph.D. Rodriguez has been working for several years at UNAM in research on a damage index, with which he made validations from real data from the earthquake of 19S of 2017, which show a promising way to advance in complementary methodologies for the analysis of the expected seismic performance of buildings (Rodriguez, 2017).

> The progressive improvement of Mexico City's Building Regulations to date has been the result of the integration of advances in seismic monitoring and instrumentation, and the development of knowledge about the seismic response of soils and the performance of buildings, which show a very valuable path towards resilience.

The seismic behavior of nonstructural elements and their interaction with the building structure is a fundamental aspect of buildings' seismic performance and functionality after this type of event. The evaluation of nonstructural elements should consider not only the materials used and construction systems, but also the importance of integrating architects in the construction and rehabilitation project teams.

A large number of specialists in structural engineering in Mexico, among which stands out the Ph.D. honorary professor at UNAM Luis Esteva, agree that innovative structural solutions for seismic A large number of specialists in structural engineering in Mexico, among which stands out the Ph.D. honorary professor at UNAM Luis Esteva, agree that innovative structural solutions for seismic protection can benefit the seismic rehabilitation of essential structures and community care. Among these innovative structural solutions, we find isolation and seismic dissipation. These solutions can be used whether or not they have been affected by the September 2017 earthquakes, given the countless importance of maintaining their operations after an earthquake.

Lessons learned from the 7S and 19S earthquakes in Mexico should be considered in the updating of standards and in the improvement of construction quality control mechanisms in the different countries of Latin America. Many countries in the region share similarities with Mexico in terms of seismic hazard conditions, structural typologies, and construction practices. The important legacy and responsibility left by the earthquakes is to put their lessons into practice with responsibility and conviction that seismic resilience is an achievable challenge for our societies.

SOURCES

Francisco García Alvarez
Civil Engineer, M.Sc. in Engineering. President of the Mexican Society of Structural Engineering. He is a member of the Mexican Society of Earthquake Engineering, the College of Civil Engineers of Mexico and the Earthquake Engineering Research Institute. He has published in congresses and technical journals and was the director of the Crisis Center that was set up jointly SMIE-CICIM for the inspection brigades after the earthquake of September 19, 2017.

Gloria María Estrada Álvarez
Civil Engineer, specialist in Environmental Engineering, specialist and M.Sc. in Earthquake Resistant Engineering. Geosciences Manager of Suramericana. She has worked in the development and coordination of studies and research in seismic engineering, soil dynamics and seismic risk. He has published more than 20 technical articles in the area of seismic engineering.

Mario Rodríguez Rodríguez
Civil Engineer, M.Sc. and Ph.D. in Structures, full time researcher at the Institute of Engineering of UNAM. His research work conducted with Professor José Restrepo of UCSD, has been the basis of the new section 12.10 of the US standard ASCE/SEI 7-16 (2016) Minimum Design Loads for Buildings and Other Structures. He has been the author of the 2016-2017 modifications to the seismic design of diaphragms in buildings of the 2017 Mexico City Supplementary Technical Standard for Earthquakes; he is an Expert in Structural Safety and professor of the course on Seismic Design of Concrete Structures in the Graduate Engineering Program of the Faculty of Engineering of the UNAM; he has also taught refresher courses for engineers in structural safety in Mexico, Peru, Colombia and Chile. He participated in the damage assessment of the earthquakes of Chile 1985, Mexico 1985, Japan 1995 and 2010, Peru 2007, Mexicali 2010, Chile 2010, and Mexico City 2017. He is a voting member of the ACI 318 Main Committee of the American Concrete Institute International (ACI), which develops the ACI 318 Regulation for Structural Concrete, as well as several ACI technical committees. He is president of MR Ingenieros Consultores en Estructuras, founded in 2005.

REFERENCES

- Administración Pública de la Ciudad de México (2017). Decreto por el que se reforman y adicionan diversas disposiciones del Reglamento de Construcciones para el Distrito Federal. Gaceta Oficial de la Ciudad de México. Ciudad de México.
- Administración Pública del Distrito Federal (2004). Acuerdo por el que se dan a conocer las Normas Técnicas Complementarias del Reglamento de Construcciones de Distrito Federal. Gaceta Oficial de la Ciudad de México. Ciudad de México.
- Colegio de Ingenieros Civiles de México (2017). ¿Qué ocurrió el 19 de septiembre? IC Ingeniería Civil. Año LXVI. Número 580. Ciudad de México.
- Esteva, L (2017). La ingeniería sísmica en México: Retos y Tendencias. Conferencia magistral, Salón de seminarios Emilio Rosenblueth, Instituto de Ingeniería UNAM. Ciudad de México.
- Esteva, L. (1988). The Mexico Earthquake of September 19, 1985 – Consequences, Lessons, and Impact on Reseach and Practice. Earthquake Spectra. EERI. California, USA.
- Miranda, E. et al. (2017). Preliminary Statistics of Collapsed Buildings in Mexico City in the September 19, 2017 Puebla-Morelos Earthquake. John A. Blume Earthquake Engineering Center. Department of Civil and Environmental Engineering. Stanford University. California, USA.
- Rodríguez, M. (2017). Interpretación de los daños y colapsos en edificaciones observados en la Ciudad de México en el terremoto del 19 de septiembre de 2017. Instituto de Ingeniería UNAM. Ciudad de México.
- Servicio Sismológico Nacional – SSN México (2017). Sismo del día 19 de septiembre de 2017 Puebla-Morelos (M 7.1). Reporte Especial Grupo de Trabajo del Servicio Sismológico Nacional. Universidad Autónoma de México UNAM.

The Sura Geosciences magazine has a specialized work team that supports the writing, editing and design activities, made up of internal sources of Suramericana and external researchers recognized worldwide, in the topics of the interrelationships of nature with the different strategic aspects of companies and society.

INTERNAL SOURCES

Gloria María Estrada Álvarez
Geosciences Manager Suramericana S.A.

Suramericana S.A.
Geosciencies Team
Ana María Cortés Zapata
Elizabeth Cardona Rendón
Esteban Herrera Estrada
Juan David Rendón Bedoya
Juan Pablo Restrepo Saldarriaga
Santiago Victoria Domínguez
Víctor Hugo Ángel Marulanda
Victoria Luz González Pérez

DESIGN AND EDITING

Taller de Edición S.A.
Direction
Adelaida del Corral Suescún

Editing
Andrés Cadavid Quintero

Design
Verônica Sánchez Cuartas

Pictures
Shutterstock, Taller de Edición,
Hugo León Aguilar Ramírez, Suramericana S.A.

Translation
Consulting and Translation company S.A.S

EXTERNAL SOURCES

Álvaro Pérez Arango
Civil Engineer from Universidad Nacional de Colombia; M.Sc. in Structural Dynamics and Earthquake Engineering from the Technical Institute of Karlsruhe, Germany. He is currently manager of the firm Álvaro Pérez Arango y Cía. Ltda.

David Jacobson
B.Sc. in Geological Sciences from Whitman College in Walla Walla, Washington and M.Sc. in Geology from the University of Canterbury, Christchurch, New Zealand.

Francisco García Álvarez
Civil Engineer; M.Sc. in Engineering; President of the Mexican Society of Structural Engineering. He has published in congresses and technical journals and was the director of the Crisis Center that was set up jointly SMIE-CICIM for the inspection brigades after the earthquake of September 19, 2017.

Francisco García Jarque
Civil Engineer; M.Sc. in Engineering. He is a member of the Evaluation Committee of Professional Experts in Structural Safety of the College of Civil Engineers of Mexico and of the Committee of Corresponsible in Structural Safety of the Government of the Federal District.

Juan Diego Jaramillo Fernández
Civil Engineer; M.Sc. in Earthquake Resistant Engineering and Dr. in Engineering. He has received academic awards. Professor of the Department of Structures at Universidad EAFIT. Has worked in numerous research projects and publications in scientific journals.

Mario Rodríguez Rodríguez
Civil Engineer; M.Sc. and Ph.D. in structures, full time researcher at the Institute of Engineering of UNAM. He participated in the damage assessment of the earthquakes of Chile 1985, Mexico 1985, Japan 1995 and 2010, Peru 2007, Mexicali 2010, Chile 2010, and Mexico City 2017.

Roberto Rochel Awad
Civil Engineer; M.Sc. in Structures; Professor Emeritus of Universidad EAFIT. Author of the books: Seismic Design of Buildings and Reinforced Concrete Design.

Ross S. Stein
Ross S. Stein is CEO of Temblor.net; Professor of Geophysics at Stanford University; Scientist Emeritus of the United States Geological Survey (USGS; Chair of the Tectonophysics Section of the American Geophysical Union (AGU), and 2017-2018 Geological Society of America (GSA) Keynote Lecturer.

LUIS NISHIZAWA - Paisaje, barranca y peñas. 1950 - Oil on wood - SURA Collection

This Mexican landscape is one of the **900** works of art that are part of the **SURA Collection,** which **began in 1972 a**nd is today considered one of the **most representative in Latin America,** contributing to the support and conservation **of the artistic and cultural heritage of the communities.**

SURA feel the art,
live culture