17th World Conference on Earthquake Engineering, 17WCEE
Sendai, Japan - September 13th to 18th 2020

SEISMIC ENGINEERING AT MEXICO CITY

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Abstract

Mexico has always been a seismic country, and the main effects and damages produced were suffered in its most populated city, Mexico City. Buildings after the Spanish conquest were one or two stories height, spans were short, and the structural system was massive stone or masonry, so they suffered few damages, mostly temples, with the earthquakes from 1589, 1611 and 1698. By 1895, the modern construction age started at Mexico Capital City: buildings became taller and span wider. Building Technology was imported, first from Europe and later from the United States, but still, seismic effects were not taken into account while designing buildings. By 1904, the International Seismological Association (ISA) was founded, being Mexico, one of the eighteen states members and creating in 1910 its first seismological station.

The first building code in Mexico City appeared until 1920, and seismic design was not considered. As the first tall building was constructed in 1930 (thirteen-story), no seismic design was included in the building code. The same situation happened with the following buildings erected from 1930 to 1940; the seismic design was only used for distinctive buildings; most engineers applied the seismic coefficient method, which used the Siberg-Cancani, among other seismic scales to get a static shear force and an overturning moment to be considered in the structural design.

As the population increase and buildings became common, critical damages affected the population, after the earthquake of 1941 (M=7.7). New building code for the city was introduced, considering for the first time, a static seismic analysis. It was the beginning of the Mexican seismic engineering, concepts and seismic theories developed at other countries were studied but new parameters specific from this site needed to be studied such as soil type, micro-zonification, constructive defective details, structural systems with a poor seismic behavior, seismic amplification due to resonance effect, foundations problems and load distribution.

After each big earthquake (1957, 1979, 1985, 2017) new seismic code was published; this codes are the result of seismic research from talented Mexican engineers such as Emilio Rosenblueth, Luis Esteba Maraboto, Leonardo Zeevart, and many others until nowadays contribute with their studies to understand each time the effects of earthquakes considering the Mexico City conditions.

This study aims to review how far seismic engineering has gone in developing countries such as Mexico; without all the research, studies and participation of many Mexican and other engineers around the world we could not have tall or irregular buildings at the city center of Mexico City nor fewer casualties every time an earthquake strikes

Keywords: seismic code, static analysis, soft soil, history, development.

1. Introduction

Mexico City has always been a seismic zone due to the subduction of its south coast, with particular soil composition and underground water with a variable level, making building design and construction a challenge. To understand the development of the city is necessary to make a review of the evolution of seismic engineering at Mexico City. Two periods in time are established: a) Arising the City, from 1900 to 1940; b) Arising seismic engineering, from 1957 to 2017. Because the problems with settlements and foundation were more critical than seismic effects in the first period considered, structural information about earthquakes and seismic design were extracted from the structural calculation reports of iconic buildings. For the second period, the concepts and research that became part of the Mexican seismic codes are presented; It is essential to mention that there is much other research, but they could not be included in this article because this work is still in progress.

2. Modernity in Mexico City, 1900 to 1940.

During Porfirio Díaz government (1884-1911), Mexico started its construction age; wharves, railroads, electric stations, dams, and public buildings were built. The most representative public buildings built in this period were settled in Mexico City, as it is the country's capital and its largest city. Buildings were structural design and erected by European and American companies; the first Postal Office, the National Theater, and the Legislative Palace (three of the most iconic buildings of this period) were designed by Milliken Brothers, an American company established at New York City. Mexican Engineers, as Gonzalo Garita, review the structural design presented by Milliken Brothers, which uses the elastic theory of structures for Skeleton Construction Plan; buildings were designed to support gravity loads only [1]. Because these buildings are three or four floors high, they are still standing and functioning.

During the second international seismological conference in 1903 at Strasbourg resulted in the drafted convention for an International organization for which states could become paying members. The International Seismological Association (ISA) was created, entering into force on April 1st, 1904, with 18 states as founding members, Mexico among them. To fulfill its commitment with the ISA, President Díaz decree the foundation of the National Seismic Bureau (Servicio Sismologico Nacional) on September 5th, 1910; nine seismic recording stations were installed in the country, establishing the central station at Tacubaya in Mexico City. [2].

In 1920 the first Mexico City building code was issued; it did not include structural design, either seismic design methods or recommendations. On January 14th, 1931, an earthquake stroke with epicenter at Huajuapan de León, Oaxaca, with low intensity; there was no building damage, so the new reinforced concrete contractors at Mexico City claimed it was the result of this new material used as rigid frames.[3].

2.1 First Skyscraper, 1930-1941.

After the Mexican revolution, constructions waited until the political and economic country situation was stable. In 1930 the insurance company “La Nacional” started building its offices in Mexico City; this building is 13 stories and 55 m. height, so it is recognized as the first skyscraper in the city. Architects Ortiz Monasterio and Bernardo Calderon consulted professor Terzaghi for the foundation solution, but there is no mention of the seismic design [4].

In 1933 the second skyscraper started its construction. The building for the National Lottery (Loteria Nacional) designed by the engineer Jose Cuevas is 63m tall and 20 story height. Cuevas study the properties of the soil and its interaction with the foundation and considered gravity loads and wind structural design. During its construction, engineer González Flores review the structural design of the building, considering seismic design [5].

This seismic design started selecting the "predominant movement" (earthquake component) felt at the site; it could be horizontal or vertical displacement. Because earthquakes registered at Mexico City shakes in a horizontal plane, the horizontal (shear) seismic force produced a flexural overturning moment that affects the foundation and steel structure. The horizontal force was the product of the mass and the surface earthquake acceleration; the Sieberg-Cancani (Table 1) scale was used to get the acceleration as it was compared to Omori recommendation about the maximum acceleration for horizontal displacement was 1500 mm/sec^2. The final horizontal force obtained for this building was equal to 15.4% of the total weight of the building.

Table 1 – Sieberg-Cancani scale used by the Geology Institute of Mexico, 1930.

Sieberg-Cancani Scale		**Aceleration (mm/Sec^2)**
I	Imperceptible	0
II	Very light	0.6 - 5
III	Light	6 - 10
IV	Moderate	11 - 25
V	Some strong	26 - 80
VI	Strong	81 - 100
VII	Very strong	101 - 250
VIII	Ruins	251 - 500
IX	Destroyer	501 - 1000
X	Very destroyer	1001 - 2500
XI	Catastrophic	2501 - 5000
XII	Very catastrophic	More than 5000

After the earthquake of April 1941, some tall buildings in Mexico City were review. An example was the case of a building settled on Paseo de la Reforma with 18 stories and 52.8m height. Even though the seismic coefficient method and the Sieberg-Cancani scale was still used, it is interesting to mention the seismic theory young engineers were studying and using for its design: a) located the seismic regions according to professor John Milne 1906 maps; b) followed the book Mechanics of the earthquake,1906, from professor Harry Fielding; c) Davidson scales classification were considered (personal, arbitrary and absolute).[6]

It was believed that the soil of Mexico City helped buildings to avoid damage because underground water worked as a damper, and considering earthquakes registered from 1907 to 1941 at the city, the probability of having a high earthquake acceleration was low, considering table 2.

Table 2 – Earthquakes registered in Mexico City from 1907 to 1941

Earthquake Grade	Number of occurrences
II	16
III	137
IV	64
V	18
VI	4
VII	2

3. The emergence of seismic engineering in Mexico City, 1942-2017.

In 1942 was published the second Mexico City building code in which structures were classified into eight different types according to their occupancy importance to be considered for the seismic design method proposed. This method was based on the equivalent static lateral force obtaining seismic forces as the product of the total building weight (considering dead and live loads) by a seismic shear coefficient, which was a fraction of the gravity acceleration (values went from 0 up to 0.1g). The seismic design was considered only for buildings over 16m tall and structures where large crowds gathered [7].

While ordinary buildings implement the seismic design method proposed by the 1942 code, distinctive buildings as the Torre de Ciencias (15 stories and 54.9m tall) built at the Universidad Nacional Autónoma de México (UNAM) in 1950 was design by Dr. Escalante, applying seismic dynamic analysis. This analysis considered a mass-spring model, which is analyzed to get the first two modes in each direction and using Dr. H. M. Westergaard's theories, the seismic shear, and horizontal story displacement in each floor was calculated. The seismic acceleration was supposed with values of g/40 for a fundamental period of 1 sec or g/80 for a fundamental period equal to 2 sec. [8].

In 1948 Leonardo Zeevaert designed the taller building in Mexico City by that time, the Latino Americana Tower. This 43 story building belonged to the insurance company with the same name as the building and was seismically designed according to the soil compression capacity, conserving weight according to its foundation solution. The dynamic seismic analysis was based on the Westergaard method in order to get the most probable base shear. Reviewed by N. Newmark, this building was designed using the modified Mercalli scale, expecting an intensity of VIII. [9]. The tower behavior after each earthquake is inspected, instruments to measure the relative motions were placed in the first, twenty-fifth and thirty ninth-story; six years after it was finished, the instrumental data was analyzed reporting that the observed values of velocity, acceleration and shear were reasonably close to the values computed. This building was the first one to be designed with a dynamic method in Mexico City.

After finishing his master's and Ph.D. at the University of Illinois, civil engineer Emilio Rosenblueth arrived at Mexico City in 1951. He became a research professor at the Geophysics and Engineering Institute, UNAM, and continue his work on the application of probability theory in aseismic design. He published his new research on the first World Conference on Earthquake Engineering at Berkeley, California, in 1956. In this work, Rosenblueth stablished that randomness of destructive seisms implies the necessity of designing on a probabilistic basis in order to get analytical, quantitative results. [10]. From that moment, his research will be essential for seismic engineering in Mexico and Mexico City.

3.1 Starting point of seismic engineering, 1957-1970.

A strong earthquake stroke Mexico City on July 28, 1957, with a Ms = 7.5 and an epicenter off the coast of the state of Guerrero. This earthquake is known in the city as the one that made the Statue of Independence

Angel fell. The most extensive damages occurred in the city center; eleven buildings were partially destroyed or strongly damaged, so they had to be demolished; fifteen more in the same area suffered considerable damage, and they had to be reinforced. This earthquake originated higher ground accelerations in some regions of the lake-bed zone. Buildings damaged had as structural system of reinforced concrete or steel frames and timber or concrete pile as foundations; some reinforced concrete frame buildings used deficient design flat slabs, scarce reinforced steel, torsional problem, soft story, and few bearing walls.

About this earthquake Zeevaert, analyzing the Latino Americana Tower seismic behavior and buildings around it, concluded that: a) destructive periods during strong earthquakes in lake bed zone range between 1.5 and 2.5 sec; b) a building during an earthquake may follow the individual random impulses produced in its foundation as related with capacity of wave transmission into the building during the time impulses are applied; c) buildings showed substantial damping effect because of the lake bed soil; d) the acceleration was constant for all the periods of vibration of the Torre Latino Americana structure with a value of 50 cm/sec2. [11].

According to Rosenblueth, now as the Director of the Institute of Engineering at the UNAM, this earthquake demonstrated: 1) Motions like this earthquake, with a recurrence period of 50 years, cause higher accelerations than the previous registered and published in the code of 1942 called; 2) the city center of Mexico exhibited prevailing ground periods making flexible structures on soft soil and rigid structures on the hard ground more vulnerable; 3) torsion effects were present when masonry walls and partitions act with the rest of the structure. [12]. The leading causes of building failure were: disregard of relative rigidity, lack of aseismic design, insufficiency of reinforcement away from the supports, pounding, differential settlement, resonance, sway, foundation failures, whip effect, and overturning.[13]

A week after the earthquake, an emergency code was written, being finished in September of 1957. According to the damages observed the following actions were taken: the aseismic design was required for all buildings except unimportant ones, base shear coefficient was increased between 0.05 and 0.1 depending on the type of structure and its location in the city (lake-bed, transition or hill zone), a linear variation of horizontal acceleration was adopted, design eccentricity in torsion was increased by a value called "accidental" equal to 0.05 times the floor dimension.

Table 3 – Base shear coefficients Emergency 1957 code and 1966 Building Code

Type of structure	Zone: high compressibility	Zone: Low compressibility
1	.06g	.04g
2	.08g	.08g
3	.15g	.10g

In 1959 a review of the 1957 emergency codes was made. The subcommittee appointed to study seismic matters proposed the following actions to be considered: a) Classification of the city soil in two zones: i) soft and transition, ii) hard; this could be possible thanks to the study Marsal and Mazari about the mechanical properties of the soil of the city and its foundation reaction [14] including seismic effects [15]; b) Classification of buildings according to its use (A=public buildings, B= habitational and office buildings, C= isolated) and types according to their structural characteristics (1= continuous frames,2=bearing walls,3= water tanks, chimneys). c) Base shear coefficients (ratio of horizontal shear at the base related to the weight of the building, including the complete live load) were elevated, as shown in table 3. These values were calibrated from the base shear estimated for the Latino Americana Tower during this earthquake. d) Selection between the three seismic methods of analysis: simplified, static and dynamic; when using the static method, seismic force should have a linear distribution through height and for the dynamic method, designed shall be based on the square root of the sum of squares of the generalized forces corresponding to the various modes in the direction considered and the use of acceleration spectra according to the ground

compressibility; e) Maximum drift shall not exceed .002, .003 or .004 times the corresponding difference in elevations (value would depend on the microzonation considered for the city); f) torsional excentricity must be computed in all stories and considered in the seismic design. [15].

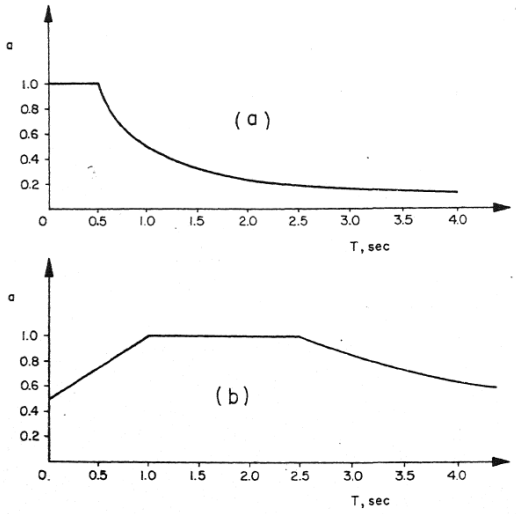

Fig. 1 – Acceleration Spectra for a) low compressibility; b) high compressibility Building Code 1957-1966

The effects of the earthquake of 1957 promote the study of selected seismic issues in order to gain structural safety, like torsion or soil dynamic behavior. Torsional oscillations were studied by J. Bustamante and Rosenblueth [16] in which they concluded that dynamic eccentricity could exceed statically computed values. As it was established that the seismic response of buildings depends on the soil behavior, Herrera, I., Rosenblueth E, and Rascón O. [17]; they began to study the dynamic properties of the Mexico City clay considering a one-dimensional theory of multiple wave reflections with its data and evaluating the probability distribution of spectral responses for various degrees of damping; results of this study demonstrated that for Mexico City the percentage of internal damping determined from lab tests of unconfined specimens subjected to free vibration was 5.36 percent of critical and it turned out independent of the frequency of vibration and that the effective damping for earthquake motions was higher than the internal damping; this model was used for evaluation of amplification factors.

In 1959 with a master of science from MIT, Luis Esteva began working at the Institute of Engineering, UNAM. One of his first works was the notes about the seismic design of buildings (1962), with Rosenblueth [18], where every seismic design method was explained with examples and solutions. In 1963 Esteva and Rosenblueth started to study the dependence of earthquake ground motions on magnitude and distance and the relationship between the frequency of occurrence of earthquakes with the frequency of occurrence of ground motions at a site. They were looking for the optimal earthquake design of buildings that could be achieved by accounting for the probabilities of earthquake occurrence and the associated ground motions.[19]

Seismic activity from 1957 up to 1966 was low with no big earthquakes nor building damages, so the review of the emergency code of 1957 celebrated in 1959 transformed into the 1966 Building Code. When this last code was published, seismic design remained with the same parameters, including the following issues: a) Separation between adjacent buildings had to be larger than 50mm or 0.006 times the total height of the building (H) for high compressibility or 0.004H for low compressibility subsoil zones; b) buildings with more than 10,000 m2 of total floor area or taller than 45m height, instrumentation with strain gauges and accelerometers was mandatory [7].

In order to design seismically out of Mexico City, the seismic shear coefficient and design spectra were needed for every region of Mexico. From 1966 to 1968, Esteva's research aimed to estimate the

distribution of earthquake occurrence in regions using Bayesian updating (for this work, he exchanged ideas with Allin Cornel.) [20]. He also studied the dependence of peak ground acceleration, velocity, and displacement on earthquake magnitude and distance, allowing him to publish the first seismic zone maps constructed combining the recurrence rates of magnitudes in broad zones and the resulting ground motions at sites and equating the return periods of intensity levels of the recurrence intervals of the causative earthquakes. These maps included modified Mercalli Intensity associated lo peak ground acceleration and return period. [21].

Rosenblueth, Elorduy, and Mendoza in 1968 studied the accuracy of the static seismic method and the dynamic method using the square root of the sum of the square modal response, comparing the shear forces and overturning moments as a result of this method. They proposed a dynamic seismic method considering the building to be analyzed as a uniform shear beam with a fixed end moment at its base and constant stiffness and mass per unit height; tremors were idealized as a stationary Gaussian process. It was concluded that there was a small difference between the three methods; static analysis gave good results except for tall buildings on hills. Also, soft-story buildings were analyzed, finding a base shear force higher than in constant rigid buildings. [22]. They developed formulas that were derived for combining the modal response of structures subjected to earthquakes, were more accurate than the sum of numerical values, or the root of the sum of their squares. These studies were limited to linear systems where two or more natural modes have approximately equal frequencies.[23]

Response spectra on soft soil were needed in order to design in zones with this kind of soil. In 1969 Esteva, Rascón, and Gutierrez stated that response spectra at the top of the layered soft soil might be predicted in terms of spectra at the base rock affected by magnification factors. Also, they studied the behavior of foundation, torsion, ductility, and overturning moment. They concluded that foundation and structural failures due to overturning moments were a problem, and to avoid these failures; it should be included higher load factors than those used for story shears and consider ductility requirements at columns and joints.

By 1970 Mexico City building code included a design spectra for seismic analysis, but all other states of the country did not have one. The Federal Comision of Electricity asked Esteva to get an estimate of local seismicity of different geotectonic regions of Mexico (“ seismic risk map of Mexico”). In order to obtain frequency-intensity curves, empirical expressions were used for the intensity in terms of magnitude and focal distance. Statistical data on the magnitudes of earthquakes that occurred during 24 years were assimilated. [24].

3.2 Growth of seismic engineering, 1971-1990.

Students of Rosenblueth and Esteva began to take more place in this field research. The next step was the study of the soil as an elastic and inelastic material, so its interaction with the seismic building behavior could be taken into account. For the 5th World Conference on Earthquake Engineering celebrated at Rome, 1974, Esteva worked with Villaverde a formulation of seismic structural reliability that analyzes the probability distribution of the maximum seismic response of a system with imperfectly known properties, [25] and with Faccioli [26] in the probabilistic analysis of nonlinear seismic response of stratified soil deposits, getting a close approximation between the results of a chosen stratigraphy and those obtained by direct numerical simulation.

Masonry bearing walls has been the most popular structural system for housing in Mexico City since 1900; more than 60% of buildings are houses, and many were affected during the 1957 earthquake. Meli, student of Esteva, in 1974 presented his research about behavior of masonry walls under lateral loads in which he concluded that structures of unreinforced masonry have a brittle type of failure and for walls with interior reinforcement behavior is nearly elastoplastic with remarkable ductility and small deterioration under lateral load except for high deformations where deterioration was caused by progressive crushing and shearing of the compressive corner [27].

In 1971 the Mexican building authorities decided to review the building code of 1966. This review ended with the publication of the 1976 Building Code, which was enriched with the research done since 1957. A separate chapter was published about each subject: Seismic design, wind design, reinforced concrete, timber, masonry, and steel design, and foundation design; these books were called Complimentary Technical Norms (Normas Complementarias de Diseño).

In the seismic field, the following changes or fulfillment were made: a) Microzonation specifying three zones according to soil depth: soft, transition and firm; b) Elastic design seismic coefficients were assigned for each soil zone, (see table 4); c) Use of ductility reduction factors for elastic forces with values from 1 to 6 depending on the type of material, structural system and detailing with values of 6,4 and 2; d) With the use of the ductility reduction computed inter-story drifts had to be increased by the ductility reduction factor. Allowable inter-story drifts were .008 and .016; e) Accidental eccentricity for torsion was increased to double; f) Seismic coefficient changed for the simplified seismic analysis method, the static method was applicable up to 60m high structures, and the dynamic analysis could be solved using modal response or step by step response; g) Design acceleration spectrum consisted of three zones; h) the force reduction factor was dependent upon the fundamental period of the structure.[7]

Table 4 – Base shear coefficients 1976 Building Code

Seismic zone	Acceleration Coefficient
1	.16g
2	.20g
3	.24g

Even though the 1976 Building code included all the results from the research made worldwide and especially from Mexico City parameters, there were still topics that continue being research. Soil mechanics to get its mechanical properties was the case for the lake-bed zone of Mexico City; it keeps changing because of subsidence and phreatic water levels. In this same year, Esteva concluded that micro zonation implies much more than influence of stratified soil formations; it implies a better knowledge of the fault mechanisms of earthquakes that contribute to seismic risk at a site, study of possible influence of path characteristics on the types of arriving seismic waves and the way local conditions affect them.[28]. In 1977 Rosenblueth and Contreras [29] developed an approximate method to get a linear combination of responses to individual components of a design earthquake; a derivation of the 100%+30% rule was proposed in an abbreviated form.

On the 14th March 1979, an earthquake with magnitude 7.6, according to USGS stroke near the coast of Guerrero affecting Mexico City; structural damage was extensive, especially in the lake bed zone where soft soil conditions amplified and filtered the motion, affecting mainly relatively long period structures. Cases of complete collapse buildings due to flexural, torsional, or compression damage in beams and columns, pounding with adjacent buildings due to excessive flexibility or inadequate separation sere observed.[30]. Seismic analysis of structures with masonry walls [31] and adobe [32] was studied to avoid future damage. Because the number of casualties was low, no changes were made to the 1976 code until 1985.

3.3 Maturity of seismic engineering, 1980-2017

On September 19th, 1985, an earthquake of magnitude 8.1 stroke on the Michoacán Gap of the Mexican subduction zone. Severe damage to a total of 7400 buildings, 265 collapsed, and 775 were severely damaged [33]. An aftershock occurred on September 20 with a magnitude of 7.5; the duration of the earthquake of the 19 of September was exceptionally long, and the response on soft soil gave place to high spectral accelerations; intensities reached values higher than the building code of 1976 called for, i.e. the peak ground

acceleration was 0.18g, three times the estimated value at the foundation of the Latin American buildings during 1957 earthquake. The damages observed briefly listed were: Brittle failure of columns due to lack of ductility; torsional oscillations of asymmetric buildings; pounding and rocking due to soil-structure interaction, large story drifts causing P-delta effects, overloading buildings, foundation failure, local soil strains, previous damage of buildings caused by prior earthquakes. The most affected buildings were those from 6 to 16 stories.

As in 1957, a committee was formed by a presidential decree to review and update the building code. An emergency code was presented including these changes: seismic coefficients were raised in 67% for the soft soil, and 33% for the transition zone, strength reduction factors suffer reductions from 18 to 33%, details in structural elements to obtain ductile behavior became more strict, uniform of stiffness and safety factors along the height of the buildings and drift limitations were stressed. [34].

Different groups from the country and outside came to study damages; Rosenblueth and Esteva, with their students now colleagues, began their research about specific problems in order to write the 1987 building code. Rosenblueth proposed a method to obtain seismic design spectra for different zones of Mexico City using deterministic and probabilistic approaches, reaching consistent results getting conservatives to design spectra.[35].Evaluating the seismic capacity of medium-rise concrete structures, Iglesias obtained the base shear coefficient corresponding to failure for buildings with severe damage and made a map of intensities of the 1985 earthquake, which was partially used in the new code [36].

The 1987 building code conserved must of the requirements of the emergency code from 1985 making the following changes: Structure groups were re-organized, group C disappeared, and group B was subdivided, soil zonation was redefined, live loads for some uses were changed, seismic design coefficients were increased, maximum inter-story drifts were reduced, separation between buildings was increased, specific parameters were introduced to evaluate the regular condition of a building.

From 1987 to 2004, seismic engineering at Mexico City continues with the study of the effects and damages reported on the earthquake of 1985; in 1988, an array of twenty-nine accelerometers were installed in Mexico City helping researchers with more statistical data. These data helped Ordaz and Reinoso in 1992 present a formulation to obtain elastic and inelastic response spectra at any site in Mexico City according to magnitude and distance of a postulated subduction earthquake [37] and Esteva presented a formulation of the establishment of optimum seismic design criteria and wrote about the future of seismic design codes; he stated that design decisions in future seismic design codes should be formulated in terms of expected multi-event time histories and not only in terms of expected performance. [38]. Since 1994 Performance-based seismic design (based on limit states design) has been used in other countries but no in Mexico City; Esteva made a reflection about its introduction in Mexican building codes; he also keeps studying reliability indexes of multi-story frame buildings. [39]

The 2004 Building code that comes from the review of 1987 was published. The main changes from the prior code were: structure groups, load factors depending on live load, geotechnical zones, and soil strengths for the different geotechnical zones in Mexico City are established.

In 2017 an intraslab earthquake stroke with a magnitude of 7.1 and depth of 57 km; because it was closer to Mexico City, the ground motion presented high frequencies as compared with interpolate earthquakes. There were damaged buildings and casualties, but they were less than the ones that happened in 1985. Must of the building with damages or collapse were constructions that had structural problems due to the 1985 earthquake, and the same mistakes were found in them: use of flat slab, short column effect, soft story. Two months after the earthquake, the new building code was published, with all the research done between 1985 to 2016.

Research about displacement-based resistant design, strong ground motions prediction, site and interaction dependent strength reduction factors, over strength parameters, change of dominant periods in the lake bed zone due to ground subsidence, base-isolated seismic behavior, among many others will continue until the main purpose is accomplished: to have a safe seismic city.

5. Acknowledgments

Authors acknowledge all researchers that have made possible the development of seismic engineering in Mexico City. This work was supported by UNAM-PAPIIT IN404318.

6. Copyrights

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