



Evolution of codes for structural design in Mexico

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Abstract

Purpose – The purpose of this paper is to provide an overview of structural design code development in Mexico, as an example of how code evolution has taken place in many countries, and to discuss the challenges faced in improving code compliance and reducing vulnerability.

Design/methodology/approach – All building codes for Mexico City (1920-2004) and current codes in Mexico were analyzed and compared in terms of their scope and contents. Emphasis is placed on understanding how design requirements, professional liabilities and overall performance requirements have evolved.

Findings – Structural codes have become more refined and complex, including at each revision the current state-of-the-art knowledge. However, code compliance and code misinterpretation are prevalent, mainly because users are not familiar with the concepts and technologies involved. Also, it is stated that government authorities lack the technical capacity to identify code misinterpretations. Finally, it is stated that, for non-engineered construction guidelines, other educational sources are needed in lieu of merely enforcing codes.

Research limitations/implications – Systematic research aimed at assessing the level of code compliance is needed.

Practical implications – A valuable source of changes and challenges in code implementation and compliance for students and practitioners is provided.

Originality/value – This paper summarizes information on the evolution of Mexican structural codes and offers a critique of the challenges and need for improving code implementation and reducing building vulnerability.

Keywords Design, Earthquakes, Mexico

Paper type Research paper

Structural design codes in Mexico

According to the Mexican Constitution, municipalities are entitled to establish appropriate regulations for urban development and housing, such as land use and building permits. Detailed regulations are given in the Federal Law on Urban Development. These rules have been interpreted for a long time so that every municipality has the power to issue its own building code, although a grouping of municipalities to issue a regional or state building code is permitted. Since Mexico has 31 states and a Federal District (Mexico City's official name) and more than 2,500 municipalities (which are part of the states), the number of possible building codes is quite large. For years, the Ministry of Social Development, which is part of the Executive Branch of the Federal Government, has tried to coordinate the development of model building codes in the country. So far, progress to achieve this goal has been limited.

Most code development efforts in Mexico have been made for Mexico City, the capital and largest city in the country. Although cities and municipalities of different sizes and located in regions with distinctly different hazards (earthquakes, winds, and



floods) have issued building codes, in most cases, these regulations are just simple adaptations, or even copies, of the Mexico City Building Code (MCBC). Agencies of the Federal Government have issued norms and manuals applicable to structures other than buildings. The most significant example is that from the Federal Commission of Electricity (CFE, 1994), aimed at designing and constructing power supply facilities. Seismic and wind hazard maps for the whole country are included in this manual. Since MCBC has been regarded as a model code for the country, evolution of this code is discussed next.

The 1920 Mexico City building code

The first Mexican code for structural design was issued in 1920. Previously, structures had been designed based on rules and requirements adapted from other countries' codes and following engineering judgment. The 1920 MCBC followed an allowable stress design (ASD) format. The code comprised few articles which included some guidelines on minimum dimensions and material stresses.

The 1942 Mexico City building code

The 1942 version of MCBC was still based on ASD (Del Valle, 1988). This code had limited requirements for seismic design. Maximum height of structures was limited to 35m. Structures were classified into eight different types according to their relative importance and occupancy:

- (1) *Type I structures*: to remain operational even when others had been destroyed by earthquakes, such as power plants, fire stations, historical monuments.
- (2) *Type II structures*: used for large crowds, such as stadiums, theatres, schools.
- (3) *Type III structures*: occupied by the public and to be used for offices, housing, hotels and industrial facilities.
- (4) *Type IV structures*: used for storage of materials and valuable objects (such as warehouses, grain elevators), or whose failure could damage other Type-IV constructions.
- (5) *Type V structures*: luxurious residences.
- (6) *Type VI structures*: dwellings for a reduced number of people.
- (7) *Type VII and VIII structures*: whose failure would not endanger population or other constructions.

Seismic forces were obtained by multiplying the building weight (dead + live loads) above the level under consideration, by a seismic shear coefficient, C_y , which was expressed as a fraction of the acceleration of gravity. C_y was equal to 0.10 for Type I structures; 0.05 for Type II; 0.025 for Type III to VI; 0.01 for Type VII; and 0.0 for Type VIII. For stress check under gravity and seismic induced forces, a 33 per cent increase in allowable stresses used for gravity load design was permitted. Seismic design calculations were only required for structures with heights equal to 16m or twice the smallest in-plan dimension, and for Type II structures.

Emergency regulations of 1957

In the aftermath of the July 28, 1957 earthquake ($M_s = 7.5$) off the coast of the state of Guerrero, a set of Emergency Regulations were issued. Before the 1957

earthquake, the practice of seismic design and construction was poorly regulated in Mexico (Esteva, 1988). Modern tall buildings were ordinarily designed by leading engineers, who followed code recommendations from the west coast of the United States. Even though the 1957 earthquake rocked a city that had a significant number of moderately tall buildings (ten to 18 storeys), and that produced peak ground accelerations (PGA) of the order of 0.06 g in the downtown soft soil area, the results of the building inventory was satisfactory. Only a few buildings collapsed and 100 casualties were counted.

Damage in several buildings located in the soft soil area prompted authorities to increase C_y (Del Valle, 1988). For the first time, C_y was made dependent on the soil type (firm, transition and soft) and on the type of construction and occupation. For structures higher than 45m, dynamic analyses were required. Soils were classified according to their compressibility and strength. According to their occupation, buildings were classified in three categories: A, included types I and II from the 1942 code (i.e. important structures); B, included types III to VI; and C, grouped types VII and VIII. Three classes of structural systems were identified. Class 1 consisted of reinforced concrete (RC) or steel structures infilled with walls aimed at increasing lateral stiffness; Class 2 were frames (RC or steel) braced either with diagonals or walls positively anchored to the structure. Load-bearing wall type structures were considered for Class 3.

Lateral force distribution was triangular. C_y was larger than that of the 1942 MCBC for the same group and class of structures located in the same soil type. However, this increase was offset by an increase in material allowable stresses. For example, the largest C_y was 0.20 for Group A, Class 2 structures located in soft soil. For the first time, a limit design approach was accepted as an alternative procedure with safety factors for flexure and axial loads equal to 1.2 and 1.5 for RC structures, and to 1.1 and 1.3 for steel structures, respectively. Changes in C_y led to the design of almost all structures to account for earthquake induced forces and displacements. Inter-storey drift was limited to 0.002 times the storey height. Torsion was considered.

The 1966 Mexico City building code

1957 Emergency Regulations were substituted by the 1966 code. An estimate of C_y , derived from inter-storey drift measured in the Latino American Tower during the 1957 earthquake, was used to calibrate seismic design coefficients. The 1966 MCBC departed from the 1957 Emergency Regulations as follows (DDF, 1966; Rosenblueth and Esteva, 1969):

Two soil types were considered. Transition soil was included in the soft soil area. Buildings were grouped into three categories (A, B, C) according to their occupancy:

- (1) *Group A*, essential facilities that should remain operational after an urban emergency, that house valuable contents (such as museums), or whose total floor area was larger than 400m².
- (2) *Group C*, isolated constructions for which an inspector (or director responsible for work, DRW) was not required, and whose failure during earthquakes would not endanger life or valuable material and equipment.
- (3) *Group B*, other structures not included in A and C.

According to the structural system, constructions were classified into three classes:

- (1) *Class 1*, frames strong enough to resist 50 per cent of all seismic loads without the contribution of walls or braces. Buildings 7m high or with two storeys were included.
- (2) *Class 2*, wall-type structures. Two-storey load-bearing structures, already included in Class 1, were exempted.
- (3) *Class 3*, elevated tanks, chimneys and other structures supported on inverted pendulum columns.

For example, largest C_y was 0.15 for Group B, Class 3 structures located in soft soil. For Group A structures, C_y for Group B was multiplied by 1.2. Seismic design was not required for Group C structures. Allowable stresses were increased when the combined actions of gravity and seismic induced loads were considered: 50 per cent for timber and steel, and 33 per cent for other metal, concrete or masonry.

The code specified three types of analyses:

- (1) Simplified static analysis for one-to-two-storey load-bearing wall constructions. For this method, wall shear strength had to be sufficient for resisting the earthquake.
- (2) Equivalent lateral force analysis where lateral forces were linearly distributed over the building height. For this method, shear strength, overturning and torsion effects had to be considered. For the latter, a 1.5 magnification factor was used to account for the dynamic torsion eccentricity; an accidental eccentricity equal to 5 per cent the maximum in-plan dimension of the building orthogonal to the direction of analysis was added.
- (3) Dynamic analysis (modal analysis) for lateral force evaluation. Design response spectra were proposed for the two soil types. Calculated forces using dynamic analyses had to be at least 60 per cent of those calculated using static analyses.

Inter-storey drifts were limited to 0.002 times the storey height for partitions sensitive to displacements. For other nonstructural elements, higher drifts were allowed. Separation between adjacent buildings had to be the larger of 50 mm or $0.006H$ for high compressibility or $0.004H$ for low compressibility areas, respectively, where H is the building height above the street level. One interesting requirement was that for buildings with more than $10,000\text{m}^2$ of total floor area or taller than 45m, instrumentation with strain gauges and accelerometers was mandatory.

The 1976 Mexico City building code

In the 1976 MCBC, important changes in format and technical content were included (DDF, 1976). For the first time, the main body of MCBC comprised a set of performance-based requirements that established basic safety rules. For each material (e.g. structural concrete, steel, timber and masonry), for selected actions (wind, earthquakes) and for parts of structures (foundations) a series of so-called Complementary Technical Norms (CTN) were issued. Analysis, design and detailing requirements were included in the CTNs. A limit-state design philosophy was adopted. Ultimate strength design was implemented for RC and masonry. Steel structures design remained based on ASD.

The main changes for seismic design were (DDF, 1976; García-Ranz and Gómez, 1988a):

- Soils were classified into three zones according to soil depth: soft (20m thick or more), transition (between 3 and 20m) and firm (less than 3m).
- Elastic design seismic shear coefficients were 0.24, 0.20 and 0.16 for the above mentioned soil zones.
- The benefits of ductile behaviour under major events was recognized through the adoption of ductility reduction factors for elastic forces, Q . Q varied from 1 to 6, and depended upon the type of material, structural system and detailing. Q was equal to 6 for steel and RC moment resisting frames carefully detailed; 4, when not all requirements for $Q = 6$ were satisfied, or when walls were used (provided that bare frames would resist 25 per cent of total shear at each storey), or for timber frames; 2, if frames or walls did not comply with detailing requirements specified for 4 or for walls made of solid masonry units; and 1.5 when hollow bricks were used. For all other cases, $Q = 1$.
- Since elastic forces were reduced, computed inter-storey displacements had to be increased by Q , and then compared to the allowable values specified in the code. Allowable inter-storey drift ratios were 0.008 and 0.016 for structures where nonstructural elements may suffer damage, and for structures where special details were adopted to preclude damage, respectively. Unfortunately, the code was not well understood by some designers who compared displacements calculated from reduced forces to the allowable limits.
- Accidental eccentricity for torsion was doubled.
- For the simplified static analysis method, C_y factors were given; the static method was applicable for 60m high structures; dynamic analysis were either modal or step-by-step. For the latter, at least four real or synthetic accelerograms were required so that their intensity was comparable to the design seismic shear coefficients.
- Design spectrum consisted of three zones. First, a linear ascending branch starting at PGA at period of 0s, to a period smaller than the fundamental period of the soil; secondly, a plateau up to a period that corresponded to the intersection with a descending branch that followed a parabolic curve. Largest acceleration for soft soil was 0.24 g.
- For the first time, the force reduction factor was dependent upon the fundamental period of the structure. Then, force reduction factors were linearly interpolated between 1 and Q for stiff structures falling in the linear ascending branch of the design spectrum. For all other periods, the force reduction factor was Q .

Emergency regulations of 1985

Although considered as a very advanced code, with criteria not adopted anywhere in the world at the time, the 1976 MCBC entered a major revision by the end of 1984. Research results had prompted the need to revise the code, such as the excessive lateral flexibility of flat-plate construction. However, the September 19 and 20, 1985 earthquakes accelerated this process. In the aftermath of these events, Emergency

Regulations were issued aimed at designing rehabilitation projects of damaged structures, as well as for designing new structures in the soft and transition soil zones (DDF, 1985).

The most significant changes were:

- Increase of elastic design seismic shear coefficients (plateau) to 0.40 g and to 0.27 g in the soft and transition zones, respectively. Also, PGAs were increased in these zones to 0.10 and 0.054 g, respectively.
- Owing to the large number of column failures, the strength reduction factor was reduced from 0.75 to 0.50 when seismic behaviour factors Q larger than 2 were used. Minimal dimensions of column cross sections were increased to 300 mm. Requirements for transverse steel were stricter.
- Live loads for offices considered for seismic design were doubled (García-Ranz and Gómez, 1988b).
- The maximum height of structures where simplified static method is applicable was reduced from 13m to 8.5m. Seismic design coefficients were also increased in this method.
- The maximum value of Q was reduced to 4, and was stated to be applicable to moment resisting frame (MRF) structures capable of resisting 50 per cent of total shear by themselves when braces or walls were used. Stricter requirements were specified for steel and RC frame structures.
- $Q = 3$ was adopted for flat plate structures and open web steel beam structures.
- Maximum torsion eccentricity at each storey had to be smaller than 20 per cent of the largest in-plan dimension.

The 1987 Mexico City building code

On July 1987 a new version of the MCBC was published (DDF, 1987). Although several changes were incorporated, it preserved most requirements of the Emergency Regulations of 1985. The most significant changes were:

- Structures were classified into two groups, thus eliminating Group C. However, Group B was subdivided into B1 and B2 according to their height, total floor area and soil type.
- Soil zonation was revised and redefined. For type II and III soils (transition and soft soils), severe design and detailing requirements were introduced.
- Requirements for non-structural components that may affect the overall seismic behaviour were included.
- Live loads for seismic design of office buildings were maintained; for residential buildings live loads were reduced.
- Specific rules were given for adequately separating non-structural elements from the lateral-force resisting system.
- Design seismic shear coefficients for the transition zone were increased from 0.27 g to 0.32 g.
- The importance factor for Group A structures was increased from 1.3 to 1.5.

- Maximum inter-storey drift angles were reduced to 0.006 and 0.012 for structures where non-structural elements are connected to the structure and when they are isolated, respectively.
- Separation between adjacent buildings was equal to the sum of calculated lateral displacements, based on elastic forces, plus 0.001, 0.003 or 0.006 times the building height above the street level, if the structure was located in soil zones I, II or III, respectively.
- It was established as mandatory to owners, DRWs and Co-Responsibles (CRs) on structural safety, to inform Mexico City authorities on structural damage attributed to earthquake, wind, explosion, overloads, differential settlements or other actions, in order to decide what to do. If damage was deemed serious, rehabilitation was mandatory. DRWs are responsible for the construction quality. CR's are individuals with technical expertise on structural safety, installations or urban development and architecture, responsible, along with the DRW, for the building design and construction.
- For Groups A and B1, CRs on structural safety (CRSS) were required, besides the DRW, to check that all studies deemed necessary are performed, and that materials and construction follow project specification and drawings.
- All existing Group A structures had to be assessed by a CRSS, and if necessary, had to be rehabilitated to comply with the 1987 code. Furthermore, these structures must be checked every five years or after a major earthquake.
- A series of regularity conditions were established for elevation and plan analysis. If regularity conditions are not met, a 20 per cent reduction of Q must be adopted.
- Recommendations for soil-structure interaction were included.
- For RC structures, two classes of concrete were established based on unit weight. Higher unit-weight concrete is required for Group A and Group B1. Strength reduction factors and detailing requirements were modified to attain more ductile frame structures.
- Structural steel design adopted an ultimate strength approach.

The 2004 Mexico City building code

A major revision of the 1987 code was published in 2004. The code comprises 257 articles in 11 titles (GDF, 2004a). Titles refer to: General requirements; Public streets and facilities for public use; Directors Responsible for Works and Co-Responsibles; Permits and authorizations; Architectural project; Structural safety; Construction; Use, operation and maintenance; Building extensions; Demolitions; and, Inspections, sanctions and appeals.

Title VI on structural safety is divided into 12 chapters. The important requirements are:

- Structures are classified into Groups A, B1 or B2. Group A buildings are essential facilities. Group B are structures used for housing, office and commercial business, hotels and others not included in Group A. Group B1 are taller than 30m or larger than 6 000m² of total floor area for soil zones I and II (firm and transition), or taller than 15m or larger than 3 000m² for zone III (soft soil). Group B2 are other types of structures.

- For analysis and design, three types of actions are considered according to their duration: permanent, variable and accidental. In the CTN on Design Criteria and Actions (GDF, 2004b), load factors are specified. A load factor equal to 1.4 is specified for combinations of permanent and variable actions. When accidental actions are included in the combination, a 1.1 load factor is required. Only when actions or loads help structure strength or stability, a load factor equal to 0.9 is used. In this CTN, a table is included for live loads with mean, accidental and maximum intensities.
- In the CTN on Seismic Design (GDF, 2004c), a new appendix was included with alternative design spectra to those in the main body of the CTN. Design spectra in the appendix are site specific. Reduction factors for elastic forces that account for ductility and overstrength are specified. Allowable inter-storey drift angles for ultimate and service limit states are also included. Spectral accelerations in the appendix tend to be similar to those in the main body, which are in turn similar to those from the 1987 code.
- Recent research developments in Mexico and elsewhere on design of steel, RC, masonry and timber structures were included. Significantly, the CTN on Design and Construction of Masonry Structures (GDF, 2004d) was re-drafted. In this case, changes were largely based on analytical and experimental research programmes, and field observations conducted in Mexico. During the revision process, emphasis was given to simplify and clarify the requirements; figures were added. The contribution of horizontal reinforcement and steel welded wire meshes to wall shear strength is now explicit and quantifiable. New requirements for detailing, inspection and quality assurance, and for evaluation and rehabilitation of existing structures are included. A new acceptance criterion for masonry systems different from those accepted in the design standards, and to be subjected to earthquake-induced forces, was included.
- Owing to the peculiar characteristics of the Mexico City soft soil area, comprehensive requirements are given for foundation design (GDF, 2004e). Geotechnical zones and soil strengths for design are established. Ultimate and service limit states for foundation design and excavation design are defined.
- The MCBC states that for buildings constructed prior to 1900 and that have suffered no damage or tilting, assessment on their structural safety is not needed. All damaged buildings should be reported and if their rehabilitation is needed, it should provide at least, similar safety levels as those established for new construction in the code.

Current status of other building codes in Mexico

The National Commission of Housing (CONAVI) has identified 104 building codes in the country; 32 are state building codes, 72 are municipal codes (CONAFOVI, 2005). CONAVI (whose acronym was CONAFOVI prior to 2006) is the Federal Government agency in charge of developing housing policy for the country.

In 1997, the National Center for Disaster Prevention and the Ministry of Social Development reviewed 25 building codes. From the unpublished data (Sánchez, 2006), the following are some of the more significant findings:

- 80 per cent of codes require a DRW or similar, whereas the remainder consider that inspectors sent by authorities are responsible for the construction work. Less than 60 per cent have a CR either on structural safety, installations or urban design and architecture.
- Minimum number of years of experience for a DRW and CR varies from 1 to 5. In all cases, a graduate from architecture or civil engineering is mandatory.
- Half of the codes reviewed do not have CTNs. In some instances, reference is made to MCBC CTNs, while in others, different standards are adopted (including the American Concrete Institute, for example). A few codes include a very short and primitive version of a CTN.
- Most codes classify structures in three groups (A, B1 and B2). Northern border towns have a much wider classification based on building occupancy.
- Typically, three soil zones are identified based on soil strata. Soil zones in one code are based on distances from active geological faults. A detailed map with geological faults is included in this code.
- 20 per cent of the codes reviewed are based on ASD; the remaining 80 per cent are based on limit-state design and ultimate strength.
- 50 per cent follow the load factors of MCBC.
- In four codes (out of 25), ASD is combined with ductility reduction factors for lateral forces!
- 50 per cent of the codes follow the seismic coefficients in the Manual of Civil Works issued by the Federal Commission of Electricity (CFE, 1994).
- Importance factor (for Group A structures) varies between 1.3 and 1.5.

Discussion, plans and challenges

From previous sections, it is apparent that codes for structural design in Mexico have evolved in refinement and complexity, as it is the case of MCBC. This type of evolution is consistent with that found in other codes around the world. However, assessment of Mexican codes has shown wide discrepancies on performance requirements and safety levels. A serious effort ought to be made to improve such codes and their enforcement.

Moreover, in recent months, simple observations (“window-car surveys”) have indicated that lack of compliance with technical standards and adequate design and construction practices are becoming problems in Mexico City and in other major cities. One significant reason for the lack of compliance with construction codes is that requirements are dissociated from current construction technology and practice, and are understood and correctly applied by only a few designers and contractors. There is a vast difference between the level of expertise and quality of practice of a relatively small group of well-informed specialists and academics, and that of most professionals and construction workers. Another explanation is that sanctions are not applied because local governments do not have the technical capacity to identify such code deviations or misinterpretations. The Mexican Society on Structural Engineering (SMIE) recently formed a task group to develop recommendations to the city governments aimed at improving code compliance. A fuller discussion on code compliance and on earthquake mitigation measures at large may be found elsewhere (Meli and Alcocer, 2004).

Currently, a Residential Model Building Code is under development jointly by CONAVI and the Institute of Engineering at UNAM. A first version of the Code is expected to be available early in 2008. This code will be enforceable in the whole country for housing construction financed with tax-payers money. This standard will be used in lieu of local codes for housing development. With the advice of the International Code Council, emphasis is given to code adoption and code enforcement procedures.

Sponsored jointly by CONAVI and the Mexican Council for Science and Technology (CONACYT), SMIE is developing guidelines for analysis of masonry structures intended to provide support information to design professionals on how to carry out structural analyses of masonry structures according to the MCBC CTN on masonry structures.

A considerable percentage (around 40 per cent) of buildings constructed in Mexico are non-engineered. This is the case for one or two-storey dwellings, typically constructed with masonry load-bearing walls, located in rural areas or in informally developed housing layouts. The latter are generally located on soils and areas not appropriate for safe building, such as on hills with steep slopes prone to slope failures, or in old riverbeds prone to flooding during extraordinary rain. Damage in recent earthquakes (see, for example, EERI and SMIS, 2006) have shown large differences in dwelling performance, mainly attributed to poor layout, lack of proper detailing, and substandard material and construction quality. For such cases, in which construction is not formal and is carried out without the help of engineers, building codes are not the appropriate solution. Simple technical guidelines are therefore necessary to advise the owner and workers on the most appropriate construction techniques, structural layout, material quality, detailing, etc. for achieving satisfactory performance. Also, with the support of CONAVI and CONACYT, SMIE is developing two guidelines, one for design and construction of new housing in rural areas, and other for rehabilitation of existing houses in rural areas. Each guideline will be 16-page long leaflets with minimal, yet comprehensive and graphic, information on how to build new housing, as well as on how to rehabilitate existing structures. Such leaflets are intended to replace the manuals that have been previously developed by academic and government institutions. Such documents had been typically 100-pages long, and therefore, their cost of printing has been too high for achieving a wide distribution among the actual builders in the field. In general, these long manuals have been used in central offices in large cities to develop scattered pilot projects for improving housing construction in rural areas.

Conclusion

Structural design codes have evolved through the years in Mexico, mainly reacting to damage inflicted to buildings by earthquakes. The most refined building code in the country is the Mexico City Building Code, which has been taken as a model code in different municipalities and states in the country. However, assessment of such codes has shown wide discrepancies on performance requirements and safety levels. Among other things (Meli and Alcocer, 2004), it is recommended that codes be implemented with procedures and requirements of different levels of complexity. For important and essential structures, a registry of specialists and peer reviews should be considered as complementary measures to reduce vulnerability. For ordinary structures, simple

design approaches, with safety checks based on key structural features, should be favoured. Also, it is necessary to strengthen and improve the technical expertise of building officials and groups that, at the municipal level, must overview the construction process.

For non-engineered construction, a wider dissemination of guidelines for new construction and rehabilitation of existing houses must be pursued. An effort must be made to influence non-engineered construction through a wider dissemination of videos, photos, etc., as well as of results of successful rehabilitation programmes conducted in Mexico or elsewhere. Evidently, rehabilitation programmes for existing, vulnerable dwelling (typically adobe houses) are essential.

References

- CFE (1994), *Manual de Obras Civiles*, Comisión Federal de Electricidad, Juarez.
- CONAFOVI (2005), *Hacia un Código de Edificación de Vivienda* (in Spanish), Comisión Nacional de Fomento a la Vivienda, Mexico City.
- DDF (1966), *Reglamento de Construcciones para el Distrito Federal* (in Spanish), February, Departamento del Distrito Federal, Mexico City.
- DDF (1976), *Reglamento de Construcciones para el Distrito Federal* (in Spanish), Departamento del Distrito Federal, Mexico City.
- DDF (1985), *Normas de Emergencia al Reglamento de Construcciones del Distrito Federal* (in Spanish), October, Departamento del Distrito Federal, Mexico City.
- DDF (1987), *Reglamento de Construcciones para el Distrito Federal* (in Spanish), July, Departamento del Distrito Federal, Mexico City.
- Del Valle, E. (1988), “Experiencias Derivadas de los Sismos de Septiembre de 1985”, *Evolución del Reglamento de Construcciones para el Distrito Federal en aspectos de diseño sísmico* (in Spanish), Fundación ICA, Ed. Limusa, Mexico City.
- Esteva, L. (1988), “Consequences, lessons, and impact on research and practice”, *Earthquake Spectra*, Vol. 4 No. 3, August, pp. 413-26.
- García-Ranz, F. and Gómez, R. (1988a), “Seismic design regulations of the 1976 Mexico Building Code”, *Earthquake Spectra*, Vol. 4 No. 3, August, pp. 427-40.
- García-Ranz, F. and Gómez, R. (1988b), “Live load specifications of the 1976 and 1987 Mexico City Building Codes”, *Earthquake Spectra*, Vol. 4 No. 3, August, pp. 461-8.
- GDF (2004a), *Reglamento de Construcciones para el Distrito Federal (in Spanish)*, January, Gobierno del Distrito Federal, Mexico City.
- GDF (2004b), *Normas Técnicas Complementarias sobre Criterios y Acciones para el Diseño Estructural de las Edificaciones (in Spanish)*, October, Gobierno del Distrito Federal, Mexico City.
- GDF (2004c), *Normas Técnicas Complementarias para Diseño por Sismo (in Spanish)*, October, Gobierno del Distrito Federal, Mexico City.
- GDF (2004d), *Normas Técnicas Complementarias para Diseño y Construcción de Estructuras de Mampostería (in Spanish)*, October, Gobierno del Distrito Federal, Mexico City.
- GDF (2004e), *Normas Técnicas Complementarias para Diseño y Construcción de Cimentaciones (in Spanish)*, October, Gobierno del Distrito Federal, Mexico City.
- Meli, R. and Alcocer, S.M. (2004), “Implementation of structural earthquake-disaster mitigation programs in developing countries”, *Natural Hazards Review*, Vol. 5 No. 1, February, American Society of Civil Engineers, pp. 29-39.

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- Rosenblueth, E. and Esteva, L. (1969), *Folleto complementario – Diseño sísmico de edificios* (in Spanish), Facultad de Ingeniería, Mexico City.
- Sánchez, T.A. (2006), personal communication, National Center for Disaster Prevention, CENAPRED, Mexico City.

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Further reading

- EERI-SMIS (2006), “The Tecomán, January 21, 2003”, in Klingner, R.E. and Alcocer, S.M. (Eds), *Mexico Earthquake*, Earthquake Engineering Research Institute and Sociedad Mexicana de Ingeniería Sísmica, Oakland, CA.

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