ARCHITECTURAL AND URBAN DESIGN LESSONS FROM THE 1985 MEXICO CITY EARTHQUAKE

Photo by Paul Conklin

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Where do architects stand regarding seismic design? Worried about their role, beset by issues of liability, and unsure of the scope and force of their decisions, perhaps the last thing they want to think about is an earthquake. But Mexico City has made it clear that architects, with their colleagues in the design and construction industry, share responsibility for disaster. To the extent that architects wish to lead the building team, they must understand the forces of disaster and work toward reducing them.

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INTRODUCTION

On September 19 and 20, 1985, two earthquakes registering 8.1 and 7.5, respectively, on the Richter scale struck the central and southwest regions of Mexico. The earthquakes originated from the subduction of the Cocos plate beneath the continental plate of North America, the most active subduction thrust fault in the western hemisphere. Felt as far away as Houston, the quake severely damaged Mexico City, some 250 miles from the epicenter. More than 20,000 were killed, and damage costs totaled between $4-5 billion; the total economic losses will greatly exceed this. Approximately 5,700 office buildings, schools, hospitals, and residential buildings throughout the central city were heavily damaged or destroyed.

The quake offers the United States and Mexican building communities a revealing if deadly "natural experiment." Unlike buildings in other countries hit by earthquakes in recent years, Mexico City structures incorporate modern design and construction techniques for earthquake resistance used in the United States. How did they fare? The answer to this question is vital not only in Mexico, but in California and 38 other states, with over 70 million inhabitants, that are susceptible to moderate-to-high earthquake forces.

In an effort to learn in depth from the experience in Mexico City, The American Institute of Architects (AIA) and the Colegio de Arquitectos de Mexico/Sociedad de Arquitectos Mexicanos (CAM/SAM) formed a cooperative program in 1985 to investigate the Mexican quake. The research project was funded by the National Science Foundation (NSF) through a grant to the joint Council on Architectural Research. This council is sponsored by the AIA and the Association of Collegiate Schools of Architecture (ACSA).

This publication, the result of this unique and fruitful two-year partnership, is making important contributions to our respective professions and countries in our continuing effort to develop seismically safe communities. Our primary goal is to help architects, urban designers, and other building professionals to better understand and apply the lessons learned and in some cases, relearned from the experiences of the 1985 earthquakes.

The Role

This effort has been based on the premise that architects have a growing responsibility and role to play in seismic hazard mitigation, and to fulfill that role, the very best knowledge and how to effectively utilize it, is needed. It is also based on the premise that designing and constructing buildings to effectively resist earthquakes requires a coordinated effort by the architect and the entire building team.

The development and use of effective resistant design and construction measures can substantially reduce the loss of life, property damage and social, economic disruption that earthquakes can cause. Design, construction, and management decisions architects make--including site plan, building form and configuration, structural and mechanical layouts, construction details and nonstructural components--determine overall building and urban performance during an earthquake. According to the National Research Council, "The study of structures ... damaged by earthquakes has shown that architectural decisions based on considerations of appearance (design), function and other such concerns can greatly influence the seismic resistance of buildings and loss of life."

Traditionally, the structural engineer has been regarded as the professional with primary responsibility for the seismic performance of a building. This is no longer true. The architect has at least as an important role to play. If an architect, for example, provides the engineer with a building concept and construction details that are fundamentally poor in their earthquake resistance, the engineer faces a difficult, if not impossible, task in the development of a safe building.

Subjects Investigated

An initial overall checklist of subjects to be investigated was developed early in the project from our research and from a series of meetings and discussions held in Mexico and the United States. This list was intended to be a means to an end, with the understanding that priority subject areas would evolve as the work developed. This happened and a number of significant generic areas of lessons learned resulted. These generic areas are listed in the next section. The initial checklist is as follows:

- **Urban Design/Planning**: land-use considerations, density and form, life lines, patterns of use, building groups and appropriate buildings
- **Role of the Architect**: with other officials and members of the building-development team in the planning, design, development, construction, and supervision process; public/client role; role before, during and after earthquake; and, attitude, awareness, responsibility in professional context
- **Design/Development Decision Making Process**: timing of decisions and the relationship to seismic considerations; opportunities of the designing/building process
- **Nonstructural**: relationship to structural considerations, mechanical, design of building, type of building, and construction; heavy cladding--partitions, fixed equipment, retrofit, damage assessment, code and cost issues; light cladding--contents and equipment, electrical and mechanical, ceilings and partitions
- **Architectural Engineering**: relationship to architectural and nonstructural considerations, and to design decision-making process
- **Architectural Design Considerations**: configuration and other design considerations: mechanical, structural preliminary layout, circulation, protection of exits, interior protection, site design, building types, building/soil interaction, materials and construction details
- **Societal Issues**: public awareness and interest, and change of use of building and parts of the city after initial design and construction
- **Code Issues**: architectural design impact considerations, the importance of architectural input in developing codes and the role of codes/professional knowledge
- **People Considerations**: designing to accommodate behavioral considerations, search and rescue, and injury relationships to building design
- **Existing Buildings**: retrofitting, rehabilitation, problems and opportunities
- **Liability Considerations and Cost Effectiveness**

Areas of Generic Lessons Learned

As mentioned in the previous section, a number of generic areas of lessons learned have evolved from our research. These areas provide the foundation on which our work has developed, and on which the more specific lessons and recommendations documented in the individual chapters of this publication have been built.

1. A more wholistic approach to building design, construction, and management is needed. There is a growing tendency in our specialized world to treat building components and activities (architectural, structural, mechanical and nonstructural design; equipment, foundations, geological and site aspects, etc.) separately, rather than how they relate and affect each other and the whole. Buildings resulting from such a fragmented approach will usually not respond as well to severe forces such as those experienced in an earthquake. We therefore need a more comprehensive, integrated approach, one that considers the following seismic design relationships more carefully.

   - building design (form, function) and structure
   - structure and nonstructural elements
   - nonstructural elements and building design
   - building design and building group/site

2. The pattern and extent of pounding damage (a significant factor in over 40 percent of collapses or seriously damaged buildings) has much greater implications for building and city design than we originally realized, much beyond the traditional thinking of one building simply impacting another in isolation. This subject needs much attention, especially as it relates to the design of building groups, site and urban blocks.

3. Other patterns of building damage, especially the high percentage of corner buildings seriously damaged or collapsed (42 percent) has also made us more aware of the integral relationship between the design of the individual building and the various scales of the urban context it is a part of. This includes: building groups, urban blocks, neighborhoods, relationship to other uses, open space and street configuration.

   We have become much more aware that a seismically safe building begins with a seismically safe community and vice versa. The two, including the various scales between, relate and significantly affect each other. Specifically, we must be concerned more with the mass, form, height and density of buildings and the community/urban context, as well as types of structures and building materials. We must now look as much at the urban design context as the building itself.

4. The criteria and characteristics for a seismically safe city seem to coincide with those of a well planned city in general, thus offering the opportunity to accomplish a variety of community and development objectives. This includes: open-space patterns and hierarchy, density and form, patterns of land use, location of public, health and safety facilities, design and location of transportation and utilities and decentralization considerations. These areas need to be explored and evaluated as a means for achieving both a viable community and one that is seismically safe, an invaluable goal at a time of limited resources.

5. Overall coordination within the design, construction, and management decision making process needs significant improvement to overcome the growing fragmentation that adversely affects the development of seismically safe living environments. There is a need for the various players--design professionals, public officials, supervisory personnel, owners, community leaders, media, etc.--involved in this process to work more closely, better understanding and maximizing their own roles, each others, and their coordinated contributions.

The Mexican experience reinforces the need for the design-development process to include and analyze the full scope of the decisions and ramifications associated with developing safe environments. This ranges from development considerations, community planning and site selection aspects at one end of the spectrum to the management, maintenance and rehabilitation of the building throughout its life time at the other. Between, we need to look at other stages as they relate to and affect hazard mitigation: preliminary design, programming, building approval process, codes and regulations, working drawings, consultant input and supervision.

We must look at how these decisions relate to the development of safe buildings and environments, who needs to be functionally involved and what input and time elements are necessary to ensure the most effective strategy. More of a team effort is essential.

6. The architectural and building community must play a broader and more active role in seismic mitigation, working toward more effectively using and applying our inherent professional know-how to improving the seismic safety of our living environments. We must begin by becoming more knowledgeable and more involved in awareness building within the community and with our clients.

   Design professionals must begin to see the design-development of a seismically safe environment as our own purview, as much as designing for energy conservation, an aesthetically pleasing environment, efficient use of land, or any other issue that is accepted as a legitimate professional concern. The misconception that designing for hazard mitigation is somehow the concern of others--especially engineers or public officials--or that simply following the building codes will solve everything, is all to common, and wrong. (Building codes are not enough in themselves to ensure safe buildings. Professional knowledge is at least as important, probably more.) Architects as leaders of the building team need to be more involved in the overall mitigation process, exploring what we can contribute, before, during, and after the earthquake. In this way we can expand our own role and better serve our communities at the same time.

7. We need to utilize more effectively what we already know about the basic principles and techniques of seismic design. While the disaster in Mexico City has allowed us to expand our present knowledge and open new areas of knowledge, it has also reinforced the importance and soundness of what we knew, changed some speculation into fact, and emphasized again the continuing importance of education and awareness building. Some of the areas that have been reinforced as being very important, include: the design of the built environment as a vehicle for mitigating loss of life and property damage; architectural configuration and form; and nonstructural elements.

The Future

The world continues to watch the still evolving story of Mexico City as it rebuilds after the 1985 earthquakes. The architectural and building communities and the city as a whole have learned and accomplished a great deal over the past 3-1/2 years, but much still remains to be done.

The congested downtown has gained much needed urban parks and open space where buildings or even blocks once stood. A new code has been implemented, much retrofitting has occurred, and innovative housing and development projects have and continue to be built. Proposals to limit building height, reduce density and implement other urban initiatives continue to be considered and implemented where possible. It is obvious from the new construction occurring that the earthquakes have left a lasting impression. But, there are still vacant buildings and other areas waiting for solutions; the problems and solutions are complex, affecting all aspects of the physical, social, economic and political environment.

It is essential in light of the Mexico City tragedy that we continue to utilize the lessons learned, and the same mistakes not be made again. This project is our own small way of attempting to do that. Mexico City has changed forever the architect's role in seismic safety and marks a new beginning for architects worldwide. We feel that the material, lessons learned and recommendations in the following chapters will contribute much toward that end.

D.E.G.
June 1988

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ARCHITECTURAL AND URBAN DESIGN LESSONS FROM THE 1985 MEXICO CITY EARTHQUAKE: THE MEXICAN PERSPECTIVE

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THE EARTHQUAKE, GEOPHYSICAL PHENOMENON

Jesús Aguirre Cárdenas

Some decades ago, the general belief was that the main cause for earthquakes was the internal activity of volcanoes. Today, without ignoring that in some cases, that cause is still valid, we know that most earthquakes, particularly the most intense, are of tectonic origin. Some other earth movements can be generated by explosions, ground collapses, slippage or settling below the surface of the earth.

In its outermost crust, the earth is constituted by layers, which we might call concentric shells, that have no continuity but are instead separate sections constituting the lithosphere's tectonic plates. This lack of continuity originates the superposition of some of their edges.

These plates are subject to movements and dimensional variations and the earth's inner temperature (convection flows) as well as the planet's regular movements are thought to have something to do with it. The movements are independent and in different directions. Friction between the layers does not facilitate slippage and the strain to move turns into potential energy. As this accumulated energy increases, there comes a time when the balance is broken and slippage or penetration between layers takes place instantaneously. This becomes the focus or hypocenter of a more or less intense earthquake, depending on the accumulated stress and/or the unbalance effect. This may even cause faults to appear as fissures on the earth's surface.

This break of balance constituting the earthquake's focus generates vibration that travels in all directions. The wave that rises vertically and is projected on the earth's surface originates the epicenter. Waves are formed from there such as those produced by a pebble falling into water and are transmitted at high speed over the earth's surface, advancing according to the terrain's characteristics.

Not all the earth's regions are equally propense to earthquakes. The seismic zones are those rather close to the cases of plates described here, where there are subduction zones, which means that one plate is stuck under another, both tend to slip due to their differing movements.

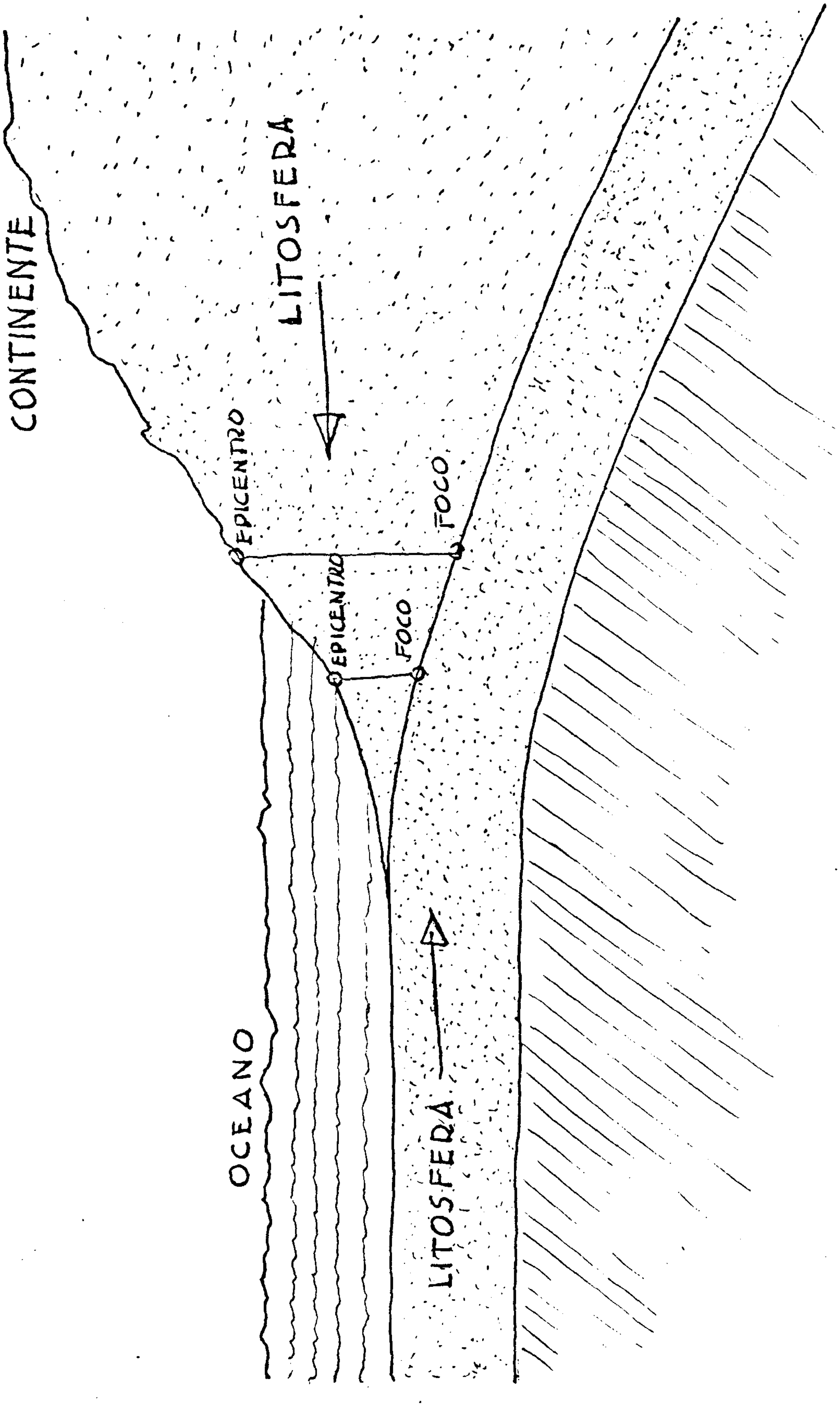
México is a seismic country, especially in the center and south areas, near the Pacific Ocean, where the plate known as Cocos is located. This penetrates, under the conditions we have described, under the continental plate, the North America plate. There are potential earthquake foci from the state of Jalisco to that of Oaxaca.

There are low intensity quakes continuously, which practically are not felt. It is only when the break of balance is of major proportion that intense earthquakes are generated.

After a strong earthquake, the balance is not always restored immediately and readjustments follow originating new quakes or "replicas" in a higher or lower number and intensity.

The plates have been thought to be segmented in what are called fractures, which have a certain independence from one another. Those constituting the Cocos plate have been called the fracture of: Jalisco, Michoacan, Guerrero, Ometepec and Tehuantepec.

The time to store up energy having sufficient strength to cause a seismic movement generally takes several years. This is called the recurrence period which in México, for some regions, has been computed at between 32 and 56 years. While that time is passing, what is called the zone of repose takes place.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This was the case of the Michoacan fracture, a zone of repose since early in the past century and therefore a much longer period than has been assumed as an average. And it was precisely the great energy accumulated during that time, in said fracture, which was released and with epicenters at not too great a distance, caused the earthquake of September 19th and its replica on the 20th of the same month.

Energy is known to be accumulating in some other fractures of the same Cocos plate, and which will cause effect in lapses and with intensities that cannot yet be forecast.

GEOLOGY OF THE VALLEY OF MEXICO

Jesús Aguirre Cárdenas

Even though we generally call it the Valley of México, it should be rather the Basin of México. In the dictionary, a valley is defined as: "Depression located between two mountains or mountain ranges, generally elongated and sloping toward the sea" and for a basin "Territory surrounded by heights".

Following the customary usage, we shall here describe the Valley of México, although in function of the word that best expresses its formation.

The Valley of México was originally a basin circumscribed throughout its perimeter by several ranges: to the North, the Sierra de Pachuca, maximum altitude 3,000 mt; to the Northeast, the Sierras of Chichucuatlan and Tepozan at over 3,500 mt; to the Southeast, the Sierra Nevada with the Tlaloc and Telapón hills and further South on the same Sierra or range, the volcanoes Iztaccihuatl at 5,286 mt and Popocatepetl at 5,450 mt; to the South, the Sierra del Ajusco, with the Pico del Aguila (Eagle's Peak) at 3,952 mt; then, to the Southwest, the Sierra de las Cruces; to the West the Sierras of Monte Alto and Monte Bajo; following this, to the North, the Sincoque and Jalpan hills and finally, further North, the Sierra de Tezontlalpan closing the circle with that of Pachuca. The average height of the level part of the Valley of México is 2,250 mt above sea level.

Consequently, not having a natural water outlet, the basin of México was a lacustrine zone in Prehispanic times. When Tenochtitlan was founded and populated in that era, people felt no need to provide an outlet for the water, nor did they have the means thereto, so that they confined themselves to building dikes-causeways and the earthworks designed by Nezahualcóyotl.

The topography of the Earth's surface, the geographic distribution of land, sea and lakes, plains and mountains, are a consequence of evolution at different geological times. The volcanic and tectonic processes have determined the physical features.

These phenomena are those that also originated the so-called Transmexican Volcanic Belt, crossing the country from West to East, Pacific to Gulf of México, with a width measured from North to South that ranges between 20 and 70 kms, with a salient to the South in the zone of the State of Jalisco, containing the Colima volcano. The other main volcanoes, West to East, are the Nevado de Toluca, Popocatepetl, Malinche and Pico de Orizaba, besides a large number of smaller vents, some of them having originated with their eruptions in remote times, large areas of stony ground, such as the Ceboruco volcano in the State of Nayarit and the Xitle in the Sierra del Ajusco, South of México City.

The Valley of México with the Capital City is situated precisely in a central position in this Transmexican Volcanic Belt.

More detailed studies of the basin's stratification have been made possible through digging for very deep wells and the Deep Drain System.

There are great variations in the materials constituting the soil, diversity in consistency, resistance, shapes, sizes, depth, extension and levels in the layers of a same material. More or less large elevations with relation to the average surface's. Ravines, depths and depressions of different size, some of them receiving lakes or channeling fluvial waters according to their shape. All this is complemented by folds, fractures and faults from different periods, without ignoring the special importance of the effects of erosion.

And as regards the materials: alluvial deposits, lacustrine deposits, clays; formations of volcanic origin: lavas, tuff, breccia; rocks from different periods, limestone boulders, etc.

To sum up, an entirely heterogeneous whole resulting from the stages of volcanic activity characterized by the generation of great masses of lava, erosion mainly due to torrential rains with alluvial deposits of sands, clays and silt and finally the lacustrine formation, due to lack of outlet for the water. We can thus appreciate the reason for the great variety in soil constitution, not only as to type of materials, mainly due to their resistance, but also as to depth of strata.

This geological formation makes its study difficult and consequently also makes it difficult to solve the resulting problems.

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SUBSOIL OF MEXICO CITY

Jesús Aguirre Cárdenas

In accordance with the foregoing, during the prehispanic era the Valley of Mexico was a large marshy area. Without it being possible to establish the date on which they began, numerous indigenous communities began to settle in different areas of the valley in more or less numerous groups, some of these attaining importance such as the urban-religious center of Teotihuacán. Tribes arrives, established themselves and withdrew without making a permanent settlement.

History relates that the group of Mexicas, perhaps in the year 1111 A.D., left the legendary and distant Aztlán and in their advance reached the Valley of Mexico, after numerous hazards on meeting other tribes. It is said that their gods had told them they would find an eagle perched on a prickly pear cactus devouring a serpent, finally reached the place of the prophecy and, in the year 1325, established there their definite settlement, thus establishing Mexico-Tenochtitlán.

Even although the exact spot has not been defined, it was certainly an island in the prehispanic marshy area of what is, today, Mexico City.

Natural islands and artificial islands became incorporated in the growth of the town and, being convinced that their gods had chosen this place for them, they concentrated work on building their city there, circulating by canal and building in two roads at right angles to one another, causeways which led to their ceremonial center.

This is the Mexico-Tenochtitlán which the Spaniards found on their arrival in 1519.

A population settlement over a lake and, moreover, with other great lakes forming an interlinked group, from south to north: Chalco, Xochimilco, Texcoco, San Cristóbal, Xaltocan and Zumpango.

An established city, located in this place in response to the religious beliefs of its inhabitants, with its Sacred Precinct, the Templo Mayor, their spriritual and geographical center.

It was essential to respect this location and, in 1522, Alonso García Bravo and Bernardino Vázquez de Tapia drew up the plans for the Colonial city.

The city of Mexico grew in importance and in population and, therefore, spread in extent over this alluvial and marshy plain. Each time it was more necessary to limit and eliminate the water. In 1555 a new dyke was built, following the idea of that constructed by Nezahualcoyotl, a wall of stone to contain the water. For some years it achieved its ends.

The city continued its development and it was essential to find an exit from the Valley of Mexico for the water, due to the danger of continued flooding. In 1580, Enrico Martínez proposed to the Viceroy the building of a tunnel in Nochistongo, to drain the waters from the valley. Work was begun in the year 1607 and, work having been interrupted, continued in 1637; but it was not until the end of the following century, in 1789, that work was completed.

The solution given was not sufficient, the flooding continued, different studies and proposals were made, now in an independent Mexico.

During the second half of the XIX century the great work of the tunnel and ravine of Tequixquiac and the Gran Canal del Desague was begun. Even though this was inaugurated in 1900, it was essential to continue extending the work afterwards. Thus, the water was drained from the Valley of Mexico into the Tula, Moctezuma and, finally, Pánuco Rivers.

Mexico City develops. Its constructions extend over the ground and prevent the water from entering the earth, the lake areas grow fewer, streets grow and, being paved, still permit the rain to be absorbed.

The demographic explosion calls for water which, as it is so close, is taken from wells. Each time more water is taken and therefore the earth contracts on having its contents removed, and its consistency is changed.

The fall in the level of the city, both by having taken the water from the Valley of Mexico and by extracting the water from the subsoil, gave rise to problems in connection with the Grand Drainage Canal, and the need arose to establish pumping systems to raise the drainage water in various places.

This situation becomes more and more serious, and during the last decades the Deep Drainage System has been constructed by using depth interceptors which receive the waters from the drainage network of the city, and a Central Emitter which takes it outside the Valley of Mexico.

On the city growing horizontally, constructions are supported on different typs of ground, until they reach the surrounding slopes on which they find floors of greater resistence and in stony areas of volcanic lava and the compression of earth under same.

The city continues to grow, and now, due to the increase in prices in central areas, has to grow vertically. The resistence of the soil cannot support directly the weight of large buildings, and the great problems of soil mechanics arise, calling for new solutions showing that the land of Mexico City is one of the most difficult in the world.

In these conditions, the urban area has been settled on three types of subsoil which are defined by the Building Code for the Federal District, in accordance with resistence, as follows:

> Area I.- Slopes formed by rocks or generally-firm earth which was deposited outside the marshy area, but in which sandy deposits in a loose state or relatively bland cohesives may exist, either superficially or in an intercaled state. In this Area, the presence of hollows in the rock and caverns and tunnels excavated in the soil to exploit sandpits are common;
>
> Area II.- Transition, in which deep deposits are located at a depth of 20 m, or less, and which is formed predominantly by arenaceous and limoarenaceous strata intercalated with layers of marshy clay; the thickness of these varies between dozens of centimeters and a few meters, and
>
> Area III.- Marshy, formed by strong, highly condensed clay deposits, separated by sandy layers with a varying lime or clay content. These sandy layers range from a firm to very hard consistency and are of variable thicknesses from centimeters to several meters. The marshy

> deposits are usually covered superficially with alluvial and artificially-filled soil; the thickness of this combination can be over 50 m.

One of the most difficult types of land, one of the largest cities on the planet, and a seismic zone. There could not be a larger number of problems and they have been sufficient for the devastating effect of the earthquakes.

NATURE OF THE SEPTEMBER, 1985 EARTHQUAKES

Jesús Aguirre Cárdenas

On Thursday, September 19, 1985, at 7:19 a.m., an earthquake shook Mexico City and some other parts of the Mexican Republic, the epicenter being located 30 km. to the south-west of the mouth of the Balsas River, close to the limits between the states of Michoacán and Guerrero, on the coast of the Pacific Ocean. The distance from this point to Mexico City is approximately 360 kms.

The earthquake was caused by an underground movement, a sliding of the Cocos Plate, of which it has already been spoken, under the North American continental plate, in a rupture area of possibly 70 x 170 kms. The depth of the focal point, at approximately 18 kms., and the hour when it took place is calculated by the different registers and distance travelled, at 7.17 a.m.

The magnitude of the movement was 8.1 degrees on the Richter scale, which represents an extremely high value taken at world level.

The propagation speed of the wave was in the order of 3 kms/sec., on covering the 360 kms. of distance in 2 minutes for the epi-focus to reach the Federal District.

On the seismic waves entering the city of Mexico they find, as has already been indicated, that a large part of the constructions are settled in a marshy area.

The most important features of the earthquake which produced the effect on the City were: its exceptional length, of over 3 wimutes of oscillations perceptible in the Valley of Mexico, the incredible regularity of the waves, the almost-uniform period of vibration of approximately 2 seconds and, in particular, its intensity.

The stratas of clay and the buildings whose period of vibration coincided with this data, entered into resonance which, in many constructions, with the duration and regularity of waves, led to collapse or heavy damage.

The subsoils with these features were the most affected; the Roma, Hipódromo Condesa, Narvarte, Juárez and Doctores colonies and the areas of Tepito and Tlatelolco, mainly for buildings with a vibration period of 2 seconds. In buildings from 5 to 15 stories high, the natural vibration frequency commonly coincides with this period, if no special precautions have been taken to modify same.

Firmer land, hillsides, with a lower vibration period, were not affected; Pedregal de San Angel, Lomas de Chapultepec, Polanco, etc.

And in land with a period longer than 2 seconds, such as the Central de Abastos and Lake of Texcoco region, there was no problem either. Possibly if there had been a high building in this place such as the Latino Americano, 42 floors in height and with a period of over 2 seconds, it would have been strongly affected.

The features given for this earthquake had not been recorded, at least during the years since the study of seismology has allowed such measurements to be taken and, therefore, the regulations in force could not have foreseen these problems.

Another problem, certainly, was that of areas of greater resistence, consolidation, which reflecting the waves - for example of hitting a mountain range - produced a high degree of irregularity in the vibrations in a phenomena which we could consider similar to that of the waves breaking on the shore.

Special mention should be given, amongst the characteristics of this earthquake, to the phenomena of acceleration, a result of the others which we have considered.

On the waves of the earthquake reaching the soils of Mexico City, formed by layers of clay between 25 and 30 meters in depth, the accelerations were amplified from the land surface to the first hard layer and, therefore, the impact of the movement on the buildings can be compared to the case of a car crashing at great speed.

Comparing the result obtained from equipment to measure the acceleration, one installed in the Ciudad Universitaria on firm ground, in the Pedregal area and which was of 40 gals, corresponding to 4% of the gravity and other equipment placed in the SCOP Center, Narvarte colony, on soft ground made up of clay layers in which acceleration was 20% of the gravity, that is 200 gals, we can draw the conclusion that acceleration in the soft ground area was 5 times greater that that on firm ground.

In view of the foregoing, we should take into account that a gal is the acceleration of $1 cm/sec^2$ which corresponds, in turn, to 1/980 of the acceleration of the gravity (approximately 1/1000 for the purposes of calculation).

$$40 \text{ gals} = \frac{40}{100} = \frac{40}{1000} = .04 = 4\%$$

$$200 \text{ gals} = \frac{200}{980} = \frac{200}{1000} = .20 = 20\%$$

In this way we can better understand the reason for the area with the higher number of collapsed buildings.

As occurs with earthquakes of great magnitude, the movements continued and numerous repetitions occurred, until by 4 p.m.

on the 19th precisely 19 earth tremors had been recorded.

The following day, September 20, they continued and a new quake of 7.5 magnitude on the Richter scale was recorded at 7.30 p.m. Logically, the buildings which had been left in a precarious state collapsed or were more affected; however, the psychological effect on the people was, logically, much greater than had been that of the previous day.

Mexico City, land and constructions, as from September 19, 1985, at 7.19 a.m., changed into as has been expressed, a "Huge Seismic Laboratory".

Of course, one of the most important effects of studying the numerous factors intervening in the quake, was that of modifying engineering activities in structural design, and that of architecture in architectonic design.

The building codes for the Federal District have been modified as a result.

The restrictions and demands which have modified some architectural conditions as a result of studying the quakes, should be taken as a challenge for the profession. New conditions intervening in architectonic programs, different analysis for solutions and, therefore, New Architecture corresponding to the creativity of the achitects.

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1985 EARTHQUAKES IN MEXICO CITY, PHOTOGRAPHS WITH COMMENTS, OBSERVATIONS AND CONCLUSIONS.

Adrían Breña Garduño

The slides taken in the Federal District were selected as those most representative for the purposes of study.

It should be noted that, for the millions of spaces built in Mexico City, in actual fact those which collapsed were a minority, together with those which had to be demolished as a result of the quake, and some which still remain to be demolished. At the present time reinforcement work is still taking place on the damaged buildings where this can be done.

It can be shown, as has already been said, that there were areas where the strength of the quake passed 8.1 on the Richter scale. A phenomena provoked by waves transmitted in the phreatic subsoil, as occurred in various parts of the first section of the city.

Supporting the special seismic intensities of some soils of the capital, it should be mentioned that, being some lustrums ago on the 11th floor in the Bonos del Ahorro Nacional building at Reforma 77, it was common to feel very slight oscillations on this level of the building which, it was later verified, were due to the passing of heavy vehicles when they went over the tram lines which existed at that time in the street of Alfonso Caso, Similar movements have been felt in other buildings of the city center.

The explanation of the case is that, there are certain saturated montmorillonite soils (absorbent clays) of such a composition that any impact on the ground surface provokes an instantaneous wave transmission by communicating vessels based on the uncompressibility of the liquids. This is what may have produced the most unusual seismic effects and given rise to the damage or collapse of certain buildings. Photos (14, 15, 16).

In other cases, the gradual dehydration of the subsoil must have excavated caverns around the foundations which, with the sudden vibration, occasioned accelerated settling of the foundations. Example photos (8,9,10 and 17).

Note is also taken that many buildings which collapsed or were seriously damaged, were located close to the subterranean railway lines. If we consider the "box" of reinforced concrete which houses the "metro", to construct same it is necessary to "diminish" the phreatic waters, giving rise to the first phase of dehydration. After burying this huge tube of square section, the acqueous content has been allowed to flow, accelerating the loss of water in permeable areas.

The explanation for the collapse of the 9 floor building in the street of Zacatecas (photos 11, 12 and 13), can be understood as the induced dryness of the subsoil, in the first instance. After, with the seismic oscillation (swing) of the entire foundation floor, the columns, now without lateral support, worked with extra long structural elements; failing in the most critical place, with the resulting overturn of the building at that point.

As regards the lightened slabs of certain buildings, it can be understood that on a structure swaying through the force of the earthquake and the tendency of the knots of same to linger, on straight angles over the plane of the slide in the perpendicular direction of the quake's tendency, the structural beam element transmits a considerable twisting movement to the slab with deficient rigidity, causing this to fail. Photos (2,4, 5,7, 21 and 22).

In summary, the following OBSERVATIONS AND CONCLUSIONS can be planted.

OBSERVATIONS:

1.- The fortunate time of the disaster. If it had not been at that moment, the world disaster of the millenium would have occurred.

2.- The uncommon foreign and particularly national and metropolitan solidarity.

3.- Mexico has tragically been, for science, the best seismic laboratory in the world.

4.- Old buildings with partition walls, tepatate, stone, tezontle and lime (without steel and concrete), suffered no damage. (Photos 23, 24 and 25).

5.- Steel and concrete structure building which suffered no damage. (Photos 27 and 28).

CONCLUSIONS:

1.- To scrupulously supervise compliance with the new Federal District Building Code.
2.- To control the malleable quality of the reinforcing iron. (Photos 6, 19 and 20).
3.- To divide the urban spaces strictly into zones.
4.- To instal stairwells of sufficient capacity and emergency stairs. Particularly in the case of hospitals, educational and entertainment institutions, public and private offices.
5.- To implement federal regions and entities with sufficient seismographs and/or accelerographs in connection with the Cocos Plate.
6.- To promote systematic and coordinated efficient intercomunication in connection with disasters, between public, private and social sectors.
7.- To avoid the over-exploitation of aquiferous (areas) and encourage the recharging of same.
8.- To rationalize urban road density.
9.- To encourage urban deconcentration.
10.- To educate the inhabitants on seismic matters.

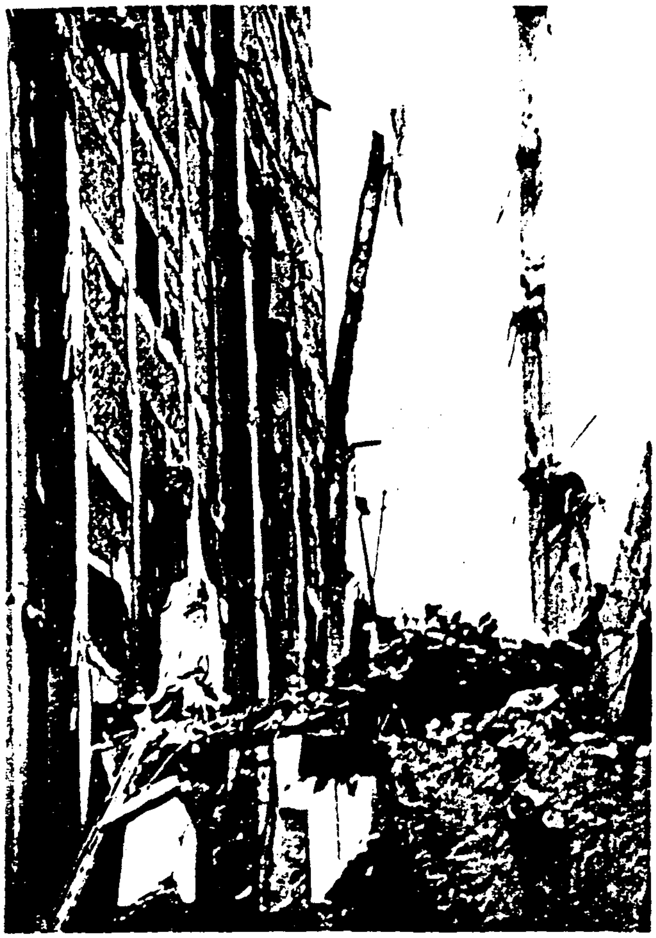
	PHOTO	LOCATION	REMARKS
1.	Reinforced concrete building. 6 storeys.	Col. Juárez	Failure of reticular slab anchoring. Note columns showing the knot anchorings which linked the lightened slabs.
2.	Secondary school No. 3. 3 storeys.	Av.Chapultepec Col. Juárez	Failure of lightened slab structure.
3.	Office building. 8 storeys	Col. Juárez	Complete collapse of the building.
4.	Office building. Ministry of Communications and Transport	Av.Universidad and Xola. Col. Narvarte.	Failure of columns and reticular slabs. Trapezoidal floor structure.
5.	Public office building. Hydraulic Works Dept., Federal District. 12 storeys	Calz.Tlalpan and San Antonio Abad.	Failure of lightened slab structure on East and South facades.
6.	Office building. 9 storeys	Plaza de Orizaba Col. Roma	Failure of reinforced concrete column, rods broken by cutting power
7.	"America" school 3 storeys	Taxqueña and Tlalpan	Building of 3 storeys and lightened slabs. Possible vertical collapse by accelerated settling.
8.	"Juárez" Dwelling Complex	Col.Roma Sur	Fracture throughout the East facade corridor by

			accelerated sinkage. It is also possible to appreciate the bending of a tube in front of the column for the same reason.
9.	"Santa Fé" Building of medical consulting rooms. 8 stories.	Querétaro 174 Col.Roma Sur	Building with a vertical settling of approx.20 cms. No structural damage.
10.	Residential building. 6 storeys.	Calle Campeche Col.Roma Sur	Sidewalk fractured by accelerated sinkage.
11.	Residential building. 9 storeys.	Calle Zacatecas	Idem. (seen from another angle).
12.	Residential building. 9 storeys	Calle Zacatecas	Collapse without damage on the first three floors. Note the extraction of a anchored and curved pilinh on the foundation beam.
13.	Residential building. 9 storeys.	Calle Zacatecas	Note the piling under the foundation beam and the structural fracture by impact, from the 3rd level of its 9 storeys.
14.	Building of the Pino Suárez complex. 22 storeys	Pino Suárez & Fray Servando Teresa de Mier	Steel structure collapsed to ground level.
15.	Edificio Chihuahua	Tlatelolco Group	Failure of anchorings on lighted slabs.
16.	Building of the Pino Suárez complez 22 storeys	Pino Suárez & Fray Sernando Teresa de Mier	Hollow steel columns, reinforced.

17. Residential building. 4 storeys	Calle Campeche Col.Roma	Failure by cutting on the 4th floor and settling.
18. Residential building. 6 storeys	Col. Roma	Failure of reinforced concrete structure in columns and lightened slabs.
19. Residential building.	Tlatelolco complex	Failure of columns and rods by cutting force
20. Idem.	Idem.	Failure of columns and rods by cutting force.
21. Residential building Chihuahua	Tlatelolco complex	Failure of lightened slab structure
22. Idem	Idem	Failure in lightened slabs and anchoring of rods on the tops of the columns.
23. Church of Santiago Tlatelolco	Central through-way Lázaro Cárdenas	First Aid installations in the church, which was not damaged at all.
24. 3 storey building	Bolívar and Nezahualcoyotl	Built with tepetate, partitions and without reinforced concrete structure. Undamaged.
25. Residential building 2 storeys	Calle Nezahualcoyotl	Building of partitions, without concrete columns or beams, which did not fail.

26. Superstructure of deep well.	East side of Revolution Monument	A sinkage of approx. 7.5 mts. with respect to ground level.
27. Office building National Lottery 26 storeys. Triangular floor.	Av. Juárez & Ejido.	Suffered no damage whatsoever. Only on the 26th floor a filing cabinet fell.
28. Idem	Idem	Photo of the floor taken looking upwards from the sidewalk. Note the perfect verticality of the chamfer in "V" form, which finishes the intersection of the SE and NW facades.

NOTE: The photographs were taken directly by the engineer Adrián Breña Garduño, in Mexico City, on professional iniative and as Chief of Voluntary Brigade No. 217 of the Mexican Civil Engineers College. The 28 photographs presented have been chosen from 230 similar.



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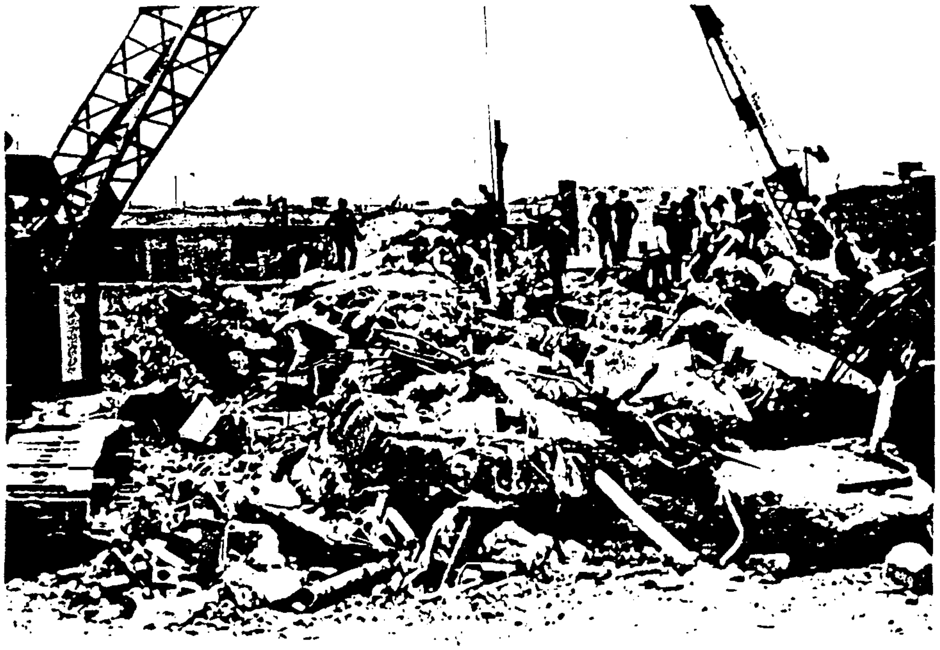

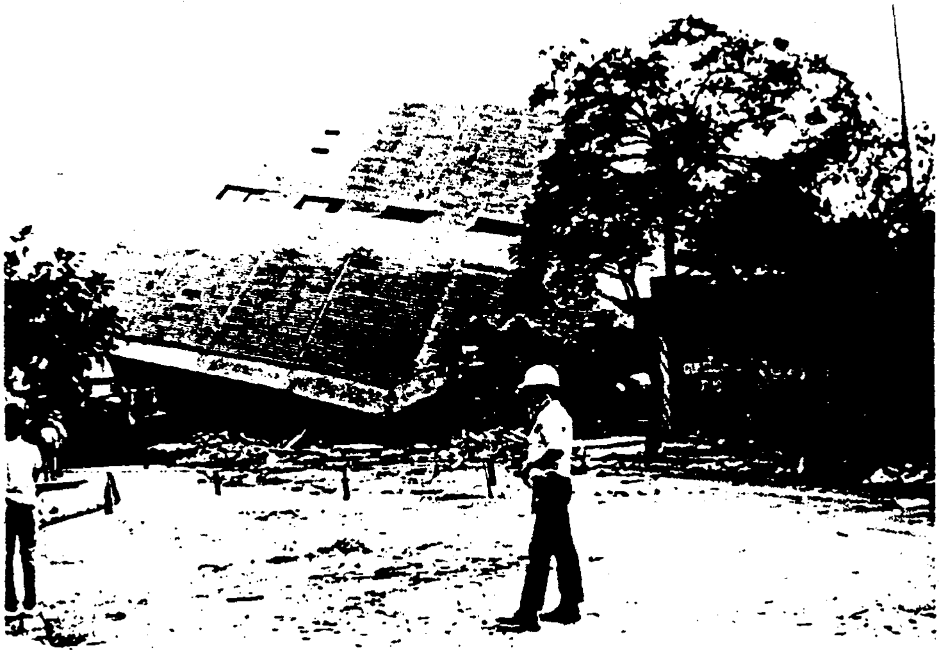

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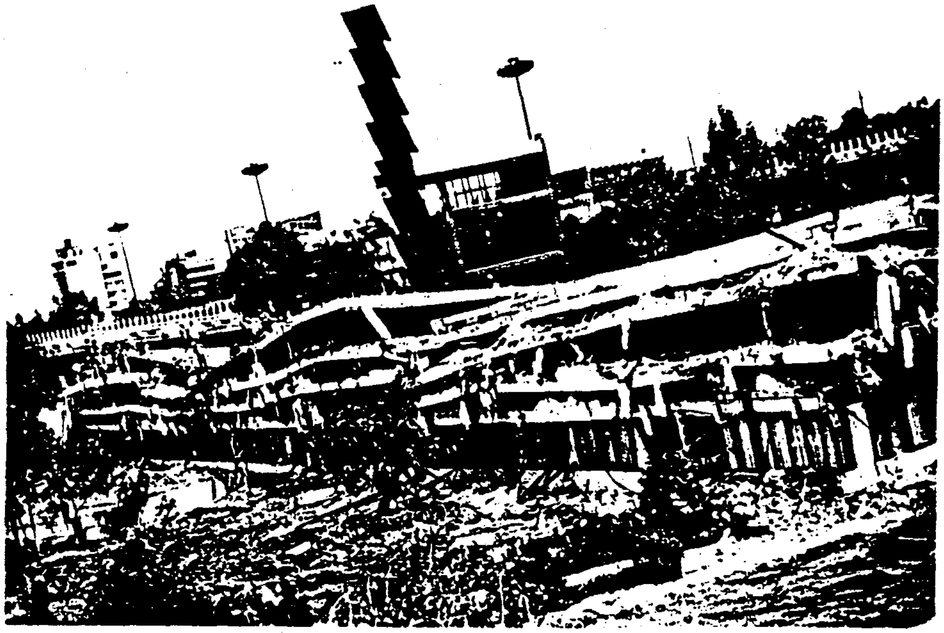

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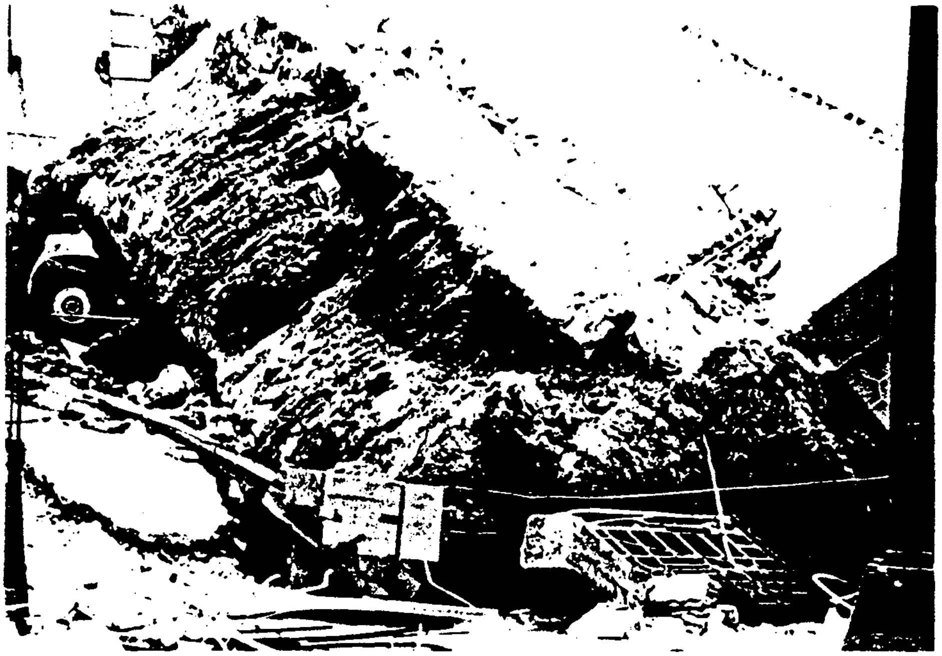

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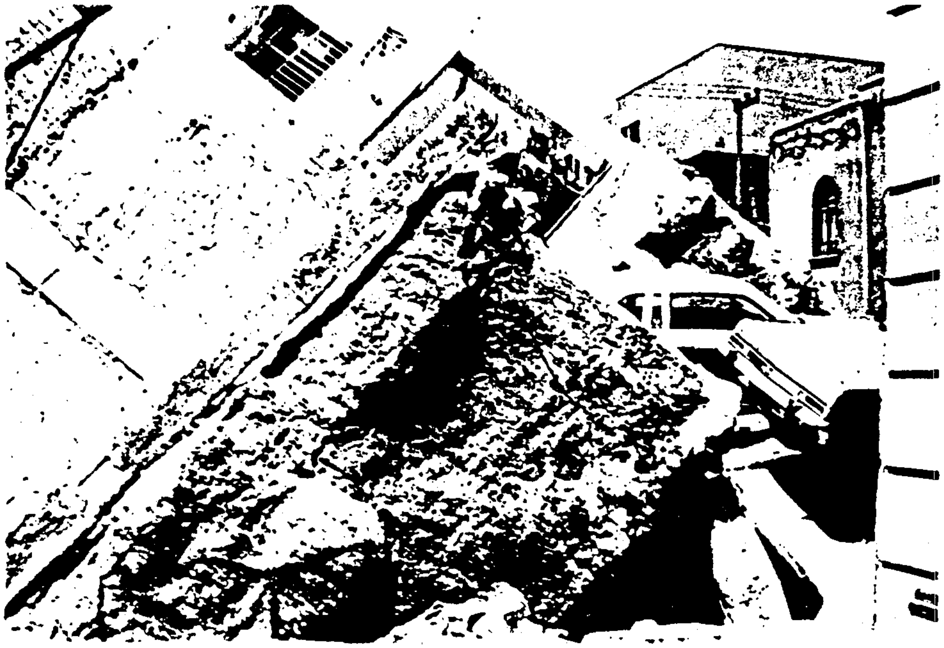

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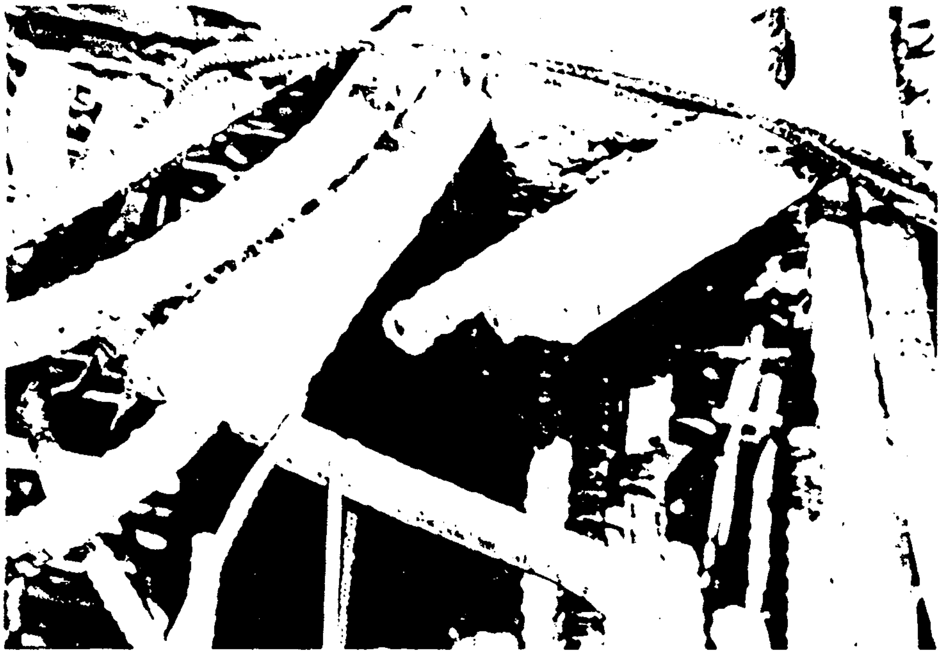

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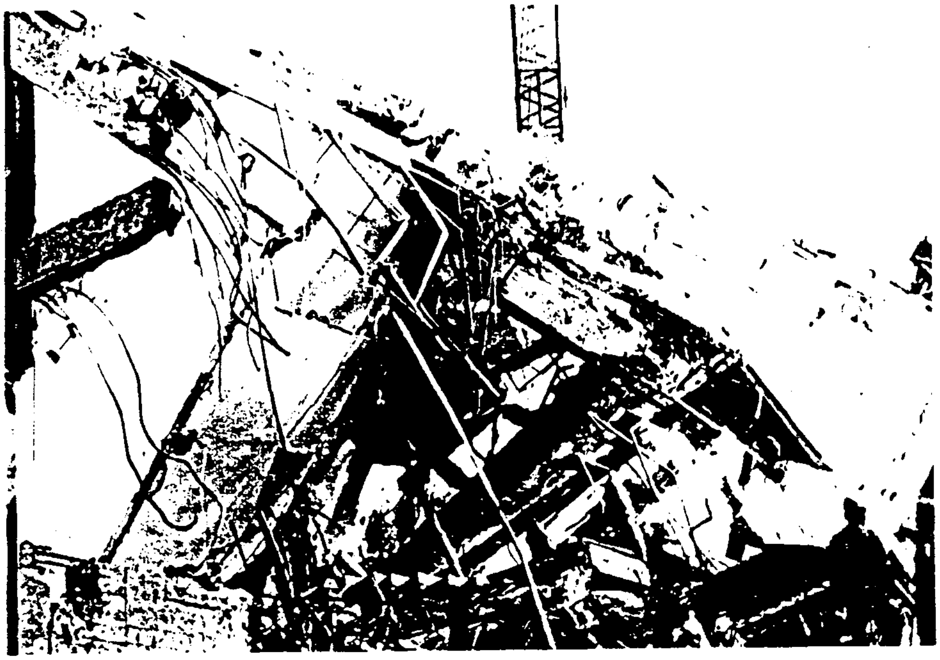

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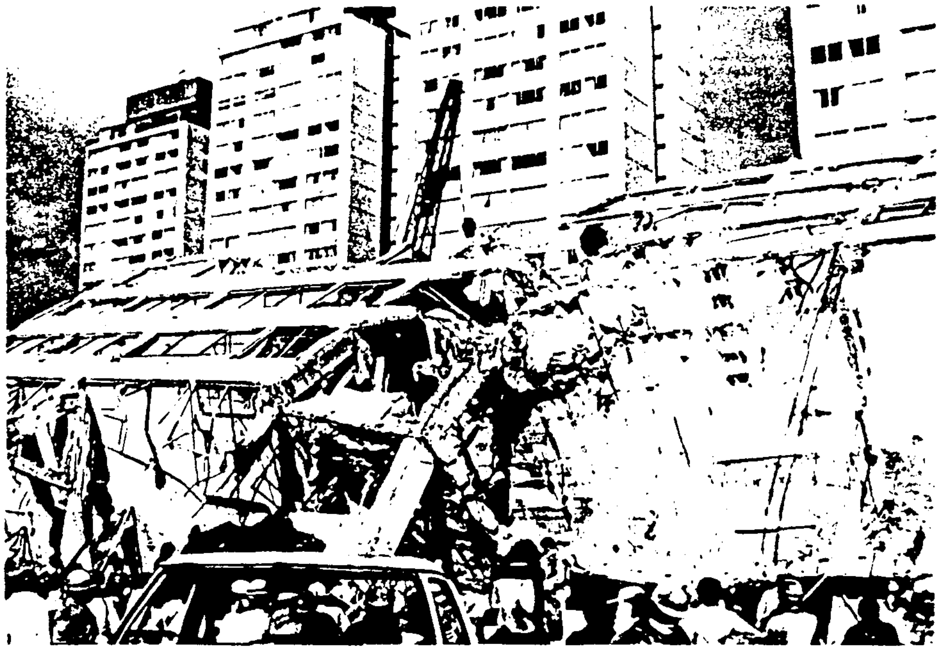

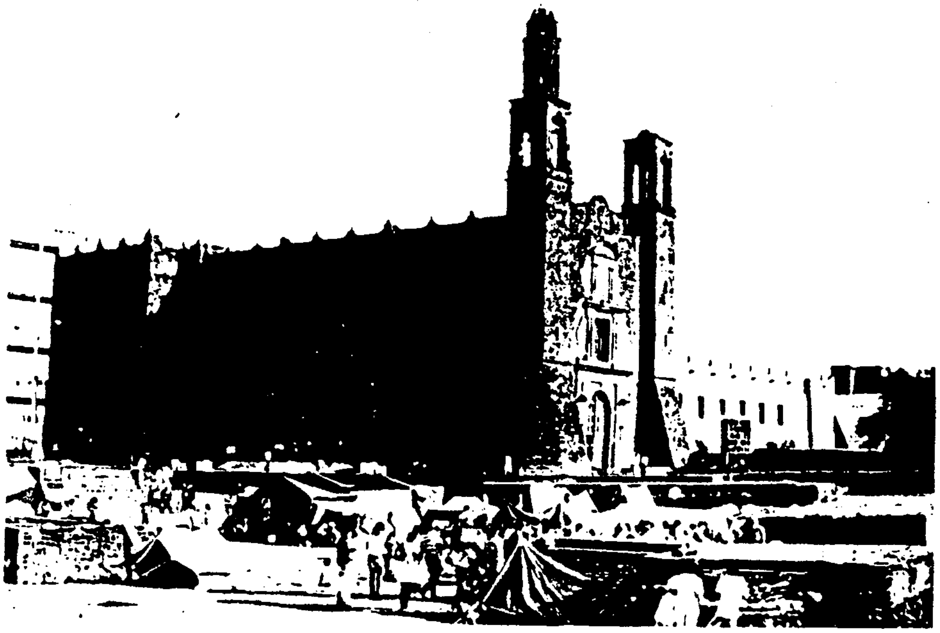

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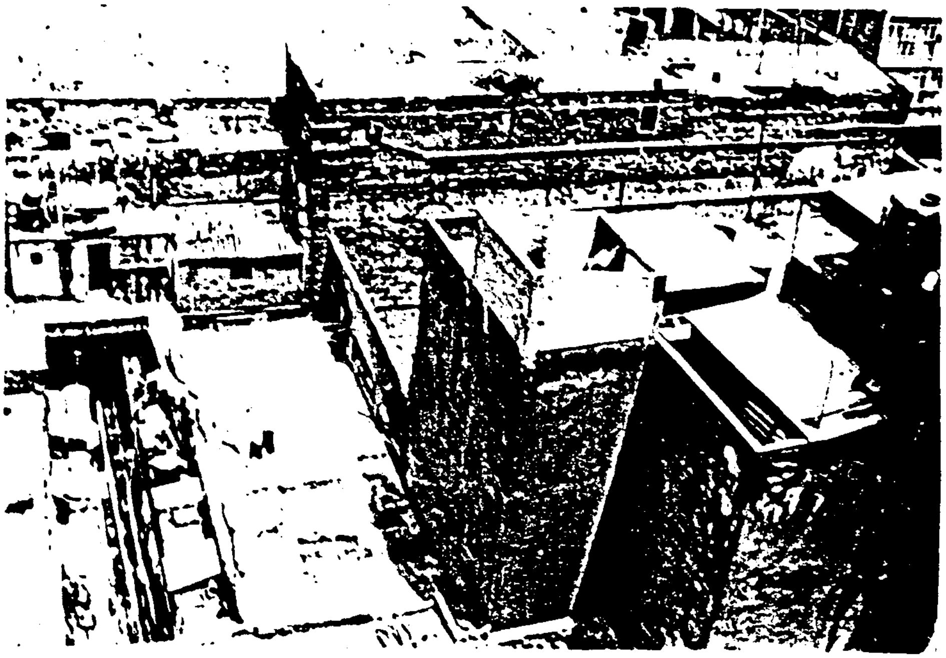

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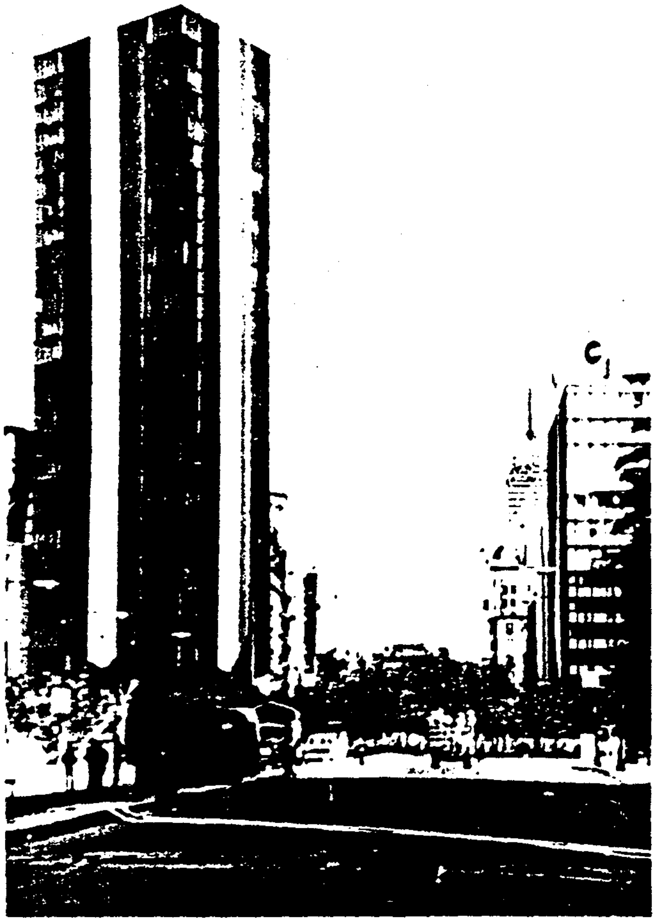

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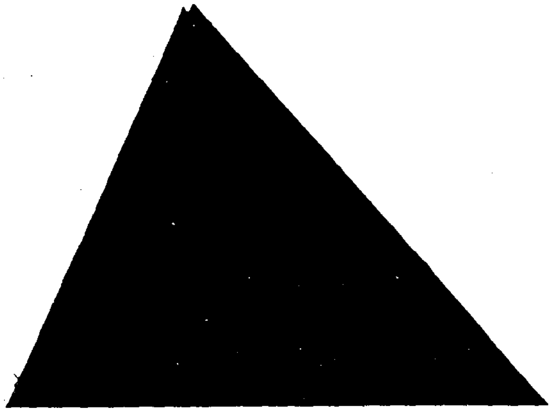

CONSTRUCTION SYSTEMS

Manuel De la Colina Riquelme

It would not be pertinent to speak here of prehispanic constructions; their characteristics have little to contribute to the subject under discussion. Construction techniques in the XVIth to XIXth centuries shall be viewed rather within the historical context. The following comments point to the final years of the XIXth century and to the present century. An exhaustive examination would require too much space and call for documentation beyond the scope of this short review. As follows, we outline some outstanding characertistics of the above-mentioned period.

It is worth pointing out that this review is limited to the central part of the Republic and particularly to the Federal District. In the North as well as in the Southeast, and also the coastal areas, buildings exhibit some characteristics of their own and for the most part are outside the seismic zone (North-east and Yucatan).

It is difficult to separate the architectural concept from the practice of the very architect who conceives it. However, the exposition mentions some buildings that are characteristic, but not of their architects. Dealing with a subject in which "failures" bear valuable teachings, it would be unafir to point out their authors as guilty, while the authors of buildings that have proved their seismic resistence might be thought to be pointed out here as admirable. If any conclusion can be drawn from the experience, it is that under seismic forces, all human knowledge is minimal and that any professional engaging in construction can only apply his utmost determination for the works under his care to be capable of protecting the lives of their occupants. The material damage can be repaired.

Construction in the late XIXth century and early XXth was characterized by heavy masonry walls, small openings and preponderance of blind wall surface over openings. Excepting some ecclesiastical or monumental constructions, the height was limited to three or four levels. On the ground floor, constructions were characterized by interlocking masonry walls, perpendicular to one another, surrounding one or several patios that served to provide light and ventilation to the interior. The floors and roofs were on basis of ood beams; the small clearings between one beam and another were spanned with boards or with small brick vaults.

Resistence to earthquakes was provided by the large walls and it is noteworthy that the colonnades and arcades surrounding the perimeters of the patios have not suffered much damage, notwithstanding their flimsy appearance.

Steel began to be used at the end of the XIXth century for some constructions: bridges, railway stations and platforms, industrial sheds, warehouses. In some cases they reflect fin de siécle French techniques (Chopo Museum). In other cases, the industrialists imported steel shapes and corrugated siding to build a beam and vault system (La Carolina). This last system did not modify in depth the traditional systems of thick supporting walls. The beginning of the present century saw the construction of several steel structures of great size (Legislative Palace - today Revolution Monument, National Theater - Fine Arts Palace).

The revolutionary period set a pattern in the evolution of construction systems. These years saw the beginning of reinforced concrete structures. French influence is again evident. Some constructions are still standing (the building that was CIDOSA on the corner of Uruguay and Isabel la Católica). It is worthwhile observing that these buildings, designed in the infancy of reinforced concrete, when theoretical-practical knowledge of its technique was empirical, have withstood successful such earthquakes as 1957's and 1985's. This provides much food for thought.

On the edges of the city to the North and East, "tenements" were erected to shelter the humblest classes. Their construction on basis of walls of heterogeneous material: adobe or "tepetate" (white rock) partition walls with wooden beam floors and with ill-constructed foundations were the seed for fatal future consequences. On the other hand, the first efforts to solve the low-rent loding problem came in these years, with the constructio n of houses for workers, but do not represent constructive advances.

Until 1930, Mexico City's urban landscape was almost uniform. A few buildings stood out by their height. There had been little modification in the manner of construction, but changes were incubating due to technical and economic pressures. Walls became ever thinner; floors and roofs were now made of reinforced concrete; and the walls that now offered less resistance to earthquakes were reinforced by concrete horizontal and vertical ties providing some resistance to tension. These constructions, though often damaged by earthquakes, seldom collapsed. Mexico's great demographic growth during the years of the middle-third of the century and sundry socio-economic factors are reflected in a population increase of Mexico City's metropolitan zone and that of some other urban centers (Guadalajara, Monterrey, Acapulco) and lead to an explosive increase in the price of land. This coincides with the development of the construction technique of reinforced concrete structures. The urban profile suddenly changes; ever higher buildings rise on all sides.

In Mexico City, however, when heights of five or six floors were reached, foundation flaws appeared. Even if there was no total collapse, many buildings were seen to lean considerably out of plumb.

The erection of the "La Nacional" building opened eyes to the possibility of constructing tall buildings. In fact, the effect of earthquakes had not been the main factor limiting height, but rather the problem of foundations on a subsoil that had little capacity for load. Piles had been used before, most noticeably in the Independence Monument, but they had had no follow-up in their application to the construction of tall buildings. Pile-based foundations would then be the key to high-rise building.

The structures of the buildings erected in the 30s were of reinforced concrete, framed type on basis of columns, beams and slabs. However, steel structures also appeared (National Lottery, Latin American House) with concrete slabs. Some structures, mainly in parking lots, were made with flat slabs, with or without drop-panels and capitals. The waffle slab type was not frequent. We must point out that seismic design was practically unknown and though many of these buildings do have adequate wind bracing and have withstood quakes throughout this time, this is more due to the intuition of their builders than to mathematical foresight.

These years exhibit an urge for investigation and invention. Soil mechanics attain high development; several engineers engage in obtaining foundation systems capable of solving the may problems presented by the city's subsoil; several ingenious mechanisms are developed to underpin foundations and control settling of the buildings; systems are developed to speed up the construction of structures and to bring down the cost of form-work (prefabricated beams, decentering-centering).

World War Two imposed a holding period but as Mexican territory was not directly affected, some important works were executed, in both the public and private sector, specially in the field of industry, and some attempts were even made for the integration of lodgings and industry. The same social-labor pressures undergone by other countries appeared also in Mexico.

At the end of the War, a new building boom came up. Mexican technicians were prepared to confront the new challenges and the architects as well as the engineers felt that they mastered both the structural design and building techniques. The analysis of framed structures, seismic analysis, design of light-weight shells and vaults, the development of high stress steels, welding techniques, new deep foundation techniques, all contributed to give the builder a feeling of confidence, extending as well to the public sector and to the investor.

That time is distinguished by noteworthy advances in anti-seismis design. Young engineers attended master classes and congresses on the subject. The design and construction of the Latino-Americana Tower would prove the advances that had been attained.

Several earthquakes of 5 and 6 degrees gave pause to think that all was not well. However, innovations continued to be tried, without having the back-up of experience. Among others, we can mention the use of flat slabs on steel columns. Under the action of static load, its performance proved satisfactory. The same thing could be observed in concrete structures in which the slabs were not monolithic with the beams.

The 1957 earthquake, of more than 7°, proved that there were serious flaws and that it was necessary to rethink the entire process of design and construction in so highly seismic a region as the center and South of the country. On that occasion, damage in Mexico and Acapulco was considerable, in addition to that suffered in other minor cities. However, there were not many deaths and in only one or two cases the collapse of a single building had caused multiple casualties, and as on the other hand such public buildings as schools and hospitals, with a few noteworthy exceptions (such as the damage in the Santo Tomás campus), had withstood the quake successfully, after a short time the lessons that should have been capitalized were allowed to fall into oblivion.

From 1957 on, the city's growth accelerated ever more and the increase in land values made high rise construction attractive.

Also, certain aspects of the Building Code were to have an influence on construction projects and systems.

Two are worthy of mention. The limitation to the building's height indices to limit the depth of structural space to a minimum, in order to obtain a maximum of leasable area. We must keep in mind that a reduction of 25 cm in the height from floor to floor in a ten floor building implies the possibility of increasing one more floor of leasable area. The obligation to provide parking space in all kinds of buildings led to designs having ground floors supported on isolated columns, while the upper floors had many walls providing great rigidity.

On the other hand, the architectural designer took little account of the effects of a high intensity earthquake. The architect designed without awareness of the risk implicit in structurak asymetries or in columns projecting beyond the facade beams. The structural designer felt sure of his capacity to design the most daring structures and seldom corrected the architect's offsets. On the other hand, both from the viewpoint of limiting the structural depth between floors and from the viewpoint of economy in centering, the use of flat plates and waffle slabs without drop-panels or capitals was begun. There were no case histories regarding their perfromance under the action of earthquakes and, in most cases, little attention was paid to their construction details.

Other systems exhibited variants characterized by the use of precast beams and small vaults supported on a framework of reinforced concrete beams and columns. There was no feed-back either regarding their seismic performance.

The enormous amount of construction executed during the seventies implied improvisation. In such a short time, it was not possible to prepare professionals or even technicians with due experience in construction. The work was performed having as goal the largest leasable area, in the least time and at the lowest cost. Everything else took second place.

On the other hand, different socio-economic pressures led to semi-abandonment of maintenance in the buildings erected in the years before the War. Many factors were adding up that contained the seeds of a tragedy.

The September 1985 earthquake evidenced the manifold defects and vices into which we had fallen.

No one in particular can be blamed for the failures of the buildings and their tragic consequences. But we must keep in mind that within a few years another quake with similar characteristics must happen again. We all have the duty of contributing with our effort in order to prevent a new disaster, but, particularly, all those who are in one way or another linked to the construction task must pay the utmost attention to the causes that contributed to building failure, and never forget, at any moment, the lessons these events have imposed upon us.

BUILDING CODES AND THEIR INFLUENCE ON DESIGN

Manuel De la Colina Riquelme

Construction in the Mexican Republic has been subjected to several sets of regulations: federal, state or municipal. Nearly all the codes are modeled on those for the Federal District, which is the most advanced and reflects more complex technical, economic, legal and social conditions than those appearing in other entities. Some cities, Guadalajara and Monterrey, and the states already have their own codes.

There are multiple Laws, Regulations, Standards and Codes applicable to construction. These range from construction methods and standards for building materials, such as steel or cement, to urban and regional planning. As can be assumed, there are different entities authorizing and monitoring the activities subject to such laws and regulations.

In the aspect pf seismic design, it is rather the Building Codes that are addressed at establishing the criteria that are to rule both the work's design and its execution. Therefore, the following comments refer only to some aspects of the regulations that have been in force in the Federal District.

Before 1942, the Code was rather oriented to setting standards to ensure adequate lighting and ventilation, to establish certain dimensional standards as minimum acceptable for the rooms and to make sure that lodgings had the necessary services for cleanliness and hygiene.

It was foreseen that the design of foundations and structures should be revised and authorized by the corps of engineers of the Department of the Federal District itself. It can be stated that all the main constructions executed in the years immediately preceding 1942 were closely examined and even their arithmetic operations verified. However, lack of experience and of knowledge in seismic design, which was then in its infancy, makes it possible to assert that most of these constructions were not reviewed with regard to earthquakes. Only those of more than five floors were subjected to some superficial computation.

In 1942, a new Code was published making seismic design mandatory. By then, buildings of some height had been erected and some had been damaged by 5 to 6 degreee earthquakes.

The criterion established by this Code was oriented to static analysis, and deems that acceleration will be uniform at all levels. The Code states as responsible for the works a duly registered professional, who could be a civil engineer or an architect.

From the start, this document was received with distaste by the professionals, as it deemed it to impair their constitutional rights by demanding posting a bond so that they could act as registered professionals. However, it was in force until 1952, in which year the modifications requested by the Colleges were made. These modifications made no alteration to the articles regarding structural design.

The strong quake of 1957, which caused serious damage to recently erected buildings, led to the preparation of "emergency standards" modifying the design concept and increasing seismic coefficients. These concepts were closely studied in the years following and incorporated into the 1966 Code. These gave more importance to the dynamic design and considered accelerations as uniformly variable from ground level to a maximum at the top of the construction. In this Code, the concept of Works Director is set forth and the trend begins to determine responsibility areas by specializations, without clearly delimiting the fields.

The contents of this Code as regards architectural design, followed the lead of the preceding ones, but reveal some pressures deriving from economic and urban aspects. The permissible height was increased (to improve profitability), the need to provide parking space became a concern (traffic jams were beginning). On the other hand, the structural design aspect is more detailed and begins to give preference to limit design as against working stress design. The Code contemplated a"Review Committee for Code Reforms", the purpose of which was to maintain its text up to date as time went by. Legal experts, however, felt that such reforms were not feasible within the guidelines of existing jurisprudence. A total revision was preferable, instead of a number of small amendments.

The Committee constituted to that effect had the representation had the representation of the Colleges of Design Professionals and of the Department itself. In 1976, the new Code appeared. Some of the concepts are similar to those of the preceding Code.

The Works Director would continue to be solely responsible before the authorities. This did not fail to cause some concern among professional circles. The case could be that the Works Director had not participated in any aspect of the design and yet, he was the only one officially recognized.

These Regulations, however, exhibit some innovations.For the first time, they acknowledge the need to establish security standards against fire. They include standards regarding electromechanical installations and lighting. Architectural design was compelled to modify many of its aspects in order to fulfil the new requirements.

Structural design was definitely oriented toward statistical and plastic methods and, in the field of seismic design, it inclined preferently toward dynamic analysis.

Wind design takes on more relevance. Foundation problems are well-defined. In view of the difficulties experiences in order to modify the preceding Code, the new version incorporated only those concepts or criteria that might be deemed as basic and left for a body of Standards the task of detailed definition of structural design procedures, life safety, building equipment, etc.

The structural standards were drawn up rather quickly and were accompanied by comments and numerical examples. How far this was beneficial is subject to discussion.

Focus on such problems is distinctly numerical, without entering upon constructive aspects and each example is dealt with in an isolated manner.

How these were interpreted and applied by inexpert structural designers' clerks is a question mark.

On basis of the Code, Standards and Comments, many constructions were erected on basis of waffle flat slabs. It will not be possible to determine the causes whereby a large number of these constructions failed.

As in design aspects, the Code also contained a large number of requirements for the work's correct execution: strict tolerance, prohibition of modifications to the approved projects, prohibition of changes of use of the buildings.

However, the September 1985 earthquakes made it evident that the best intentions of a Code can literally collapse, if those who are to apply them neglect any link in the chain between the wish to have a building and its concept and realization. If anything can be said, it is that the disaster cannot be attributed to the Code, as a number of constructions executed under far inferior standards than those provided therein remained standing, while works supposedly executed under the stricter standards collapsed.

After the earthquakes, new Emergency Standards were drawn up. Perhaps they were not necessary at that moment, in which noone was thinking of building, but in cases like this, perhaps a measure of this kind may serve to soothe fears, which are not always obedient to reason.

Before the earthquake, a new Building Code was under study, its publication being stopped by the events. It was officially published and took effect in the month of July, 1987.

EFFECTS OF CHANGE IN OCCUPANCY TYPE

Manuel de la Colina Riquelme.

The causes provoking structural failures under the action of static or seismic loads are innumerable.

One of these is excess load or irregular distribution of the loads in building.

Some constructions present well defined loads from the project stages: hotels, hospitals, apartment buuildings, schools, even though these undergo remodelings that alter the distrbution of the forecasted loads. In some types of buildings, determination of loads is uncertain: industrial, administrative buuildings. The problem becomes more acute when such constructions are not projected for a well determined end. This type of construction have multiplied in all the great cities.

Building Codes define the typical loads that can be foreseen in such constructions, but when areas to be leased are involved, the loads fluctuate through time. While a tenant may require large open spaces with light weight furniture, the next may require building concrete vaults, or concentration of excessive loads due to filing cabinets or safes.

Although it is said that the office of the future shall eliminate a great deal of paper, as of now, paper and filing systems constitute very heavy loads. The filing cabinets are not only heavy, but sometimes they require in turn vaults to secure them against theft, alteration or loss through fire. These loads are generally not foreseen in the design, and building managers seldom take the trouble to check that the tenants do not overlook the structural elements.

In the zone comprised between the Zócalo (main square) and the Viaducto Miguel Alemán, and on the Tlalpan causeway, a large number of buildings could be seen to have been erected without a precise purpose. They were characterized by large open areas in several floors.

In many of these, large freight elevators had been installed, capable of raising light trucks to be loaded at any of their many floors. The loads were distributed irregularly, as some areas were allocated to raw materials, others to machines and others to finished products in the garment industry. There were within one same building light manufacturing, banking operations, school activities. Such combinations created the utmost irregularity in the loads.

Almost all of these constructions exhibited deficiencies in design and execution. The goal was to obtain high profitability, in the hope that an earthquake like 1957's would not be repeated, and in fact it was not repeated; it was worse.

If such buildings exhibited faults in conception, design and execution, the loads were almost always within the foreseen limits. But through time, other constructions had undergone radical changes in use.

Some offices became workshops; homes or apartment buildings became offices and received totally unforeseen loads. Walls were also eliminated that in some cases might have helped to impart rigidity to the structure.

The Building Code stipulates that plates stating the maximum permissible live load be fixed on all constructions. These are rarely left in their place and leasing contracts do not always state the load limits foreseen for the building. There is no doubt that this was a contributing factor in damaging the structures of several buildings.

In the future, the authorities as well as the owners and managers of buildings should apply the utmost perseverance to watching that the buildings' load capacity it not exceeded.

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SOCIO-ECONOMIC FACTORS RELATED TO THE 1985 EARTHQUAKES

Manuel De la Colina Riquelme

This is the subject that perhaps has received more attention from newspapermen, sociologists, politicologists and economists. This is the field of their specialities and it would be presumptious for an architect to invade fields the disciplines of which require a specialized preparation. Thus, the following comments should be taken as complementary to the already performed studies and as a contribution to those yet to come.

The main causes for property damage, personal injury and death were the collapse of some buildings, trapping those who were inside them at that moment, the total or partial fall of some buildings on neighboring property or vehicles parked in nearby lots, and the fall of non-structural elements such as ceilings and partition walls. Fires provoked by failures in electrical and gas installations were a factor that contributed to some disasters, as in the case of the Hotel Regis and the SyR building on Juárez Avenue. Fortunately, as the city does not have an extensive network of domestic gas, damage for this cause was limited. Industrial gas and petroleum derivates pipelines stood up without causing serious damage. The water supply, electric power and the drainage network, although severely damaged at some points, could be repaired and these services could be restored within a few days.

The security services were not under critical pressure. The police and fire departments, ambulance and emergency modeical services were not paralyzed at any time even though many health-care buildings were seriously damaged.

Although the Mexican Army is prepared to give help in case of disaster, in the metropolitan area its members always acted with great discipline, under the orders of civil authority.

The response of the city's inhabitants was admirable.

Perhaps before the earthquake, the spirit of sacrifice and generosity of a society that was deemed as an example of selfishness, indifference to the pain of others, urge to exploit, might have been doubted. The response to the disaster gave the lie to such ideas. From the first moment, the volunteers dashed to the rescue of victims. Without technical guidance, without knowledge whereby to perform nigh risk work, often with no other tools than their own hands, hour after hour, their dedicated their efforts; struggling against time, they succeeded in restoring to life many that had been given up for lost. The rescue of newborn babies, some from the arms of their dead mothers, thrilled the whole world. Without underrating the generous help from abroad, we can say that it was the firm and valiant response of the Mexican people that allowed it to bring city life back to normal.

Within a framework of such positive values, how could a drama with such negative aspects have occurred?

The specialists have described with great talent and knowledge the labor, legal, medical, social, political and economic aspects. However, they have left aside the causes for the collapse of so many buildings.

What factors contributed to their failure? Ignorance of structural design? This could have been a contributing factor, but many buildings that remained standing had been calculated by the same methods as those that collapsed.

Flaws in architectural design? Evidently the asymetries, the limited structural depth between floors, the use of waffle flat slabs, the use of columns without adequate lateral bracing were contributing factors, but they could have been taken into consideration in the structural design. Careless execution? This is beyond doubt and perhaps was not studied with attention, but the urge to rescue victims and clean the streets made it difficult to expect that each collapse could be studied by experts. However, some lessons were drawn and will serve for future constructions to be more secure.

Conditions are known to have existed that led to construction flaws. Unfortunately, some of these still exist and, if they remain uncorrected, there is the risk of a repetition of the disaster.

Many personal aims contribute to the execution of a building. Someone requires a space to carry out his activities. He will make cost-profit studies and take into account the possibility of leasing or building. There will be investors aware of the existence of a strong market for leasing of space who will study the possibility of building. They will ask for preliminary studies from specialists in the field of design and real estate investment.

They will study the legal, financial and fiscal aspects. If the results of such studies are positive, they will almost certainly come to the conclusion that it is attractive to construct the largest possible leasable area, within the least cost and in the shortest time. They will then commission the design and, in many cases, skimp on both the time and the cost to develop it.

In such conditions, the project will show serious deficiencies, as limitations on time and available economic resources for its development lead to lack of study, as regards both foundation and structural design as well as construction details.

Another aspect of the design, is that involving public buildings. Some are developed by the government agencies' own technical areas; in other cases, design services are contracted with outside professionals. A common case has been that the architectural design is assigned to one professional, the structural to another, and those pertaining to mechanical installations to one or more specialists. The coordination that should be in the hands of the architect remains to be done by the agency itself and is seldom given detailed attention.

In both the public and the private sectors, contracting is done through bidding, and the competition is generally assigned to the contractor having the lowest bid.

Most construction companies lack specialized departments in all branches of construction. Therefore, once the contract has been secured, they will subcontract a volume of work that is usually in excess of 50%. It is a known fact that they will try to subcontract at the lowest prices, and therefore, with companies having limited experience and technical capacity.

The earthquake pointed out these flaws sharply, but even before that, the following had been common experiences: flaws in installations; waterproofing that proved useless at the first rain; doors and windows that fell down at the first impact. Due to the deficient manner in which plans and specifications were prepared, the contractor had many ways open to evade responsibility.

Field supervision requires wide experience. The boom in the 70s originated an increase in the number of constructions. That an adequate number of supervisors would not be available should have been expected. Several works coordinating companies were established, but their high fees made their services inaccessible except for constructions of major importance.

In the comments on the Building Codes, it is pointed out that all works required must be supervised by the Works Director, and the Codes leave open the possibility that he be assisted by qualified technical personnel.

In large size jobs, this supervision was performed with due attention and nearly always had an experienced "resident" who reported to the Works Director on all the details of execution. In medium or small sized works, supervision was deficient and, in some cases, non-existent. The Director's monitoring was limited to weekly visits, some short talks with the construction foreman, some notes and a signature in the log, without a detailed review of the work in progress. The quality of the work was left to the contractor's good will and in the final instance, to the capacity and knowledge of the construction foreman.

The construction foremen or "master" builders have been a decisive factor for the execution of the work. The "master" supposedly is a man with a practical knowledge in his specialty; form-work, reinforcement, carpentry, plumbing, etc.

Although in most cases lacking in higher education, the "masters" have been characterized by the knowledge acquired throughout many years in the construction industry.

Many of them received their training by the side of fathers or relatives who, in turn, had already a great deal of experience.

With the sudden increase in construction activity, there was no time to train a new body of "masters", either through field practice or through theoretical-practical studies. The few existing training centers were rather oriented to heavy construction instead of building construction. Official attempts to promote training have had limited success.

The labor market attracted a large number of unprepared workers from neighboring states. This personnel could hardly perform technical labor in the mechnical industries. A large number looked for work in construction, performing manual tasks, without knowledge of the end purpose of such tasks.

Even this affluence was not sufficient. During the seventies the construction industry turned to feminine labor. Women has participated before in construction, but their role had been limited to light work, such as installation of acoustic tiles.

From this, they went on to perform heavy work such as materials cartage and specialized tasks; installation of lead plates in waterproofing, or placing stone sheathing.

It is fair to point out that the use of such feminine labor had no effect whatsoever on structural failures, as their participation in these tasks was practically non-existent.

The use of untrained labor reveals the contractor's urge to lower labor costs. On one hand, it implied a higher profit, on the other hand more competitivity in bids. Apparently, no one realized that construction quality was deteriorating.

The owner or investor obtained better leasibility, the contractor better profits, the qualified worker an improved salary while the untrained labor was exploited in many ways, not only as to salary but also in the lack of legal benefits and even the most elemental safety leasures. Rushed design, lack of supervision, incompetent execution, lack of experience, all of this contributed to thousands of buildings collapsing or being severely damaged in the September earthquakes.

Another factor that might have contributed to correct, in part, such deficiencies was inoperative. The financial institutions; mortgage and insurance companies were passive. Both limited themselves to relying on the expertise of the works directors. For legal and economic reasons, they never participated actively in the investigation of damages to the buildings, nor on the steps that could be taken to prevent them. Their actuarial studies told them that most buildings were not insured, and no government building was. Therefore, their attitude is understandable though not commendable. The earthquake shook even Lloyds of London. The disquiet soon calmed down; claims were minimal as compared to the magnitude of the disaster.

Many teachings can be drawn from this picture. Professional training levels must be raised; it is urgent that professionals in the structural and design fields acquire practice in the execution of works. In supervision, this practice is essential; it is not possible to pass on from theoretical study to field work direction. Training of the technical personnel or of construction foremen cannot be left to chance.

In some specialties, such as welding, there is already a background of good training; in others such as electricity and air-conditioning, there is personnel available with practical training: this training must be expanded to other fields, particularly to the construction of concrete structures.

Excellence in construction does not derive from the wisdom or genius of a few project designers. It requires the participation of an entire society.

The above reflects some of the factors that influence the construction process. Another factor that contributed to magnify the damage was lack of maintenance. Much of the housing that was destroyed or severely damaged was in low-rent zones, in the central part of the city. These were old buildings that had been deteriorating. The differential settling characteristic of the city's subsoil had cracked their walls; deficient waterproofing, leaks in sanitary installations, had damaged the walls and wood joists; different works in adjoining plots often weakened the deficient foundations; rains, flaws in drains, saltpeter, had contributed to weaken foundations. The tenants complained to the authorities or else made repairs on their own.

The owner was accused of exploitation. He argued that it was no longer possible to perform even the minimal maintenance services.

Nearly all of these lodgings had "frozen" rents. The law froze the rents, but established no mechanisms for these to be modified in any way as time passed. Long before the earthquake, there was a huge discrepancy between management and maintenance costs against rentals. The landowners gave up maintenance, as income from rentals was of no interest against the value represented by the land, the construction's worth being almost nil.

The earthquake caused damages of such magnitude that repair or reconstruction by the owners was not feasible.

The only viable solution was expropriation of the buildings and reconstruction by the authorities.

This has solved, or is in the process of solving the problem of some victims, but the possibility remains that a new quake may destroy a large number of buildings still lacking adequate maintenance. Giving a political- economical solution to this situation is complex, but the necessary steps must be taken to eliminate this latent danger. The new Building Code makes proper maintenance mandatory.

The most recently constructed buildings that were destroyed or severely damaged did not suffer from lack of repair as much as from structural or construction defects, but even these exhibited lack of maintenance. Some buildings that had suffered cracking and even severe damage in 1957 bot only had not had their foundations renewed, but floors had been added; other buildings were abandoned but,without having been repaired or reinforced, they represented a risk for neighbors and passers-by, and finally collapsed in 1985.

Buildings that had already suffered serious damage in construction joints, instead of eliminating some levels or installing buffers, kept their construction defects until their destruction in 1985. The collapse of the Nuevo León building illustrates how caused other than technical can contribute to disaster. Many years had passed since works had been started to correct foundation problems. Bureaucratic formalities, legal actions, disputes between the building's dwellers and the administration, watsed away time that might have been used in correcting flaws.

What has happened is tragic, but will be so even more unless the necessary steps are taken to correct the causes of deficiencies in the design, construction and maintenance of buildings.

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URBAN DESIGN AND THE CITY'S BEHAVIOUR IN THE FACE OF THE EARTHQUAKES

Xavier Cortés Rocha

Every city is a reflection of the society which inhabits it and its evolution is determined by the changes suffered in said society; changes in the social structure, such as those affecting land holdings: changes in the economy, which affect the type and quality of public services; changes resulting from the adoption of new technologies, which are reflected in building procedures and the changes deriving from cultural concepts which modify the life-style of the inhabitants and, therefore, the urban program and nature of the buildings.

The city of Mexico, one of the largest and most populated in the world, was built on a lake, in a seismic area and was, for several centuries, at the mercy of the flooding with which it was periodically afflicted; and even though this last danger has been averted, the first two situations impose conditions on the city's development the forgetting of which cost our society very dear in September 1985.

In the city of Mexico a type of structure based on supporting walls have been successfully developed throughout the centuries, for buildings of up to five storeys, the efficiency, safety and economy of which is beyond doubt. However, the economic pressure on urban land, caused by the migratory process and by the natural growth of the population since the forties, made the constrution of higher buildings desirable. This urban pressure was combined with a cultural pressure, international architecture characterized by open structure buildings based on columns, which offered undoubted advantages especially adaptability, and abandoned the traditional system of building in the search for modernity.

The basic principle was that all could be calculated and, therefore, everything could be built, any architectonic solution was valid and more so in the measure in which they approximated the solutions in vogue in Europe and the United States. Le Corbusier and Mies van der Rohe were the examples to follow, and they were successfully followed.

The new system offered the possibility of obtaining greater economic benefits from a plot of land by building to a greater height; and this situation favored enormous speculation, with well-located urban lots, and therefore new buildings of seven, eight, twelve or more storeys replaced the old buildings of two or three storeys in the best areas of the city, putting more and more pressure on the land and congesting public services. The unlimited densities on many occasions drowned the community structures of traditional colonies and districts.

The earthquakes of 1957 and 1985 put on red lights; however, the conclusion which was to be desired, in the sense of searching for structures appropriate to the type of compressible soil and the seismic nature of the region, was put to one side and the coefficients of structural calculation modifed instead.

We should not fall again into the error of thinking that the safety of Mexico City's constructions is based solely on an increase in the safety coefficients, but the opportunity should be taken to readapt the conduct of urban development, establishing an urban program for each district and not leave the future of this city to the unresitricted game of speculation.

As regards constructions in the compressible soil area, it is necessary to look again into traditional typography and building on the basis of diaphragms which absorb seismic force, and using frames where this is essential. This will condition but not limit the imagination and creativity of the architects; on another aspect, from a general limitation in height and density more benefits can be looked for than inconveniences, in the search for a city which becomes each day more human.

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SOCIAL COMMUNICATION MEDIA AS REGARDS EARTHQUAKES

Sara Grinberg née Topelson

After the earthquake, the communication media became an essential and negotiating social instance: a forum for debate, an inspector of official speeches, parliament, space for contention, examiner of public action, social memory, public opinion, permanent interlocutor of the governmental emergency boards, multiple expression of a baffled but revived civil society, channels for printed social statements and social communication channels to and from the State.

Three dailies and one magazine - Excelsior, La Jornada, Uno Más Uno and Procesó - assumed the open commitment to continue describing the difficulties of reconstruction.

The newspapers displaced private and public television, to the degree of recording an additional demand for newspapers and a surge in readership and following for some of them in particular. Concern for the testimonies of those affected by the earthquake and those injured, and anxiety to make known the different facets of the event, which television and radio could not fulfill.

The first effects of the earthquake of September 19th were felt on the communication media themselves. Televisa's master antenna crashed and took the four private channels off the air. Radio Formula caved in and the rubble killed several journalists. Other newspapermen, El Día's, were trapped in the Regis Hotel. A La Jornada reporter died in a building. Several Channel 2 reporters died among the rubble in the Chapultepec building. The tragedy turned some journalists in subjects of information and victims. About twenty reporters lost their homes in the earthquake; two of them lived in the

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Nuevo León building in Tlatelolco.

The heavy informative machinery started rolling against the confusion. Several special editions went on the street on Thursday, September 19th, itself.

Due to the delay in Televisa's information, the intention to minimize the effects that could be observed in Channel 13's informtion, the confusion and propensity to emphasize normality in that channel's newscasts, and the superficiality and interest of radio to become a social information service rather than journalistic broadcasting, a good part of the most attention-worthy news about the earthquake of Thursday, September 19th, was the print media's attribution.

The communication media wanted to facilitate the return to normal conditions or to dampen people's panic, particularly because during the first ten days after September 19th, quakes continued at a rate of four per hour. Private television returned immediately to its entertainment programming, because "life must go on" as stated by the emcees of some musical programs. Government television circumscribed the disaster's images to its traditional newscasts and always emphasized that that the worst had passed and that México City was gradually resuming its routine. Thus, television and radio had operated as fast information media during the first days.

The use of photographs was a keynote. On Friday, September 20th, even dailies that had never used photographs to illustrate their texts - such as El Financiero - supported their notes and reports on the disaster with impressive takes of collapsed buildings. On the first day, the photographs were basic in order to determine the magnitude of the disaster.

The reader came to understand the emergency after seeing some images on television and confirming them through newspapers.

The word solidarity was printed in large letters on newspaper front pages. The newspapers emphasized concrete facts: "the capital became humanized", "The best proof flowed that the best wealth of Mexicans are Mexicans themselves".

El Universal: "solidarity first". "Life must go on, come what may", in La Jornada, "our people has virtue and civism". Excelsior made a call to social unity, exalting the solidarity that had been exhibited.

At the start of the emergency, radio and television were given more attention, through which forty million people receive the highest volume of information feedback.

The newspapers had important threads of information in their hands, photographs, information, reports, damage evaluations of their own, cartoons, analysis, editorials, articles, displays, columns and all that could serve to reveal the reality.

Media information policy was to record, step by step, the evolution of events. In general, the newspapers took note of the proofs of social solidarity and of the government interest to attend to the events.

Two months after the earthquakes, information went back to normal.

The experience did not last long, but it proved to the print media themselves, what they are capable of.

Carlos Monsiváis:

> "Called up by its own impulse, the citizenry decides to exist through solidarity, through frantic coming and going, hasty crowding together, concern for other lives ... Without prior notice, spontaneously, immediately, brigades of twenty five to one hundred people are organized, small volunteer armies ready for effort and transformation, where there were boards and bedsheets, stretchers appeared; where idle onlookers gather disciplined ranks appear passing objects hand to hand, pulling on ropes, anxious to save at least one life".

THE SOCIAL RESPONSE

Sara Grinberg née Topelson

Peoples fundamental reaction was spontaneous and almost marginal to any organization.

On the stage of the great metropolis unhinged, without electric power or water in many sectors, without public transportation, with serious deficiencies in telephone communication, subject to "information" by state radio and television as Televisa's signal disappeared for several hours, traffic jammed in many zones, telecommunications cut off to the interior of the country and abroad, many banks and businesses closed, prey to rumors and false alarms, the citizenry reacted in different manners. Some engaged in their daily activities, as if nothing had happened; others locked themselves in this homes; yet others ran to make panic purchases in the supermarkets; other merchants increased prices or hid merchandise in order to speculate with first necessity goods; and finally many more, thousands and thousands, as many as three hundred thousand according to an estimate, dash with speed and resolution to help in the manifold tasks imposed by the catastrophe: they are the volunteers.

The volunteers are mostly young people who appear spontaneously without any call or summons, right where they themselves feel that their solidary presence is useful, turning the great city into a huge laboratory of new forms of organization. The fragile basic organization constituted is the volunteers brigade made up of relatives, neighbors, friends, schoolmates or workmates or people who barely meet at that moment. This is a small organization, very autonomous, nimble, lacking hierarchies and commands, and in the prevailing majority of the cases, also adequate means and instruments for the tasks they intend to perform. The only brigade members who have a prior organization are the boy scouts, the Red Cross members, the alpine rescue members, the CREA (Council of Resources for Assistance to Youth) and some other group. As to resources, only young people such as those from Lomas and Anáhuac University have them and with relations that allow them to lighten partly the communications problem, through their radio transmitters; they gather over a thousand tons of clothing, food, medicine, etc., and they have also the means to travel.

Most volunteers are disorganized; they are inexpert, but they have a great will to help, taking over immediately the most different tasks: removal of rubble, rescue of trapped persons among the ruins, gathering and transporting all kinds of means of assistance, blood donation, vehicle traffic control, transfer of wounded, organization of shelters, provision of food, medical attention, etc. In many cases, they perform truly heroic acts anonymously in which, to save a stranger's life, they endanger their own.

Firemen, police and the army also become visible on the streets, the presence of the volunteers being no doubt decisive; it is these who, overflowing the government, multiply everywhere, taking over the city and evidencing the possibilities of citizen participation.

The great spontaneous mobilization of the citizenry and the astonishing solidary popular response, together with governmental stupor and bafflement, are perhaps the most impressive sociopolitical lessons of the earthquake.

The most active victims were the inhabitants of the most damaged sectors: the departmental complexes of Tlatelolco and the Multifamiliar Benito Juárez, the Tepito neighborhood and the Morelos district. In general, they refuse to leave their homes or apartments and remain nearby, camping out in a park, the central sidewalk of an avenue or a public square. They meet in lengthy assemblies, discuss, form new organizations, elect representatives and issue petitions demanding investigations, determination of responsibilities, punishment of negligent authorities, payment of indemnifications, delivery of houses, etc. At a later time, they go to present their demands to different administrative entities (Ministry of Urban Development and Ecology, FONAHPO, Comptrollership, etc.), the Chamber of Congress and even the presidential residence at Los Pinos.

As regards the private sector, the immediate call of the Business Coordinator Council to all businessmen was manifest, exhorting them to give assistance to the authorities and to the assistance organizations and to be solidary. Also from the start a businessmen's campaign was organized to gather food and medicines and the BCC recommended not to make panic purchases, an attitude that was seconded by different organizations of merchants, dealers and wholesalers which assured that the supply of basic products was sufficient and secure. However, many merchants increased their prices.

CONCAMIN and CANACINTRA criticized that the country should have been so lacking in coordination and preparation and asserted that an emergency plan was necessary, in the preparation of which private initiative should collaborate.

The assistance provided by the company and the businessmen as individuals should also be mentioned, which was constituted by cash (several billion donated by the outstanding figures in private initiative and the best known groups: Espinosa

Yglesias, Volkswagen, ICA, Alfa, Modelo Brewery, Industrial Minera México, Bimbo, Ford, among others) and goods and services such as television time for social service, loans of heavy machinery and trucks, pharmaceutical products, hospital service, etc. Televisa deserves a special mention as, without departing from its characteristic style, it succeeded in attaining legitimacy as "the great communicator".

In the educational sector, participation of the public and private universities stands out among assistance work for the victimized people. Although that of public universities was more numerous - about 7,000 persons participated from the National Autonomous University of México, and 400 from the Autonomous Metropolitan University, and rector Carpizo made calls, public statements and the voluntary donation of three days pay by the NAUM's workers and academic personnel, the fact that the private universities and particularly Anáhuac, from which 500 volunteers participated, succeeded with the intentional support of commercial television, in giving wider diffusion to their initial activities.

Finally, the Catholic Church acted rapidly and decidedly, although with little echo among the volunteers. The Primate Archbishop of México, Cardinal Corripio, offered 900 buildings (churches, parishes, etc.) to shelter the homeless, announced the constitution of a Catholic Aid Fund and reported on the donations received, which amounted to several hundred million pesos.

THE OFFICIAL RESPONSE

Sara Grinberg née Topelson

Before the September 19th earthquake, there was no emergency plan in force and in conditions to be applied to any type of great tragedy in the city. In 1983, mayor Ramón Aguirre received a document - The Protection and Restoration System of México City - prepared at his predecessor's request by the Engineering Systems Institute of the National Autonomous University of México and the General Secretariat of Works and Services of the Department of the Federal District. This project, which was at one time even the subject of a decree in the Official Gazette, includes plans of action to mitigate and prevent damage that might be caused by natural disasters (earthquakes, floods, etc.), plans for emergency attention and even a general plan for recovery. The Ministry of the Interior and the Ministry of Urban Development and Ecology han performed similar exercises. However, none of these plans has succeeded in getting over the barrier of political indefinition as regards precise allotment of authority and responsibility for their application.

The first main measures taken by President Miguel de la Madrid to face up to the tragedy were the start up of the DN-III-E and SMA-85 plans of assistance to the population by the Army and the Navy, and the constitution of two boards in charge of attending to the solution of the problems caused by the earthquake. The National Board was headed by the Secretary of the Interior, Manuel Bartlett, and the Metropolitan Board by the capital's mayor, Ramón Aguirre, and by the Under--Secretary of the Interior, Jorge Carrillo Olea, as technical secretary. In this last board, representatives of several Ministries took part as well as of several Federal Government institutions.

Together with these measures, the President of the Republic gave priority to the rescue of victims and assistance to the homeless, suspended his tour through the State of Michoacan and decreed three days of national mourning.

Facing the situation, the president assured that the government had material and human resources sufficient to confront the tragedy and that "we were prepared to go back to normal". On his part, the Secretary of the Interior stated, also in this sense, that in general terms the situation was under control. This first image was in evident contrast to the chaos existing in the city of México.

After the second earthquake, the President appeared before television cameras. He qualified the event as a "great tragedy" and acknowledged that "it has surpassed us in some cases". In his speech, he extols "the people's extraordinary solidarity" and appeals to the "fundamental unity of Mexicans", calls for "serenity, firmness and courage" and expresses his condolences to the relatives of those killed. He asserts that the capital is not destroyed.

In this period, reconstruction shall be linked mainly to the recognition of problems of a political-administrative nature and in particular to a great offer of economic, administrative, political and cultural decentralization. The president also promises to investigate and impose penalties in case of responsibility and insists on honest handling of the funds raised, for which he constitutes a National Fund of Reconstruction with participation of the umbrella organizations of the "production factors". At the same time, other lesser boards were constituted to make possible including new experiences of a local character for participation of specialized groups (technicians, businessmen, etc.).

On the other hand, the government announced that donations would be used mainly for reconstruction of schools and hospitals and the critical problem of housing for the victims is being handled in an uncertain manner.

It is worth pointing out that within the future reconstruction and decentralization, the democratization of México City was absent as a problem.

Eight days after the earthquake, the President began to assign specific missions to his collaborators: the capital's mayor was instructed to preside over a board to review the city's construction codes; the Secretary of Programming and Budget to promote the review of urban development plans, inducements to decentralization and reinforcement of cities in the interior of the country.

The action performed by the city government and by several governmental agencies of the central government, decentralized organisms and state-owned corporations, though variable according to the institutions, contributed in ample terms to face up to many problems, mainly through the application of security measures, of actions directed at rehabilitating public services and at assistance to the affected population.

However and notwithstanding these efforts, problems of great extent began to emerge, catalyzed by the seriousness of the situation. In ample terms, the limited character of the government's actions stands out against a great and spontaneous mobilization as main phenomenon, to which is added the emergence of new groups and that of some already existing social organizations. This mobilization gets ahead of the governmental action, then is constituted in parallel to it, and is finally neutralized through institutional channels.

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THE RECONSTRUCTION

Jesús Aguirre Cárdenas

As a result of the tragedy and of the serious problems arising from the earthquakes, a few days afterwards, on October 4, the President of the Republic, under decree, created the National Reconstruction Commission, on considering "That the number of victims and the magnitude of the material damage produced by the earthquakes of September 19 and 20 last, have no precedents in the history of the country..." The Commission was presided over by the President of the Republic personally.

Likewise, the Commission was to be supported by the following Committees:

Reconstruction Committee for the Metropolitan Area of Mexico City.
Decentralization Committee
Committee on Financial Matters
Social Assistence Committee
Coordination of International Assistence Committee
Civil Safety Provision Committee

On October 9 the Commission was installed to take immediate charge of reconstruction.

A Presidential Decree was issued in the creation of each of the above-mentioned Committees.

It is of special interest to note that the Reconstruction Committee for the Metropolitan Area of Mexico City was subdivided, in turn, into ten sub-committees, which support same:

I. Directive Board for the Study and Integration of Proposals;
II. Sub-committee to Assist and Integrate the Affected Populace;
III. Sub-committee for Urban Rearrangement and Reconstruction Plans;
IV. Sub-committee for Ecological Improvement;
V. Sub-committee of Construction Rules and Procedures;
VI. Sub-committee to Modify and Adjust the Methods of Urban Life;
VII. Sub-committee for Popular Housing and Dwellings;
VIII. Sub-committee for Decentralization and the Deconcentration of Activities;
IX. Sub-committee for Financing Alternatives and the Assignment of Resources, and
X. Sub-committee of Social Mobilization for Civil Defense.

In this way, the Government of the Republic took charge of the problems arising from the earthquakes, and incorporated the participation of the citizens as represented by different sectors of capital society into its reconstruction work.

The spirit of solidarity of everyone was evident, and a real reconstruction team was formed.

The Program for the Renovation of Popular Housing was an outstanding example as regards organization and results, and was created as a public decentralized entity on October 14, 1985, under the coordination of the Department of the Federal District and the Ministry or Urban Development and Ecology, and which completed its work on March 31, 1987.

The purpose of the Program was to take charge of "the damage suffered by the dwellings in the Federal District, occupied by low-income families..." For this purpose the expropriation of a large amount of properties in the affected areas was taken as a base, the buildings on which would be reconstructed when this was possible, or new housing would be built and charge taken of the "other activities required to carry out the Emergency Program for the Renovation of Popular Housing in the Federal District".

After a quick study, action followed immediately: minor repairs, rehabilitation, demolition, construction.

A great human team was formed to take part in this important work and various entities were coordinated to support the work, in a "Democratic Coordination for Reconstruction": the Government of the Republic, Organizations of those Affected by the Earthquake, Institutes and Universities, Technical Support Groups, Colleges, Chambers, Foundations and Civil Associations.

Quick, efficient and economic action was essential. The result: an urban experience without precedent.

A professional participation of special interest in this action was that of the guild of architects.

On February 6, 1987, the International Architects' Union, a worldwide organization affiliated to UNESCO, assigned the "Sir Robert Mattew" award to the program "Housing Reconstruction of the City of Mexico" and in its justification states: "This program is an example of what the governments of developing countries can do when faced by the problem of collective housing to improve living conditions, an area within which architecture plays an essential role".

In summary, great tragedies call for great solutions. Joint work, human solidarity.

TRAINING OF THE ARCHITECTURAL DESIGN PROFESSIONAL

Jesús Aguirre Cárdenas

It is well known that the backbone of the architecture student's training is the subject of Architectural Design, formerly called Architectural Projects. With the passage of time, it has been given ever more importance, both as a general concept and as regards time alloted to its study.

Some decades ago, this subject was only taught in the final two or three years of the career. At present, it is in most schools of architecture a part of the Curriculum, from beginning to end, in all the semesters or years, as the case may be.

It is not only that the time to teach it has been increased, but that it has been acknowledged as transcendental as essential to the formation of the future architect.

Even though the increase of students at the schools does not make it easy, respecting the traditional methodology has been attempted: individualized teaching; however, some think that modern Didactics might provide another type of solutions, mainly for the problem of both number of students as lack of professors.

This being the axis subject of the career, what gives it importance, it should be taught better, with the best professors and with the most selected class contents, for an ideal learning result.

Individualized teaching implies personnal attention by the professor to each of the students, which requires having few students for each professor, and a higher humber of hours of this last dedicated to teaching.

There are few very good professors of Architectural Design and these have not much time available for teaching.

However, there are many candidates to teach the subject. As it was the one to which more time was given in training, when students, all those who finish their career feel capable of taking over teaching. Besides, there is the belief that prior time is not needed for general planning and preparation in particular.

This is a great mistake, particularly due to the importance of the subject. There is no particular concern by the professors for a prior analysis of the whole of the problems in the teaching-training process for design, nor for the methodology to be followed, and even less to identify the true concepts integrating the teaching's contents, nor the organization the subjects should have, for true training to be obtained from their sequencing.

And at the end of the stage, although it should be throughout the process, what to evaluate is not known, nor how the evaluation should be made, both for the purpose of having the student receive one more lesson by being made aware of his successes and errors, and for the professor himself to have feedback so that if necessary he may correct his future activity.

We should add to all this that the architect's true formation consists in preparing him for his professional performance: to do architecture. And, as we shall see below, every design should be capable of being built; from the school, and especially in the last years, architectural design teaching must be integrated with that of technological subjects in a true Integral Workshop. This is still a major problem as the schools.

Integrated professors, with the capability to teach both areas simultaneously, are truly the exception. But even professors who, while being from different areas, accept and know how to impart the course integrally, are also few.

And so, the student ends his career having received his knowledge piecemeal and compelled to be taught in his professional practice both by necessity as by some failures, that from the moment the first activity focused toward the production of an architectural work and until the end, thinking and acting must be in an integrated manner, as this is the essence of architecture.

Those Architectural Design professors are an exception, who are concerned with having the student, in his architectural concept, think simultaneously that his project should also be subjected to a structural design and that, in this, there are highly transcendent factors, such as that they might be subjected to earthquakes, perhaps of great intensity, and that therefore, architectural design and structural design should give as answer the possibility of erecting a building that will withstand that possible event.

Some professors are of the opinion that in teaching of architectural design, concern for structural aspects or what can be built should not enter, at least in the first years of student training, because this constitutes a restriction on creativity, because imagination should be left free, and that these problems are given due importance in other subjects.

The earthquakes have proved to us, in very tragic manner, the need that solutions to architectural projects respond integrally to the static and dynamic forces to which they shall be subjected and that this should be learned, not when there are lessons like this one, but since the professional's training begins.

THE ARCHITECT'S SCIENTIFIC AND TECHNOLOGICAL TRAINING

Jesús Aguirre Cárdenas

What importance should be given in the architect's training to the subjects constituting teaching in the technical area?

Architecture is realization, and Architecture's realization is Technology.

If architectural projects are not realized, architecture has not been done, it shall have remained merely as architectural design. The basic object of architecture is the creation of inhabitable spaces, according to man's needs. If the space has not been created in these conditions, if it remained a project, human needs have not been fulfilled, and therefore the architecture is not complete, it remained only at one of its parts, which is design.

Even though we currently live at a time when most of the activities of all men are controlled by technology, we might call it the "era of technological domination", we should give it is proper importance through balanced use, as an assistance, as a support, as an efficient solution to problems in general, but not in a dominant position of human activity.

Thus, in our profession, technology should be the instrumentation of architecture. We should for no reason allow it to be dominated, controlled by technology. This last should be only the instrument for execution and consequently, it is one of its parts.

Technique allows us, through man's intellectual and physical work, to use, transform and make use rationally, practically and efficiently, of all that nature offers us, in this case to turn the architectural concept into reality.

We take the architectural design as basis for training in the schools, as the main body to which must concur all the other areas of knowledge that will constitute the specialist, who is now in this sense essential, in order to solve the needs of our social community.

Chronologically, professional work has three successive stages: prior study and analysis, project and construction. The technical aspect participates at each of these stages, but its participation grows from the first to the third.

In the first, analysis, it is necessary to have an idea of which are the problems that would appear and the technical resources we have, so that we may compare them against the solution that would be feasible to arrive at with all the other factors that enter into the work to be executed.

An example of this would be to know the type of terrain we have available, its strength, the problems it might present for foundation laying; the seismic characteristics of the zone, the problems there have been in earlier cases and the precautions to be taken for resolving both the infra- and the superstructure; consequently, height and shape possibilities. Technical problems that may be of great importance in some cases.

The student should be made to feel this during his training, that these studies should participate from the initial research, and that analysis is not, as generally, focused exclusively on some of the user's conditions.

At the second stage, which comprises the project, technology now has a more important participation. According to the statement we made at the beginning, we now say that it is a conditioning factor for the project to be capable of being built.

Starting with the preliminary project and all the more with the project itself, any idea of the architect must be totally practicable. What rather frequently happens is absurd, that it is necessary to make amendments to the project when it is already at the construction stage, so that it cannot be practically executed according to the blueprints.

We should always understand what a blueprint is: A <u>complete</u> set of instructions of how our mind's conception can and must be realized.

And if we have underlined the word complete, it is because we should leave nothing to the initiative of the builder. The solutions should be integral, with all the data and instructions for the construction to be made exactly as projected. Here, the architectural design and the technological solutions should be one and the same: the project.

It is to this stage of the architectural process, although it is not the one where technology most directly participates, that the most transcendental teaching-learning process should pertain for the architect's training, and this is generally the failure of many schools: <u>the project must be capable of being constructed integrally</u>.

Teaching of architectural design and teaching of technology and divorced in the schools and it is expected that, in practice, the professional shall learn by himself how to integrate both areas of knowledge.

If the material end of the architectural design is to construct the building, it should have as essence, since it is conceived by the architect, the possibility of being constructed.

An important example of this is that having been drawn into blueprints, that is in two dimensions, crossing of installations among themselves are not taken into account spacially, or of these with the structural elements or the dimensions thereof for architectural detail or for the height of the space between galleries. Many times, having impaired these structural elements also means to impair the building's strength, and therefore these are points of major sensitivity to seismic movements.

Structural computation represents a special problem in teaching. The student needs to understand that the use of materials is not indiscriminate, that it is necessary to know that a task pertains to those materials and that their response thereto is very different according to their constitution, and that some in their natural form and others industrialized, allow us to forecast their behavior in order to use them rationally in a practical and efficient manner to make the buildings strongly capable of construction while being adapted to the architectural projects, as more or less work means a higher or lower quantity of material, which occupies a place that should be specially foreseen from the stage of architectural design.

The structural design is of great consequence at this stage, as being in total concordance with the architectural design, it must give the answer to the necessary security, as human lives, few or many is of equal importance, shall be under its roof, perhaps at critical moments such as those of an earthquake. In this, all the existing information and all the available experience should be exhausted, to that by making use of the technology related to soil mechanics, foundations, structures and earthquake studies, the danger may be reduced to a minimum.

The third stage, that of construction, is practically all technology, but a technology that must respect the architectural design and the structural design totally, provided the preceding stage was handled in the way we have just mentioned.

Here, an important distinction must be made: that technology and construction must not be taken as synonymous. It is true that all the technological knowledge we use in the profession has construction as its final purpose, but not all this knowledge is by itself precisely construction.

As an example, the structural analysis and design, including the use we make of mathematics to that effect, economic studies, costs and budgets, management and organization of and for the works, and all that we might take as factor properly integral to construction: facilities, materials, construction procedures, equipment, machinery, etc.

Construction, the action by which that which has been projected is realized, should provide knowledge starting with the elemental facts about materials. This, coordinated with the equipment, machinery and with the participation of human labor, makes possible the construction systems that, with great variety and constant changes give us the adequate answer to each of the construction problems that arise.

We must teach that solutions are not simply recipes, but

but rather concrete answers to the analysis of the different cases and that this is a series of actions, some of which may be simultaneous, while others must follow a sequence with the very important intervention of time.

We must here make a special mention of the fact that the technique that leads us to the end of the project's realization is as important in the costly multi-use constructions as in the solutions for the simplest social interest popular lodging, from the moment in which technology can help us in the economic factor through serialization, modularity, standardization, prefabrication, etc. Due to the fact that housing is surely the most important problem we have in our Latin American countries, we architects are compelled to study the most adequate technology according to the specific cases, in order to incorporate it into our architectural designs. I believe that the housing solution is only a subject of architectural design, it leaves solutions into the hands of other professionals.

Therefore, in training the students in our schools, we must insist on technology from the simplest to the most complex.

Knowledge of the different applications of the technique having been acquired, we should pass on to the second stage of training, that of integration of technique with the architectural design, which implies at the same time theoretical-humanistic subjects.

This should be carried out in an integral workshop in which the students develop complete projects as must be done in professional practice, including in the blueprints all the elements allowing the person in charge of construction to execute the "work order", which means that which has been drafted, that which the architect has conceived.

We know perfectly that this didactic methodology presents serious difficulties for its realization, but we are convinced that knowing how to do it is the ideal solutio for the professional's training. This is why we have the duty of finding the adequate procedures, in order to so implement it according to the cases.

If we should be concerned in general terms about the quality of the professors for the different subjects making up the curriculum, teaching at this integral workshop should be by maximum quality personnel. It is necessary to find them to have the dual character of being very good architects, in the practice of their profession or having practiced it for a long time, and at the same time professors with true teaching vocation. This should rule professorial selection. This is why we said before that this is the stage to which the most transcendental teaching-learning process must belong.

This does not mean that we believe that a professor must impart the integrated knowledge, this is practically impossible. But what we must indeed prevent is the divorce we mentioned between design and technique.

Logically, the basis for integration should be a subject for architectural design, to which professors specializing in the different areas may apply the knowledge pertaining to each of them, guiding the student in order to integrate into a single problem the solution of all the elements that will lead him to a complete project and above all fulfilling the essential condition of being performable with said project.

This is were the professors must prove their quality, that having the necessary knowledge in their area, and respecting the participation of other professors, they may know how to guide each in his own specialty so that the student and not the teacher may be the one to integrate.

The teachers are usually too concerned with the architectural design per se, and each would like to influence the solution.

The type of buildings is not that important for the subject as that the solution apply the utmost diversity of knowledge.

The key to success is prior programming of all the work, taking into account the relationship with time, the participation of the different areas and throughout the project's process.

The position that professors in construction, structural computation, installations and costs, for instance, should wait until the architectural design has been concluded to begin their participation, is false. As we already said, from the very analysis of the problem, study of each of the subjects can and should be begun.

Construction professors should be interested in starting to think about the different options for procedures and materials, for instance, that may be applicable, so that with their help, the best solution may be devised from the preliminary project.

Those of structural computation may have a participation in decisions from the start, as to the possibility of size of skylights, whether or not an independent structure is necessary and type and materials thereof.

The installations professors can give criteria on different needs and types also helping in the work process, and the costs professors the data and analysis that, while serving as an exercise, may be applicable and even giving orientation for some definition.

The subjects that would be most advisable to cover within the technical area for this workshop are: construction, structural computation, installations and some administrative aspects.

At the end of the work, it is essential to determine the weight or percentage of evaluation that each of the subjects must have, to prevent some of them from dominating in the final results without taking into consideration the part of the others in the solution, which generally happens with architectural design.

Finally, as the technique within the profession covers a large number of subjects in which knowledge is ever deeper and more extensive, and as it would not be advisable for any reason to do so at bachelor's degree level in order not to saturate learning contents, it is recommendable that in the higher demand areas, post-graduate courses be established, first at specialization level in order to delve into the practical aspects that may be necessary, and at master's degree level in order to, besides that, train professors and initiate the preparation of researchers that are so badly needed, both of them, in architecture.

Including in the curriculae the mandatory requirement for the student to participate in the works that are been realized, would be of great importance, so that he may participate effectively in the problems that appear in construction, becoming aware from close up of the difficulties that may come up and the solutions that should be foreseen for all of the processes in a construction job.

To summarize, for the integral solution of the problems of Architecture, for the performance of the job, it is essential that the architect be trained not only in architectural design, but simultaneously in the entire technological area that is related with the profession; in such a way that when performing an architectural design, he will be providing solutions that can be constructed, having the necessary judgment for his project to contain the essential answers to ensure the building's stability, both against static and dynamic forces, mainly as refers to the effects of earthquakes in those places where the phenomenon may appear and according to the soil characteristics, materials, construction procedures, equipment, labor quality, etc.

He must feel how each material works, what is the response of internal stresses against external stresses and besides, how they jointly act, which means how a building structurally acts. With this knowledge, he may participate in the definitions of structural computation and finally, when participating as a builder, have the judgment to know how to distinguish, when faced with special problems, what can be done and what should not be done.

PREPARATION OF THE CITIZEN FOR EVENTS OF DISASTER

Sara Grinberg née Topelson

In the morning of September 19th, 1985, men and women converged on the destroyed areas, driven by a common impulse: the solidary excitement articulated by urgency. They shared the reflex action characteristic of those confronted by a sudden catastrophe, and which appears to be an instinct of the species.

The independent popular organizations at quarter or district level functioned reasonably well during the earthquake. These are genuine organizations, with a genuine popular and social raison d'etre and could very well perform as base mechanisms for a civil emergency plan.

The first to reach the places where some rescue was necessary were the relatives, friends and neighbors of the trapped victims. After them came the firemen, police, relief personnel, Red Cross ambulance personnel. Among all of them, those who directed rescue operations at each particular site were those most capable, most experienced, most dedicated, or loudest voiced.

All of a sudden, among the daily activities and stress, an unusual attitude appeared. As the opportunity for the encounter opened without premeditation, lifelong strangers could recognize one another. Step by step, they acquired the quality of citizens: the catastrophe allowed them to see themselves as co-citizens and then they made their debut in citizenship. The city that had slipped from their hands became theirs again.

Since then, the citizen has become conscious of the need to be prepared to face up to any type of disaster that may occur.

Government authorities in their turn participate as far as possible in this preparation of the citizen, the most important points being as follows:

To educate the citizen through in-depth knowledge of his/her home, place of work, school, and frequently used buildings as regards the procedure to be followed in case of disaster in them.

Routes to be taken to leave the premises
Exits nearest to the place where one is
Evacuation schemes
Persons responsible for evacuation of the building.

Performance of mock evacuations is fundamental in schools, workplaces, apartment houses, commercial centers and recreational centers (movie houses, theaters, etc.). In this last type of buildings, training should be focused on persons working therein, as they will be in charge of timely evacuation.

A first aid unit should be available, which must be checked each week to make sure that it is in optimum condition.

A blueprint of the building should be installed in each location, showing the place where the person is and the surest way of escape, as well as legends with the instructions proper to each case.

To use communication media to make the citizen conscious that he lives in a seismic zone and that he should be prepared to know how to act in case of an earthquake. To this effect, informative spots shall be created to be transmitted by radio and television in clear and understandable language for the people. Publication of explanatory pamphlets on earthquakes and disasters is advisable, to be distributed through schools, community centers, churches, etc.

PREPARATION OF PUBLIC SERVICE IN CASE OF DISASTER

Sara Grinberg née Topelson

The action taken by the capital city's government and by different agencies of the central administration, decentralized organisms and state-owned corporations, although varied in function of the institutions in ample terms, indeed contributed to confront numerous problems, mainly through application of security measures, actions oriented to the rehabilitation of public services and to assistance to the affected population.

However and notwithstanding these efforts, problems of great magnitude began to appear, catalyzed by the gravity of the situation. In ample terms, the limited character of governmental action stands out against a great individual and spontaneous mobilization as the main phenomenon, to which are added the emergence of new groups and that of some already existing organizations. This mobilization took the lead over governmental action, then was constituted in parallel to it, and was finally neutralized by the institutional channels.

On basis of these observations, the public service should have a detailed knowledge of the construction codes and regulations. In order to be able to supervise the buildings, the condition in which they find themselves and the security they offer in case of a disaster.

It must be trained to counsel the citizen in the application of the codes and regulations in force in the seismic zones, as well as to provide the necessary guidance to improve security in the buildings.

Loss of life, injuries and material losses in earthquakes can be reduced with the practice of a preventive program and of an effective application of resources when the disaster occurs.

It is necessary to coordinate the participation of the different metropolitan services such as the Fire Department, the Police, the Rescue Services such as the Red Cross, as well as the Army.

REPERCUSSIONS OF THE EARTHQUAKES ON THE ARCHITECT'S PROFESSIONAL PRACTICE.

Manuel De la Colina Riquelme

The earthquakes had a direct impact on the activities of many architects. Projects executed throughout many years of professional life were destroyed. Professionals who had acted as Responsible Works Directors had to confront the threat of being sued both by their clients and by the authorities. In the critical period immediately following the quakes, they had to perform urgent expert inspections in order to determine the risk presented by the damaged constructions. Relatives and friends requested their help to perform emergency repairs and there were plenty of calls due to the prevailing psychosis.

Once some degree of calm had been restored, reconstruction work, expertise reports both of an official and of a private nature, projects to reinforce and remodel many damaged buildings, kept many architects busy. There was time only to solve the most urgent problems.

Over two years have gone by and it time to examine what happened and to determine the path to be followed.

Structural flaws were not to be ascribed directly to the architectural designer. Most architects have nothing to do with this aspect of the project. Flaws of non-structural elements can be attributed to the architect, even when such details were only studied in their aesthetic design aspects and their construction was left in the hands of contractors, who seldom have the experience or the inclination to study them as factors that can contribute to damage in case of an earthquake.Supervision of the work by the architectural designer was generally limited to finishes, whether interior or exterior; and those details that can contribute to limit or eliminate damage in case of a quake were seldom studied or verified on site.

If we are to prevent new calamities, the professional shall have to amend its practices. From the start of his professional training, he must be made conscious of the need to see the structure as an integral part of the project and not as some nuisance that the structural designer adds to the architectural project. The same applies to the integration of mechanical installations into the project; they must not be viewed as mere add-ons.

Lack of coordination between structure and installations has become manifest in cuts made by mechanical installation personnel to structural elements.

It is impossible to know how many buildings were damaged because their structure was weakened by cuts made by plumbers or electricians.

It will be healthy for the future architect, from his first years of study and even more in the first years of professional practice, to act within the construction field under the direction of experienced builders. He will learn how to handle materials and how these are incoporated into the architectural work, through tools and equipment used by workers. He will understand that each material has its own characteristics and that it is a mistake to try to use it in conditions inappropriate to its performance. He will have the opportunity to observe that flaws in design soon become manufest through cracks, fampness, peeling. Sometimes, he may clearly observe structural performance under wind pressure, earthquake action, thermal changes, subsurface water pressure and many phenomena that seem improbable in text books and even lacking in "practical" interest. These observations shall make him aware of the fact that design is not a matter of draughtsmanship or mathematics, but instead something deeper that implies becoming imbued with the construction materials' own nature, until he comes to feel a certain identification with them.

One of the reactions, both of persons outside the profession and among the architects themselves, was to ask for better training in the field of structural design. That such a thing is desirable cannot be denied, but at the same time one must acknowledge that it is neither practicable nor would it necessarily be beneficial for improving the quality of the architectural design. This covers many disciplines and it is not logical to assume that the architect has to master each and every one of them. Granted that his training in the technical field of structures should be improved, it does not seem viable to assign many more hours to the courses related to these disciplines, within the time limits imposed upon professional training. What does seem more feasible is to redirect teaching within the limits imposed by school programs.

Possibly more time could be assigned to study the performance of the structure as a whole, under different load conditions: static, dynamic, seismic, wind, accidental settling; models may be used allowing the student to visualize deflections and interactions between such elements as beams and columns; modern means of audiovisual education may illustrate different causes for structural failure. It will be possible to update teaching systems, preparing the future professional to make use of the powerful means provided by computers. The design professor shall have to accept that awarding prizes to "daring" but unperformable designs means promoting a trend to irresponsibility; "my imagination has no limit, the structural engineer shall make any excess into a reality". On the other hand, the structural design area should put utmost emphasis on making the student understand that mathematics is not a magical wand that can make the bothersome structural elements disappear. Professors in cosntruction methods have to lend more attention to the interaction between structure and non-structural elements under seismic action.

On the other hand, architectural design, structure, installations, construction methods, must be integrated as the student gradually acquires the necessary knowledge. It might be assumed that perhaps, some day, work teams constituted by students from different university schools could be put to work together. An experience of this nature would open their eyes to the true significance of teamwork.

This still leaves bringing active professionals up-to-date. The universities, the Polytechnical Institute, the Technological Institutes, the professional colleges may promote conferences, symposiums, cycles, making available to architects, engineers and construction technicians, the teachings derived from experience in the field of construction in seismic zones, both within the country and abroad.

This is looking to the future. Meanwhile, the architect's task goes on. If something is to be concluded from the disaster, it is that the architect drawing up projects in a seismic zone cannot lose sight of the fact that quakes of 5 degrees will probably happen in less than five years. That within a period of ten or twelve years quakes of 6 degrees can happen, and that within twenty-five or thirty years even stronger movements may occur. If the life of a building is normally considered as of more than thirty years, we could say that all buildings currently projected for the central and southern parts of Mexico will be subjected to several strong quakes and perhaps to one or two of great intensity. It is not logical, or morally acceptable, to draw up projects without keeping very much in mind that the design and construction must ensure that all buildings have the necessary strength to prevent collapse and that their construction details allow minimizing damage, prevent risk both to the inhabitants and to those passing by or living in the vicinity, and to foresee easy, fast and economic repairs of the inevitable damage implied by a major quake.

The architect and the structural designer must establish an intimate collaboration from the start of the project. The structural designer shall have the obligation or pointing out the serious risks implied by defective structuring. The architect must understand that it is his responsibility as much as the structral engineer's to arrive at a solution that will not prove a danger under an earthquake's onslaught. The architect should participate actively in order to make sure that construction details note only ensure the required beauty and usefulness for the building's daily operation, but that windows, partitions, external coverings and internal finishes will have the proper permanence before the seismic movements.

Both, as well as the consultants in installations and the different specialists participating in large scale projects, must apply the utmost effort to make their individual contributions into a harmonious whole. It is a common experience that this lack of due coordination is a cause of damage to the structure, or from one installer to the work of another, because the project did not define the precise space that each construction element must occupy.

The relationship between architect and contractor is often conflictive. For good execution, utmost harmony is necessary and the architect must exercise utmost perseverance in making of the contractor a collaborator and faithful interpreter of his design.

The architect has great responsibility for the coordination of all the aspects of the project and its execution. Due to the deficient technical preparation of the personnel in charge of executing the work, it is likely that the most detailed blueprints and the most precise specifications will be executed defectively and that this will be a reason for not only a bad appearance but also serious risks in case of an earthquake or other disaster. Work supervision and even worker training are required on site. It is clear that this is not an obligation imposed by the professional services contract, but it does come from a long tradition of master buuilders and architects since long gone times.

Somewhere in these essays, there are comments on the need for the architect to make the owner or public servant in charge of monitoring a project's development, conscious of the importance of looking after all the aspects that may lead to an impairment in security. Misunderstood savings may in the long run turn out to be costly or even tragic. Client education sometimes is a cause for bitter experiences but, if the architect often struggles to attain better quality or better appearance in his design, how can he fail to struggle even harder for the stability and permanence of the building he is projecting?

ARCHITECTS, CLIENTS AND EARTHQUAKES

Manuel De la Colina Riquelme

The architect's relationship with his client is always ambiguous, something of an attraction-rejection sort of thing. If the results of an earthquake are added to this duality, the resulting triangle usually will reflect all the facets, from comedy to tragedy. We only need to recall the case of the architect who committed suicide in 1957 because he could not confront the consequences of the collapse of the building at the corner of Frontera and Alvaro Obregón.

The architect-client relationship usually follows quiet paths when construction of a private home is invokved. Family or friendship bonds smooth out the natural difficulties implicit in any construction.

A different situation appears when the architect-client relationship derives from public works or speculative investment. The economic pressures driving the client do not find an adequate response in the architect's professional training. This last seldom focuses on the budgetary stresses of the public servant or the financial pressures of the investor, opposed the architect's aim to attain optimal quality in the architectural design.

In both cases, there is a trend to restrict the resources available for the project's execution. In both cases, there is pressure to shorten the time available for the project as well as for construction.

The client, whether a businessman or a public servant, sees time spent on design as an additional cost impacting the investment or as a dead weight on the programs pertaining to a certain bidgetary period.

The consequences deriving from lack of study in public works are difficult to document. Their results are for all to see.

A large number of the buildings that collapses in the 1985 earthquakes were built for speculative purposes. Even some of the buildings housing government agencies had been erected by private investors and acquired, through purchase or lease, by government agencies. It is not logical to blame public works for all that happened.

The errors incurred upon by real estate speculators are well known although difficult to prove. Unfortunately, their practices are still in force and it is not unlikely that a new tragedy is being prepared for the year 2000.

It shall be difficult to verify the sequence of facts, but some coinciding chains of events can be inferred from manifold cases of destroyed or damaged buildings. The architect's role was limited to preparing a preliminary design that served as basis to prepare the structural mechanical designs. At most, the architect prepared some plans of facades and some details of vestibules or services. In many cases he was unaware of the criteria followed in the structural design.

From the start of the project, the investor already had in mind who the builder would be. This last had already executed similar buildings for him and guaranteed the cost of the construction.

Besides, he offered the client, as part of his services, to take care of the structural design. Such design would be oriented at obtaining utmost economy. It is a known fact that seismic design offers different computational options, based on the structure's probable behaviour.

The cheapest solution might be attained on basis of the most favorable hypotheses for design. But if such hypotheses did not correspond to the construction systems applied in the field, it was evidently a gamble against fate. If a large scale earthquake did not occur, the damage would easily be repaired; in case of a major quake, there was the hope that the damage would not go as far as to cause the building's collapse and total loss.

In this speculative type of constructions, the architect was seldom a decisive factor. The investor chose those professionals who, through lack of experience or need for work, easily acceded to execute the preliminary designs, and the blueprints needed for building permit formalities. Their work ended there. After the earthquake, cases came up in which,when attempting to clear up construction criteria for buildings still standing, the supposed project architect could not be found or knew nothing about the construction as built.

It is not easy to fault such professionals for their behaviour. They were following a procedure established long ago for official works.

In many government agencies, the "architectural" project has been entrusted to a professional; the structural project is assigned to a designer, but without participation by the architect, and the mechanical designs to consultants who may even be unknown to the architect.

This system of work, whether in the field of government works or in speculative works, is not favorable to the conjunction of a well-integrated project. Lack of coordination between the project's different components will multiply and lead to construction deficiencies which, in their turn, can cause serious damage to the construction in case of an earthquake.

In those cases in which the client-architect relationship was well-defined, risk was lower. Even in these cases, the architect was not always a positive element, either through lack of experience in seismic design, or because he deemed that the structural design problem was not his responsibility, or because he imposed capricious solutions in the structural field, or because he allowed himself to be inclucenced by economic considerations.

The architect is seldom trained in seismic design. From his professional training, his bent has been toward the project of static constructions that are unalterable through time. The client has the same idea; what he is going to build shall be eternal and he shall not have to worry about providing it with maintenance.

The architect as well as his client must face up to the fact that any building and each of its constructive elements are subject to constant change. Sometimes, these changes are due to fluctuations in temperature and humidity and are almost imperceptible. Occasionally, the cnanges are violent and of great intensity: earthquake, wind, settling.The architect must be aware of the probability that such changes may occur, and must make his clients aware of the fact that any project must take into consideration and prepare for the effects of such elections on the construction's dimensions.

A great effort is required of the architect in order to make his client aware, but if it falls on deaf ears, it will be almost impossible to overcome his negative attitude.

The client will often think that the architect's recommendations are theoretical subtlties and, in not a few cases, he will believe that his sole aim is to make the job more costly in order to fatten up his fee.

The isolated effort of some architect or other shall be sterile unless joint action is launched with participation of the

Colleges of Architects and Engineers, the Chamber of the Construction Industry, Insurance and mortgage companies and the authorities directly involved. All have been accused, in some degree, of guilt or negligence in the disaster.

A disclosure campaign regading the causes of the damage observed and of the technical means now available to prevent them would be a healthy measure.

In all fairness, it should be made clear that it is not the eventual action by one or several groups of professionals that can prevent a new disaster. Only a conscious and sustained action by all the sectors involved in the field of construction and of society in general, can lead to healthier practices, to ensure the construction of buildings capable of withstanding seismic action.

BUILDING METHODS IN VIEW OF THE 1985 EARTHQUAKES

Manuel de la Colina Riquelme

The earthquakes on September 19th and 20th, 1985 came to be something like a court of final appeal before which all the buildings in several cities in our Republic had to appear. Mexico City is beyond doubt the city with the highest number of buildings and the widest range of construction systems. Some of these prived their quality while others failed miserably, with the resulting number of victims and damages.

The earthquakes' statistics provide interesting data that may serve as orientation for future projects. Architectural form, building height, materials and structural systems, construction details, were factors that in one way or another limited or amplified the damage. By examining such statistics and comparing them with the buildings that were left standing, some mysteries arise. Buildings that had been built before the development of seismic design and which were accordingly not computed to that effect, in some cases exhibited minimal damage, next to others that, having been designed in the light of the latest advances in science, exhibited serious failures. Many steel structures built without adequate seismic design, although severely damaged, did not collapse. Concrete structures exhibited the amplest range of responses to the earthquake, from collapse to insignificant damage.

Some comments on the systems used before 1985 may be of use for orientation of future projects.

Low height buildings, of traditional construction type, suffered little damage. Some that were seriously damaged had exhibited noticeable deterioration since long before the earthquake. Other such buildings were seriously damaged by the collapse or crumbling of walls or parapets of neighboring buildings.

Light weight constructions on basis of thin shells generally withstood well. Already in 1957, this type of construction had been seen to exhibit rather than structural damages, tilting of their columns, due to settling of their foundations. The thin shells used in ecclesiastical constructions, on basis of hyperbolic paraboloids that sometimes spanned 20 meters or more, also performed satisfactorily in this case.

Some hanging type constructions withstood the earthquakes successfully. The light weight of these covers, as well as their flexibility, no doubt helped to withstand the stresses originated by the quakes.

The same could be said of light-weight covers on bases of steel trusses and siding. It was curious to observe in such city districts as "Algarín", "Los Doctores" and "Tránsito", the difference in performance of these covers in two weeks. This zone had suffered a severe hailstorm a couple of weeks before the earthquake. On that occasion, the number of industrial roofs destroyed was considerable. Those that remained standing or had been repaired suffered no major damage from the earthquakes. This illustrates the fact that architects and the structural engineers should not overlook any factor from view that might threaten a construction's security.

Since early in the century, the manufacture of steel beams had begun in Monterrey. Before that time, steel structures and structural shapes were imported. Even after local manufacture of shapes began, and due to economic reasons, reinforced concrete construction was generally preferred over steel. However, some structures such as "La Nacional" and "Lotería Nacional" were designed and built in steel. The first has perimeter walls and coverings of concrete. It has withstood earthquakes successfully through half a century.The second also has exterior concrete walls. This last suffered some limited damage in 1985.

Several other steel structures built since the thirties did suffer damage of certain magnitude and have had to be reinforced or dismantled. These structures were not adequately designed as to stresses from quakes, nor did they have the additional strength provided by concrete sheer walls as did the above-mentioned constructions.

Steel structures constructed since the War received due attention as to seismic design. Dynamic study methods have already been developed to compute deformations and their effects on structural stability. The Latino-Americana Tower is a clear example of the capacity exhibited by well designed steel structures. It has successfully withstood the 1957 and 1985 earthquakes.

Some other steel structures, such as the Petróleos Mexicanos Tower, passed the 1985 test without patent damages. However, some failures were observed, some of them well known. Although not to the point of collapsing, several buildings were so severly damaged that they had to be abandoned and are in process of being reinforced or dismantled.

Design criteria have been gradually modified. As always, economic factors powerfully influenced design. The earliest steel structures were on basis of standard I beams, channels, angles and plates.

The beams on hand were of the "compact" type; they represented a limited risk as to possible failure through buckling. Structures like the Latino-Americana Tower were executed with imported beams of this type, and even fabrication was made outside the country. Later on, the use of welding allowed the fabrication of built-up beams on basis of plates, and the use of tubular columns and composite I-beams was developed. The main fault of these structures was the heavy plates needed to join columns and main beams; this implied great difficulty in the installation of electric and mechanical systems. Such problems were gradually overcome and lighter designs were then attempted to make the steel structure competitive against that of concrete.

Columns continued to be tubular; this shape allows attaining easily the desired moments of inertia in relation to their two axis. On the other hand, beam design substituted standard

I beams by open-web beams. This change influenced in several ways the seismic performance. The lower rigidity of the open web beam increased the deflections, which led to damage in non-structural elements. On the other hand, the multiple components of the open-web beam made it possible for local failures through buckling to appear, and it so happened. Use of this type of beam in the future shall have to be evaluated according to the observed performance.

The beams in these buildings had been connected to the slabs in order to have the steel and the concrete work jointly. This increased the moment of inertia under static loads, but contributed little to seismic strength. The systems thus conceived could prevent failures through buckling in the upper chord but not in the lower chord. The last did not receive due shoring or wind bracing in many cases.

Reinforced concrete structures showed uneven performance. The multiple criteria used in their design makes a well-founded evaluation difficult. Structures based on beams and columns with or without vertical shear walls can be said to have exhibited acceptable performance. Some failures were due to errors in design and construction as welll as to the impacts received from neighboring buildings. In many cases, such impacts were received halfway up the perimeter columns, where they offered scarce resistance to the impact's effect. Some failures can be attributed to deficiencies in the design and placing of the stirrups in columns as well as beams. Other failures can be attributed to deficiencies in construction: inferior quality concretes, deficient or poorly installed equipment, lack of covering according to that required by specifications.

In the years immediately preceding 1985, various new systems had come into use, tending to reduce costs or time of construction. These were on basis of prefabricated concrete beams (whether reinforced concrete or prestressed concrete) and small vaults.

Although their performance under the action of static loads is very satisfactory, they contribute little to increase rigidity in case of earthquakes. The buckling effects in the main beams are not here compensated as by the additional rigidity afforded by monolithic slabs.

Another very fashionable type of construction was that of flat slabs, whether on basis of solid or waffle slabs. The first structures of this type werr used in parking lots, warehouses and industrial plants. They were on basis of solid cslabs without drop-panels or capitals. Failures of these constructions were many and we might say that their future use should be restricted or discarded.

Before 1957, several structures were built on basis of flat slabs, on steel columns. There were already some doubts about their performance in an earthquake. The destruction of several structures of this type in 1957 determined that they should no longer be used. Again, the urge to lower costs led several builders to devise steel and concrete combinations. The steel should take tension and the shears through a lower chord line and an open-web, which was to be anchored in a concrete slab that could withstand the compression stresses. Its performance as secondary elements, subject to static loads, is satisfactory.

In some cases in which this type of beam was integrated into the frames that were to withstand seismic effects, serious deformations were observed through buckling in the lower chord. Under static action, it works in tension, but under seismic action, compressions can appear provoking the buckling that was observed.

Prestressed concrete has been used in many industrial constructions and in bridges and viaducts. Exceptionally, it is a part of framed structures. Its performance was generally satisfactory. This reflects agood design and the fact that the strict conditionstions in its fabrication and assembly lead to a superior quality over the average observed in reinforced concrete cast on site.

The conclusion is that many factors affect the quality of a structure. Good design is fundamental. This should be based not only on theory or on the mathematical model, but on experience.

On the other hand, execution in the field should be done under the strictest standards, taking into account such factors as available materials and labor. Cost reduction, unreasonable reduction of execution time, lack of supervision, shall lead to inferior quality work. This cannot be accepted under any circumstances if we want to avoid another disaster.

PERFORMANCE OF NON-STRUCTURAL BUILDING ELEMENTS IN EARTHQUAKES.

Manuel De la Colina Riquelme

Synopsis.- The following observations refer to buildings of several floors. Non-structural elements must be anchored to the structural elements in such manner that under accelerations from an earthquake, they will not fall off, come unfastened, suffer fractures, or cause damage to structural elements or persons. At the same time, it should not be attempted to anchor them rigidly to two different structural elements; beam and column, two beams (or slabs) on different levels, etc. Designers must keep in mind that in an earthquake, the relative movements between different elements on a same floor or between two neighboring levels, can be quite large and that the necessary clearances must be left to anticipate such differential displacements. The following comments are based on experiences and observations made in a large number of constructions and on the damage from quakes in the past forty years.

A. EXTERNAL COVERINGS

Stone facings, whether natural or artificial, have suffered serious deterioration in earthquakes. There have been cases in which areas of many square meters in stone or marble have fallen. The same can be said for coverings in ceramic tile, vitrified earthenware or Venetian glass mosaic. The solution to these problems is highly complex, almost impossible to solve in many cases.

Generally, coverings are anchored to outer walls, but in some zones they are in contact with structural elements such as columns and beams. Further on, the problem of masonry walls framed between beams and columns is dealt with. The advisability of preventing direct contact between the walls and the structural elements will be discussed.

If construction joints can be left following the advisable separation in walls with regard to the structure, damages to coverings can be reduced. However, local damage can still be caused in the nooks and corners and it is advisable to leave clearances. If the structure includes shear walls and stone sheathing is applied thereto, the problem is reduced, but even so, it is necessary to leave construction joints at each floor's level.

The lengths of contact between structural elements and masonry can be reduced if the masonry walls are left outside the line of columns; e.g., supported on slabs extending 50 to 60 cm beyond the column's face. Still, construction joints will be necessary between one level and the following, and if walls of great length are involved, expansion joints will be required. All this brings serious sealing and maintenance problems as time passes, so that the architect should give much attention to the relationships between structure, walls and coverings.

If masonry sheathing is to be used, it is necessary to lend attention to the anchorings of the individual stone ashlars. A single piece coming loose can cause serious damage and even injury or death to people.

Glass sheets or marble or granite slabs facings have occasionally been set on metal frames. Such applications can follow the methods used in curtain wall construction, as will be seen below, and they are satisfactory.

B. CURTAIN WALLS

Curtain walls have had very acceptable performance as to their resistance to earthquakes. Their design, when executed by experienced contractors, normally takes into consideration thermal expansion and contraction effects and wind action. From this to taking into consideration seismic movements is a relatively simple step.

In Mexico, the use of curtain walls began in the 50s. Already in the earthquake of 1957, some of these, made of aluminium shapes and glass, proved their capacity to withstand movements of great intensity without major breakage of glass.

Through time, aluminium and glass curtain walls have been built; aluminium, glass and stone plates; stainless steel and glass precast concrete, as well as different combinations of materials. The first concrete curtain walls were attached to the reinforcing bars in concrete structures.

This dangerous practice was soon discarded and attachments used currently, without counting on very sophisticated systems, are adequate to withstand seismic movements and stresses.

In order to attain satisfactory solutions, it is necessary to count throughout the project on a close collaboration between the architect, the structural designer, the curtain wall designer and the manufacturer or contractor in charge of execution. It is advisable that all precautions be taken on site to make sure that all the parts integrating the system be mounted or assembled with accuracy and that the indicated clearances be maintained. The above implies that periodic meetings be held between the specialists involved and that at the design stage as well as at the construction stage, all be imbued with the importance of collaboration between those constituting the working team. Sometimes the presence of the architect, the structural engineer, the aluminium designer, the glass installer, the sealants specialist and, occasionally, other specialties; thermal insulators, fire protection, etc. will be required. Although it is true that curtain walls have proved to be a satisfactory solution for buildings constructed in seismic zones, their design should never be left to chance. Deformations induced by seismic vibration can cause severe damage to a curtain wall constructed without due foresight.

C. PARTITIONS, WINDOWS, GLASS

Traditionally, window frames have been set tight with masonry. This has caused the wall's deformations, in case of an earthquake, to exert pressure on the glass, with the resulting breakage. There is currently the trend to leave a certain clearance between the metal frame and the masonry. However, if the fastening systems are not designed to allow some play without deforming the metal, glass will continue to break. This can also happen if the fastenings are set up in such a way that when the frame is deformed, said elements come in contact with the glass. At the present time, tempered glass is not mandatory in high rise construction. This might be advisable for some facades on high traffic streets in which breakage can constitute a considerable risk.

D. MASONRY WALLS

The outer walls commonly used in Mexico are of solid brick in baked clay or cement. In some cases, hollow concrete or vitrified clay blocks have been used. When the wall has been set up in such a way that it will come in contact with structural elements, it has been seen that under the action of an earthquake, the wall is cracked and in some cases even fractured, and parts of the wall fall off. This can be seen specially in hollow block walls. Occasionally, these damages represent a foreseen risk, as the wall is part of the structural system, and the savings in reinforced concrete have been deemed as compensating the expense incurred in repairing the wall periodically.

Although this may be acceptable in some industrial buildings, it is not so in other cases. One such is that of hotels where the cost of walls and decorations, though high, represents a small fraction of the loss of income by loss of the use of a large number of rooms.

An in-depth economic study may help to orient the decision in this regard. If incurring in serious damage to the walls is unacceptable, the use of "floating" walls is feasible, in which separation is left between the structural elements that confine the wall at its ends and its upper part, leaving the wall anchored by its base. It would be dangerous or costly to fix it only at its lower end; on the other hand to fix it rigidly at both its upper and lower part, leads to damage to the wall from the differential movements that appear from one floor to another in a building. The solutions that have been given to this problem have been varied and some success can be said to have been attained. We must keep in mind that this implies that some cracks will appear along foreseen lines to allow compensating differential movements between the wall and the structure.Damage thus caused is easily repaired. In some buildings, the cost has been so low that even insurance could not be claimed as the cost of repair was lower than the deductible.

E. INNER WALLS AND PARTITIONS

In general this type of divisions are of light weight construction and are not linked to the structure, except through screws.

The dry type gypsum board, etc., walls, suffer little damage. Some walls such as elevator shafts, ducts or sanitary services are built of light weight brick or hollow tile brick. It is common to observe that damage to these elements is of great intensity; sometimes displacements of more than thirty centimeters have been observed. Lack of adequate attachment is the cause. In such walls, all the construction precautions indicated for outer walls must be taken.

As a consequence of the strong displacements indicated, other damages are caused to suspended ceilings, doors and installations. All this implies serious danger for the building's dwellers.

The architect must take the utmost care with the construction details and specifications for those walls that are a permanent part of the building. Likewise, through memoirs or reports regarding the finished building, the building's management should be made aware of which precautions it should take in relocating non-permanent walls, e.g., those limiting the spaces of different tenants. Likewise, it is advisable to instruct management regarding loading and construction methods that should be followed by future tenants or users of the building.

F. CEILINGS

The construction of suspended ceilings has been left largely in the hands of the contractors. As a result, the damage suffered by these elements is manifold. Restricting this study to the seismic aspect, we can point out that ceilings built of plaster or mortar can suffer more damage that those built with tiles on a metal grid. It is obvious that in one case, any impact extends to practically the entire ceiling, while the multiple joints between tiles allow limiting the damage. From experience derived through many years, some recommended practices can be pointed out.

The ceilings should be preferably of modular construction, og tiles installed on a metal grid. The suspension should foresee that an earthquake will provoke lateral displacements which in their turn may generate strong interaction between the ceilings and the building's vertical elements. The suspension needs to have diagonal bracing and struts, besides the usual light, vertical suspension.

The greatest damage can be seen in the contact between the ceiling and the corners of columns or walls, but damage can appear in the contact lines of lengthy straight surfaces.

It is feasible to minimize such damage by leaving a certain clearance throughout all the perimeter of the ceiling, avoiding direct contact with the vertical elements.

The suspension system may be coordinated to the requirements of light fixtures, ducts and other installations, but in all cases the possibility must be kept in mind that an earthquake may provoke impact between the ceiling components and those pertaining to installations.

G. INTERIOR FINISHES

Damage to plaster surfaces applied on brick or block walls is unavoidable. If the wall is of the " floating" type, such damage is generally negligible and easily repaired, except in major intensity quakes.

Plywood, cellulose or gypsum board partitions seldom suffer major damage by themselves.

Stone sheathing - granites, marble, travertines, vitrified clay tile coverings - may break, fall off or lose their vitrified surfaces. Their performance will follow that of the wall over which it is applied, but damage from direct action of the coverings themselves can also be observed. This appears very specially in corners, nooks or in points of contact with metal elements: curtain walls, window frames, etc. An advisable practice is to provide elastic joints at the intersections of brittle finishes applied on partitions that are at right angles, or in the union of such finishes with other rigid materials. The architect should give utmost attention to construction details, and in collaboration with the structural engineer, determine the appropriate measures. One example: in very flexible columns with marble sheathing, joining the slabs to the column or among themselves with mortar should be avoided; it is preferable for the marble to be self-supporting, resting on metal angles. The corner joint detail is important, as it as it can easily be damaged. This type of details requires good collaboration between the designer and the marble cutter and the setter.

H. CONSTRUCTION JOINTS

As far as possible, construction joints should be avoided in seismic zones. The risk of actual movements being superior to those foreseen in the design is very great. The risk is also great that the execution of such joints in the job may not be even remotely similar to that in the design. Although there are many standard examples of construction joints, they are nearly always directed at deformations through thermal changes. Earthquakes provoke differential displacements that occur not only in a single direction, but commonly have important displacements in two orthogonal directions (and at times even three).

When detailing such joints, the architect will find very little guidance in the usual construction treatises. Therefore, he will have to use his own experience and judgement to determine the ideal form of solution, keeping in mind that displacements will be much karger than those experienced from thermal changes and that such relative movements may take place in any direction and at a rapidly changing pace. Graphically, said displacements might be visualized as circular or elliptical in three dimensions rather than a straight line.

We infer that it is not simple to arrive at a solution and that the architect should keep very much in mind that in those joints occurring on the circulations that communicate two bodies in a building, it is essential that failure of one joint is not a motive for obstruction or to cause tripping or falls. It is well known that such phenomena easily turn into panic that can be as dangerous as the quake itself.

I. STAIRWAYS

The stairways are basic elements for a building's security. In case of an earthquake, elevators will commonly be out of service, due to failures in power supply. The stairways, in such cases, are the only means to evacuate a building. The architect must keep in mind that stairways being a basic element for a building's safety, all the time invested in their design is fully justified. Stairways as decorative or aesthetic means are out of these considerations. In some buildings, there were cases in 1985 in which the staircases collapsed while the building itself remained standing. Structural designs should see to it that stairways suffer minimum damage, whether from structural failures or shedding off from their walls and finishes that might obstruct circulation. Of course, access doors must be such as to ensure that they will not be jammed through deformation of the walls in case of a quake.

Almost always, a stairway that is satisfactory for emergencies caused by fire, is so also for an earthquake. There are some differences. A stairway that under the action of fire does not suffer major crosswise stresses, might collapse under the effect of an earthquake due to such stresses. A stairshaft that is satisfactory from a seismic viewpoint can represent a grave danger in case of fire, unless the fill-up elements in the building joints are fireproof. Lack of joints causes structural problems and the fact that the damaged walls may obstruct the stairway is unacceptable. To sum up, this problem deserves a thorough study.

The items outlined here are only some aspects to which the architect must give the utmost effort in finding an adequate solution within the design, taking into consideration seismic aspects. There are many others in which he has to intervene directly or indirectly. The list could be interminable, but we shall point out some of them.

In the repair of damaged buildings, it is a common practice to call the structural design specialist. The reinforcement leaves the building standing and capable of withstanding future quakes, but this is in detriment of its utilization and therefore profitability. In such cases, a close collaboration between the different disciplines can redound in favor of all concerned.

A particular aspect of cost-profit studies is that regarding insurance. As stated in the preceding paragraph, the architect can provide valuable indications regarding rescue values, repair means or on how to recycle damaged buildings, thought capable of being saved, by modifying their use.

In seismic zones, periodic inspection of the buildings can detect in time certain flaws that are accumulated through time and which, due to their slow accumulation, are not kept in mind by the users or dwellers. The architect may point out those irregularities, which can prevent an accident if corrected in time.

The conclusion is that the architect has an enormous responsibility when drawing up his design. This is always true, but even more so when buildings erected in seismic zones are involved.

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COMMENTS TO THE (1987) BUILDING CODE FOR THE FEDERAL DISTRICT

Manuel De la Colina Riquelme

Before the earthquakes of September 19th and 20th, 1985, happened, the 1976 Building Code, then in force, was in process of being revised for the purpose of being repealed and replaced by a new Code, more appropriate to the needs of a metropolis that had become the most populous in the world and was built over a huge area, embracing the most diverse characteristics as to geology, topography and ecology. After the quakes, the authorities of the Department of the Federal District correctly opted to perform an intensive study of the causes contributing to the serious damage suffered and to determine what preventive measures should be incorporated into the new Code, in the light of such experiences. This effort was not in vain and the current version reflects multiple contributions by sundry specialists in the field of construction and, particularly, by those who have specialized in seismic structural design.

The Code was published in the Official Gazette and came into force on July 3rd, 1987. This Code, as that of 1976, shall be complemented by a body of Technical Standards that as of now (September) have not yet been officially published.

Starting from July, any construction, expansion or modification of an existing work, change of use, repair or demolition, requires a permit to carry out the proposed work, according to the Code. Repairs are understood to include especially those required to leave the buildings damaged by the quakes in inhabitable and structurally sound conditions.

The Code is divided into Thirteen Titles; each Title contains one or several Chapters and each Chapter has several articles numbered consecutively throughout the Body of the Code, with a total of 353 articles. Their contents cover the different requisites that must be fulfilled in order to execute any construction work within the boundaries of the Federal District.

The Code follows a philosophy addressed at making of the city and the Federal District a more harmonious habitat tending to improve the quality of life for its inhabitants. It seeks to preserve those urban and architectural values inherited from our historical past and proposes to order new constructions in a manner leading to its inhabitants' physical and spiritual welfare and, most specially, it seeks to provide due security to people and buildings. Not less than fifty articles are aimed at different security aspects, including those referring to horizontal and vertical means of egress, emergency exits, fire protection, and the storage and handling of toxic or explosive substances, etc. The Third Title is directed at "DIRECTORS RESPONSIBLE FOR WORKS". Title Four sets the conditions to obtain Building permits for construction, and the Sixth Title refers to STRUCTURAL SECURITY, or Safety.

In this essay, I will circumscribe myself to comments on the Third, Fourth and Sixth Titles as regards the architects professional practice and comments on security aspects most directly related to seismic design.

The Third Title, referring to Directors Responsible for Works, goes back to the 1941 and 1976 Code, which defines the legal figure for "Responsible Director" and makes him liable for all the technical aspects, both of the design and actual building.

The 1976 Code already outlines the possibility that the Responsible Director may share his responsibilities with other specialists, particularly those of structural design.

Starting from this concept, the new Code establishes a new figure which is the Co-Responsible Director, who answers solidarily with the Responsible Director, as regards design and execution on a work in his specialty. We can see that this is a shared responsibility and that the Responsible Director continues to bear the burden of responsibility for both design and the construction. We have to suppose that as time goes by the courts shall have to interpret the legal aspects implicit in these regulations.

Chapter One of the Third Title, defines the concept and establishes the procedures to continue being acknowledged as a Responsible Director. It provides for a Qualifying Board to issue a dictum on the capacity of the candidates for Director or Co-Responsible; said Board is still to be constituted. It also states that the Director's registration must be renewed every three years.

The knowledge a candidate to Works Director must evidence, covers not only the contents of the Code itself, and its Contemporary Standards, but practically all the legislation relative to urban design and construction, as well as the laws applicable to preservation of the national historical and artistic patrimony.

How such an extensive range of knowledge shall be interpreted by the Qualifying Board is still to be seen.

The Code states that the Works Director must count on the backing of Co-Responsible directors, in those cases which the Code specifies.

This does not prevent the Director from being, in his turn, registered as a Co-Responsible in any of the specialties indicated below. There could be a case of a Director acting at the same time as Co-Responsible, but practically we must assume that different professionals will appear as Directors and Co-Responsibles for a specific work.

Contractual and legal type problems, as well as the economic repercussions on construction are still to be seen, but these are not likely to be serious or insurmountable, as there are antecedents in the case of responsibility for electric installation projects.

Chapter II of this Title defines the concept of Co-Responsibles and determines the conditions to be registered as such, in a similar manner to that provided for Works Directors.

It acknowledges three specialized fields; that of Structural Security, that of Urban Design and Architecture and that of Installations. Architects may be registered as Co-Responsibles in the Urban Design and Architecture fields as well as in that of Structural Security, fields which are likewise open to civil engineers, municipal and military engineers. The Co-Responsibles in Installations, besides the above, may be mechanical or mechanical-electrical engineers.

The Co-Responsibles must answer both for the contents of their specialty's design and for the quality of the executed work and its adherence to the approved project.

Several articles in this Title have the purpose of providing the authorities with the means to monitor fulfillment of the obligations incurred by the Directors and Co-Responsibles and prevent possible abuses or defaults on their part.

The Fourth Title sets forth the procedures to be followed to obtain a building permit. These are similar to those in the preceding Code, but put more emphasis on land use and buildings classification according to their type and size range. In the case of constructions that due to their size or use may disrupt communal life, the Code provides that it shall not only be subject to application of the Regulations by the authorities, but to review by a board of citizens' representatives.

The documents required for the permit application are defined, and the main types of license that may be applied for are defined: new works, expansion or alteration, change of use, repair and demolition. It likewise states the cases in which no permit is required, as when small jobs, minor repairs or normal maintenance are involved.

Chapter II of this Title establishes the requisites for the occupancy of building and establishes that when occupation is authorized, the authorities shall fix plates on the building stating the use to which the building may be put. Those buildings that, due to their size or use, may constitute a major risk, must renew periodically the use and occupation permit.

The requirements regarding Structural Security of Constructions are contained in the Sixth Title of the Code. Its text states the generic requisities for design, but leaves the definition of specific procedures for structural design according to the materials or systems to the Complementary Technical Standards, as well as for particular actions such as earthquakes and wind.

Constructions are classified into groups: A, B, B.1 and B.2. Groups A and B.1 are deemed as the most essential for the community's life or those which are occupied by a great number of persons.

Structural design for these constructions is required to provide a higher degree of security than that expected for group B. Finally, group B.2 covers very low risk or unimportant constructions.

Furthermore, the Federal District is divided into three zones: I, II and III. Zone I includes the high zones, outside the ancient lake-bed; II is the transition zone; and III covers the ancient lake-bed characterized by highly-compressible deposits that reach a great depth. While zones I and III are well-known, Zone II is a bit undefined, and what zone to assign to a piece of land in a particular location in the transition zone can only be determined with certainty through soil mechanics studies. Experiences, both from recent quakes and from others of similar high intensity, have been indicating that damage caused to constructions is not determined only by chance. Several factors exhibit a strong influence as to the probability of irreparable damage or total destruction of a building. The Code takes the implicit risks into account and so states in several articles. It acknowledges that the influence of architectural design is decisive for a construction's seismic performance. Regularity of design, compact shape, without sharp changes in volume in either floor plan or elevation, leads to less rigid conditions for design; while irregular architectural projects are to be subjected to more stringent conditions in seismic design.

The earlier Code already took into consideration that many of the structural flaws under seismic action were due to the impact between adjacent structures and required that they be separated.

The new Code acknowledges this danger and makes the conditions to be provided for by the design more stringent, in order to prevent impacts between buildings or between the different bodies or a building having construction joints.

The risk caused by the fall of cladding is taken into consideration. It gives special attention to stone cladding and to precast elements on facades.

It likewise states the care to be given to the design of suspended ceilings made up of heavy sñabs or panels.

Inspection of damages caused in the September earthquakes showed that structural performance exhibited unexpected irregularities, because some interior or partition walls introduced unforeseen rigidity imparting elements that provoked excentric responses in the structure, altering the design hypotheses. The Code requires that such elements be taken into consideration in design and that the conditions foreseen in the design be followed during construction. It makes the Works Director as well as the Co-Responsible for Structural Security liable for such observance.

It states that heavy furniture or equipment, overturning or loosening of which may cause structural damage, must be fixed in such a way that this danger be averted.

A reason for weakening of the structures that may have contributed to some failures, has been the practice, widespread among the personnel in charge of executing hydraulic and electromechanical installations, of making cuts or perforations in primary structural elements, such as beams and columns. The Code prohibits such alterations, unless they are approved by the Works Director or the Security Co-Responsible.

The Code establishes general design criteria, oriented to "plastic" design. Its prescribes the loads and load combinations to be taken into consideration and the safety and service conditions the structures must fulfil. However, it leaves open the possibility of following other design procedures, whether analytical or through models or prototypes, as long as it is proved before the competent authority that the safety and service requirements established in the Code are being complied with.

Chapter VI of this Sixth Title states the bases and requisites for seismic design; however, the specific methods will be detailed in the Complementary Technical Standards.

Seismic design shall take into consideration the foundation-structure interaction and may include in the design the rigidity provided by inner or perimeter walls, as long as adequate binding between such walls and the structure is ensured.

The Code provides that the seismic coefficients shall take into consideration the zone in which the building is to be erected, the highest value being that applicable to Zone III, i.e., ancient lake-bed, and the lowest to Zone I, i.e., to low compressibility terrains; an intermediate value shall be applied to Zone II. The basic coefficient is that applicable to Type B constructions and shall be increased by 50% for Type A buildings.

Design may be executed by following one of three alternate methods, but such application is limited according to the building's characteristics.

Although the Complementary Technical Standards have not been officially implemented, their preliminary text clearly indicates that the simplified seismic design method shall only be applicable to constructions on basis of bearing walls and of low height. This includes most single family buildings, but not habitational complexes and condominiums which are usually several floors high. The static method may be applied to computation of framed structures, on basis of beams and columns, or else windbraced or with shear walls as long as their height is not of more than 30 meters and their structural characteristics have no strong irregularities. The dynamic method may be applied in all cases.

From the practical design point of view, this last method is the most complex and the one requiring more time from the structural designer. However, using computers, it is viable to determine bending moments and shears in the structural elements, without investing excessive time. Some design offices have available their own equipment and programs and other designers farm out said computations to the specialized offices or to the universities.

Chapter VI states in detail the minimum separation there must be left between a construction's limits and the lot line according to the projected height and to the estimated displacements, but never to be less than 5 cm. This criterion shall be equally applicable to construction joints in buildings constituted by several bodies. This Chapter also states certain precautions as refers to windows and installations of glass panes, but leaves the detail of these concepts to the Complementary Technical Standards.

Chapter VIII, regarding foundations, points out obligations to keep into consideration seismic actions.

Chapter XI, of this same Title, indicates the cases wherein structural security must be verified through load tests and establishes the conditions to perform these tests.

We can see that the Code reflects a painstaking study of the experiences derived from the earthquake. It is to be hoped that its contents shall be studied and applied with all rigor. This may give us the hope of having safer buildings under the action of future quakes. Unfortunately, due to the geographic situation of this metropolis and to the geological characteristics of this zone, we can assert without possible error that sonner or later we shall suffer seismic movements similar to those of 1985.

Our buildings must be in conditions to withstand them, without endangering the lives of their occupants.

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SUMMARY OF IDEAS FROM THE SEMINAR "THE COSTS OF REBUILDING"

Jorge Luis Castillo Tufiño

INTRODUCTION

The earthquake of September 19 and 20, 1985. With its aftermath of damage and tragedy, left open an infinity of truths on Mexico, some unknown and, in some cases, even unsuspected, some of which are the instantaneous blossoming of the solidarity of the Mexican (including those living in the United States and their descendents) in the face of their brothers' misfortune; the lack of provision against emergencies of this magnitude; the peoples' capacity for response and organization; the insensitivity of some individuals and "public servants" who flourished on the needs created by the hecatomb; the solidarity of peoples and governments of over sixty countries and of various international organizations and the outstanding

Worthy of separate comment is the solidarity of the dweller in the capital, characteristic of the human being who believed himself irredeemably lost. Now we are aware of this, and it persists in us despite the dehumanization to which we are submitted by living in the largest city on earth. It is evident that solidarity can handle all the possible range of causes, styles and different levels of consciousness; it can be exercised during critical situations and provide what is asked or what is needed, more or less unconciously and because this is inevitable. On the other hand, it can be given to prevent catastrophic circumstances, before these become a reality, and consciously remedy the avoidable.

Evaluation of material damage

We should note that, insofar as regards appraisal of the damage, very variable figures have been handled (the estimates made by various entities - SHCP, CEPAL - International Consultants, etc., varied from 1 to 5 billion pesos in October 1985. Although we should all take into account the following concepts:

- The repair of buildings
- The removal of debris, demolition and cleanup.
- Partially, studies and plans for new buildings.
- Furniture and equipment destroyed r impossible to recover.
- Damage to public services and infrastructure (water, drainage, electric power and telephone distribution networks, sidewalks and road surfaces).

From the attached tables, we can conclude that:

A) The quality of the building construction in the affected area is better than good on, in general, its still remaining standing after enduring an earthquake measuring 8.1 on the Richter scale.

B) The damage occurred in the area where it could have been foreseen that it would happen. The vast majority in seismic zone C and some in zone T.

C) Unfortunately insurance is not utilized in Mexico as much as necessary, despite its location in an area of high earthquake risk.

Costs at a time of inflation

It the country's present situation of inflation, it is not easy to establish fixed costs for constructive systems. The earthquake and its effects coincide with this question and reconstruction is hampered; day after day costs increase out of all proportion.

A basic factor to be taken into consideration in carrying out work during times of frequent price increases and periods of high interest rates, is the crushing cost of money, for which reason the time factor becomes fundamentally important. For this reason it is important to point out that, although the savings in building time which can be offered by a system are important, even more so is the time saved in overall execution from the moment a housing project is conceived, for example, until it is delivered to its users, since the time consumed in acquiring the land, preparing the plans, processing permits and licences and obtaining credit, is many times greater than that of the construction itself.

In this way savings in building time may be insignificant if other aspects of the program fail, over all the flow of economic resources.

It should be noted that with each passing day, the financial cost may reach from 2 to a thousand during the period of thr work; or from 1 to a thousand during the preparatory period.

All these factors should be known, foreseen and evaluated with an exact and realistic criterion, by the cost analysis of the work in order to weigh applicable scales and avoid excessive increases in the final cost.

In the search for revenue-producing systems, the following must, among others, be considered:

1. The components making up same must, within reason, be indestructible (it is not important if this is after processing)

2. A lower scale participation of materials with a high inflationary impact should be looked for and, by contrast, those materials the prices of which increase at a lower rate should be utilized as much as possible.

3. It is convenient for materials to be light and, at the same

time, resistent, as this reduces both foundation and building costs.

4. Costs can be reduced by simplifying finishings with suitable elements.

5. The manpower to be used in the systems should be minimal and easy to carry out.

6. Transportation of the building elements should be handy and accessible to the various work areas.

These characteristics, although well-known, continue to be the marrow as the main goal in creating constructive solutions.

We can see that the building systems which exist in our country combine some of the features indicated, and therefore partly resolve costing problems. However, there is still much to do in this connection, and meanwhile to speak of totals and their fluctuation in the systems, is to speak of the value of the materials and manpower which make up same and, to the extent that these vary, the costs of the building systems will also normally vary.

It is evident that the large majority of these systems are focussed towards the goal of building economy and speed, and all the sectors involved are involved in the task of supporting the creation and diffusion of technologies which can provide immediate solutions to the problems of the industry.

NOTE: The foregoing information is taken from the papers of Javier Rodríguez Gómez, Civil Engineer, and Manuel de Santiago, Architect, during the Reconstruction Costs Seminar.

ON THE SEISMIC EXPERIENCE OF SEPTEMBER 19, 1985

Fernando López Carmona

For the profession of "Architect", the theme of this work, in addition to the "scientific" problem of knowing all the physical variables which intervene in analyzing the stability of structures, calls for adding to the compositive program a rational attitude obtained, both by judging the results of a specific earthquake, and of appraising the wisdom of the usual practice in which the constructive experience of this city is incorporated.

Despite the evident deficiencies in the "scientific" knowledge also in traditional knowledge on the subject, there are, however, practical results in the behaviour of the buildings which form a building typography which is very efficient against the seismic risk.

The typography establishes the limits and nature of the buildings.

> Limits which the demands of many programs of contemporary society struggle to broaden.
>
> A nature which was deranged by social factors which should be reexamined and evaluated with honesty and courage.
>
> In an effort to recreate, in extending this constructive typography useful information must be added from both viewpoints of this imperfect knowledge.

From the answer, both as regards the structure and as regards the soil, we can obtain valid observations, such as the necessary distance of safety between the soil vibration periods and those of the structure and, better yet, a building typology which guarantees that the "dispersion ranges" do not again become confused and superimpose themselves between one and another of the multiple factors of the problem.

All this is implicitly recognized in very explicit recommendations from its particular viewpoint, which incorporate the technical rules complementary to the Code on defining conditions to apply simplified methods, factors and coefficients for a stricter analysis, even excluding some properties from the scope of the Code.

On another aspect, there are some very positive experiences which have produced buildings with very complex utilization programs, and yet the inclusion of resistent elements "typical" of that traditional constructive mentality which the old masters in old school defined in a composition axiom, "on soft ground rigid buildings, on rigid ground flexible buildings, has given very good results.

The bulk of the failures collect in buildings the dimensions and outlay of which are a result of the program for urban use which they satisfy; they are those the main use of which is the work in offices or manufacturing shops located to the south of the City's historic center in working class districts, the nearness of which to the Civic and commercial Center is conducive to such uses. Considerations of a mercantile nature led to buildings of between five and fifteen storeys with concrete frames and others with reticulate tiles; conceived for rental and naturally without specific users, they had to be very versatile and provide for any interior disposition of premises; this liberty of internal form was also looked for in those with specific purposes and users.

This actitude will give rise to a judgement of all the factors of the program without excluding any; without transferring to the expert decisions concerning the building without accepting generic solutions which, of necessity, exclude interaction with other specific needs of the place and time of our city.

These buildings resulted inadequate both to the seismic danger, as regards urban imagie since they were conceived with the illusion that the methods of structural analysis would show up mistakes or, at least, provide trustworthy data to resolve these with assurance; it was believed that the quantitative could replace the qualitative.

And the urban image was damaged, because on disassociating the constructive from the arquitectonic, ideal theoretic plans were fallen into which looked only for questions of "design" which, without the limitations established by constructive restrictions, resulting in generic answers disassociated from physical reality and the social conditions under which they were built.

They must be rebuilt; it is not in our hands to change their program of use, but we can change their conception to incorpoate that necessary typology of safety where earthquakes are concerned, both in its traditional outlook and in the "scientific".

The structures of stone rubble cemented with mortar, characteristic of the architecture of the past, should be appraised from their own environment, and we should not measure them by present standards which were not taken into account when they were conceived.

The abundance of our monumental inheritance is the best argument to explore the validity of that criterion, the assess the concepts on which they were built, to legalize same and, if possible, to strengthen with some elements which, without altering this criterion, correct to improve some special aspect of structural behaviour.

Seismic activity is, without a doubt, the main factor for destruction; the rubblework without metal reinforcement cannot oppose these requirements with flexibility, or do so either to the permanent demands of gravity, if not by the geometry of their elements and the overall action of the entire complex.

It is this overall and joint action of the elements which must be retained; the fragile response of the rubblework is its weakness, but also its strength, since the large fragments which separate the fragile fractures still remain unaltered as regards their intrinsic capacity for response as a material, and upon the reintegration of the unit by repair of the cracks the overall response of the complex is reborn unaltered.

There are, however, other small fractures of the elements in critical areas which are associated with the foregoing; minor damage achieves prejudicial proportions if there is no permanent replacement of broken pieces. Lack of maintenance will be the reason for losing these buildings.

We cannot state, with the same assurance, backed by experience, if the internal condition of the reinforced concrete remains unaltered even though it has not broken, after a malleable redistribution of efforts, but we can , in contrast, state after a "fragile" redistribution, that the new condition of isostatic balance of the structure is not dangerous if we replace the lost material, on refilling the cracks again with the same material or with another one similar; the safety condition is that no hollows or caverns remain which, on reduction of the area, allow the stress to grow above the materials' capacity.

At the present time we have techniques and materials which allow us to guarantee the filling in of these cracks.

From the first statistics of October 2, 1985, on the damage done by the September 19, 1985, earthquake in Mexico City, there are two outstanding points which should be commented on; the minimum damage to the rubblework masonry with with supporting walls as a main element of the structure which forms a traditional constructive typography in this city, with limited dimensions in height and girders between floors and flat or arched roofs with rubblework. Five of these collapsed and anothet four were seriously damaged. A total of nine, of 285, which is 3.15% of the total, and by adding others which are not classified it would be 15, that is 5.26%.

In buildings with steel frames there were 8 collapses and one seriously damaged, or 2.8%.

In contrast, of structures with concrete frames 107 collapsed, plus 51 of reticulate tiles, making 158, which is 55.4% of the total, in addition to another 33 of reticulate tiles, plus 38 seriously damaged which makes 229, or 80% of the total.

This great difference leads one to think because:

Continuing with the analysis of the seismic data

For a 5 storey building	96	33.6%

from 6 - 10 storeys	139	48%	
from 11- 15 storeys	26	91%	165 in 285 = 57.8%
from over 15 storeys	1		

And by age:

Prior to 1957	69		
From 1957 - 76	146		
From 1978	47		
Total	262	193	in 285 = 67.72%

From the total by age from 57 to 78	193
Height from 6 to 15 storeys	165
difference	28

By simple arithmatic we can say that the 28 buildings are 5 storey, which signifies 9.8% of 285, and that they are of dates after 1957. This signifies that 28 of 96 are 29% of the damaged buildings of 5 storeys or less.

There are now very conscientious analysis prior to this which speak of how many of the ideas held with respect to earthquakes in the center of Mexico City were exceeded, on the soil-building interaction and it can be seen from the change in the hydraulic conditions of the subsoil, that there are many other aspects which should be considered in order to hold trustworthy data as regards the changing condition of this soil-building relationship.

This relationship, in addition to varying with urban evolution which demands more water from the subsoil, which absorption surfaces and creates hydraulic flows which, according to demand, make some areas critical while reserves remain in others, probably also make it necessary to be more cautious in the use and interpretation of the results shown by analyzing the behaviour of the soil, the structure and the materials forming same.

We must recognize that there are many sifnificant factors which should be incorporated to the present methods of analysis in order to be sure that the response of the soil and the structure is known with sufficient precision.

This is reflected in the increase of demands both quantitative and qualitative in the new Building Code for Mexico City; the Code also mentions qualitative aspects arising under such demands, and as a result those of safe practice taken therefrom are followed.

It is up to us architects to collect this indication and incorporate it in our work.

We should readopt the constructive practice which gave such good results in the catatrosphy and extend it in time and in scope on reconstructing the buildings which the city needs.

This demands that the profession exercise its activity within our cultural environment, without responding to suggestions to adopt foreign trends without a prior appraisal which takes into account the undoubted importance of the seismic threat in the permanent building program for Mexico City.

To incorporate encompassing walls with group the necessary rigid nucleus in the interior, to locate rigid walls, without interfering with the practical utilization of the constructed volume is part of the problem.

To overcome preconceived mental diagrams is more difficult.

To place everything in harmony with construction procedures for cost control and formal intentions, within the conditions established by comlplementary technical rules and, moreover, make ourselves more conscious of questions such as:

- Maximum allowance eccentricity
- Wall systems placed to resolve torsion.
- To supply of loads to support the different backing systems.
- The necessary horizontal horizontal bond through inter-floor plates.
- Volumetric proportions of the structure.

We will define and and so specify, the opportunities for formal expression.

Regularity requirements in elevations and ground plans which reduce seismic forces to analyze stress and thus represent important savings, are reasons which must be considered by reasons of professional ethics.

This will assuredly soon result in a typography which, on protecting the users of such buildings against earthquakes, thus create a character which by incorporating this concern, identifies itself with the previously-established urban image which was so ill-used by the illusion that everything could be calculated and was therefore possible.

To base this attitude on a judgement which assesses all the program's factors with leaving any out; without transfering to the specialist decisions concerning the building without accepting solutions which necessarily exclude interaction with other specific needs of the place and time of our city.

This professional conduct imposed by the earthquakes on the combined program and extending this to all the facets of the building process, will result in finding ourselves and the image of our city once again.

AREA OF CONSTRUCTION IN MEXICO CITY : 875 KM^2

AREA AFFECTED (BASICALLY CENTRAL AREA) : 88 KM^2

(SEVERE DAMAGE: 23 KM^2, MEDIUM AND MINOR DAMAGE 65 KM^2

OCCUPANCY OF DAMAGED AREA: DWELLINGS, COMMERCE AND OFFICES.

SEISMIC AREA: C (CONDENSABLE LAND) AND T (TRANSITION)

Table 1. Geographic location and extent of damage in Mexico City.

SOURCE: Newspaper reports in the capital's daily papers.

BUILDINGS ERECTED IN MEXICO CITY: 1,000,000 (APPROX)

BUILDINGS AFFECTED (19.9.85)

DWELLINGS	:	3,745	(0.365%)
COMMERCIAL	:	840	(0.084%)
EDUCATIONAL	:	704	(0.070%)
PUBLIC OFFICES	:	196	(0.020%)*
PRIVATE OFFICES	:	149	(0.015%)
HOSPITALS	:	41	(0.004%)
REACTREATIONAL	:	33	(0.003%)
INDUSTRIAL	:	19	(0.002%)
		5,727	(0.573%)

* 110 RENTED FROM PRIVATE ENTERPRISE

MAGNITUDE OF DAMAGE TO BUILDINGS:

PARTIAL OR TOTAL COLLAPSE	:	860
STRUCTURAL FRACTURES AND COLLAPSE	:	1,237
MINOR DAMAGE	:	3,630
TOTAL		5,727

TABLE 2: Damaged buildings, and type of damage.

SOURCE : Metropolitan Emergency Commission

TYPE OF STRUCTURE	DAMAGE	YEAR BUILT			No. OF STOREYS				SUBTOTAL BUILDINGS
		-1957	58-76	1877-	5	6-10	11-15	55	
Concrete frames	COLLAPSE	35	59	13	36	62	9	-	107
	SEVERE DAMAGE	9	19	7	8	23	4	1	36
Steel frames	COLLAPSE	5	4	-	4	2	1	2	9
	SEVERE DAMAGE	1	-	-	4	-	1	-	1
Flat slabs	COLLAPSE	3	35	12	23	23	4	-	50
	SEVERE DAMAGE	5	20	11	9	18	8	-	35
Rubblework masonry	COLLAPSE	7	4	1	10	2	-	-	12
	SEVERE DAMAGE	2	3	-	4	1	-	-	5
Others	COLLAPSE	-	1	1	1	1	-	-	2
	SEVERE DAMAGE	2	4	2	6	2	-	-	8
SUBTOTAL COLLAPSE :		50	103	27	74	90	14	2	180
SUBTOTAL SEVERE DAMAGE:		19	46	20	27	44	13	1	85
TOTAL :		69	149	47	101	134	27	3	265

NOTE: Until 1957 there was no building code; between 1957 and 1976 the subsequent emergency rules and code were in force and in 1976 the new building code of the Department of the Federal District came into force.

TABLE 3: Distribution of damage in buildings by construction type, age and height in Mexico City.

SOURCE: Preliminary report of the Engineering Institute of the UNAM, with data available as at 30.9.85 on 265 damaged buildings.

HOTELS	60,000	MILLION PESOS
SCHOOLS	30,000	"
INDUSTRY *	40,000	"
HOSPITALS	100,000	"
TELECOMMUNICATIONS	100,000	"
PUBLIC BUILDINGS	105,000	"
INFRASTRUCTURE	150,000	"
DWELLINGS	325,000	"
MISCELLANEOUS	125,000	"
TOTAL :	1,035	BILLION PESOS

* Basically clothing industry.

TABLE 4: Estimate of material damage.

SOURCE: AMIS and Ministry of Finance and Public Credit

	Number	Estimated Total	No.of disasters ≥ 100 million	Total Paid
Buildings and contents	8,581	109,419 M̄	161	39,884 M̄ (36.4%)
Life (28-01-86)	?	4,000 M̄		
Vehicles (28-01-86)	994	114,090 M̄		

TABLE 5. Claims received and total indemnified by insurance companies'

SOURCE : AMIS

Total losses (AMIS and Min.Fin.& Pub.Cred.)	$	1,000,000,000,000	Pesos	
Losses claimed (fire ins.)	$	200,000,000,000	"	(20%)
Average loss per building (5,727)	$	34,900,000	"	
Average loss per claim (8,581)	$	23,300,000	"	
Indemnifiable loss (AMIS 10.12.85)	$	109,400,000,000	"	(11%)
Non-indemnifiable loss	$	90,600,000,000	"	
Insurance companies with claims (AMIS 10.12.86)	$	34		
Average maximum liability per insurance company	$	2,957,000,000	"	

TABLE 6. Total, claimed, indemnifiable loss and miscellaneous averages

STRUCTURE DESIGN FOR EARTHQUAKES

Enrique Landa Verdugo

INTEGRATION OF THE ARCHITECTURAL PROJECT

In a high intensity seismic region, architectural projects of all kinds must contemplate in their design the need to have all the adequate structural elements to withstand the stresses provoked by the earthquakes.

This can be attained in several manners. A free structure calculated to withstand stresses, reduce periods and amplitude of oscillations, can be a solution.

Another may be locating walls to support shearing stresses, and reduce oscillations and periods.

Yet another, the installation of crosspieces between the building's frames, to receive the stresses diagonally and contribute to reduce the period and the amplitude of the building's oscillations.

Each of these solutions shall be adapted to the architectural project, taking into consideration its peculiar requirements.

The first case requires a very heavy structure, for it alone to support the stresses. It is economically costly and can be justified when the building requires great flexibility.

The second solution is the most appropriate, that of using the building's own elements to support seismic stresses. It is generally the most economical.

Having these three possible solutions, it is feasible to make a mixed structural project, in which the stresses are taken up by the structure and shearing walls, or by structure and crosspieces, and even in some cases by structure, crosspieces and walls.

We submit three cases as examples:

The first, a hospital, probably one of the most complex of architectural projects.

The second, a concrete building with crosspieces, for use as offices.

And the third, an office building, reinforced by walls, crosspieces and structure.

CASE: HOSPITAL 20 DE NOVIEMBRE

When the Institute of Security for State Workers has been recently created, it decided to buy a private hospital that unfinished on Coyoacan Avenue in Mexico City.

Having examined the existing structure, although it had not suffered damage in the 1957 earthquake, it was decided to reinforce previously for higher seismic stresses than those suffered in 1957.

Taking into account the architectural project, it was found that the two upper floors could be eliminated, and the option was taken to take the quake stresses through concrete walls in order to take up the shearing stress.

With close collaboration between the architect, the structural engineers and the medical advisers, several attempts were made to locate the walls, reviewing these from the viewpoint of hospital operation, architectural project, location symmetry by building wing and support capacity against the quake's stress, and as the case may be torsion.

In each floor, the ratio of number of walls, which increased in the lower floors, the continuity of same, and the different architectural project of each, were studied.

The following parameters were taken:

A.- Placement of the walls in the ends of each Wing, on the facades and in the Wing construction joints, with the central units, leaving in the first case a window in the center and the in second a passageway in the central skylight or in the end skylight.

B.- Placing the inner walls in both directions, seeking an axis of symmetry.

C.- Continuing the walls in the vertical direction, increasing them as the floors were lower, with others, also according to the axis of symmetry, constituting even complete rooms with their doors.

According to the preceding guidelines, a complete preliminary project of the hospital was prepared, divided into four Wings, structurally independent, one central unit and several annexes.

This preliminary project was reviewed structurally, modified, expanded and adjusted, both to architectural and to structural needs.

When the 1985 earthquake came, the building's performance was as forecasted.

CASE: OFFICE BUILDING, LIVERPOOL # 88, MEXICO, D.F.

Characteristics:

Irregular shaped 9 level office building.

Erected on the floor of an ancient lake bottom, with a structure of slabs, beams and columns. It was designed structurally according to the seismic standards promulgated after the 1957 quake.

The zone in which it is was severely damaged by the 1985 earthquake.

The building suffered damages, originated by torsions, due to its irregular shape, and to its oscillation period being close to the earthquake's period.

It was decided to repair it, and a structure was designed on basis of shearing walls built of reinforced concrete, and on the facades, metal crosspieces, forming a grid from street level to level 9 for the purpose of reducing the oscillation period to less than one second, and of withstanding the seismic stresses according to the new regulations.

The foundations were reinforced for the new seismic stresses and the new static weight of the concrete walls, attaining with these an adequate structure-foundation interrelation.

CASE: REGULAR SHAPED 12 LEVEL OFFICE BUILDING

Erected on the floor of the ancient lake bottom, structure of reinforced concrete flat slabs.

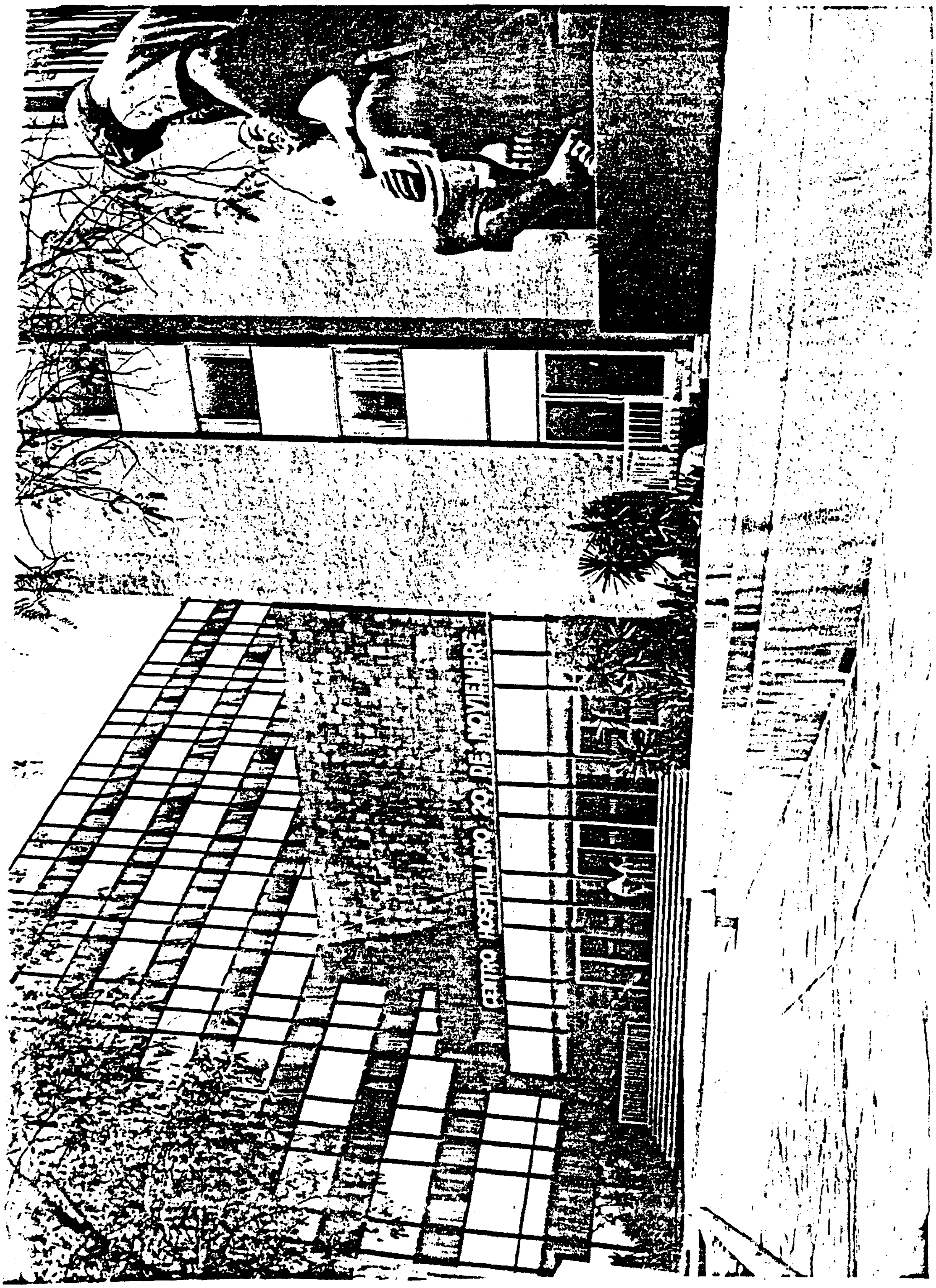
It was designed according to the seismic standards promulgated after 1957.

The zone it is in was subject to medium damage by the earthquake.

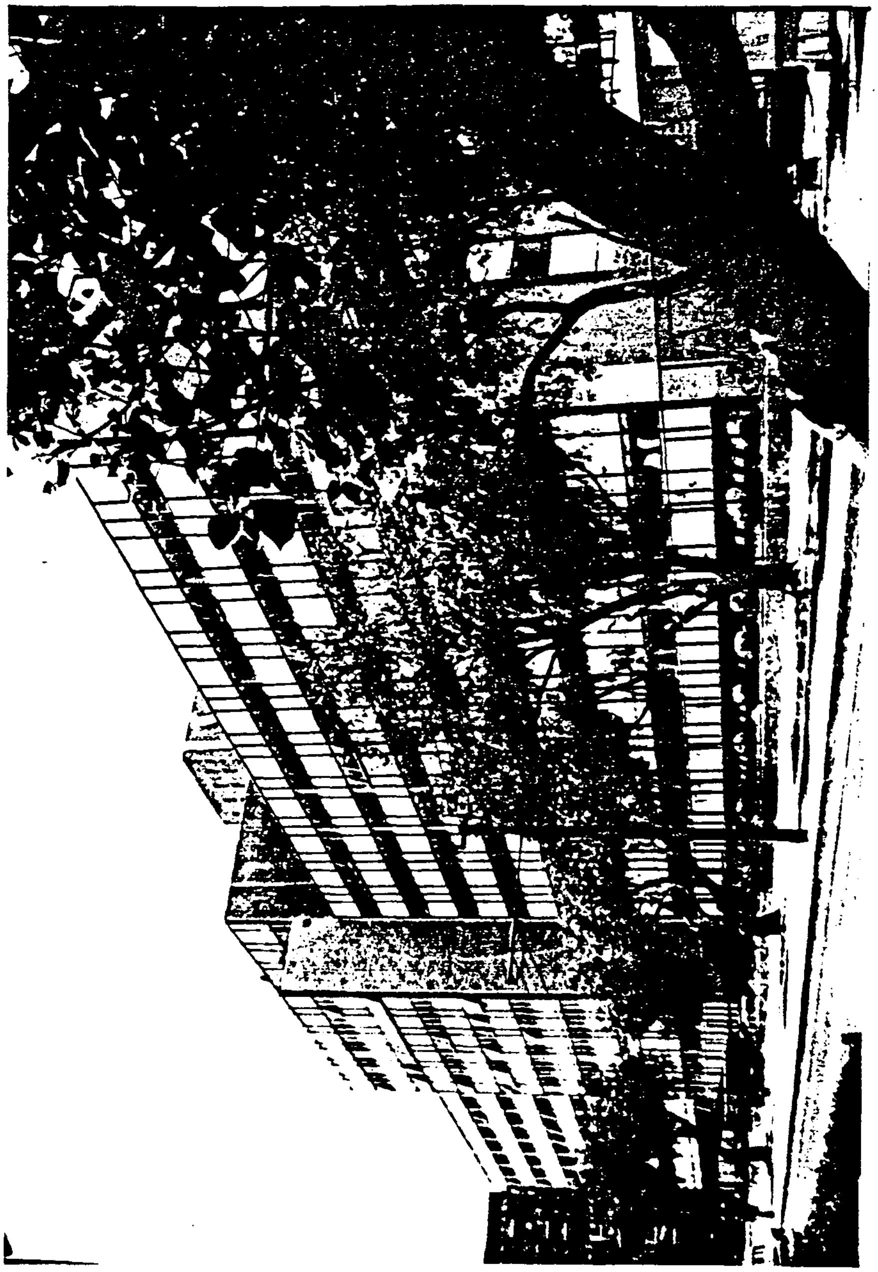
The building suffered medium damage, due to its oscillation period being very close to that of the quake, having a flexible structure. It was decided to restructure it in order to adapt it to the new 1985 seismic standards.

Having four facades and being very narrow, a complementary metal structure was projected on basis of crosspieces on the upper floors and shearing walls in the cellar.

The foundation was reinforced for the loads the crosspieces-walls system would transmit in an earthquake, and the capillary cracks and breaks in the plates and columns were injected by application of epoxy glue.



MUROS DE CORTANTE
EN FACHADAS



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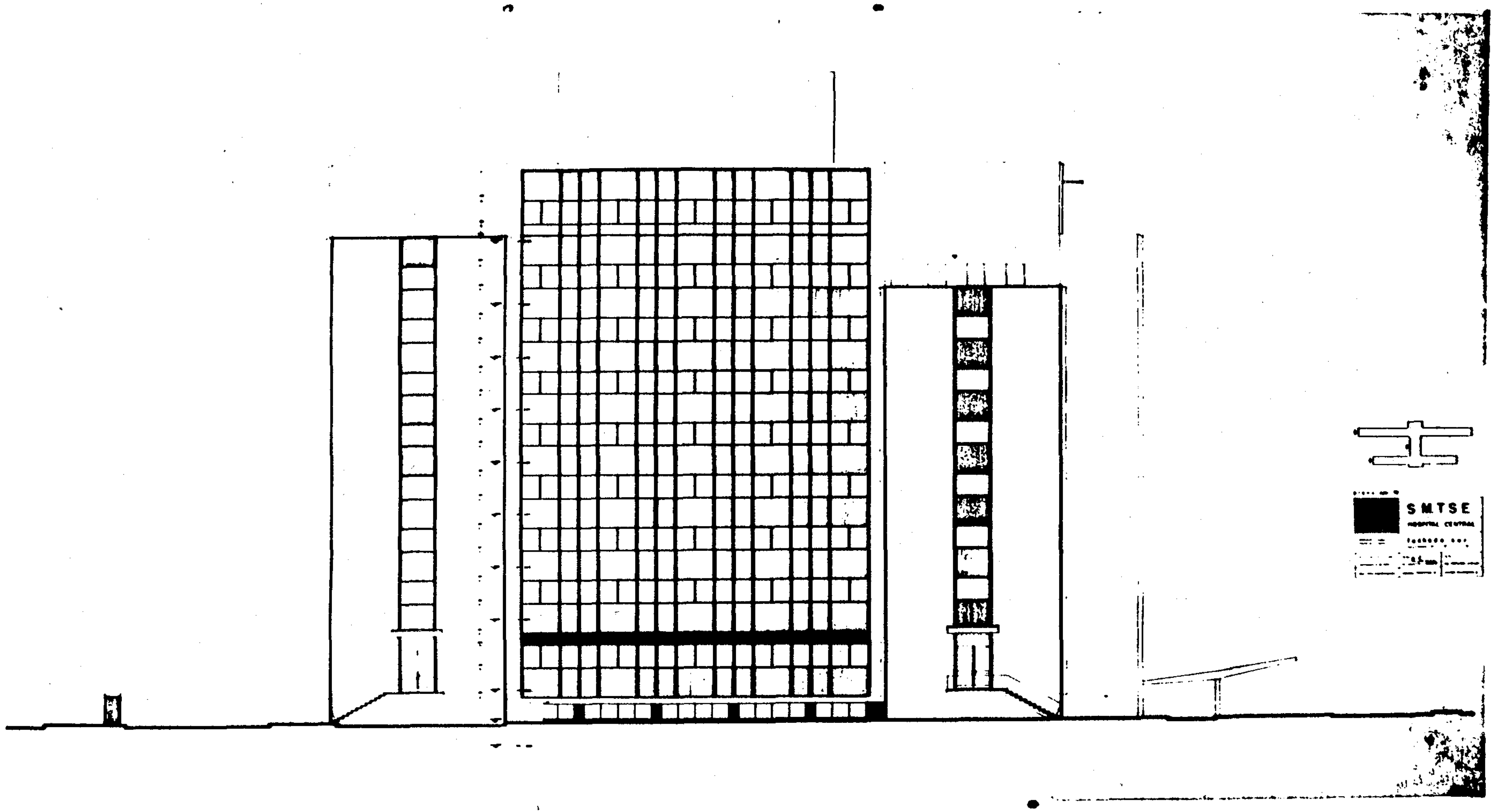

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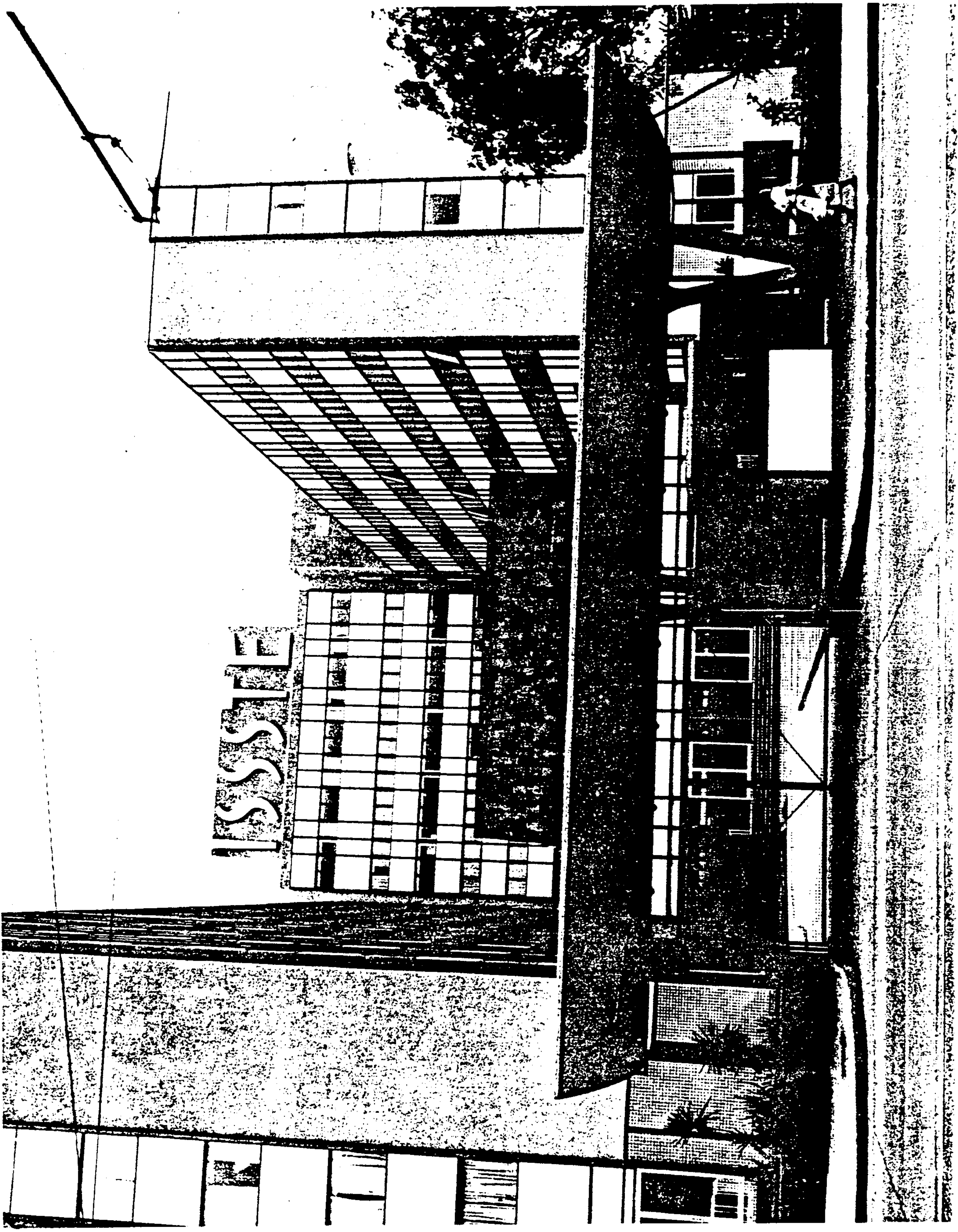

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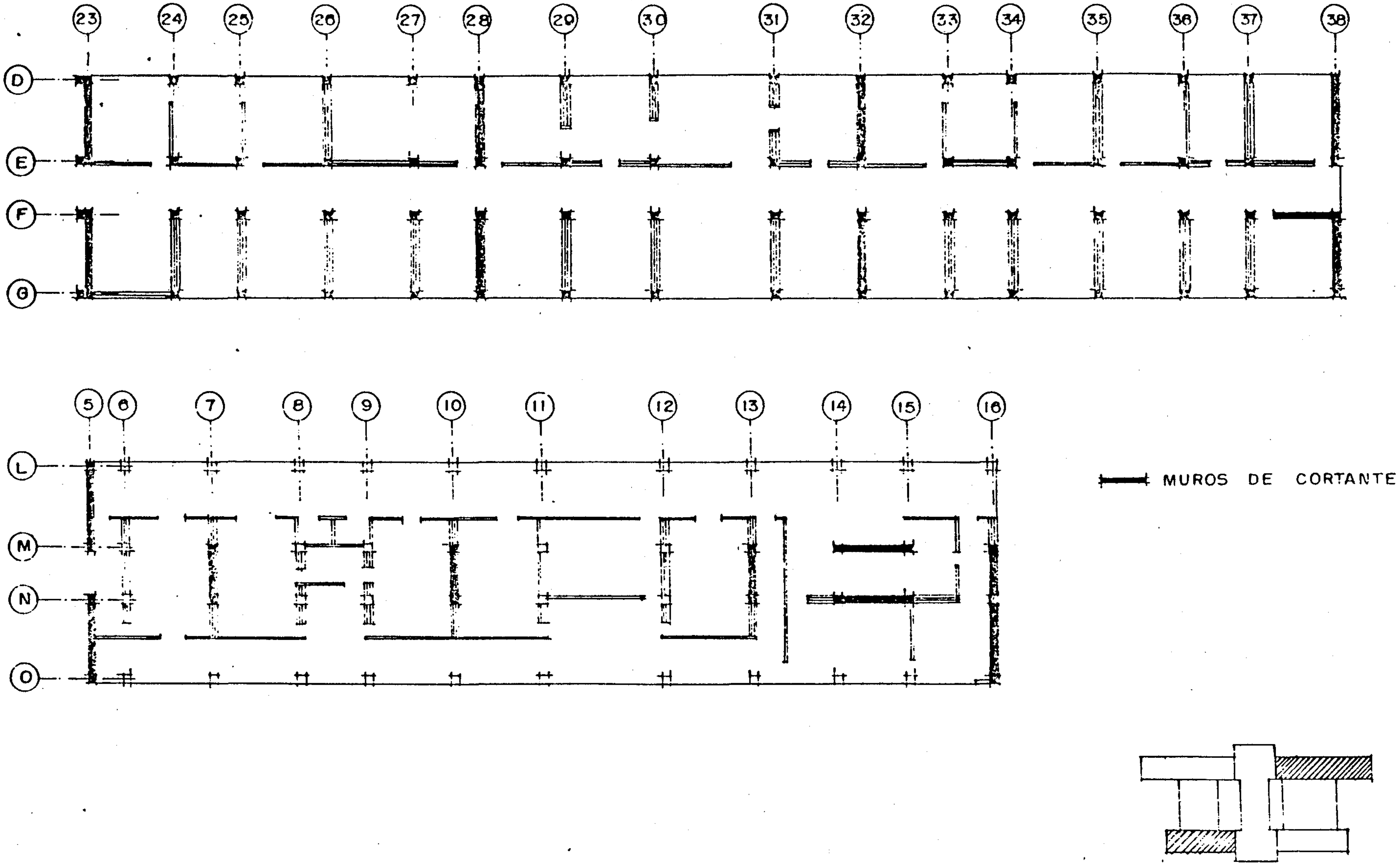
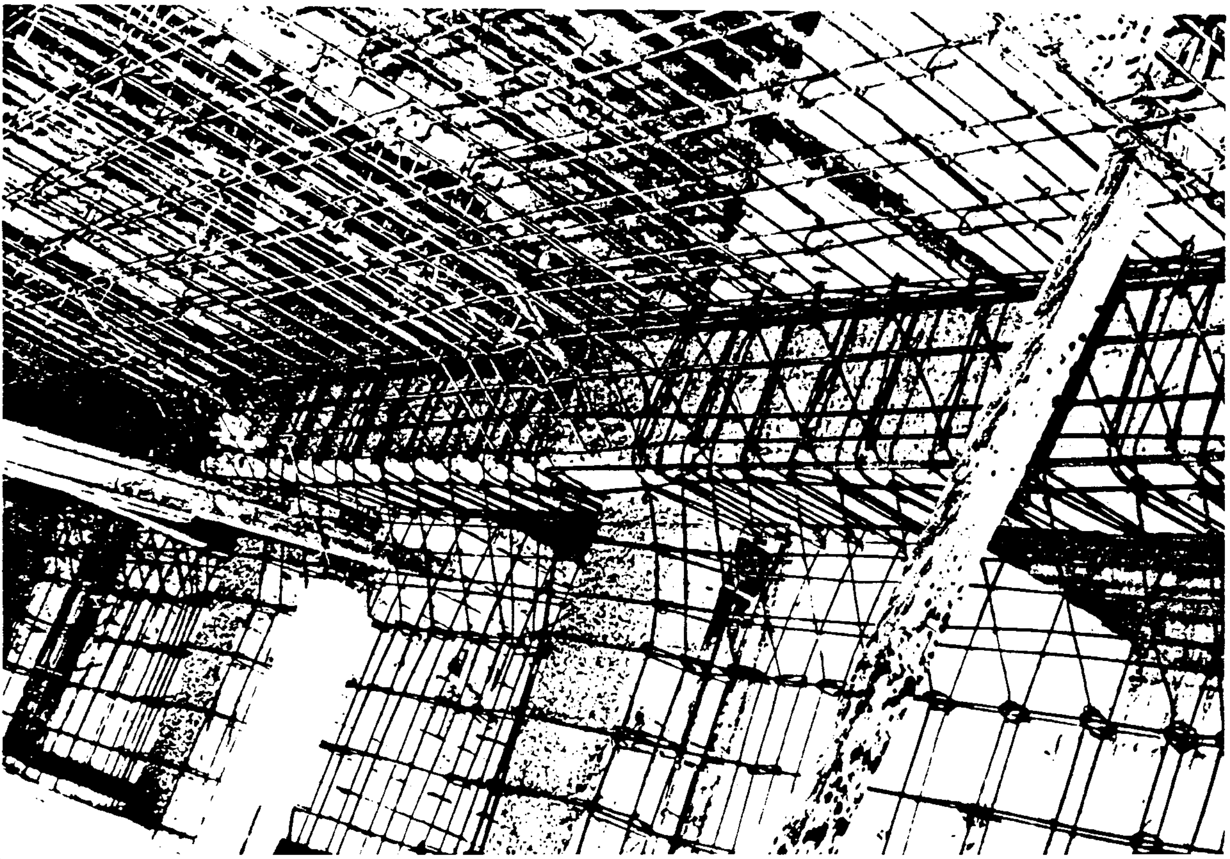
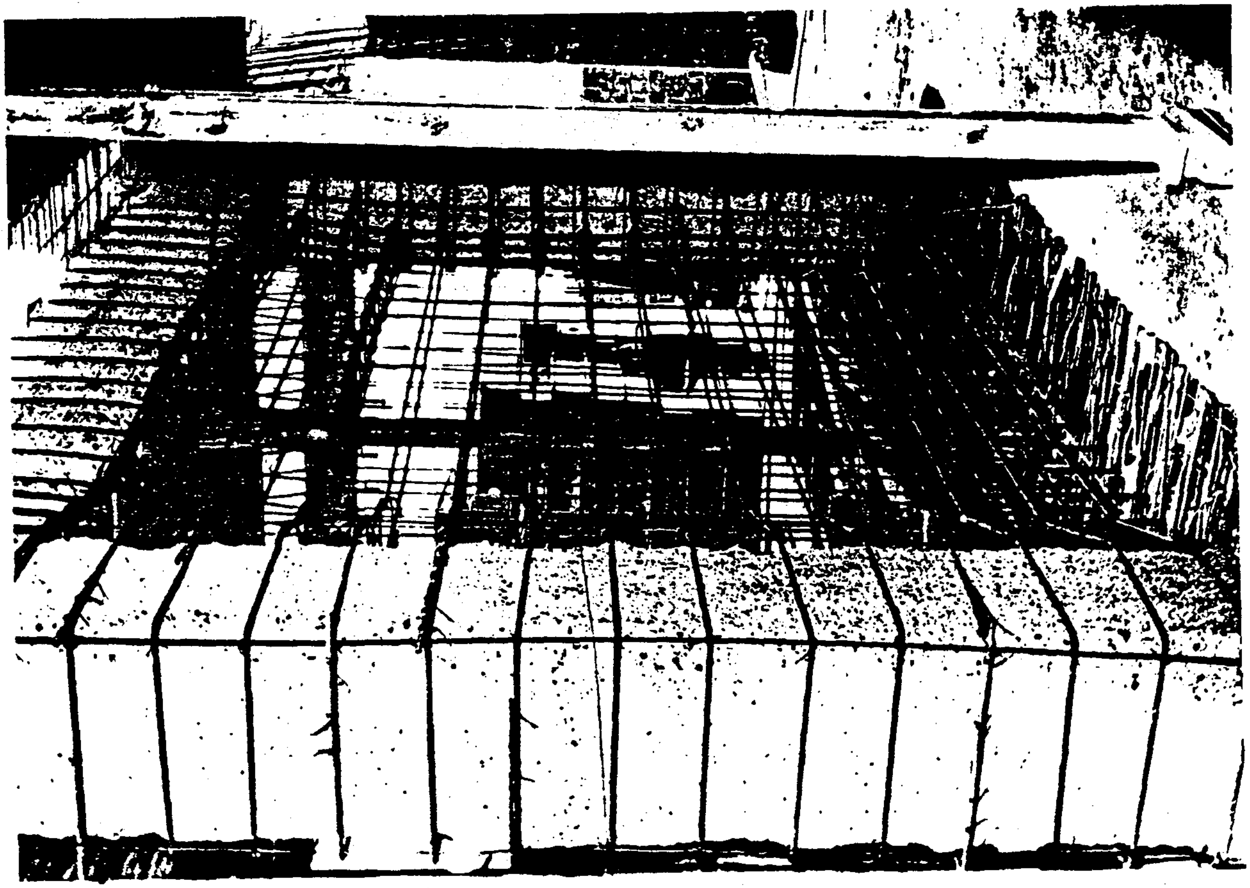


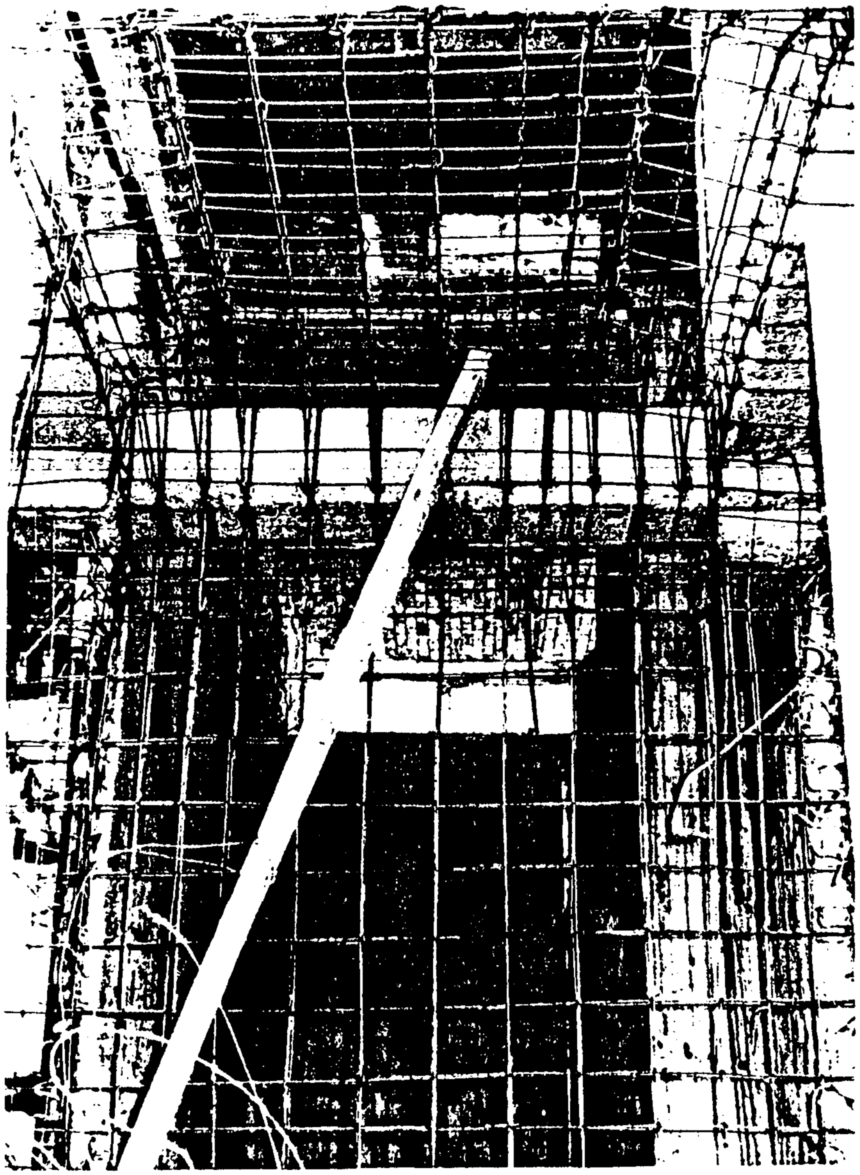
HOSPITAL 20 DE NOVIEMBRE

Armado y cimbrado de muros

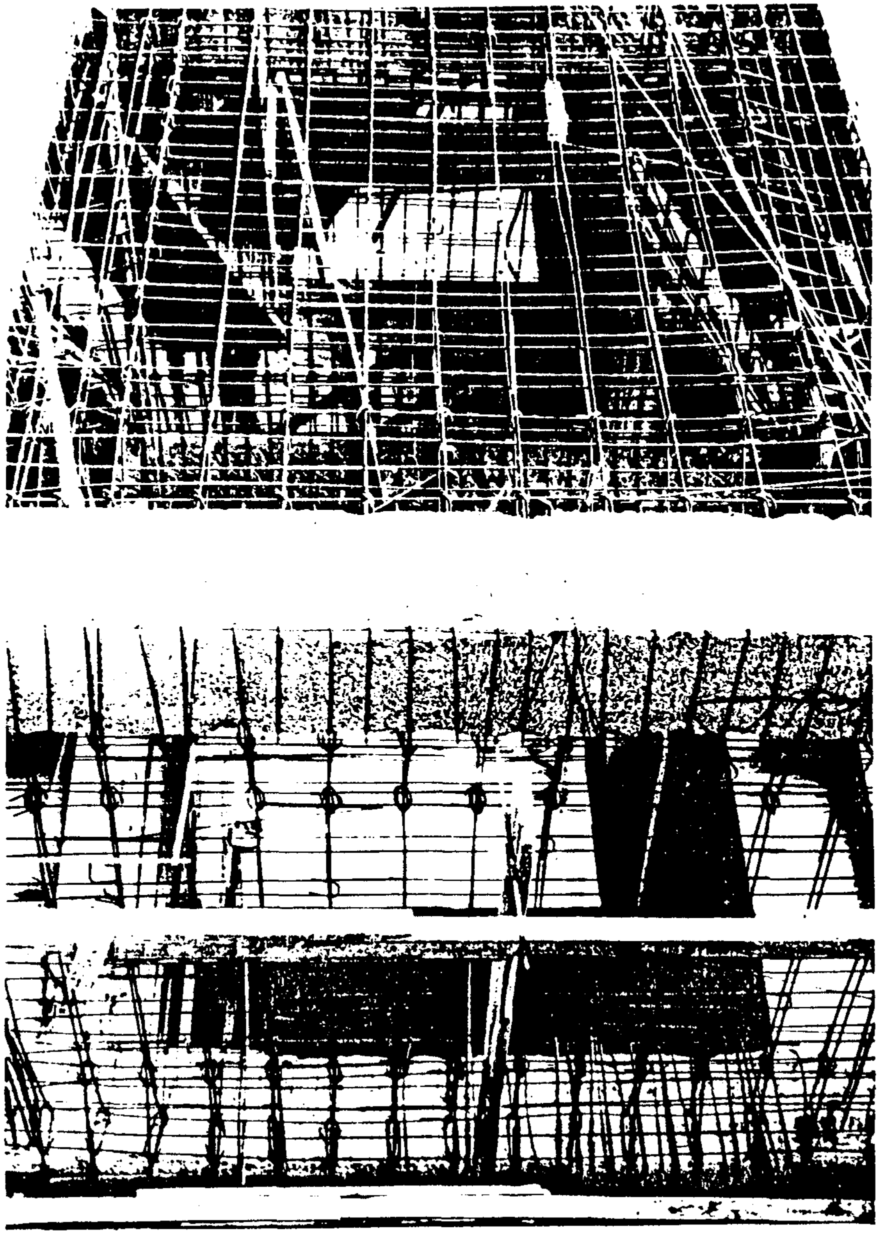


Estructura existente



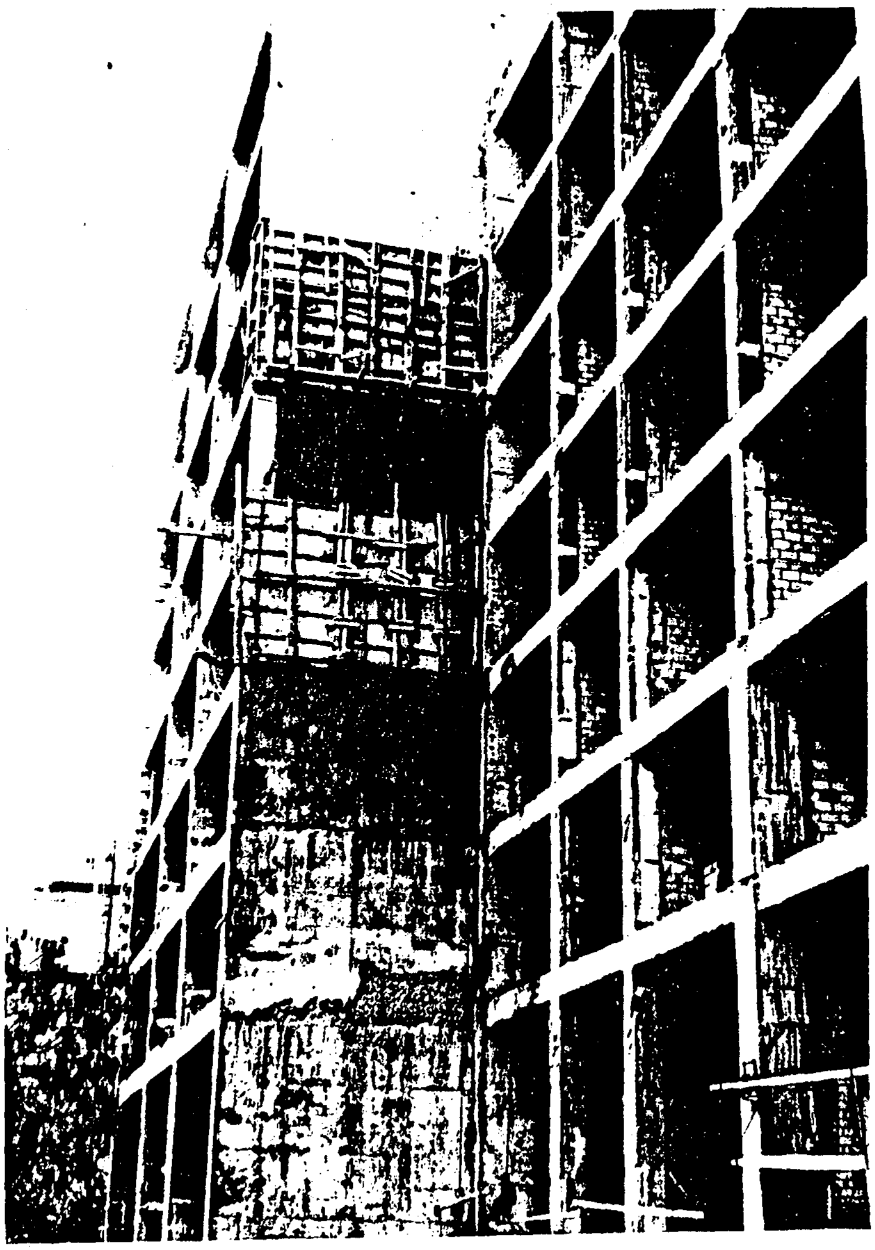


Armado De Muros En Las Dos Dimensiones

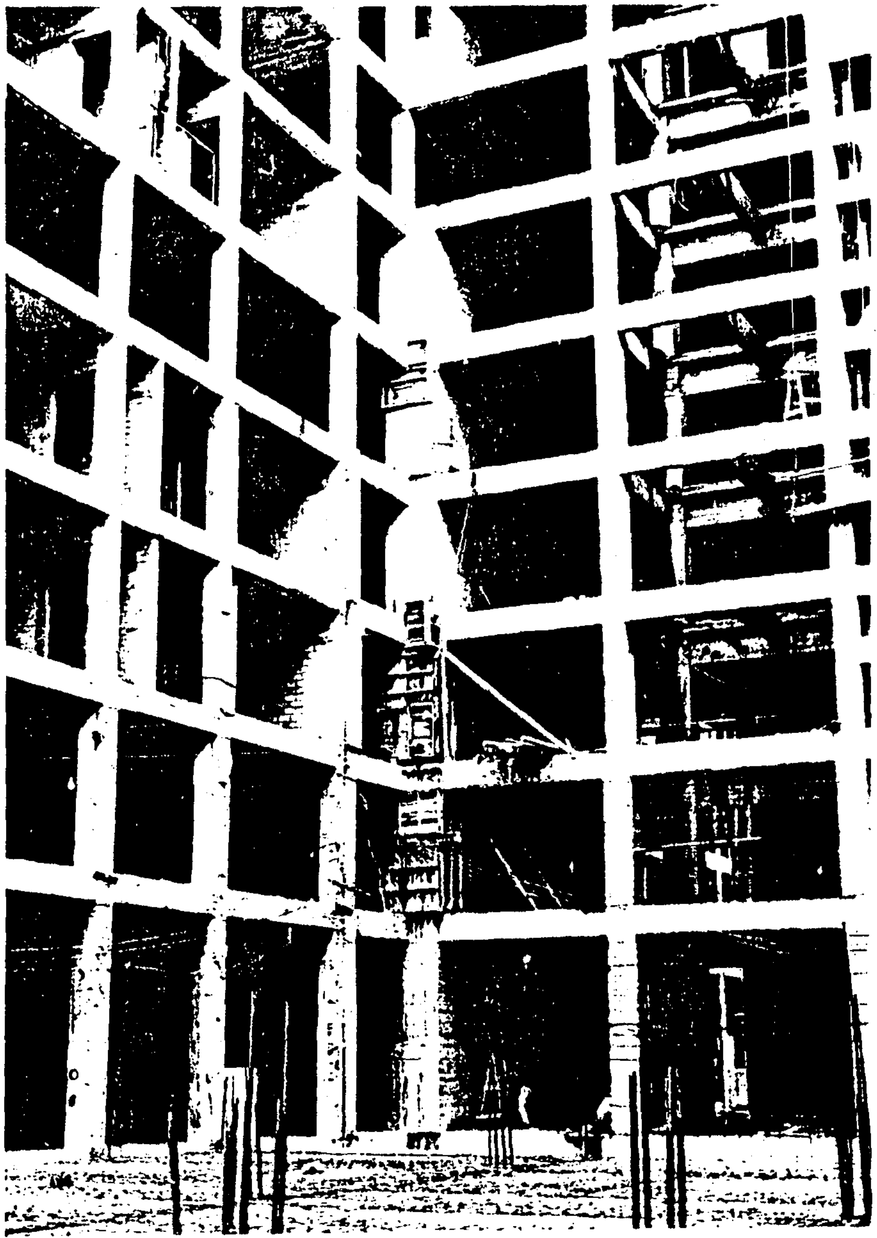


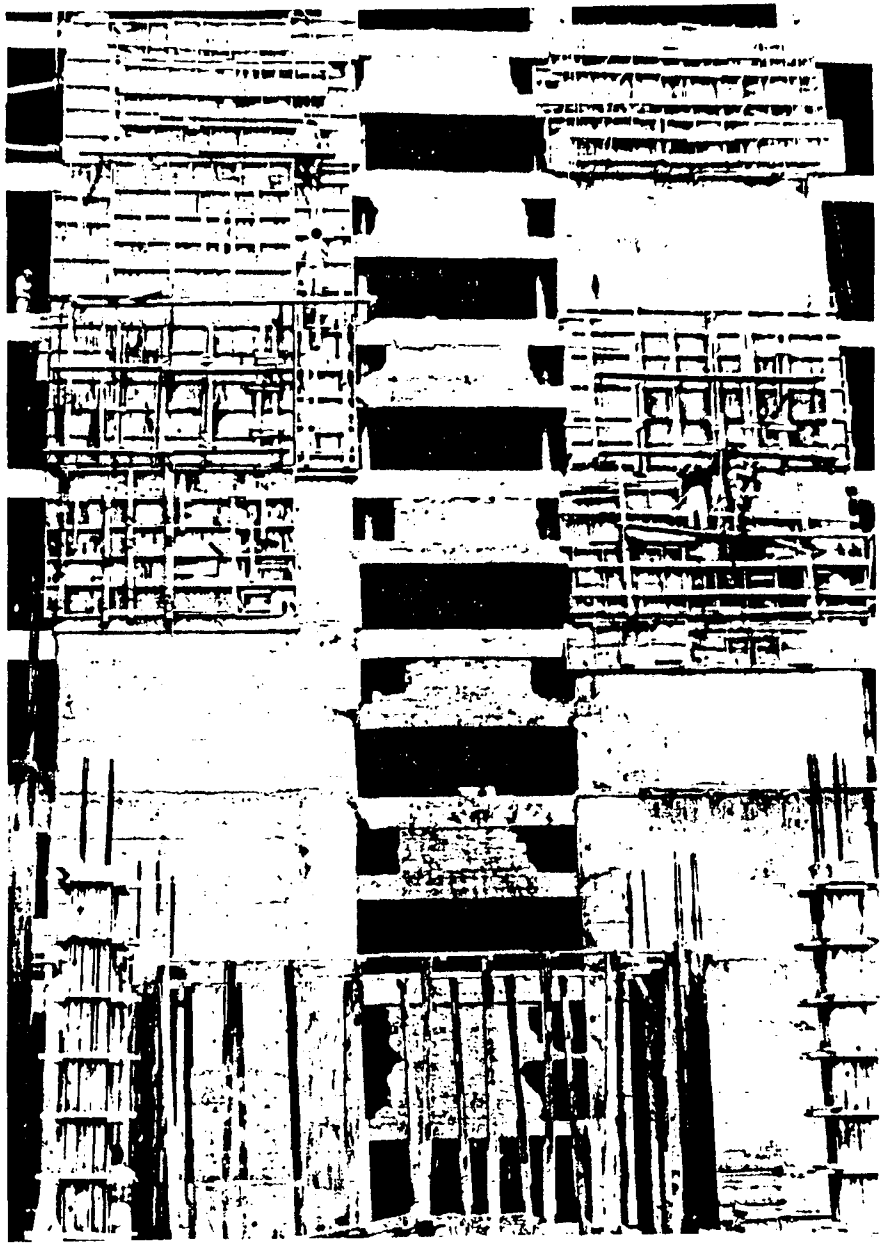
Armado De Muros Formado Angulos

Armado, Colado Y Cimbrado De Muros De Fachada



Armado De Muros





Muros De Fachada Posterior En Proceso De

Caso: Edificio de Oficinas, Liverpool # 88, México, D.F.,

Características:

Edificio de oficinas de 9 niveles de forma irregular.

Asentado sobre un suelo de antiguo fondo del lago, estructura de losas, vigas y columnas. Fue diseñado estructuralmente conforme a las normas sísmicas reglamentadas después del temblor de 1957.

La zona en que se encuentra fue severamente dañada por el temblor de 1985.

El edificio sufrió daños, originados por torsiones, debido a su forma irregular, y a que su período de oscilación se acercó al período del temblor.

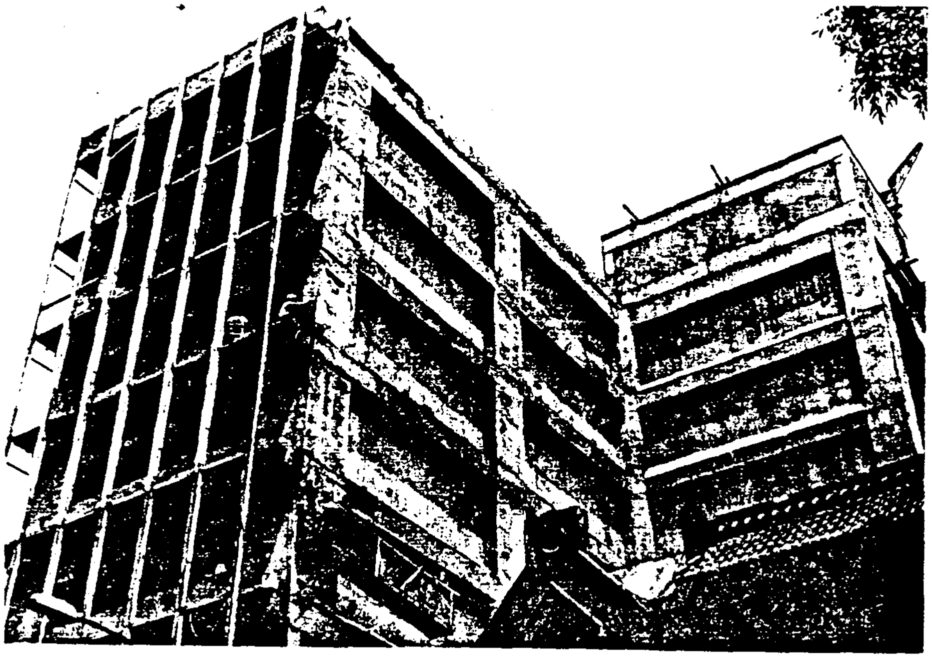
Se decidió repararlo, y se diseñó una estructura a base de muros de cortante construídos en concreto armado, y sobre las fachadas, crucetas metálicas, formando una celosía desde planta baja al nivel 9 con objeto de reducir el período de oscilación a menos de un segudo y soportar los esfuerzos sísmicos de acuerdo a el nuevo reglamento.

Se reforzó la cimentación para los nuevos esfuerzos sísmicos, y el nuevo peso estático de los muros de concreto, logrando con éstos, una interrelación estructura-cimentación adecuada.

REFURZO DEL EDIFICIO DE OFICINAS UBICADO EN LA CALLE DE LIVERPOOL # 88 MEXICO D.F.

LANDA Y ASOCIADOS, S. C.
P. DE LAS PALMAS 755 · 12o. PISO

Muros De Refuerzo En Colindancia

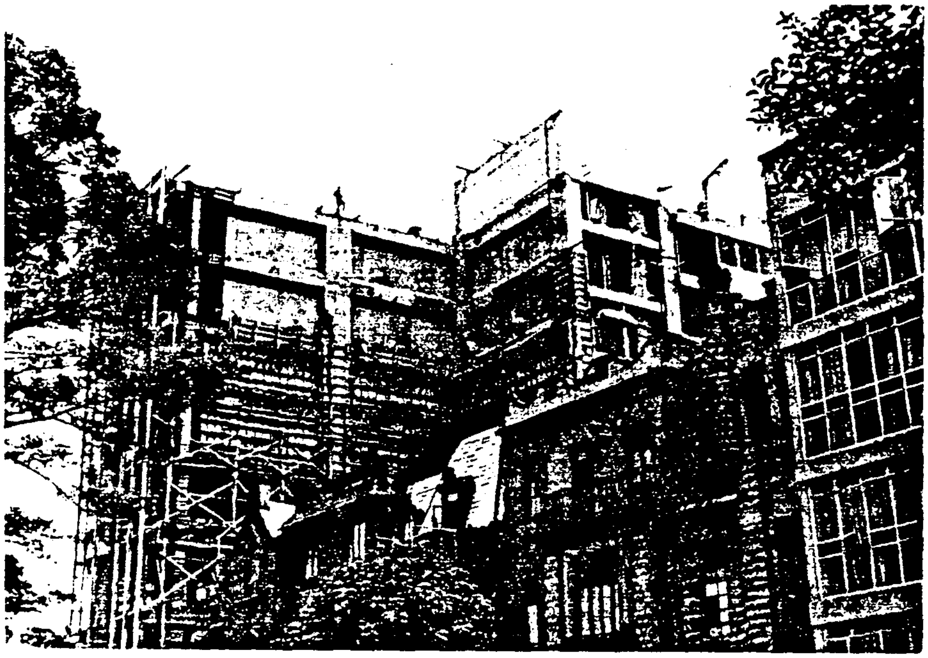


Angulo De Refuerzo Con Muros De Cortantes

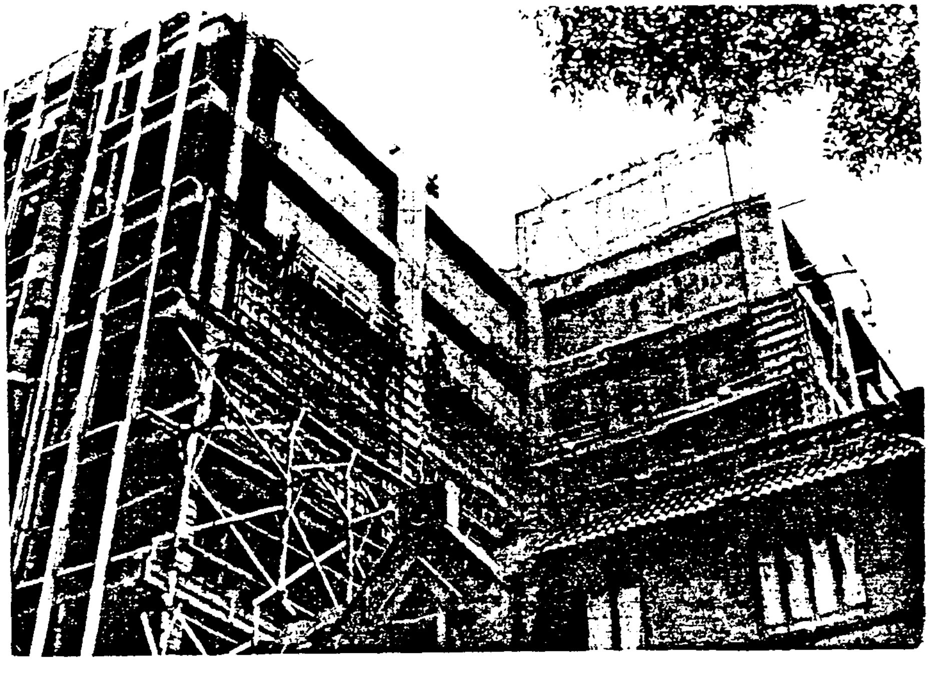
LANDA Y ASOCIADOS, S. C.

P. DE LAS PALMAS 756 - 12o. PISO

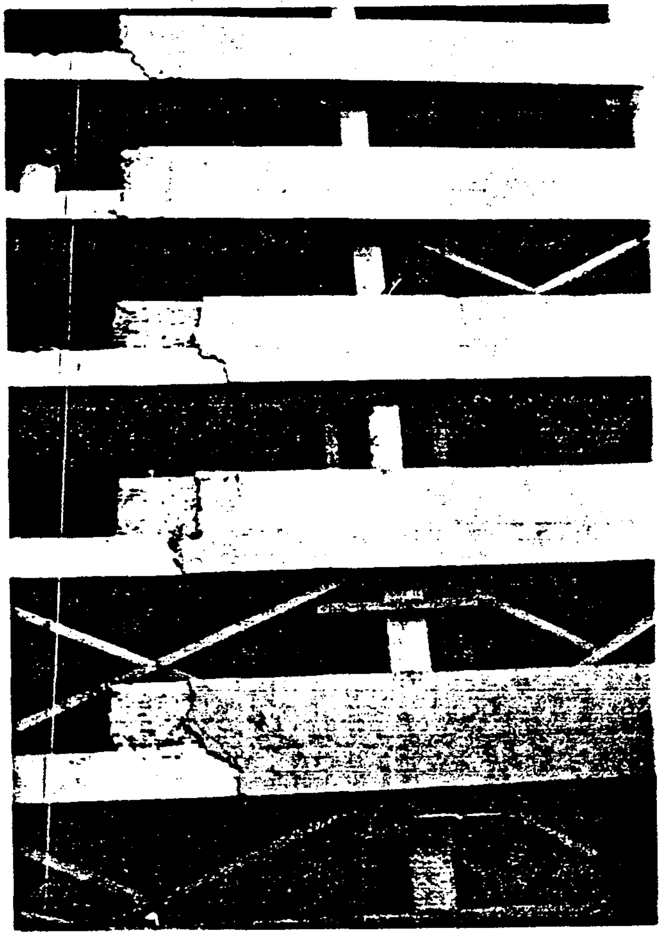
Muro De Cortante
En Colindancia
Usando Unicamente
Un Entreje En Pisos
Superiores



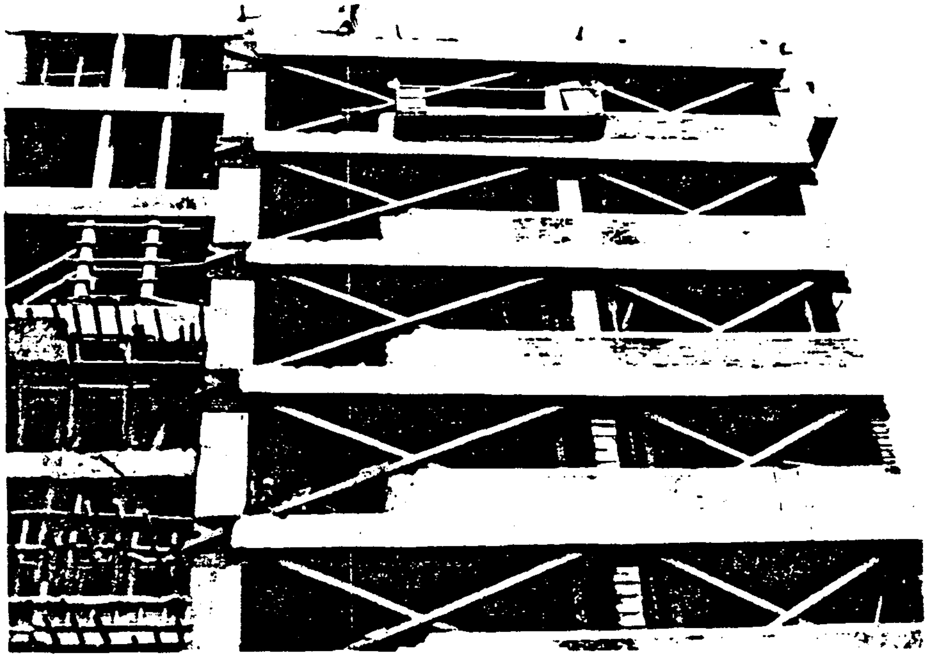
Progreso Constructivo
De Arriba Hacia Abajo
Para Los Muros De Cortante

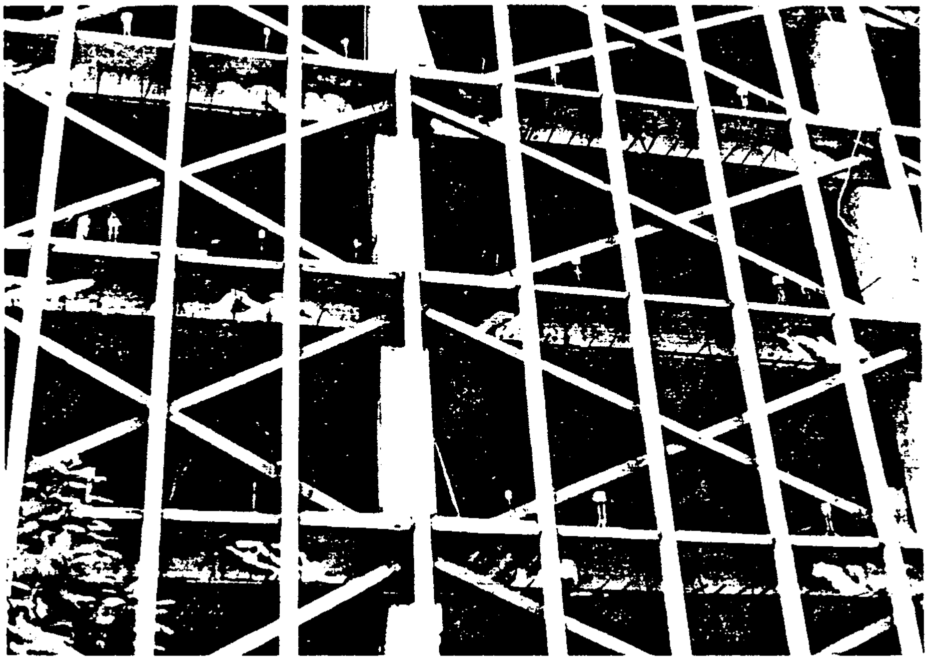


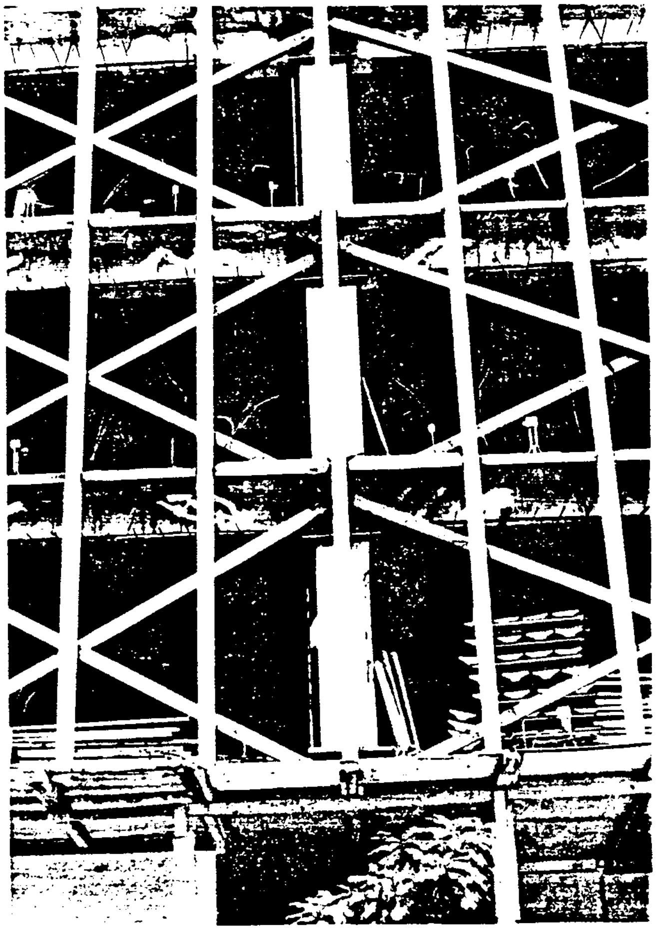
LANDA Y ASOCIADOS, S. C.
P. DE LAS PALMAS 755 · 12o. PISO



Crucetas Metalicas
En Fachada Posterior



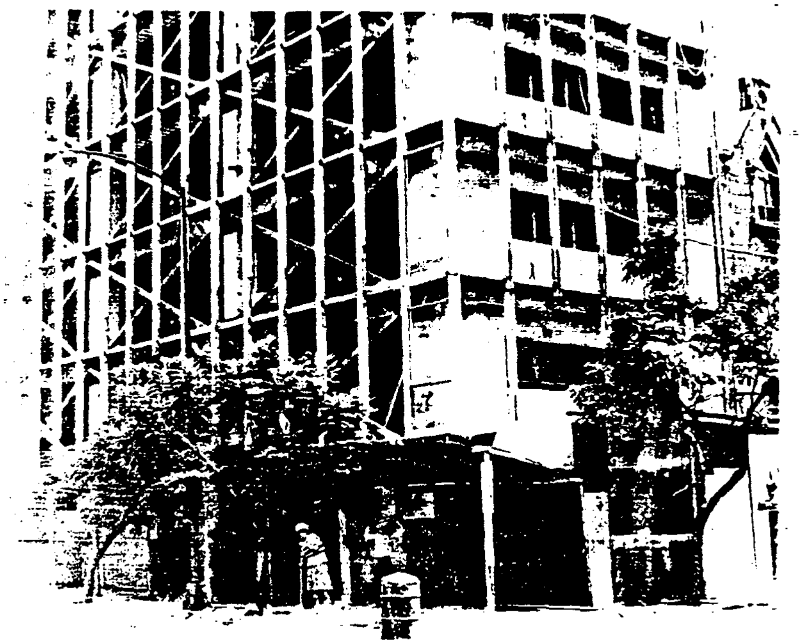


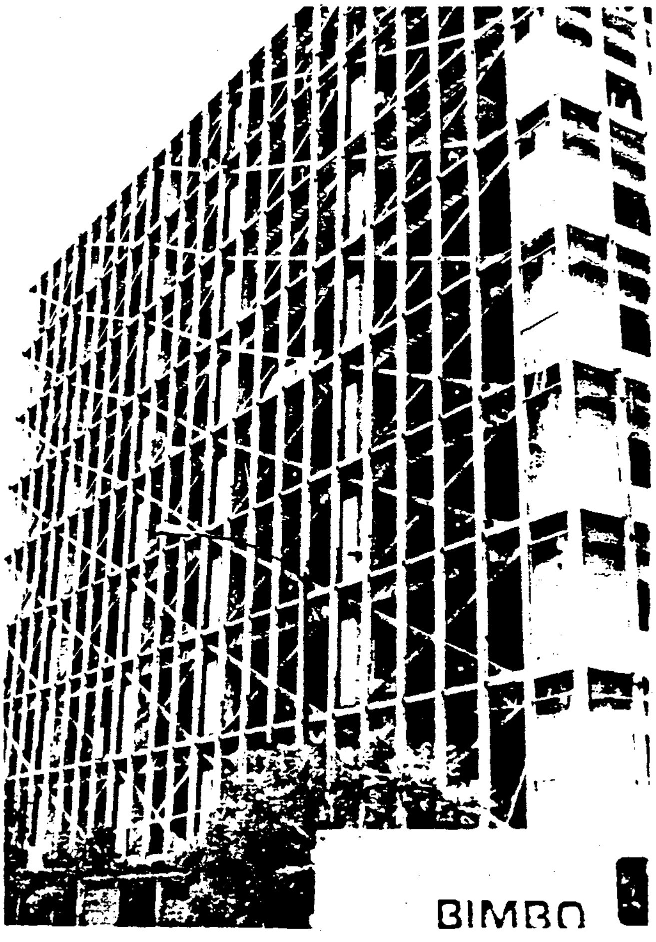


Crucetas Metalicas
En Fachada Principal

LANDA Y ASOCIADOS, S. C.

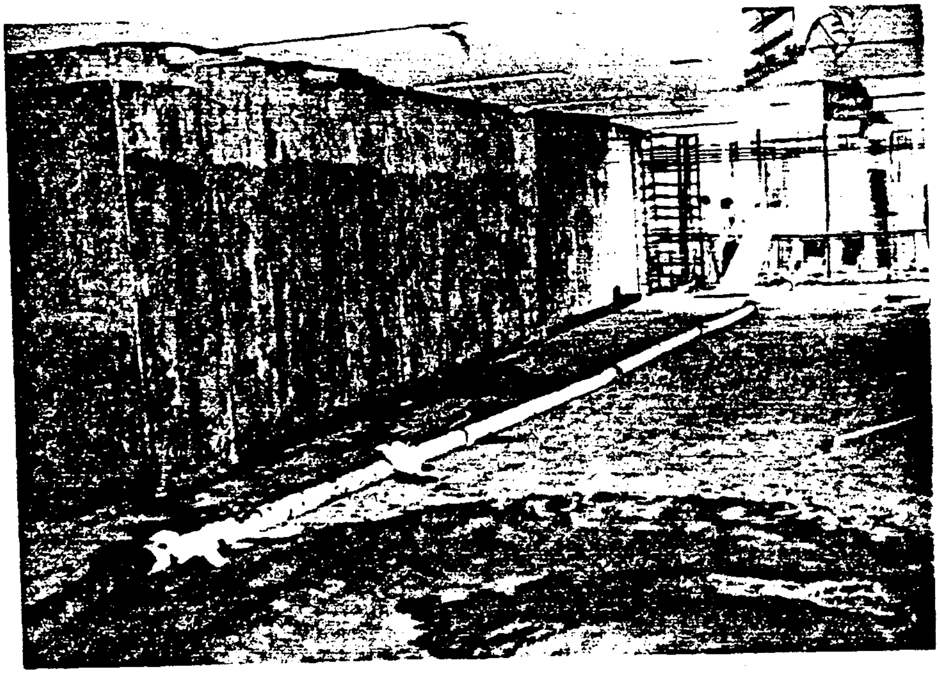
P. DE LAS PALMAS 755 - 12o. PISO

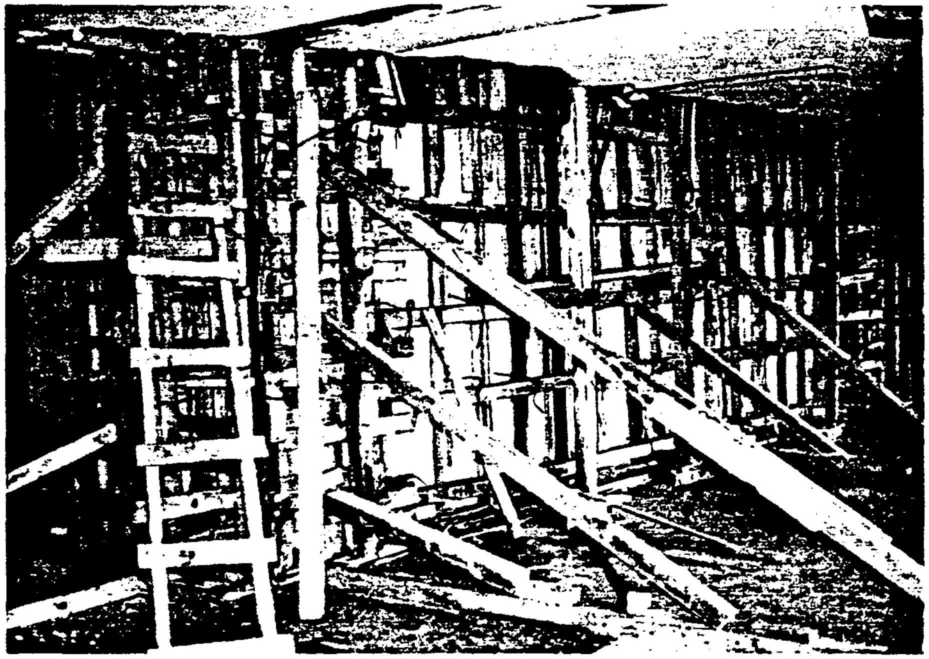




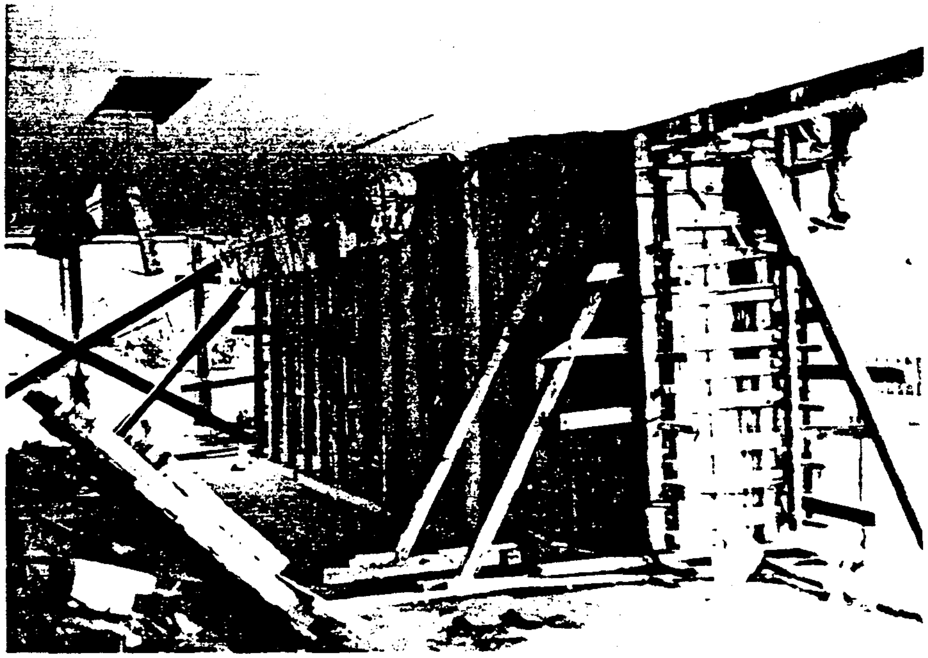
Fachada Principal Con Crucetas

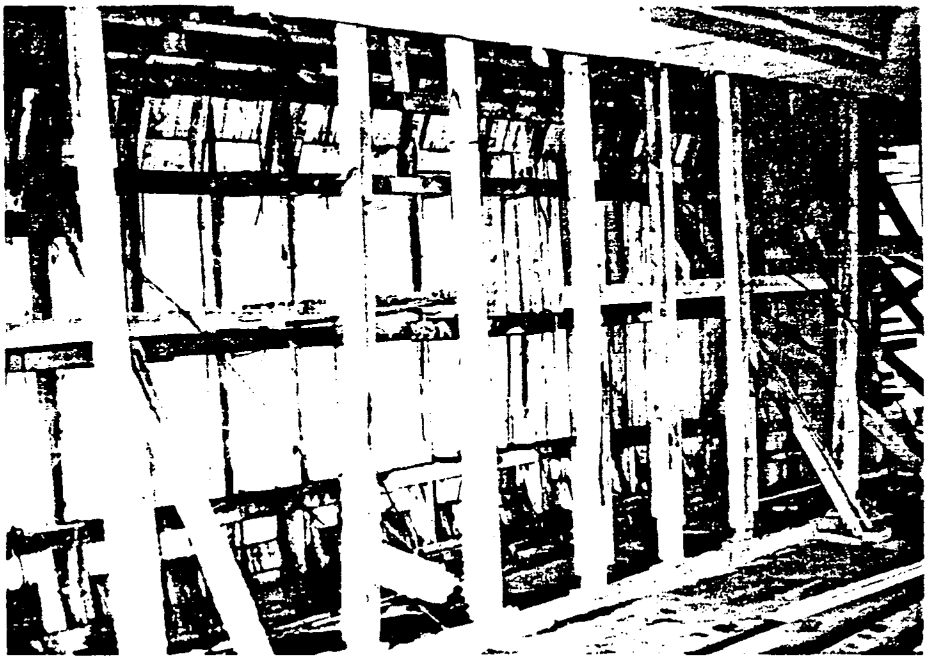
Muros De Cortante
En El Interior
Corresponden a Colindancias

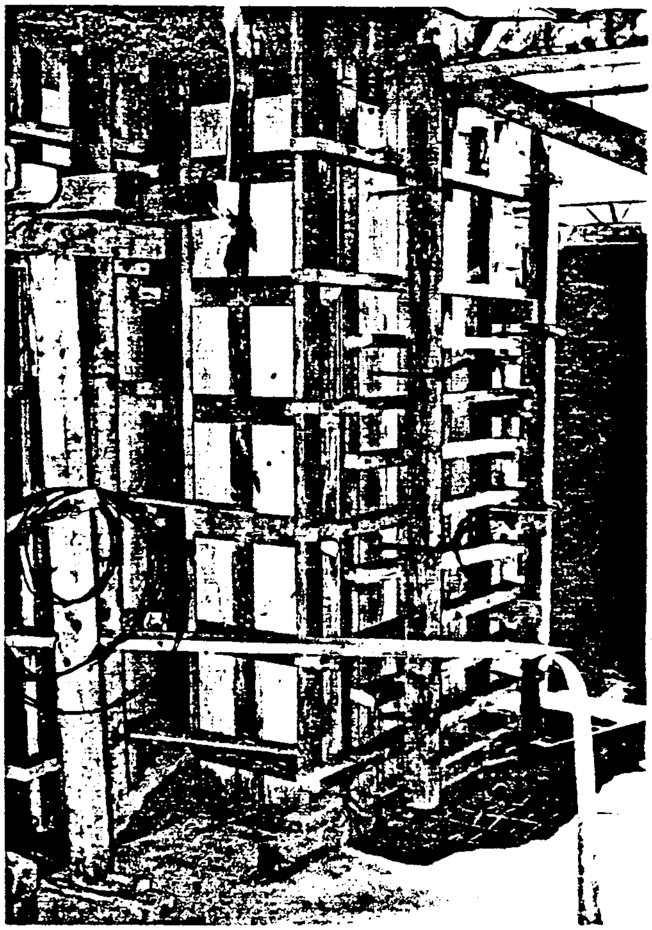




Cimbrado De
Los Muros Interiores

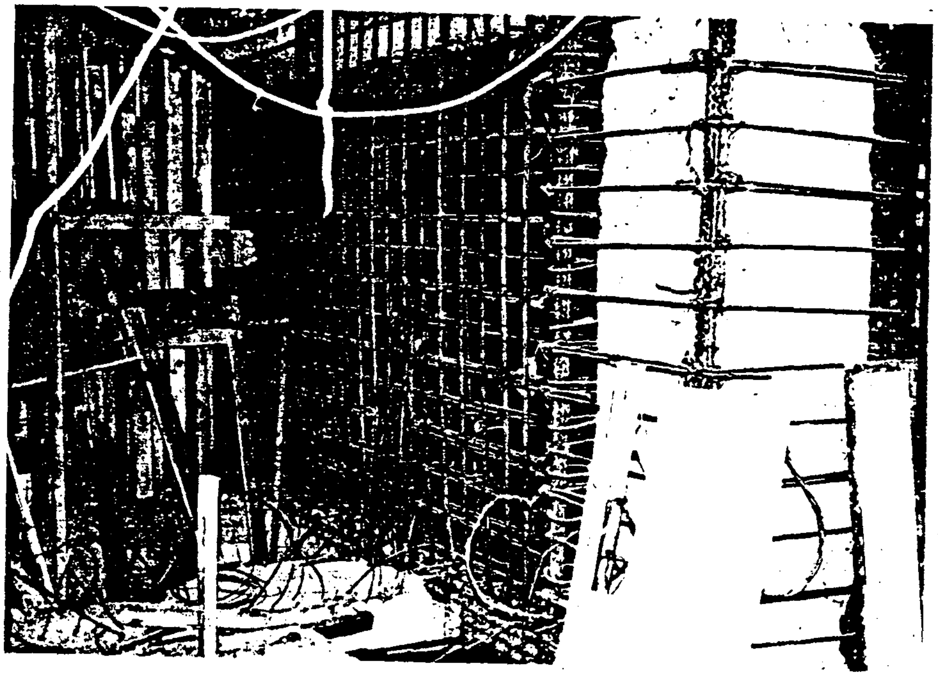


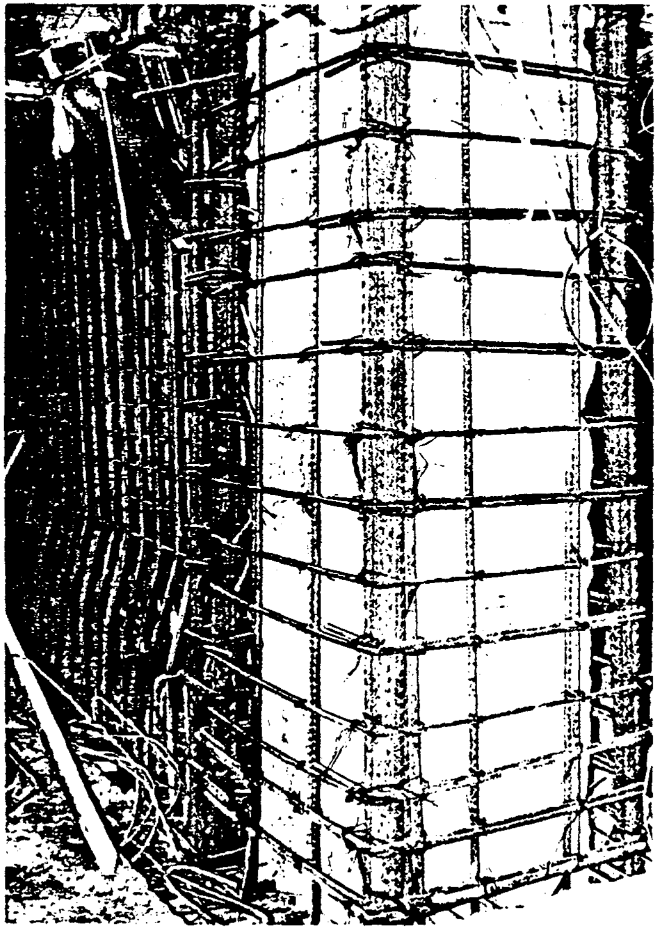




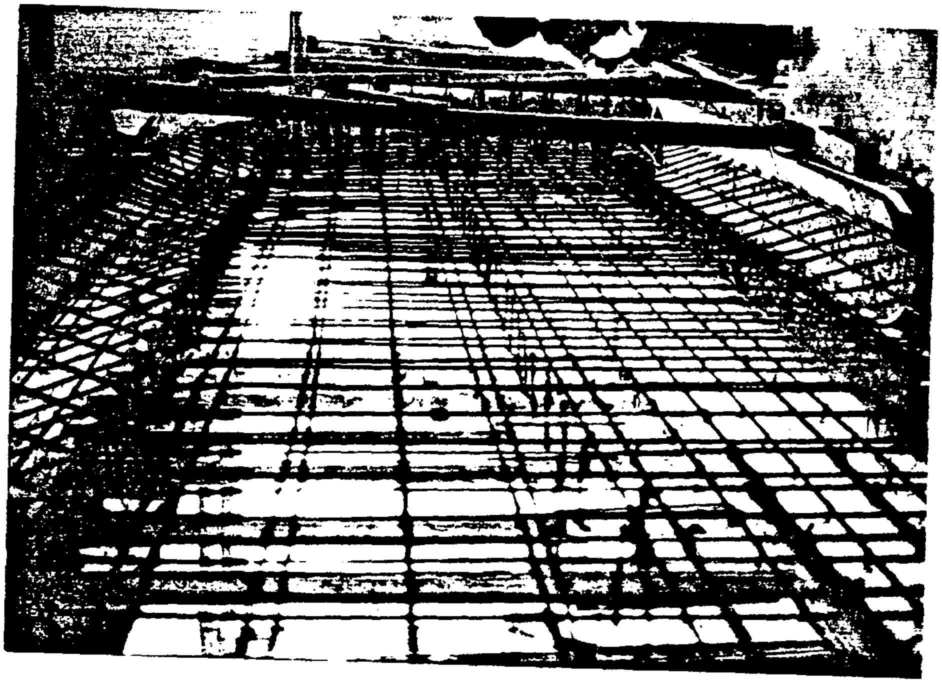
Cimbrado De
Muros Perpendicolares
A Fachada

Cimbrado
De Columna Adyacente
A Los Muros De Cortante

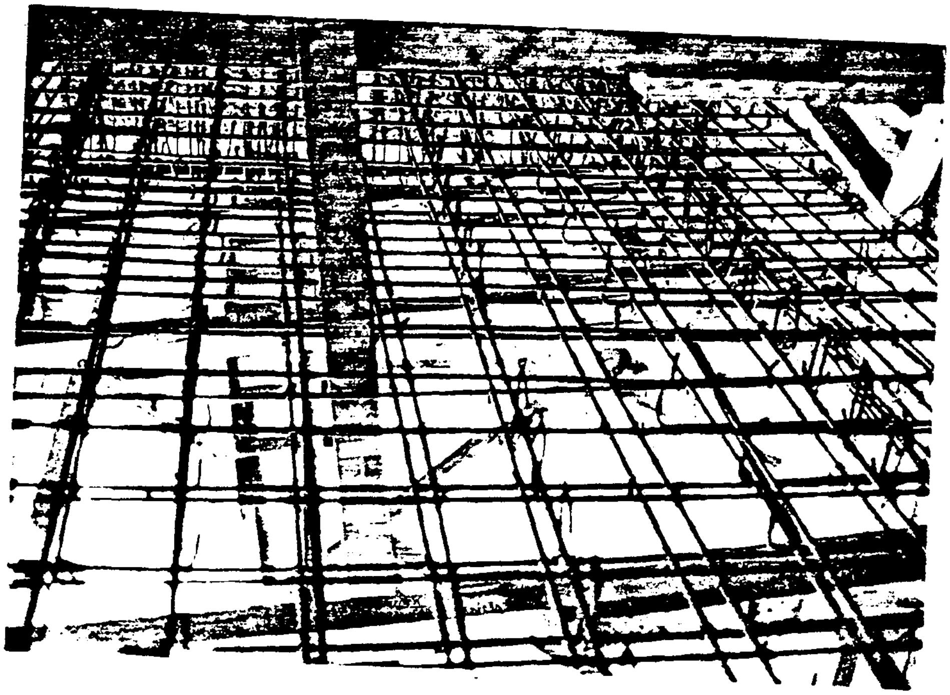


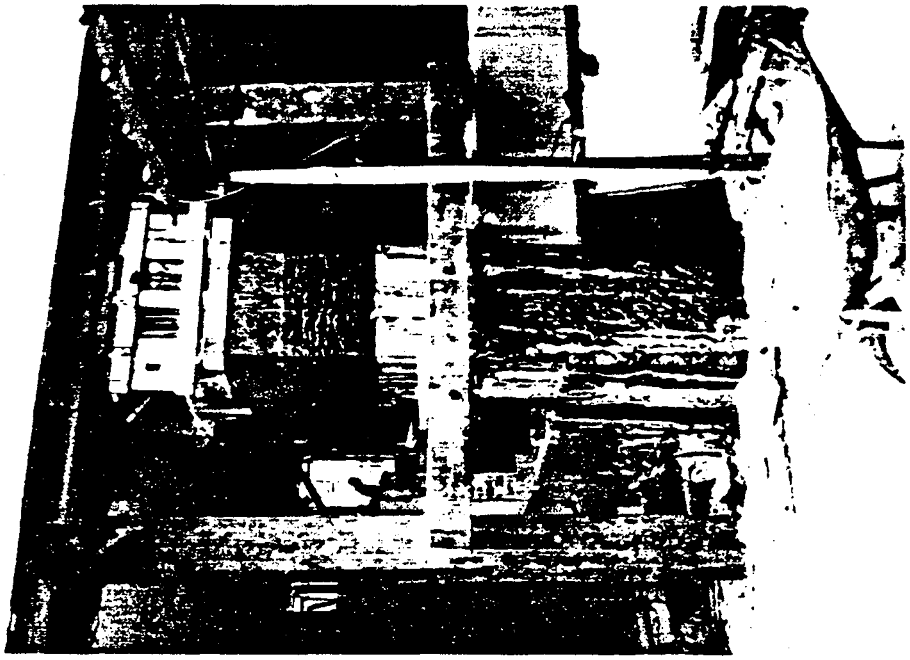


Armados De Muros
Y Columnas

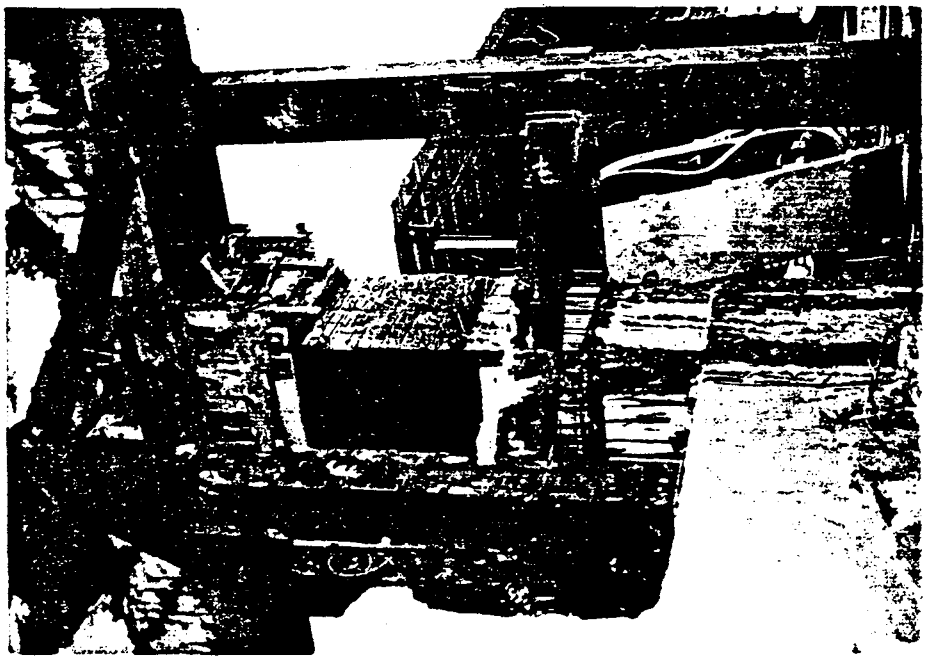


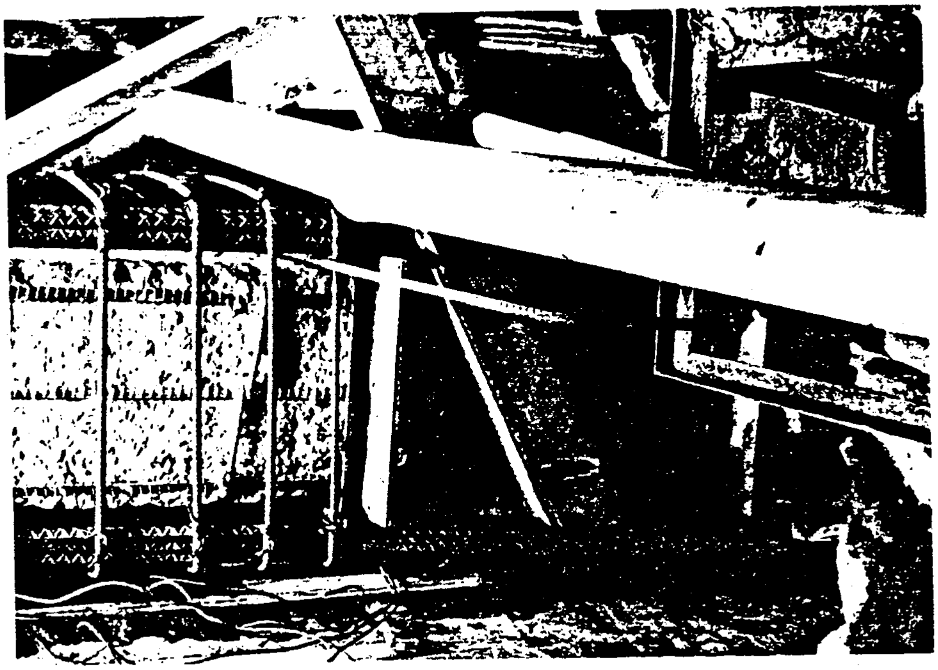
Armado de Muros En Planta Baja





Reparacion Y Colado De Columna Dañada
Con Resina Epoxica





Ligas Columna Cruceta

Fachada Original Con Crucetas Al Interior

Caso: Edificio de oficinas de 12 niveles forma regular.

Asentado en el suelo del antiguo fondo del lago, estructura de losas-planas de concreto armado.

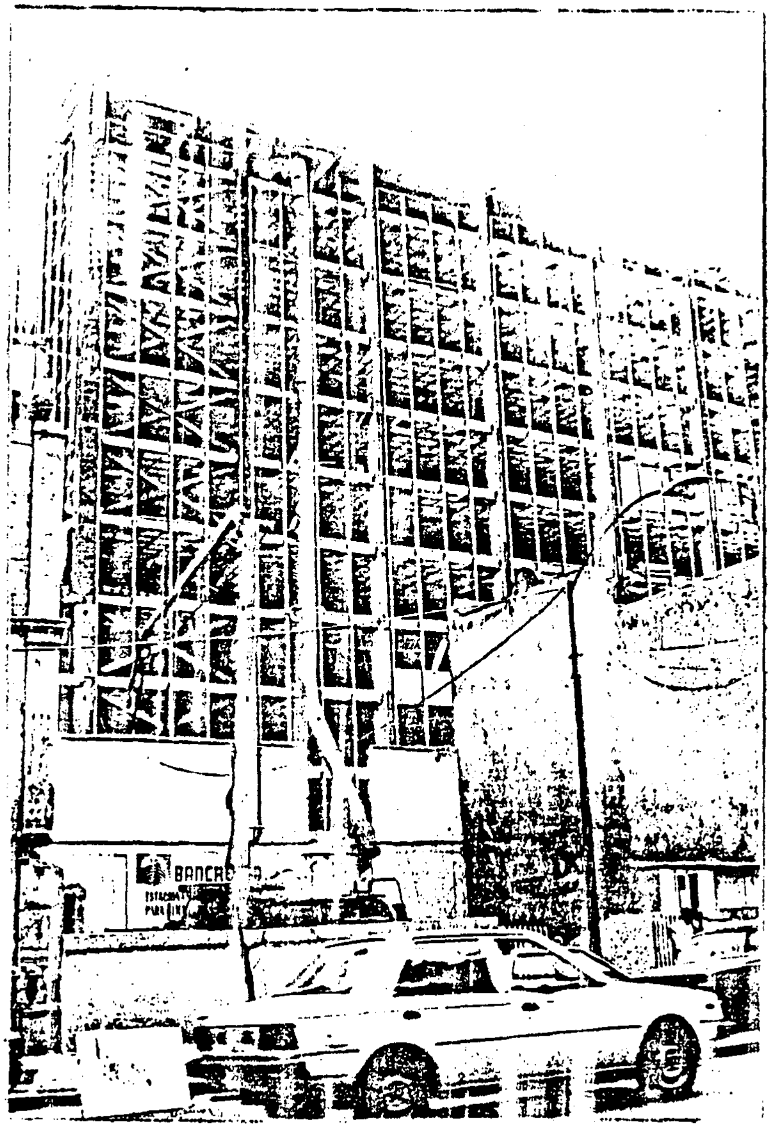
Fue diseñado conforme a las normas para sismo reglamentadas después de 1957.

La zona en que se encuentra fue dañada medianamente por el sismo.

El edificio sufrió daños medios, debido a que su período de oscilación se acercó mucho al del sismo, por tener una estructura flexible. Se decidió reestructurarlo para adecuarlo a las nuevas normas sísmicas de 1985.

Al tener cuatro fachadas, y ser muy angosto, se proyectó una estructura metálica complementaria a base de crucetas en los pisos superiores y muros de cortante en el sótano.

Se reforzó la cimentación para las cargas que trasmitiría en un sismo el sistema crucetas-muros y se inyectaron las grietas capilares y roturas en losas y columnas mediante la aplicación de pegamento epóxico.



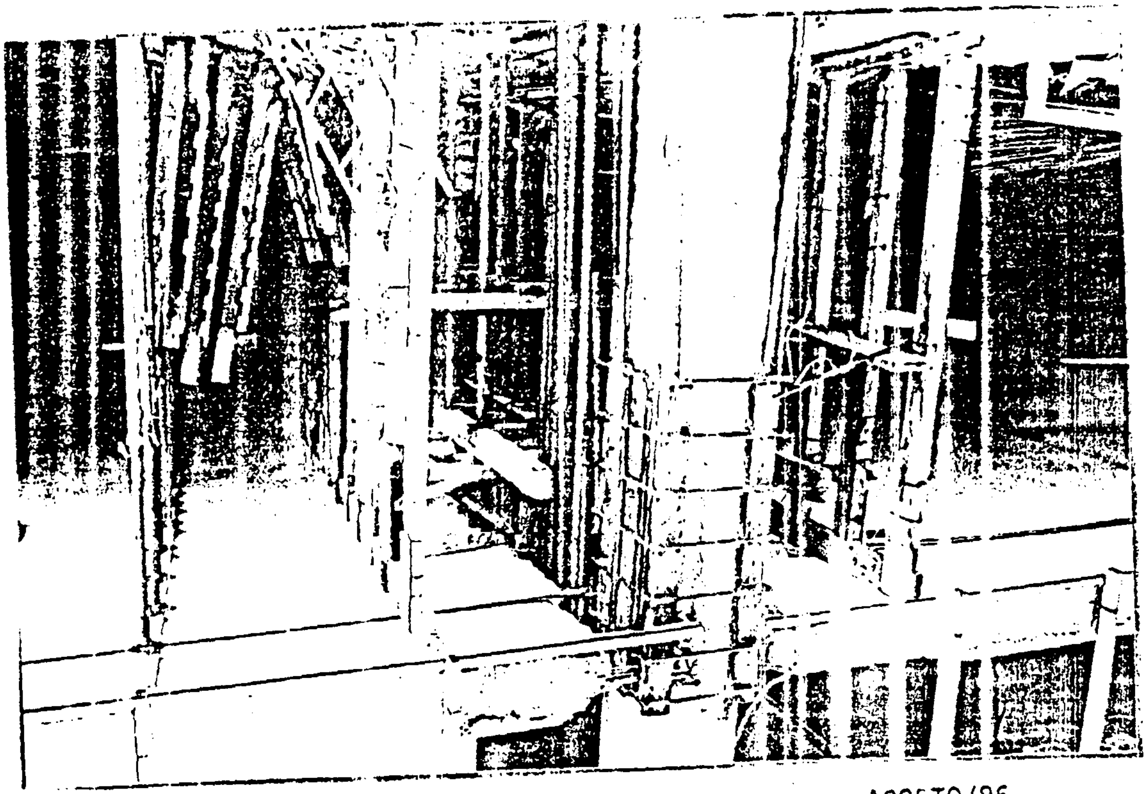
NOV/86

Refuerzo De Crucetas
En Los Extremos Del Edificio

REFORMA No. 243
BOMBA TELESCOPICA

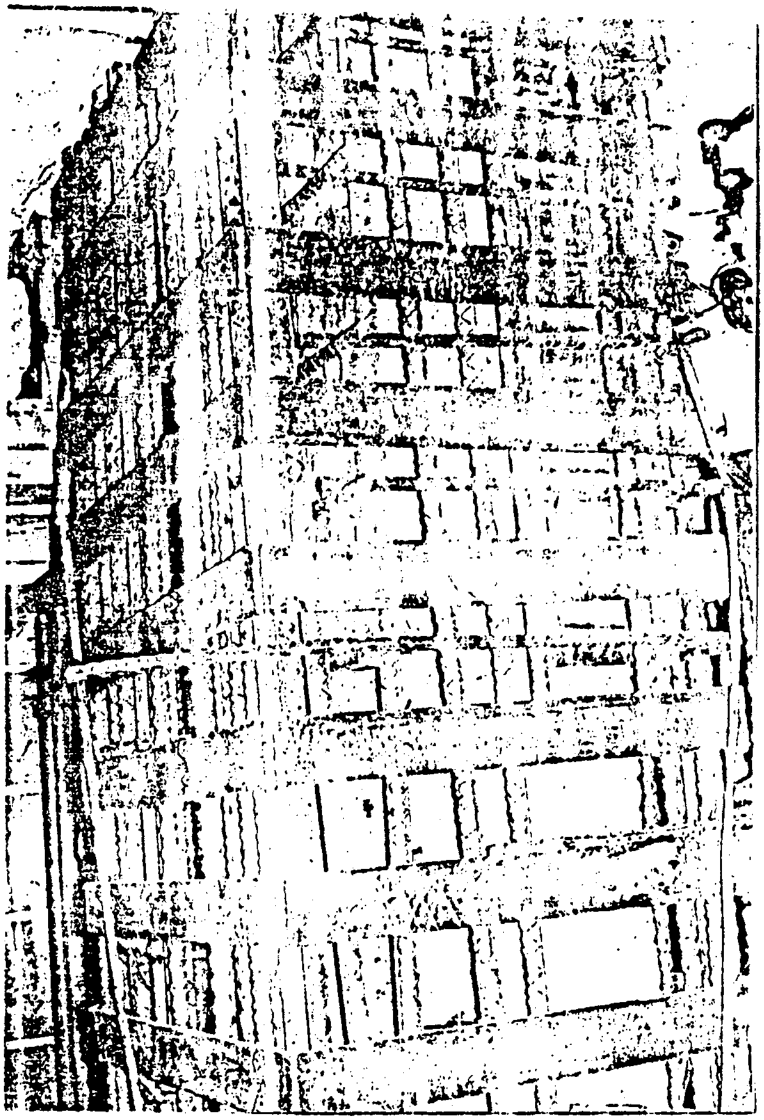
Fachada Principal Con
El Inicio De Las Crucetas
De Arriba-Abajo

AGOSTO/86
REFORMA No. 243
CONJUNTO DEL INMUELBLE



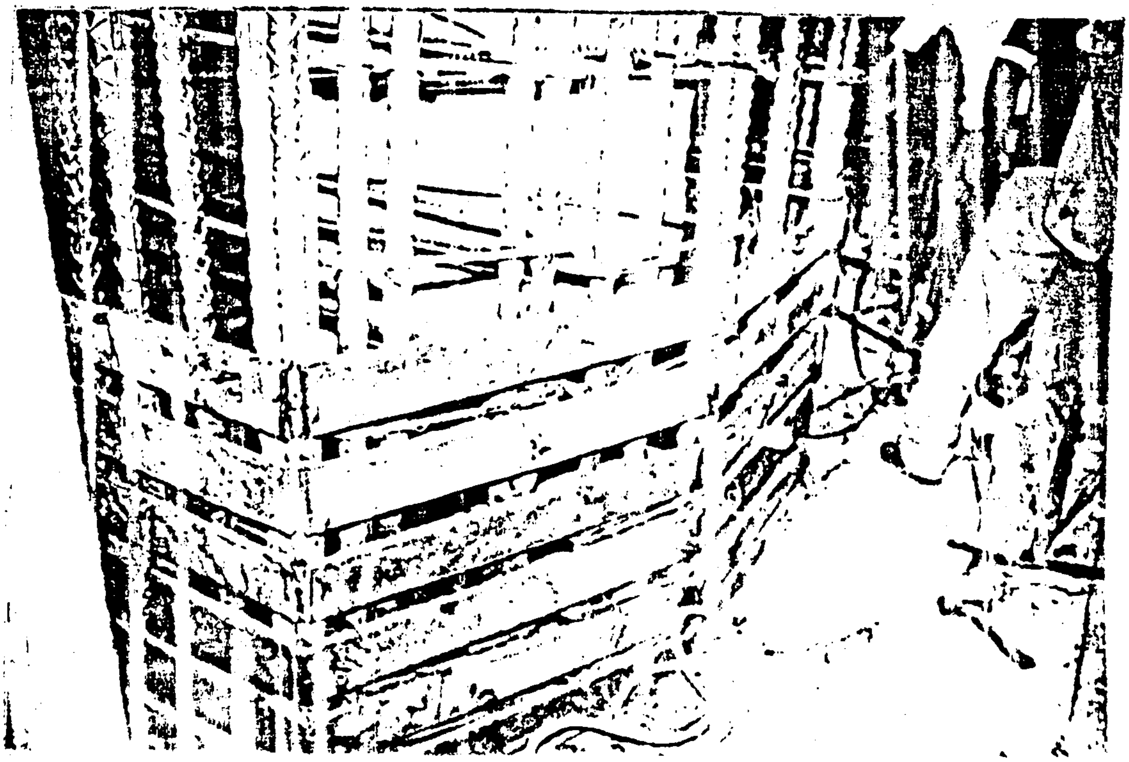
Reparacion De
Columna Danada

AGOSTO/86
REFORMA No. 243
COLUMNA 8-B EN 1er.
NIVEL

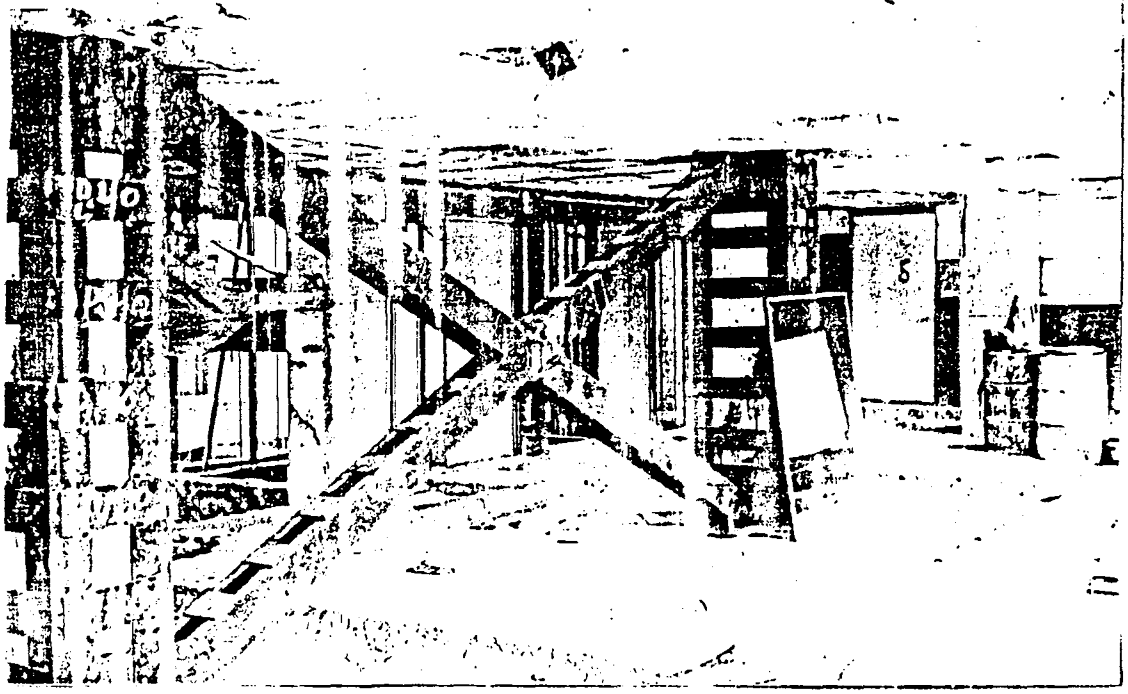


Armado Del Refuerzo
Columnas En Marcos
De Planta Baja

AGOSTO/86
REFORMA No. 243
COLUMNA 8-B

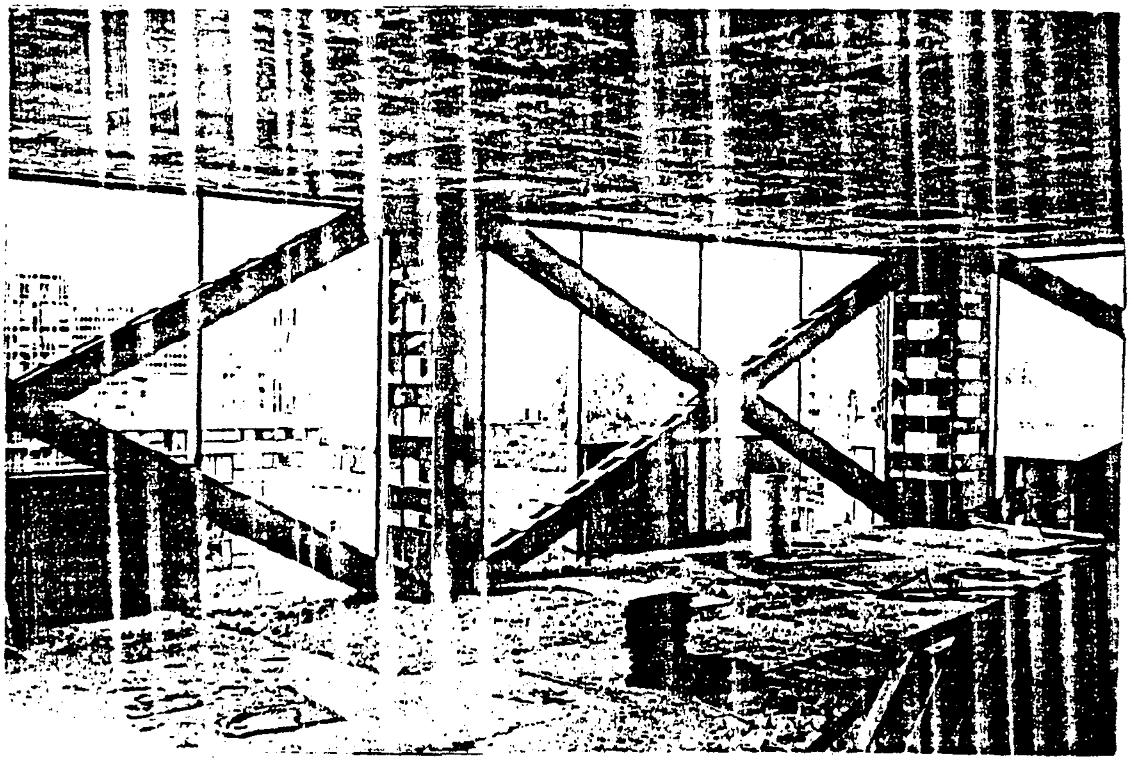


AGOSTO/86
REFORMA No. 243
COLUMNA C-8 NIVEL
SOTANO.



Crucetas en pisos superiores

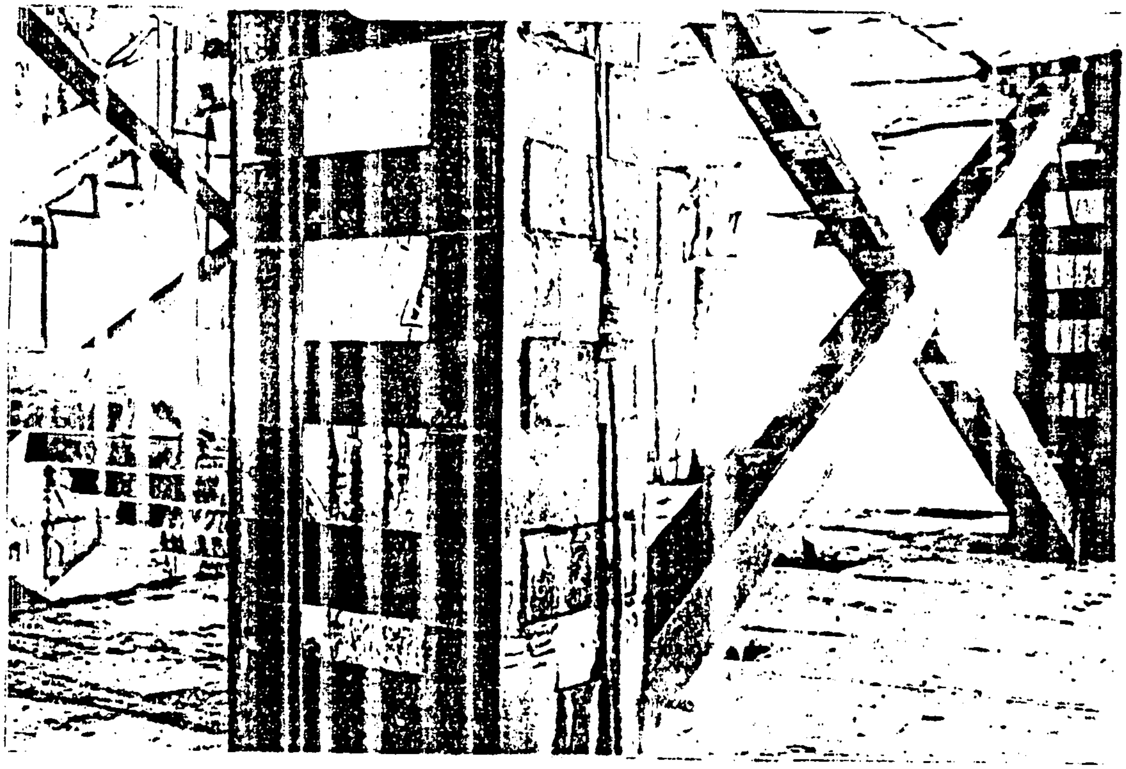
AGOSTO/86
REFORMA No. 243
CONTRAVENTEO EN CLARO
INTERMEDIO.



AGOSTO/86
REFORMA No.243
CONTRAVENTEO DE ACERO
EN FACHADA.

Detalle del refuerzo de
columnas y anclaje de crucetas

AGOSTO/86
REFORMA No.243
DETALLE DE COLUMNA EN
4° PISO.



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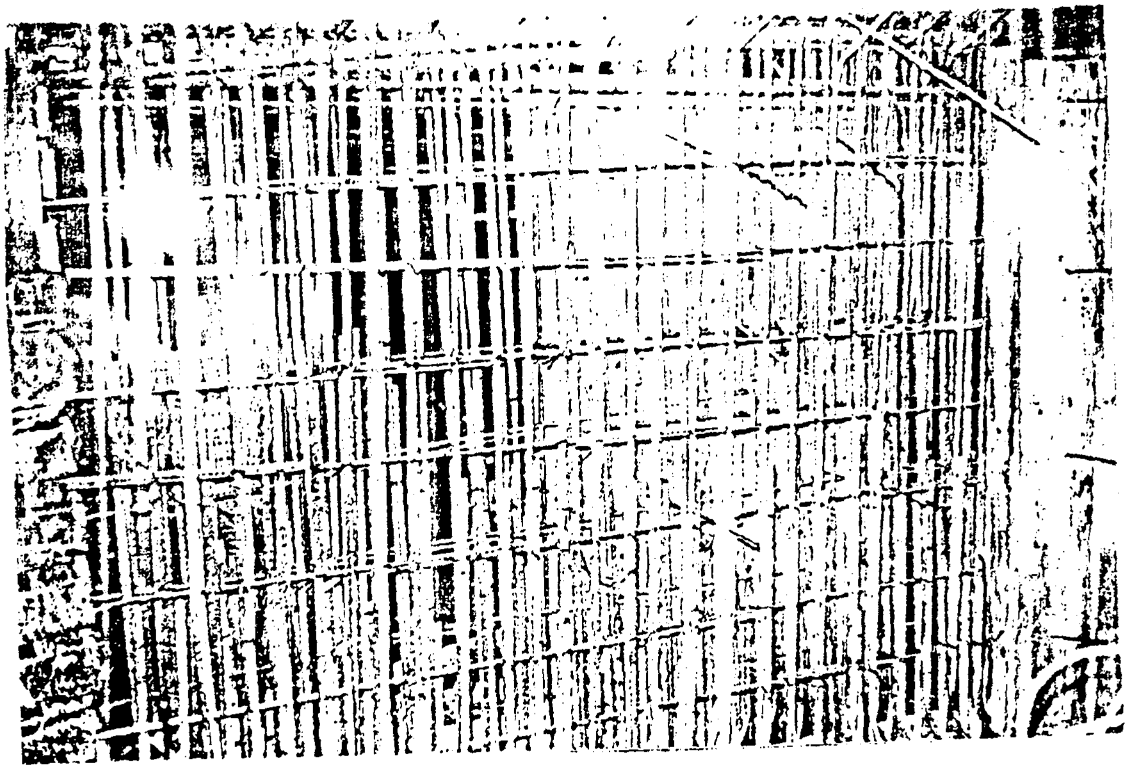
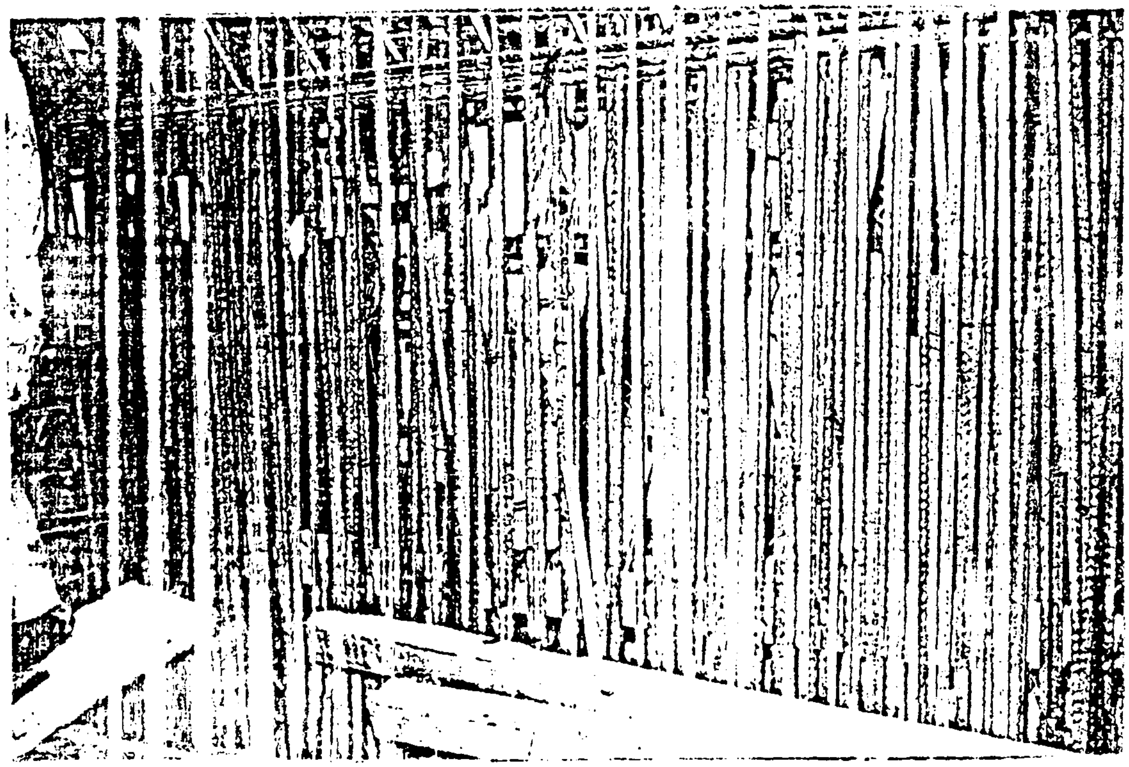
REFORMA No.243
PLACA EN CELOCIA DE COLUMNA.



Muros de cortante en
refuerzos en el sotano

NOV/86
REFORMA No. 243
ARMADO DE MURO EJE 8

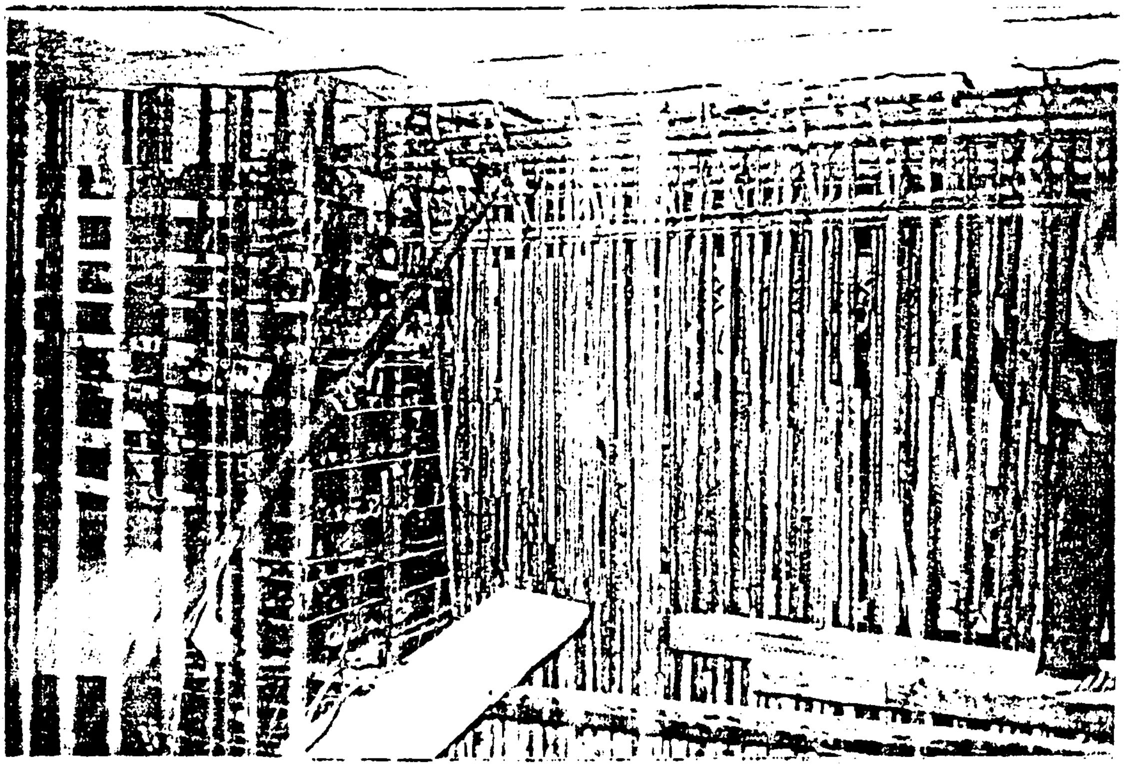


NOV/86
REFORMA No. 243
ARMADO DE MURO EJE 8

Refuerzo de
columnas en
el sotano

NOV/86

REFORMA No. 243
COLUMNA 8C EN NIVEL
SOTANO



NOV/86

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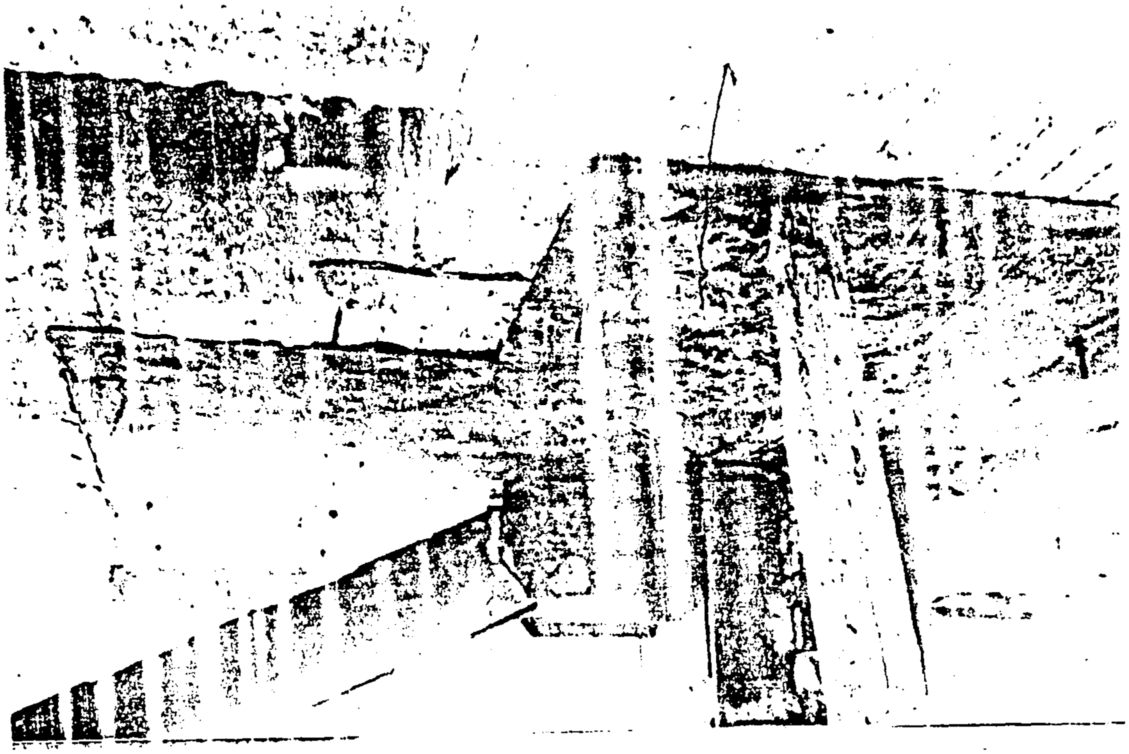
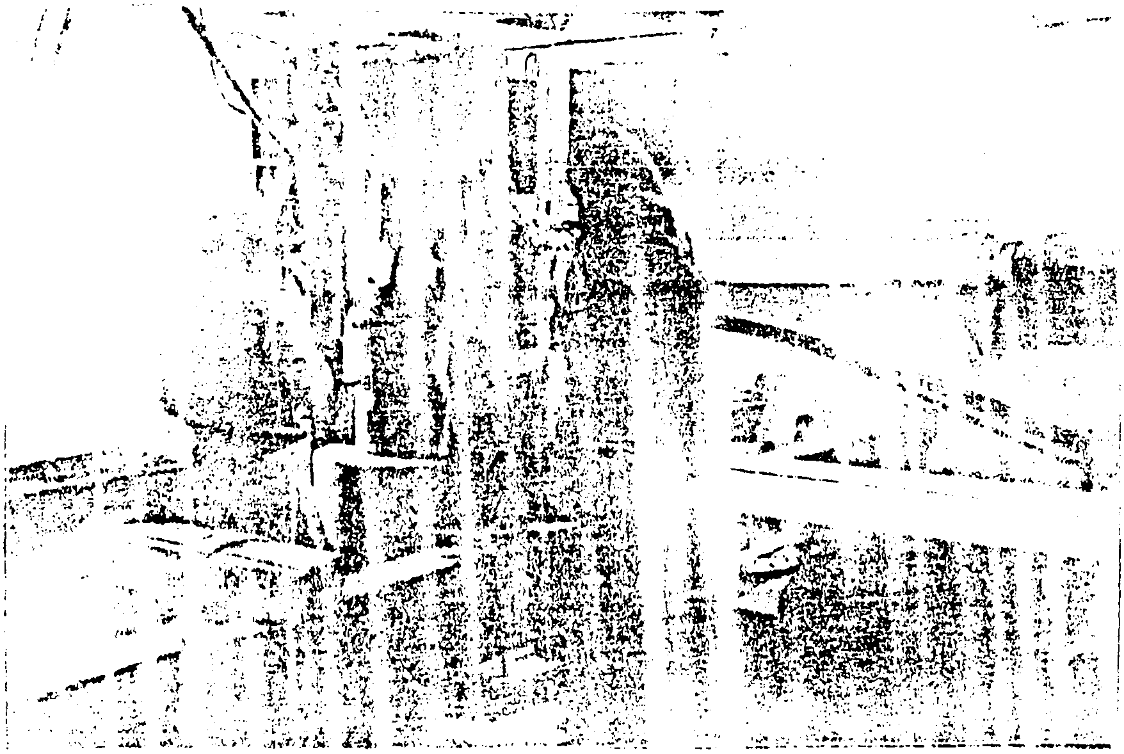
MURO EN EJE 8



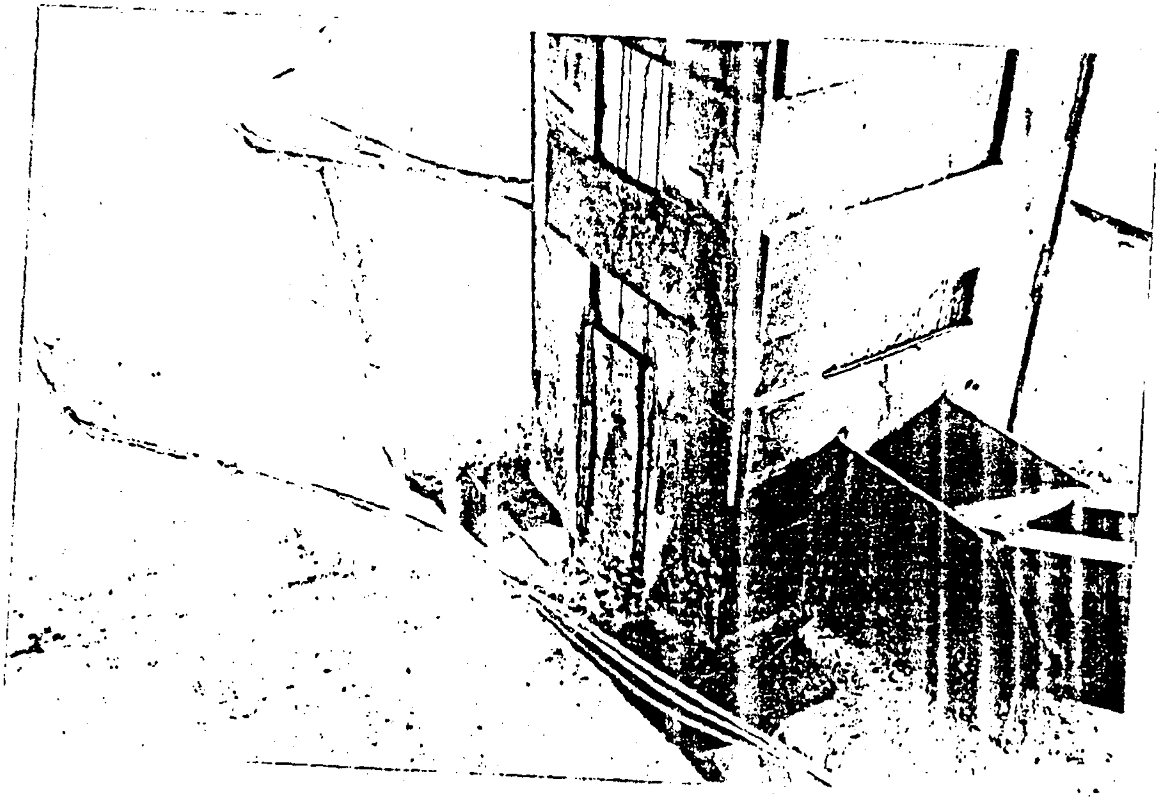
Placas de liga con la
losa existente

AGOSTO/86
REFORMA No.243
FIJACION DE PLACA EN
LECHO BAJO DE LOSA.



AGOSTO/86
REFORMA No.243
PILOTEO EN CELDA DE 1 A
2 Y DE D A E.

AGOSTO/86
REFORMA No.243
UNION DE PISO Y COLUM-
EN 6° PISO DE ESTRUCTU
RA.



AGOSTO/86
REFORMA No.243
DETALLE DE ESTRUCTURA
PSIO 6.

ARCHITECTURE AND EARTHQUAKES IN PREHISPANIC AND COLONIAL MEXICO.

Sara Topelson de Grinberg
Paola Nieto Barcé

In the seismic regions of Mexico and in the city itself, from Prehispanic times, the design and construction of buildings has been firmly linked to the seismic phenomena. Exact details exist of the many earthquakes which have occurred throughout History in the city of Mexico, and something is also known of the structural resources utilized by the builders during the time of the Viceroys, thanks to which buildings of that period are still standing.

In the Prehispanic era, the vast majority of constructions were build on firm ground, and therefore forms which did not call for special behaviour in the materials were utilized.

During the building of Mexico-Tenochtitlán, in which buildings began to be erected on an island, these were carefully analyzed, designed and built, for which purpose the Mexicas used various deep foundation systems in order to support their work on the resistent layers of the subsoil.

In the construction of more complex and larger buildings, the deep foundations called for specialized processes and techniques of which very little is known. The most important event was the building of the Mexico-Tenochtitlan Urban Group, in which the constructions managed to adapt to the special conditions of the

Valle de Anahuac based on observations, ingenuity and accumulated experience. This gave rise to a typification of anti-seismic construction being achieved throughout History.

The Spanish Conquistadores implanted, in turn, their challenge of raisinf a new city on what had been the capital of the Aztec Empire. The city council of Mexico was established in Coyoacán. The order to organize the Spanish city was complied with between the years 1521 and 1522. Alonso García Bravo coordinated the work of drawing up and marking the limits of the plots of land for the most important buildings in the city.

The houses of the conquisadores were those founded and constructed first, groups in which the architects wished to follow the formal and constructive traditions of the residences of Seville and Andalucia, but had to provide same with structural systems sufficiently capable of resisting on very low resistence land, since this had previously been covered by the waters of the Lake and were subject to telluric movements. Tezontle, worked stone, mud and lime were used, in addition to ashlar and various elements which had been taken from Prehispanic construction.

With these the walls were built on which coverings of wood beams were rested. Walls reached one meter in thickness in order to provide the work with stability in the event of earthquakes and to avoid the filtration of water and other humidity.

Pumping methods were used in the foundations to overcome the water problem, and solutions were always looked for which were trustworthy and would guarantee the permanency of the constructions during earthquakes.

The homogeneity which applied to the city of Mexico during the XVI, XVII and XVIII centuries, was due to the use of the same materials, the wall thicknesses which we have already mentioned and the fear of facing the effects of the earthquakes, which assuredly destroyed or seriously damaged various constructions during these centuries. The average height of the buildings at that time was two or three floors at most, which gave them a horizontal nature providing unity to the Urban group.

Buildings dedicated to religious purposes, of which we speak below, formed part of the main organization of the city and also followed Spanish models, while submitting themselves to the adaptation necessary for the city of Mexico due to the soil and earthquake conditions.

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Social Communication methods in connection with the Earthquakes.
The Official Reply.
The Social Reply.
Public Service preparation in the event of Catastrophy.
Preparation of the Citizen in the event of Catastrophy.
Architecture and Earthquakes in Prehispanic and Colonial Mexico.

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  Secretaría de Desarrollo Urbano y Ecología y Fomento Cultural
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CHURCH AND CONVENT OF THE ANCIENT TEACHING IN MEXICO CITY

Fernando Pineda Gómez
Sara Grinberg née Topelson
Paola Nieto Barssé

This convent was founded by Sister María Ignacia Azlor de Echeverz, a wealthy, noble and virtuous lady who obtained in Spain the royal schedule and license to constitute the foundation, which was done on June 23rd, 1754, under the title of Our Lady Del Pilar and having as patrons Saint Michael and Saint John Nepomucene. It was rather a school for the education of girls from the main families in the viceroyalty.

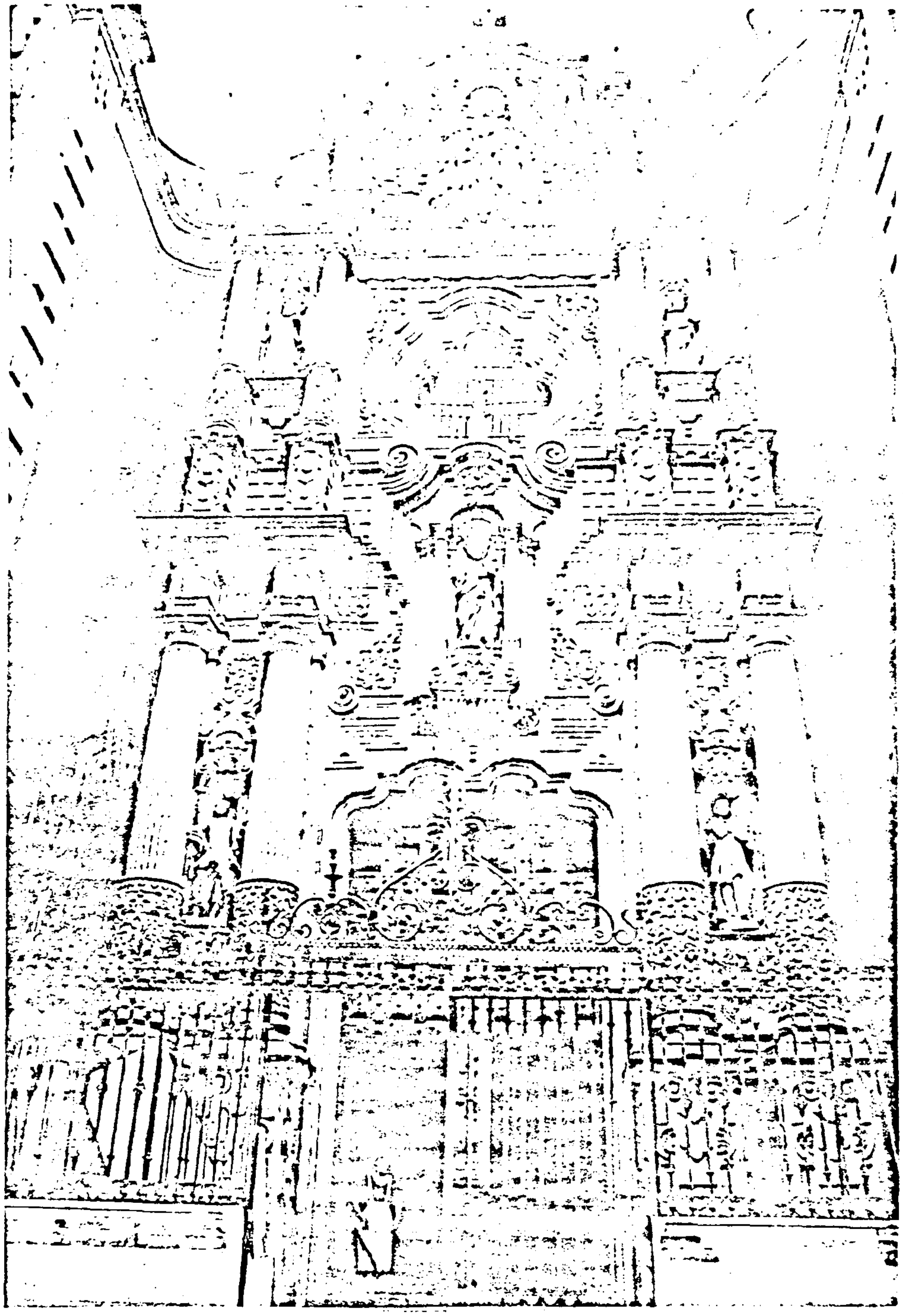
The convent was constituted by a yard with its cloister, 50 cells, work and nursing rooms, lodgings for the pupils, class rooms and other offices.

After the death of Mother Azlor, construction began on the church in February 1772 and concluded on February 1st, 1778, when it was consecrated by archbishop Alonso Niñez de Haro y Peralta. Unlike most churches for nuns in this city, access to this church is through its base, the nuns entering the upper choir through side corridors that also house latticed galleries. Besides, two locales were used at either side of the main altar, protected by gratings and curtains for mass attendance by nuns who were ill or had some difficulty in going up to the upper choir.

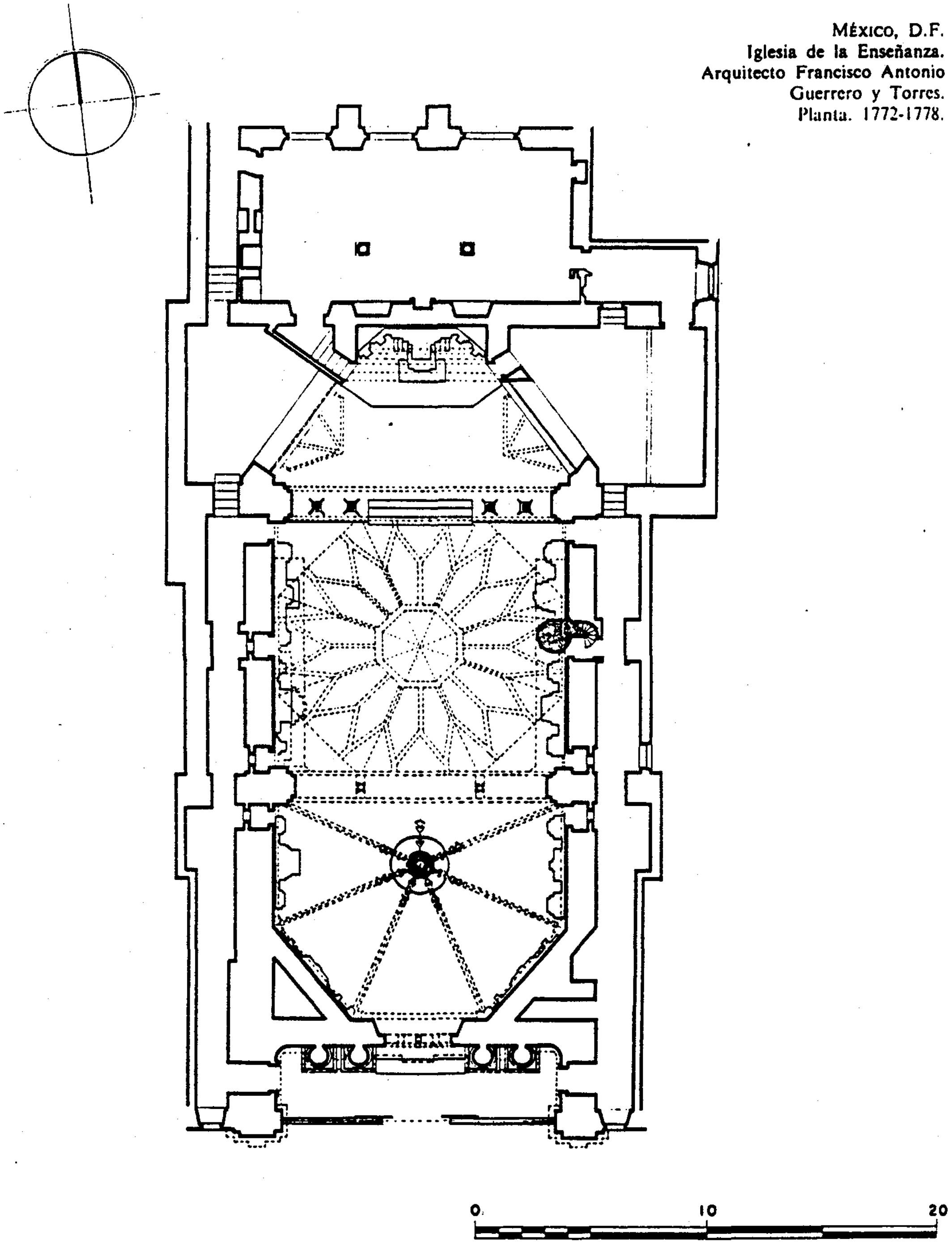
The main altarpiece is an extraordinary example of anastyle baroque and the lateral altarpieces, niche type, as well as the large paintings to the sides of the main altar, give this small temple an almost unique stamp or architectural wealth and harmony.

The facade giving on Donceles street, unlike the inner altarpieces, is a quiet composition set back from the street's lineup, made of hewn stone, with the access door and the choir window flanked by pairs of correct columns in two spans and a beautiful pediment.

This temple was completely restored not too many years ago, by the Federal Government, and is now open to worship. The convent, after the exclaustration of the nuns which took place in 1863, was converted into the Palace of Justice and now houses the Courts.



MÉXICO, D.F.
Iglesia de la Enseñanza.
Arquitecto Francisco Antonio
Guerrero y Torres.
Planta. 1772-1778.



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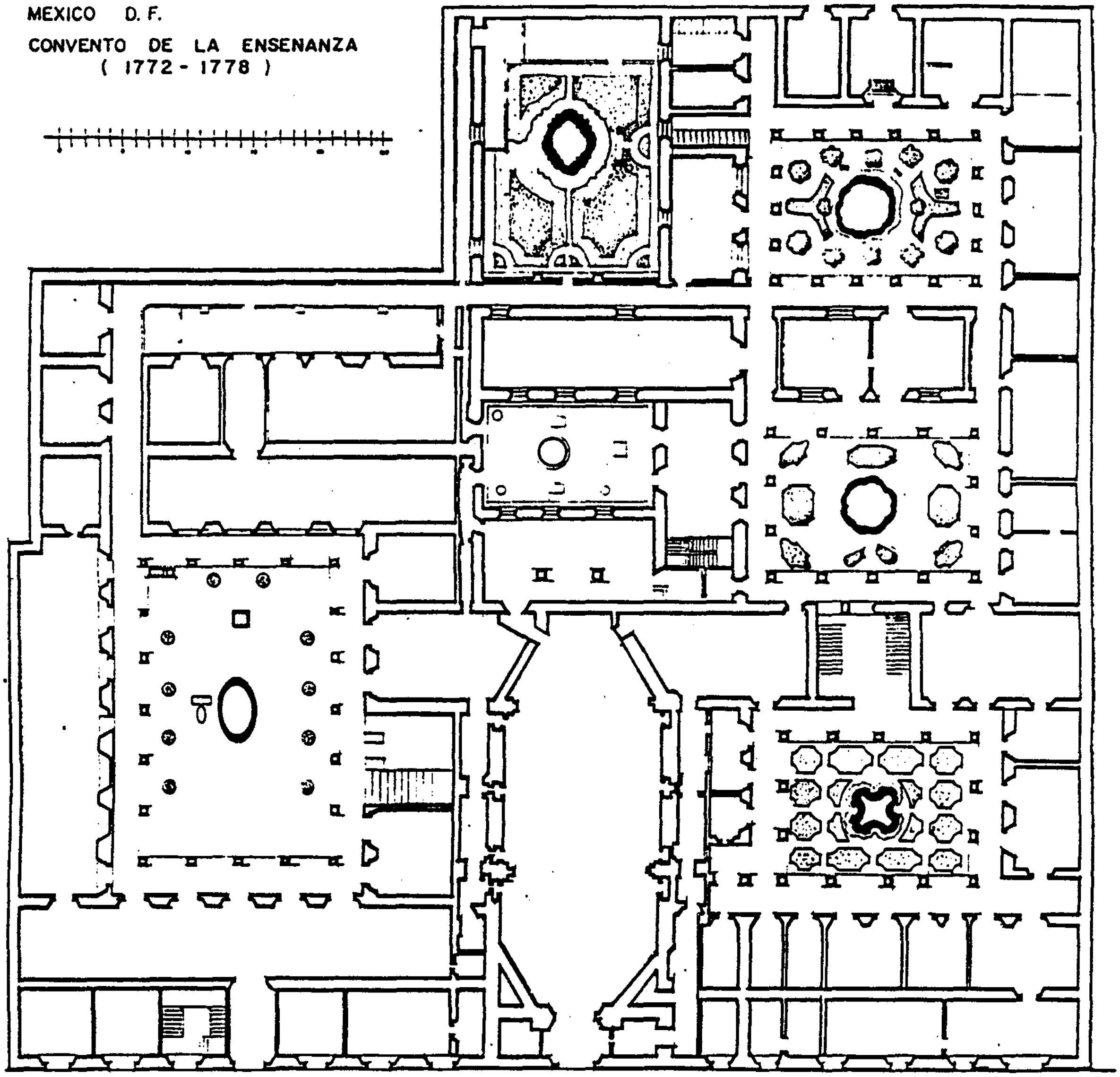
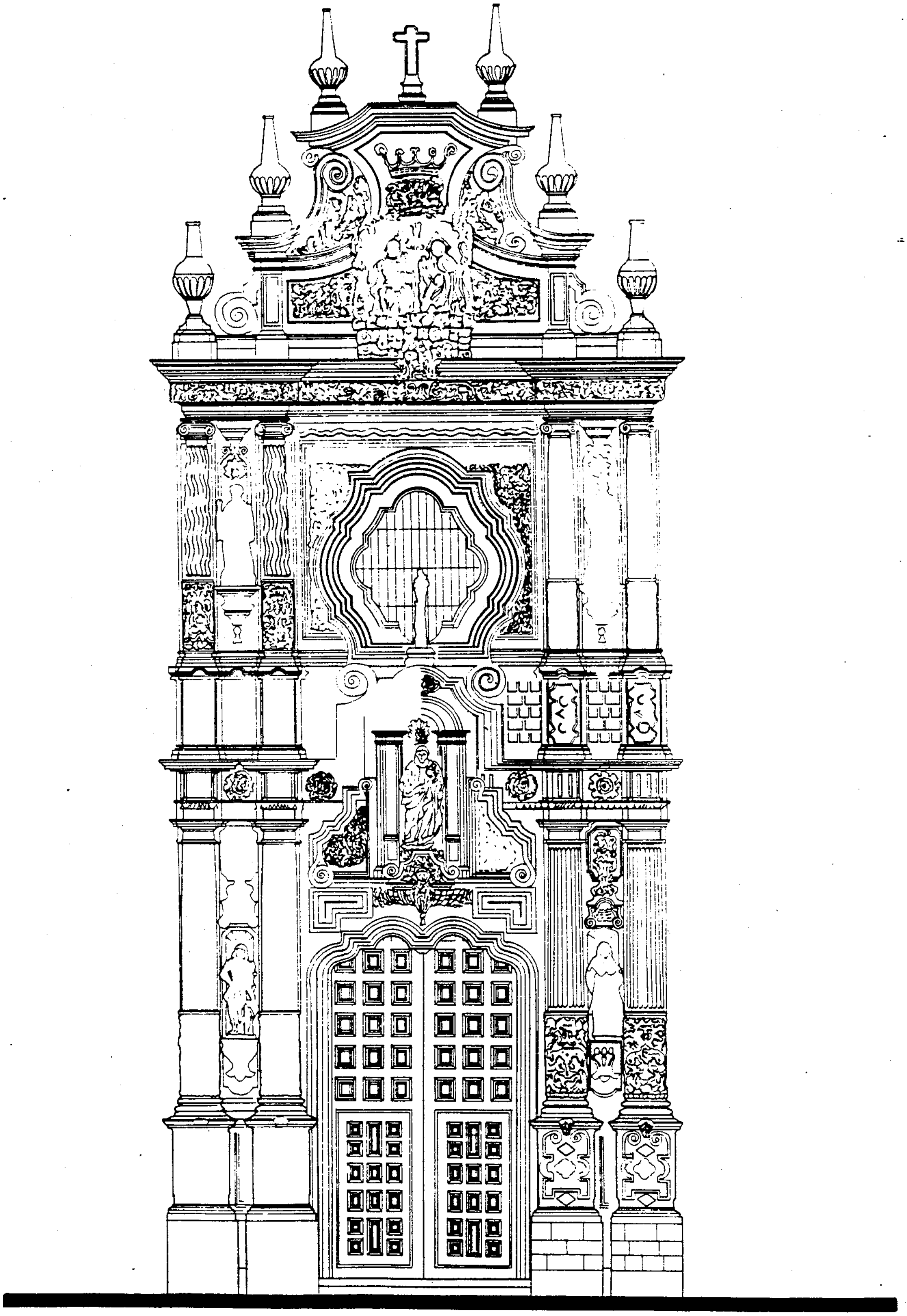


MEXICO D. F.
CONVENTO DE LA ENSENANZA
(1772 - 1778)



MEXICO D.F. IGLESIA DE LA ENSEÑANZA

MONUMENTAL CONVENT AND CHURCH OF SANTO DOMINGO IN OAXACA

Fernando Pineda Gómez
Sara Grinberg née Topelson
Paola Nieto Barssé

This great complex holds the Church with its atrium, the Rosario Chapel and, within the Convent, the porter's lodge, the cloister with its great staircase, the Domina Room, the de Profundis Room, the Refectory and the Chapter. Behind are the Hospice, the Library, the Infirmary, the Novitiate with its oratorium and the orchard.

Work on Santo Domingo can be said to have begun early in the 2nd decade of the XVIth century; Father Gay asserts that this was in 1552. When the community took abode in Santo Domingo in 1608, the choir, the presbitery, the main staircase, the windows and the doors were still missing. The perimeter stone wall was erected about that time and finally, we know that the Temple's decoration was begun from 1659 when the Oaxaca Dominicans called in a master from Puebla to perform the plastering and gilding of the church's barrel vault. The tower was built on the following year, and plastering and gilding of the upper choir was done later. Therefore, the work on the Convent of Santo Domingo lasted over one century.

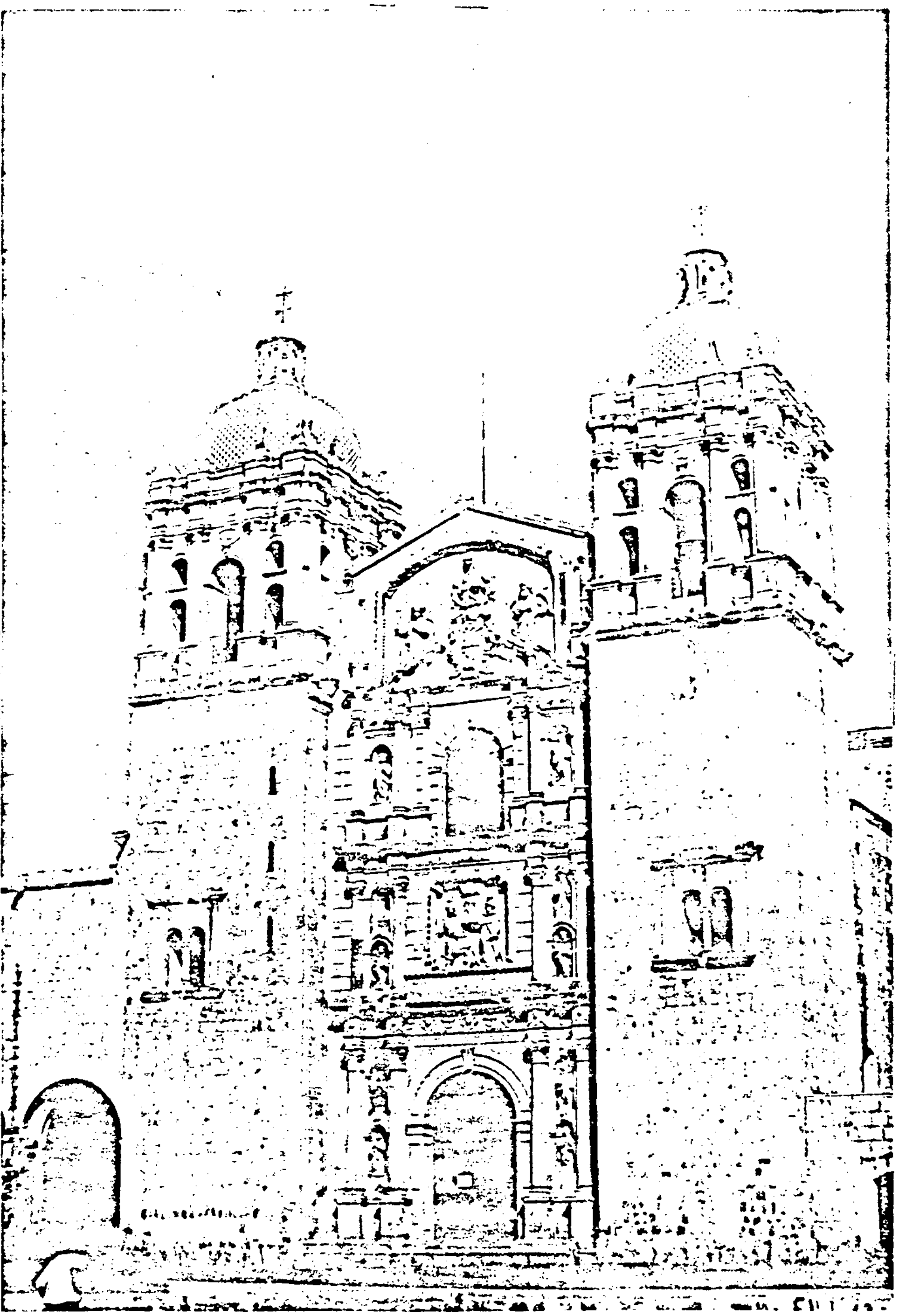
The Temple's major axis is East to West and the main facade faces West. In the center of this facade, between the door and the choir window, there is a large space where Saint Hippolytus and Saint Dominic are in relief. This tableau can be considered as the escutcheon of the old Province.

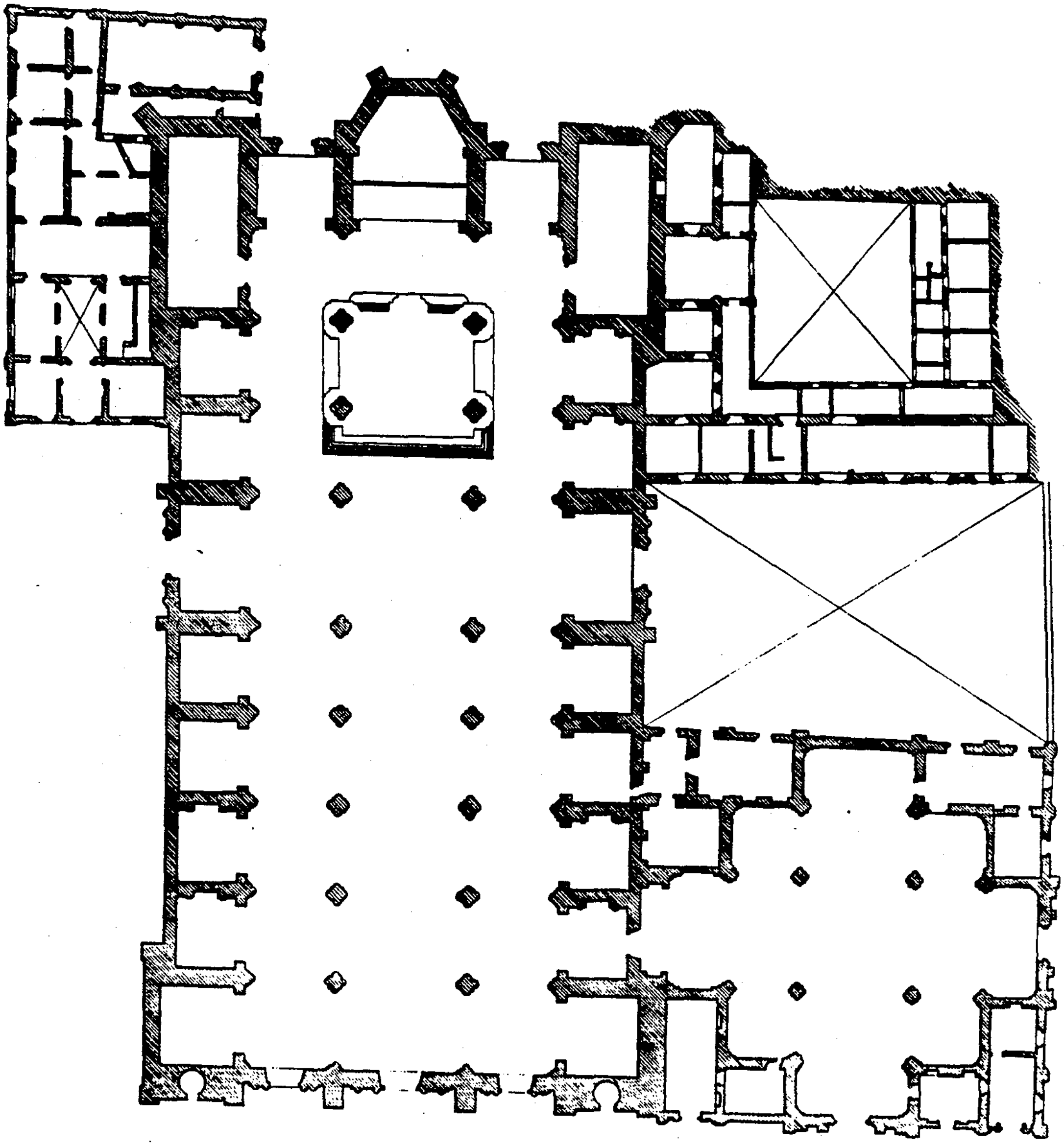
In the upper part of the window in the last sector of the facade, below an arch, are the 3 theological virtues, around the escutcheon of the Order.

The facade is framed by two wide and high towers, the highest in this City, others being built low for fear of earthquakes.

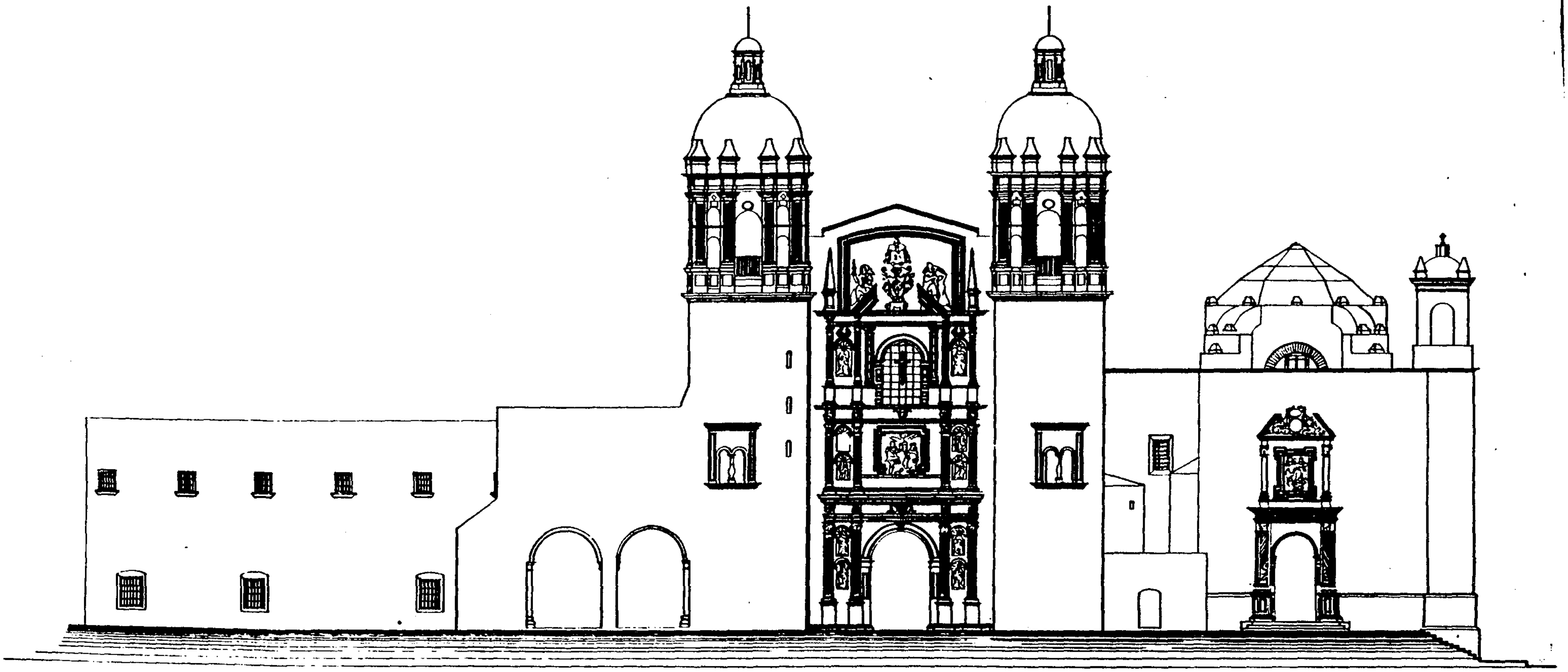
In the year 1859, due to the Reformation laws, the Dominicans were expelled from this Convent. During the Independence War it had been occupied by royalist soldiers and since that time Santo Domingo has always been a barracks, the convent being captured by the Insurgents, later by the liberals, and was finally occupied by the National Army. For this reason, many modifications were made to the convent which disfigured its aspect.

The Dominican Temple went back to the hands of the clergy during the Porfirio Díaz regime and from that time Archbishop Gillow, with citizen cooperation, began the works of restoration, opened the Rosario Chapel to worship in 1898. After work on the Chapel was concluded, that on the Church followed having lasted 4 years, and the Dominicans took their beautiful Temple over again from August 1938.





SANTO DOMINGO OAXACA



SANTO DOMINGO OAXACA

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CHURCH OF THE MOST HOLY TRINITY IN MEXICO CITY

Fernando Pineda Gómez
Sara Grinberg née Topelson
Paola Nieto Barssé

In the year 1526, a hermitage and a hospital for the needy began to be erected on land awarded to that purpose on the corner of the present day streets of Emiliano Zapata and La Santísima, in the eastern portion of the Historical Center. This hermitage, dedicated to the Saints Cosme and Damián and to Saint Amaro, lasted until 1568, when a community house was established, inhabited by Saint Clara nuns until the year 1579.

The very deteriorated hermitage was torn down and a church was erected in its place, opened in 1677. This church underwent extensive repairs from 1755 to 1783.

There is no certain information regarding who was the author of this last version, but the Church, with its large facade and its beautiful tower is one of the best examples of churrigueresque style in México City, and it is still in use and providing character to this neighborhood.

As the Church had sunk by a little more than 2 meters, the corner of these streets was turned into a pedestrian zone a few years ago. This allowed recovering the Church's original level as well as that of the facades, so that today they can be admired in their original dimension.

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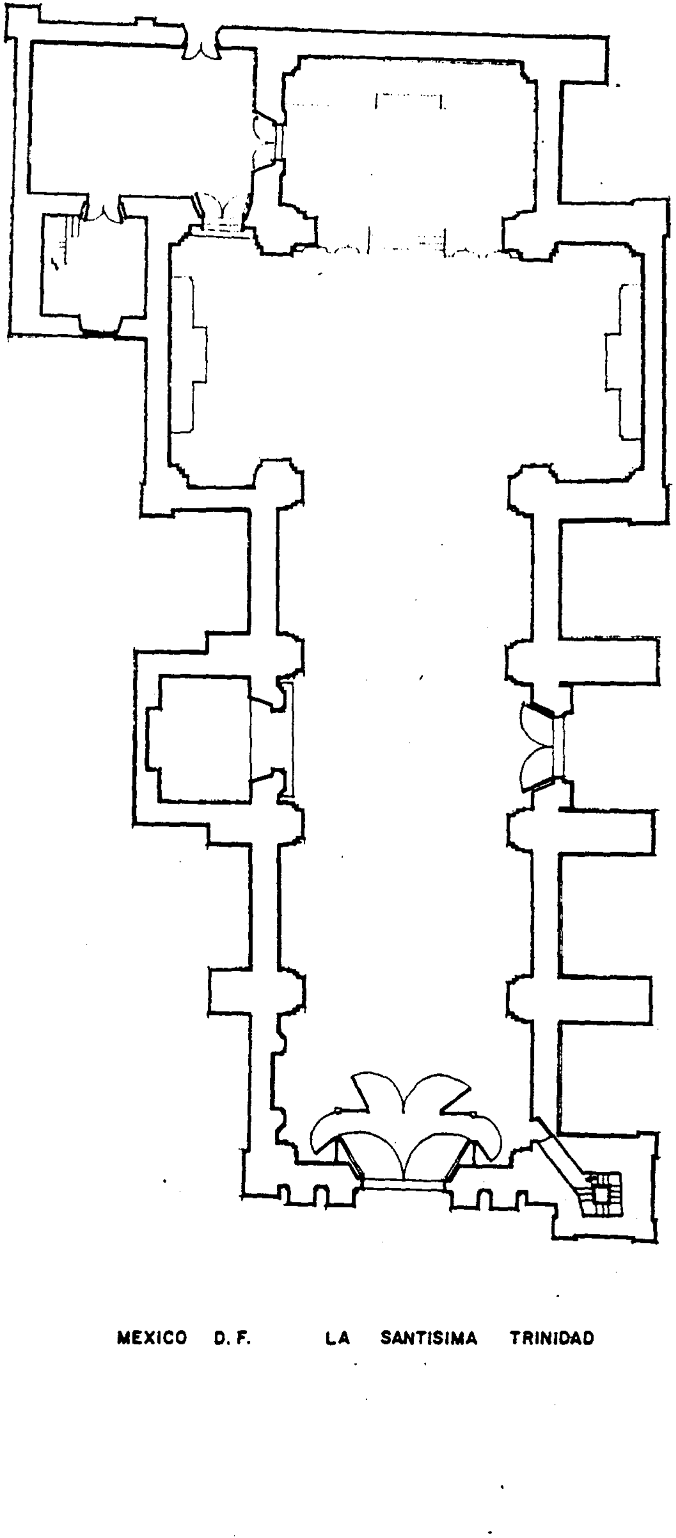

MEXICO D. F. LA SANTISIMA TRINIDAD

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RESTORATION WORKS OF THE MEXICO CITY METROPOLITAN CATHEDRAL AND CHAPEL

Fernando Pineda Gómez

From the year 1524 on which the works for the first Major Church began under dedication to Saint Mary of the Victory, until 1793 when Don Manuel Tolsá was appointed as Director of the works to conclude the Cathedral, which he executed excellently during the final years of the colonial period, long, costly and sustained work was done by illustrious architects, master builders, artists and craftsmen who used their best efforts to erect this very beautiful religious group of buildings, rightly deemed as the most beautiful and valuable in America.

However, since the existing Cathedral was begun in 1563 and up to our times, the long series of repairs of all kinds made on the monument has not ceased either, trying to remedy the deterioration caused not only by the passage of time but also by the fact affecting all the buildings in the Historic Center, which is but the hopeless sinking of the buildings in a terrain with very low resistance capacity. To increase our problems, in recent times, pollution, excessive vehicle traffic, vibrations from the METRO subway and the deep drain works, have contributed in a higher or lower degree to aggravate the harmful effects for the Cathedral and the other monuments in the Historic Center of México City.

As a brief summary of the recent interventions in this great group, we shall mention the repairs carried out by Architect Juan Cardona from 1870 to 1876. In 1890, Architect Luis G. Anzorena repaired arches and vaults.

Architect Ramón Agea carried out repair work for three years from 1895 to 1898. Flaws appeared again in 1905, correction of which was entrusted to Architect Luis G. Olvera.

In 1927, the "Technical and Conservation Board of the México Cathedral and Metropolitan Chapel" was organized by the Bureau of National Assets, depending from the Ministry of Finance. Work was suspended for 2 years while the Board made its studies and research, and they were resumed in 1929 by removing the earth from the panels between the masonry walls of the foundations and casting a plate of reinforced concrete. The computations and the project were submitted to the Board by Architects Manuel Cortina García and Manuel Ortíz Monasterio. The project was carried out between 1929 and 1930.

In 1934, these same architects began the works to renew the Chapel's foundations.

In 1939, Archbishop Don Luis María Martínez reorganized the Diocesan Board of Order and Decorum that had been constituted in 1937, and appointed as Technical Director of the Works Architect Nicolás Mariscal, who worked on repairs since 1940.

In the year 1942, Architect Antonio Muñoz García was appointed by the Technical Bureau and submitted a painstaking study of the structural problem of the Cathedral, from which the following aspects are deemed interesting and quoted verbatim:

> "What are the causes for the Cathedral's movements, particularly those that have originated deterioration recently.
>
> For this investigation it is advisable to recall what the Cathedral's foundations are.

Presbyters and Licenciates Don Pablo de Jesús Sandoval and Don José Ordoñez state in their work "The Metropolitan Cathedral of México" that it cost 40 years to build it and in the following manner:

First: this site was excavated until water was reached; then it was staked out over the whole surface occupied by the building until solid ground was reached; everything having been leveled, a bed of mortar was laid one foot thick, on which a hard stone masonry platform was built to the square's level; the building was to start from there.

The stakes or small piles 15 cms in diameter and 3.50 mts long were placed in a square pattern of 60 cms.

The "tezontle" volcanic stone platform was extended irregularly beyond the contours of the construction offset, because on the eastern side where placed against the Choirboys College, the platform stands out by 4.70 and 7.00 mts, while in the zone of the Chapel, the salient reaches 14.50 mts. Its thickness, according to Architect Luis G. Olvera and the perforation he made, is 2 mts. The Technical Board also states 2 mts in the Southeast tower's area, but specifies 1.80 and 1.30 mts for other places.

On the general platform, "tezontle" masonry walls were offset to hold all the walls of the Temple and the pillars or isolated supports at wall crossings distributed lengthwise and transversally according to the series of pillars, with their angles filled with triangular prisms. If the square's level determined that of the upper face of the platform, the entrances would necessarily be not less than 3.60 mts from said levels as this figure is on the average that of the heights of the foundation walls this being the reason for the <u>stepladders</u> whereby the Temple was reached through its first entrances, which were those to the North, and which their name to that street for a long time.

The height of 3.60 mts was no doubt compelled by the width of the naves of 11.095, 11.665 and 15.745 mts and the highest dimension of the bases of the pillars which is 3.485 mts, in order to make it possible to spread out as far as possible the concentrated loads to the utmost extension of the platform.

The stepladders have now disappeared and the entrances are at street level, if not lower.

We must of course recall the 1629 flood, which made it necessary to raise the level of the square and of the Cathedral's surroundings by terracing them. We have also pointed out that according to the gradings of 1856-1857 and 1924-1925, the Cathedral has sunk 570 mm over a period of 68 years. With such records, it is not difficult to acknowledge that all the masonry comprised between the platform and the offset of the superstructure has sunk.

The builders certainly foresaw sinking and for this reason stilted the foundations, and now, what was a support foundation has become almost a flotation foundation. And so it would be, were it not due to the panels being full of earth, and those places below the freatic water level being full of water, this last being 2.20 mts below the Cathedral's offset near the Chapel's spiral staircase.

Causes for unequal movements:

1st. General lowering of the Valley of México's depression.

2nd. Drain works of the Valley of México and drain works of México City.

3rd. Underground water currents, going from SW to NE.

4th. Nature of the terrain with unequal compressibility.

5th. Resistance capacity of the terrain.

6th. Unbalance in the distribution of the building masses.

7th. Earthquakes, among which are to be mentioned specially the terrible one of June 19th, 1958 and the strong ones of November 2nd, 1894 and 1895.

The foundations were completed in 1611 or 1615, and in 1629 came the worst flood that has been known in México City. Work was suspended for 6 years and meanwhile, the entire square was terraced, the earth being carried in in canoes by Indians. The level of the square was raised, although by how much is not known, and this reduced the level of the entrances to the Temple, which were in the extreme North, as between 1626 and 1641, the Chapel was used as Church.

Gradings between the years 1907-1927-1940:
The depression is observed to grow ever more as the years go by. This has accelerated in the last 13 years as against the first 20 of the period being discussed.

The increase in the last 13 years acceleration can be attributed to the increase in extraction of deep waters through artesian wells.

All this keeps revealing a more compact, firmer, with less water, less subject to compression in the North and South boundaries on the Temple's site.

Determinant causes for the Cathedral's flaws:
The determinant cause is the buildings that have been placed against it in the region located from the crossways to the North; elsewhere the Chapel of the Souls and the current offices of the Miter and also by the buildings that were placed against it until the year 1933 to the Northeast and East, which were the Seminario and Central Hotels.

The buildings of these Hotels were torn down in 1933, and with them disappeared one of the causes affecting the Cathedral.

Conclusions:
1st. That the Cathedral's general sinking is due above all to the terrain's resistance incapacity.
2nd. That the unevenness of sinking is due more than to anything else to the terrain's uneven

resistance with the area occupied by the building.

3rd. By the shape and extension of the area it occupies, it must have a definite trend to a depression in the center of the area, which is hardly noticed, precisely due to the lack of uniformity of terrain resistance, the cause being neither the dome, nor the choir, nor the presbytery nor the main altar.

4th. That the unbalance of the building's masses, the heaviest being on the South facade and the two towers, has not been sufficient either to overcome this unevenness in terrain strength.-

5th. That the causes for the Cathedral's flaws we are discussing and which have been mentioned since 1855, began no doubt because of the construction of the Main Altar in 1850, the remodeling of the old Seminary in the Central Hotel and due to the sewerage works of the Valley and the city's drainage.

6th. That little or nothing can be attributed to the earthquakes regarding the deterioration we are discussing.

7th. That the hotels and the Choirboys College having disappeared, the deformations in the Sacristy, the transept and the eastern processional nave, have ceased.

8th. That the general depression of the Cathedral, as that of any city, is due to the city itself which is gravitating on the surface of a compressible surface.

What measures should be taken to prevent sinking that compromises its stability:

1.- It will be practical and effective to empty the panels of the earth filling them, substituting their action by a structure providing rigidity to the foundation.
2.- Relieve the central nave from the load of the main altar and of the presbytery's solid platform.
3.- Refrain from placing buildings against the Cathedral.
4.- The idea of continuing to make use of the foundation panel's voids as ossariums must be discarded because it compels to cut the masonry beams.
5.- As of now, there is no need to reform arches."

(So far, Architect Antonio Muñoz's Report).

On the night of January 17th, 1967, possibly caused by an electrical short circuit in the vicinity of dry wood of the Pardon Altarpiece, a terrible fire was started and when the firemen arrived, having been called late, they extinguished the fire with their powerful hoses's water streams, but they also contributed to the destruction of many objects that might have been saved.

Summary of damage: the Pardon Altarpiece was affected, losing its pinnacle and the paintings included therein, which were the Virgin of Pardon, Saint Sebastian, the Divine Countenance, Juan Correa's great Apocalypse and a small Virgin of Guadalupe. A large part of the choir's chairs was destroyed, although sufficient elements were left to reconstruct it. As regards the organs, also of great baroque wealth, the pipes were a total loss, although the ornamentation was largely saved. The painting on the dome "Assumption of the Virgin" by

Ximeno y Planes, was irredeemably erased by the fire. The Altar of the Kings was deteriorated by the smoke that reached it.

However, the fire did not harm the structural elements, as reported by Engineers Alberto J. Flores and Manuel González Flores, designated as experts by the Ministry of National Patrimony.

During all that year 1967 and the next two, a great controversy came up between two factions of artist and intellectuals who adopted totally opposite positions: those who were in favor of complete restoration of what had been destroyed and those who suggested radical changes, based on liturgical changes deriving from what had been resolved at the Second Vatican Council.

Several proposals were submitted, within this posture of radical changes, which would have altered severely the inner spaces of the Cathedral, arguing that what had been lost was irreplaceable and that, therefore, it was the opportunity to change the scheme the Cathedral had always had, in benefit of better visibility and a greater participation in liturgical acts by the community. They did not take into account that "the inner space of the Cathedral cannot be encompassed at a single glance, as it is a COMPARTMENTED SPACE, with Mudejar reminiscences and deriving from the treatment given to the Spanish cathedrals" (Architect Agustín Piña D.).

In the pro-restoration faction, the possibilities of reconstructing what had been lost were carefully analyzed, as well as the substitution of the lost canvasses for other similar ones, which was done with the Altar of Pardon.

The organs were splendidly restored in Holland as to the musical instrument, while the decorative woodcarving was done by highly skilled artists who also replaced the seats in the choir.

In brief, Restoration was opted for, which was performed at great effort and considerable cost, but it gave our Cathedral back all its excellence and dignity. The work began in 1970 under the government of President Díaz Ordaz and when Don Miguel Darío Miranda was Archbishop of México.

In 1972, due to the high degree of deterioration exhibited by the Cathedral and the Chapel, the Federal Government began the studies that would lead to the work projects. Among them was that of renewing the foundations of the Cathedral and the Chapel, restoration of the Sacristy's great paintings, restoration of the monumental organs and of the altarpieces, and the complete electrical installation.

For the foundations, taking into consideration that between the Cathedral's floor level and its foundations there is a level of crypts, the possibilities of driving the piles were looked into, using the hollow spaces left around the pillars by the construction of the crypts. This was ideal to transmit the pile's stress to the structure, as well as to facilitate the construction of the pedestals without interfering at all with the niches area, having access from the parish level.

This restructuring lightens by approximately 25% the foundation work, by supporting this load on a strong layer that is between 38 and 40 meters deep. By using the piles, descent of the buildings in relation to the surrounding terrain can be controlled as well as differential sinking within the structure itself.

The criterion for restructuration was to make full use of the original foundation, taking advantage of the modifications made in 1943 by Architect Antonio Muñoz, according to the already mentioned studies and projects.

In the Chapel, restructuring turned out to be much more complicated, due to the poor quality of the original foundation, the previous partial interventions and the great variations in subsoil conditions and due to the presence of prehispanic constructions.

The behavior of the structures was monitored throughout the work process.

Total:	Control Piles	516	
	Cathedral	383	
	Chapel	133	
	Concrete	6,500	m^3
	Steel	900	tons
	Earth removed	29,642	m^3

Electrical installation:
The system's design comprises the location of a single electrical substation fed by one input. It is located in a garden zone, North of the Chapel and East of the Cathedral. It is of the subterranean type and complies with the Federal Board of Electricity's standards. In order to facilitate the operation and maintenance work, the main sections that make up the network were made independent of one another and their control panels are located at the places where the personnel in charge of their operation is assigned. Thus, the outdoor illumination panel operated by the Department of the Federal

District is located next to the electrical substation and the panels for interior illumination of the Cathedral and Chapel are in their respective vestries. The entire system was renovated and executed within the above mentioned security standards.

The Cathedral's Sacristy contains large paintings by late XVIIth century baroque masters Juan Correa and Cristóbal de Villalpando. The Assumption of the Virgin and the Entrance of Jesus into Jerusalem are by the first named. Villalpando is represented by the Church Militant, the Church Triumphant, the Glory of Saint Michael and the Apocalypse. These great canvasses were removed from their place and subjected to a long and painstaking process of restoration and this temporary removal allowed attending to the cracks there were in the walls were they were placed.

Restoration of the organs:
The organ, manufactured in Spain by Don Jorge de Sesma, arrived in 1693 and was assembled here by the technician Tiburcio Sanz, this work concluding in 1695.

The organ's facade was constructed by the Architect and cabinetmaker Don Juan de Rojas, creator also of the choir's seats. José de Nazarre built the second organ in 1735.

These organs, as we already said, were severely damaged by the 1967 fire. The sensitive restoration work was executed in Holland, by the firm Flentrop Orgelbouw and the assembly process was begun in July 1976 and concluded in February 1977.

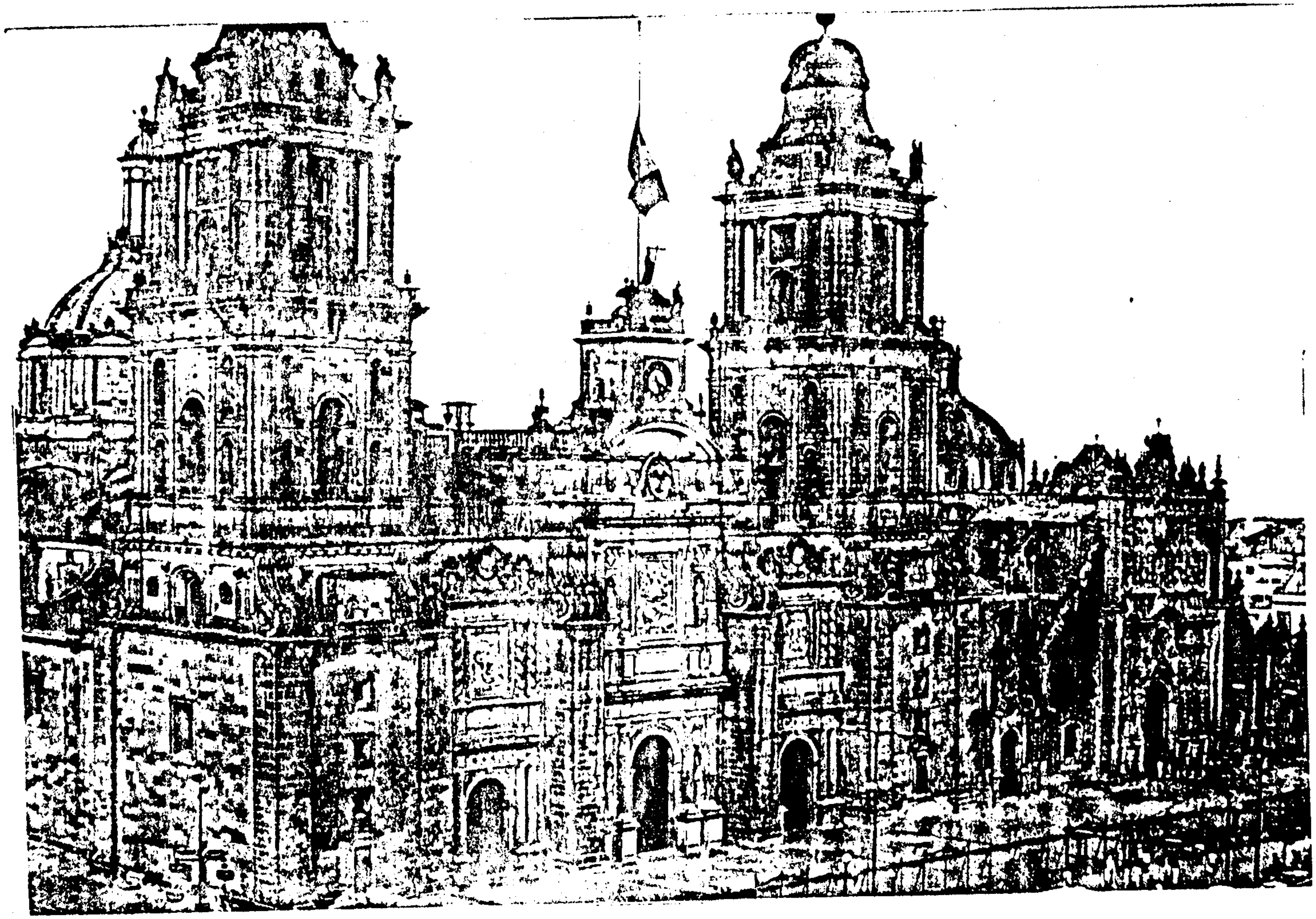
Demolition of the old Curia and of the Chapel of the Souls, that had been recommended by Architect Muñoz in 1942, was fortunately not carried out. The Ex-Curia was separated from the Cathedral's body by a construction joint and the buildings of this annex shall house the Cathedral Museum, soon to open to the public.

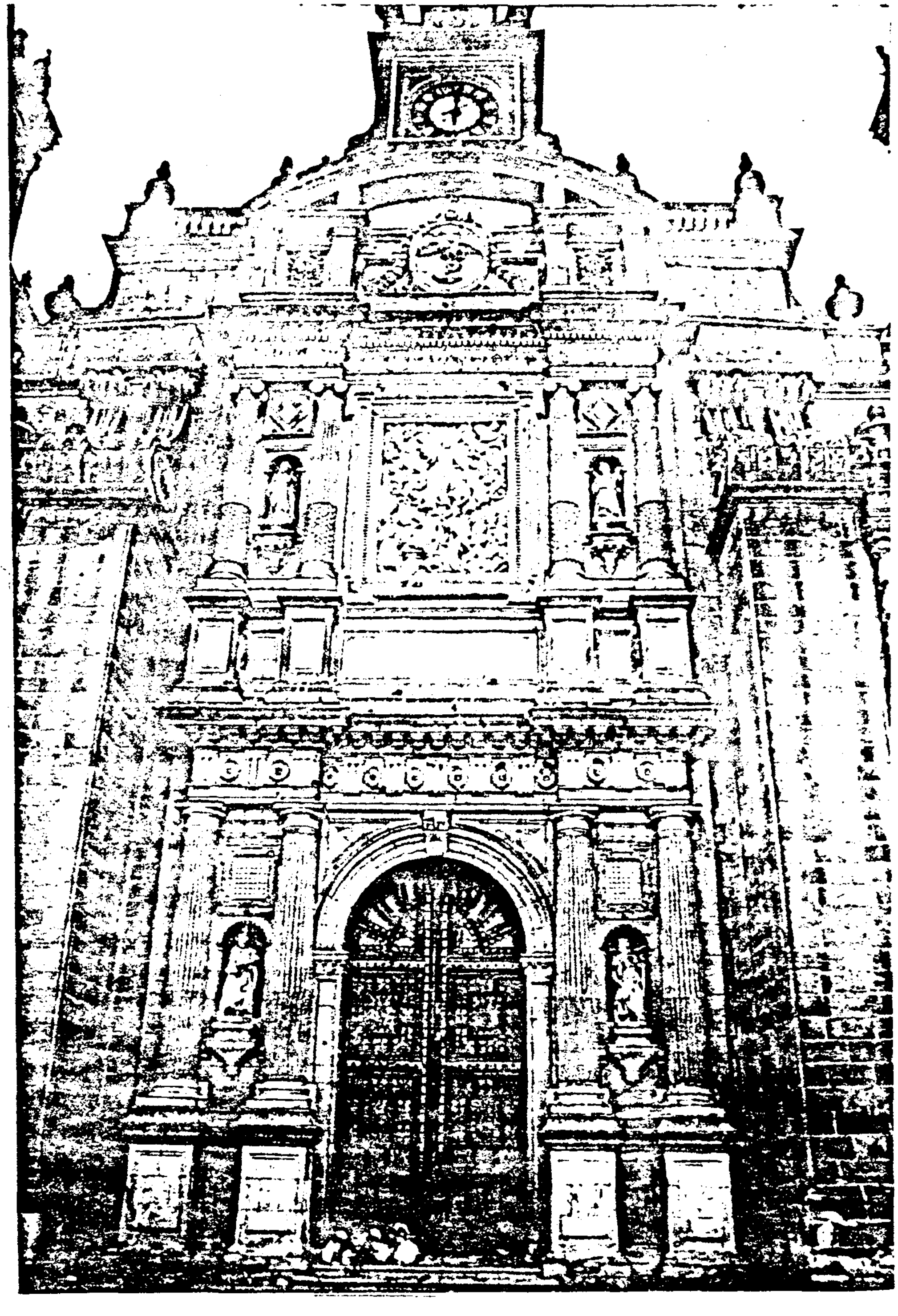
The recent 1985 earthquakes damaged the ciborium of the Chapel's main altar and caused a lengthwise crack of a certain gravity in the West processional nave of the Cathedral, which has by now been corrected almost entirely.

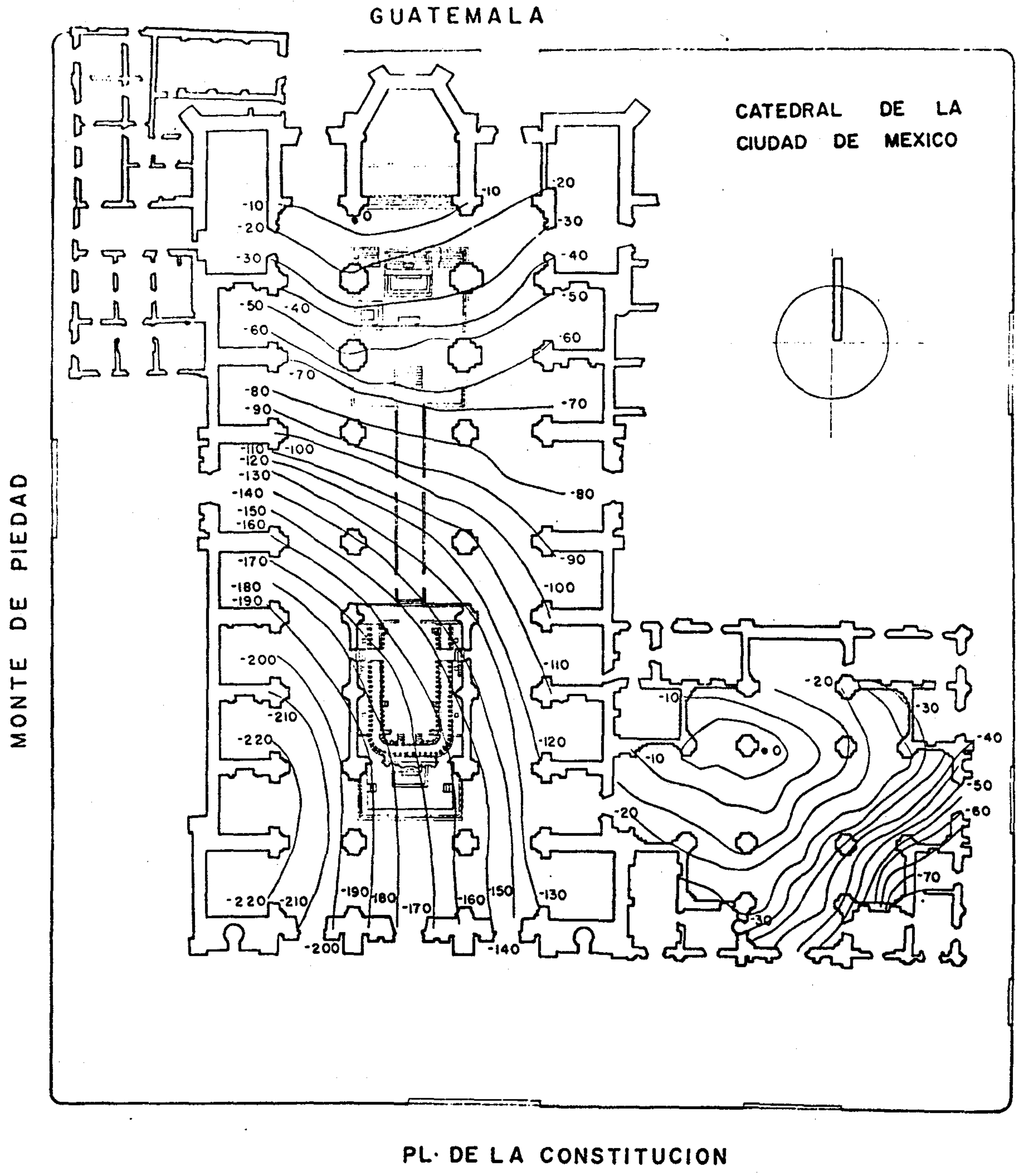
The pavement of the East and West atriums has been completed. That of the South atrium lacks the parts pertaining to the Chapel, which shall soon be completed. The small atrium facing North has also been completed, adjacent to Guatemala street, and they are clear of rubble, clean and fit for traffic.

The constant work of maintenance of the covers and planes, and the correction of cracks and fissures has been performed adequately, and we are in expectation for a really effective treatment for stone elements exposed to weather, which lately exhibit a condition of accelerated deterioration which is a cause for much concern.

What has been set forth above in a very summarized manner is the work of the Government of the Republic to conserve the great group of the Metropolitan Cathedral and Chapel, so beloved by all Mexicans and so relevant within Mankind's Cultural Patrimony.



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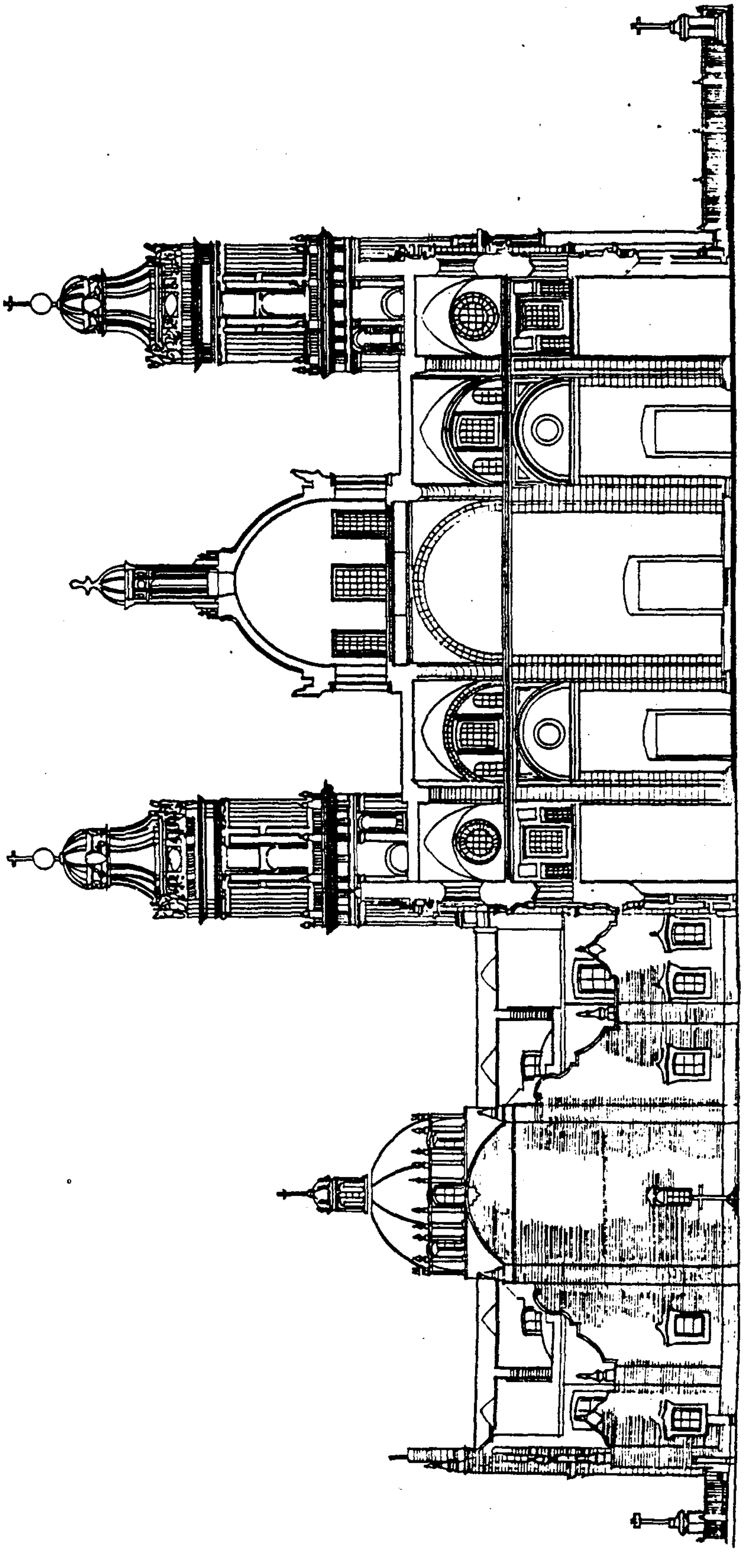

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ARCHITECTURAL AND URBAN DESIGN LESSONS FROM THE 1985 MEXICO CITY EARTHQUAKE: THE UNITED STATES' PERSPECTIVE

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ARCHITECTURAL LESSONS FROM THE 1985 MEXICO CITY EARTHQUAKE

Christopher Arnold, A.I.A.

INTRODUCTION

About 250 miles from Mexico City, a section of the earth's crust in the Pacific Ocean, the Cocos Plate, moves roughly three inches a year as it thrusts itself under the Mexican land mass. On September 18, 1985, this plate suddenly broke away from the adjacent crust, moving between three and six feet. The resulting earthquake, of Richter Magnitude 8.1, was one of the most powerful in history.

In the following days, dozens of smaller ruptures occurred as the plate continued to release energy. The largest - Richter Magnitude 7.5 - came 18 hours after the first. These quakes severely damaged Mexico City: thousands were killed, and damage costs totaled $4-5 billion. The total economic losses will greatly exceed this. A total of 5700 office buildings, schools, hospitals and housing buildings throughout the central city were significantly damaged or destroyed.

This earthquake and its effects are of great significance to the United States because many of the structures damaged or destroyed in Mexico City incorporate modern design and construction techniques comparable to those in the United States. There are many lessons to be learned both from those buildings that were damaged, and those - the majority - that survived.

The earthquake severely tested all aspects of the city: not only its structures, but its subways, utilities, and transportation system, and the whole economic, social and political process for dealing with such a catastrophe, from immediate response to recovery and eventual reconstruction. For architects, the lessons can be grouped into three areas of concern:

- Issues of architectural design that impact on seismic performance.
- The relationship between architectural and structural design.
- The architect's role, among all the players, in decision-making that relates to seismic performance.

BACKGROUND

Of the three groups of concern noted above, the first issue is probably that of the most significance, because it directly affects the central role of architects, that of building design. In studying Mexico City for lessons, these background issues must first be outlined. The first is the nature of the major earthquake on September 18, 1985: the second is the general evolution of building codes, and the third is the general context of architectural design in Mexico City in terms of those buildings that were affected by the earthquake.

The Earthquake and Its Effect

Mexico City sits nearly 1-1/2 miles above sea level, ringed by mountains. When Cortez conquered the Aztec city in 1519 this basin was partly filled by a lake, which the Spaniards drained and filled in.

In the centuries since, Mexico City has grown into a modern metropolis of 18 million people. Much of the modern city is built on the high ground surrounding the old lake bed, but its central business district remains atop the lake bed's layers of sediment which have a high water content. Extensive ground subsistence has been a feature of downtown Mexico City for decades, causing buildings to tilt dramatically, even without earthquake activity. This geologic setting tends to amplify the seismic waves created by distant earthquakes, so that the site of Central Mexico City provides a particularly bad situation for seismic attack.

In the September 1985 earthquake, instruments in the outskirts of Mexico City recorded maximum accelerations of 0.04g. In the area of the old lake bed, accelerations rose to 0.16g. These are not particularly large - a maximum acceleration of 1.25g was recorded in the 1971 San Fernando, California earthquake. But the Mexico City motion continued strongly for over a minute (as compared to about 12 seconds for San Fernando) and the ground vibrated slowly at about a 2 second period. This period corresponds to the natural frequency of buildings in the 6-20 story range, depending on their configuration and construction type, and so the forces in many of these buildings were amplified so that towards their roofs they might experience 1.0g. It was this amplification, combined with the long duration of shaking, that caused the damage.

Could such a phenomenon occur in the U.S.? The evidence is not clear-cut, but ground conditions in the San Francisco Bay Area, the Los Angeles Basin, and certain areas of the central United States give cause for concern that under certain kinds of earthquake source activity, some of the Mexico City phenomena might be encountered.

Because of the nature of ground conditions in Mexico City, the earthquake damage was confined to an area of approximately 25 square miles, with severe damage concentrated in a zone of approximately 9.5 square miles. Outside these zones damage was essentially non-existent. These areas of damage must be related to the approximately 385 square mile area of the Metropolitan city. Thus, damage was highly concentrated, and within the high damage zone, represented a major disaster. Mexican engineers have given an informative analysis of its distribution, its type, and its causes.

Of some 5700 buildings listed as damaged, 950 were destroyed, 2300 severely damaged, and 2450 suffered medium to minor damage. Of these damaged buildings, 65% were residences, 12% were schools, 6% were offices (public and private) and 0.7% hospitals.

These percentages can be misleading as to systematic effects. The damage to hospitals (5 destroyed and 22 severely damaged) represents a loss of about 30% of the available hospital beds. Damaged government and other public buildings forced about 150,000 public servants to be relocated elsewhere. Total housing losses represented some 76,000 units, which increased an already present housing deficit of 30%. Officially recorded deaths were approximately 6,000, though the actual figure (including unrecorded casualties) may be three to four times as much. Forty-thousand people were injured.

Codes and Regulations

The problem of Mexico City's vulnerability to earthquakes had been recognized for many centuries, and particularly in the last few decades, but such is the resilience of city location, that the old downtown area has continued to expand vertically and horizontally into its present high density of modern structures. In recent decades, successive implementation of improved building codes has attempted to deal with the problem.

The authorities first enacted a seismic building code in 1942. This was made considerably more demanding following a Richter Magnitude 7.5 earthquake in 1957, and the result was a modern seismic code comparable to any in the U.S. at that time. New regulations, including provisions regarding dynamic analysis, were issued in 1966 and 1977. A basic problem of the 1985 earthquake is that its intensity exceeded by a wide margin that which had been anticipated in the code. In these circumstances, one issue is not why so much damage occurred but how so many buildings survived.

While a seismic code provides a technical baseline, how it is enforced and interpreted involves issues of judgment and procedure. The authority responsible for drafting codes and issuing construction and occupation permits in Mexico City is the Federal District Department. Responsibility for complying with code provisions is usually placed with the registered engineer or architect who is given the construction license, and thus department engineers rarely check computations and drawings except in special circumstances.

Mexican sources comment that a great deal of freedom has thus resulted in the design and supervision of construction of privately owned buildings. This has led to a tendancy for building codes to be regarded by Mexican engineers more as guidelines than as rigid regulations.

The Architectural Context

Like most major cities, a period of massive expansion occurred in Mexico City in the two decades after World War II. This period of rapid growth coincided with the world wide acceptance of an 'International Style' in architecture. In fact, Mexico in common with other Latin American countries, most notably Brazil, had pioneered the new style, a fact recognized in architectural publications of the late thirties. The International Style with its simple planes, large glass areas, and lack of decoration, lent itself particularly well to Latin American building technology which converted from a masonry based technique to one of reinforced concrete with masonry or glass infill. This technology, economical in its use of expensive steel, was in perfect accord with desired aesthetic effects of the modern style.

While the sheer volume of construction during the period of expansion resulted in a wide variety in construction quality - as it did in all other expanding cities - the new Mexican architecture acquired acclaim in three major directions. One was for the shell structures of engineer Felix Candela, beginning in the late forties. These graceful and daring structures were very popular in architectural circles and were influential in the promotion later of similar type structures, of a more conservative nature, in the U.S.A.

Another notable Mexican architecture was that of architectural efforts to solve the increasing housing crisis in Mexico City by the construciton of huge high-rise housing projects towards the center of the city and around its perimeter. Though this approach to solving urban housing problems is now often discredited by housing experts, primarily because of the social and economic disruption often caused by the wholesale rehousing and dispersion of families and communities, the Mexican achievements in this field were remarkable. Typical of these were the Juarez and Tlatelolco projects, constructed quite close to the center city, in 1950 and 1960 respectively. The former housed 3,000 persons in 984 apartments: the latter housed 70,000 persons in 11,900 apartments, located in 101 buildings (Figure 1). Both these projects suffered significant damage in the 1985 earthquake.

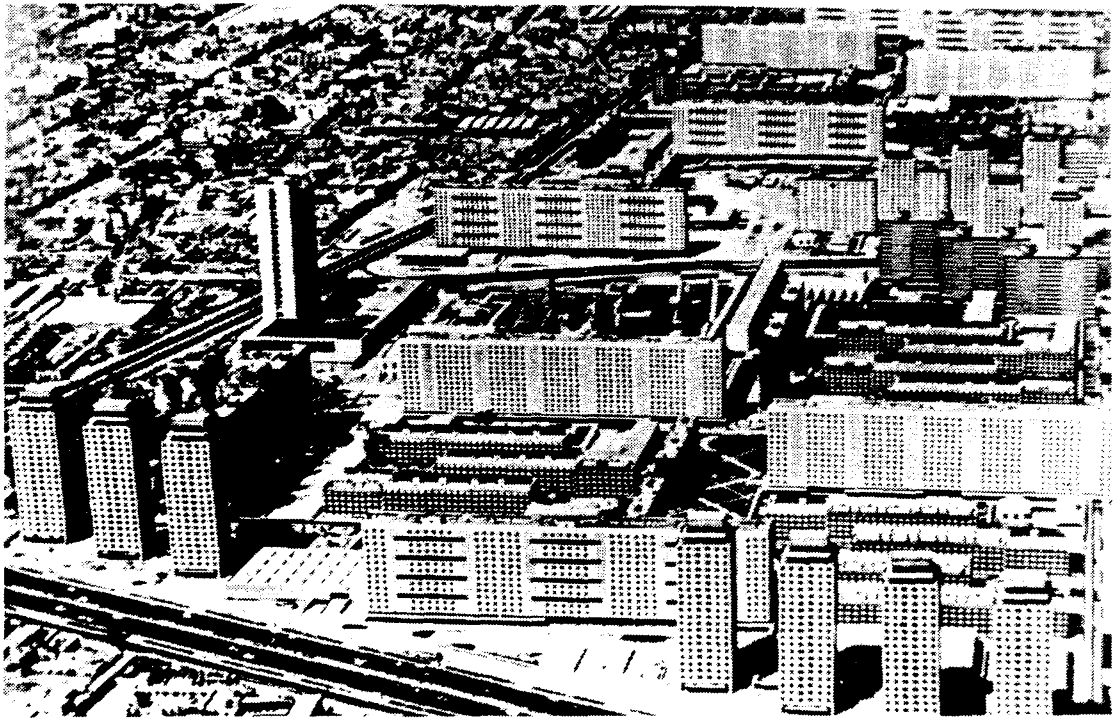


Figure 1. The Tlatelolco housing project, 1960.

The third Mexican architectural achievement that brought international acclaim was the planning and design of the University City (UNAM) on the city's perimeter. Here, the national architecture of the International Style was combined with a historical Mexican exuberance in the use of materials, and public mural paintings in which Mexican artists excelled, gave richness and meaning to otherwise blank concrete walls.

The architecture of modern Mexico City represents a mix that is characteristic of the world's great cities. Beautiful Spanish Colonial structures still stand, isolated and almost obscured by the tide of later development. The buildings of the early expansion period (1950-1960) follow, for the most part, the spare dictates of the International Style, as a reaction against the flamboyant classical structures of earlier decades (Figure 2). Later buildings exhibit the concrete 'brutalist' styles of the seventies and the mirror glass walls of today that can be seen in any city. The design and construction quality of many of these later buildings is equal to anything in the world.

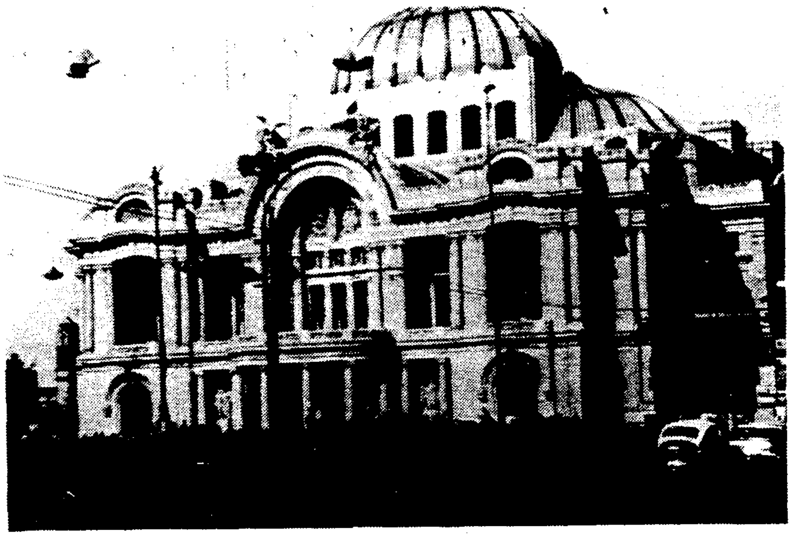


Figure 2. The Palace of Fine Arts, Mexico City

Notwithstanding the many huge new structures, much of the scale of the old city remains, so that even in the center of Mexico City two and three story residential structures are interspersed with mid-rise offices and residences (Figure 3). New freeways and expressways cut through the old grid pattern (Figure 4), but the Paseo del Reforma, introduced as a vision of a Parisian boulevard in the mid-nineteenth century, still remains as a landscaped surface thoroughfare of great elegance, punctuated by traffic circles around ceremonial statues and fountains.

Figure 3.
Low-rise residential structures in downtown Mexico City.

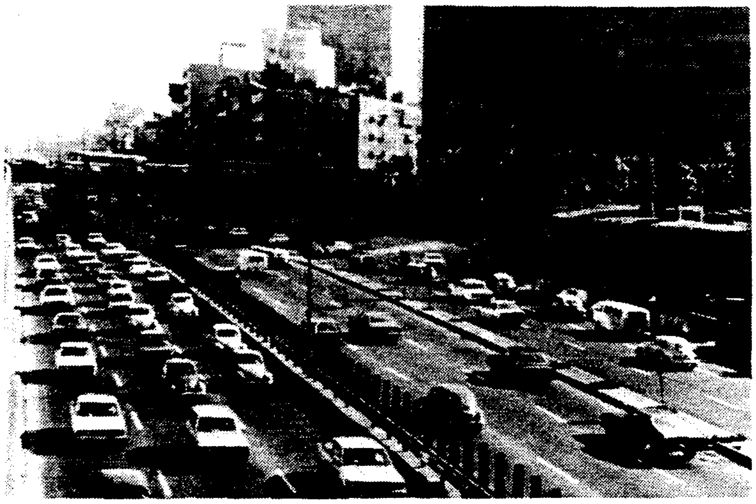


Figure 4.
Typical freeway around the downtown area.

BUILDING DAMAGE AND ARCHITECTURAL DESIGN

Analyses of building damage conducted by Mexican engineers show that of those buildings severely damaged or destroyed, 26% were constructed before 1957, 56% between 1957-1976, and 18% after 1976. While only 1% of one to two story buildings were damaged, for buildings between 6-12 stories the average damage rate was 11%. The most vulnerable building type was the medium height reinforced concrete structures with no structural (shear) walls, employing a flat slab or waffle slab floor structure. These buildings failed at the columns or at the column to floor joints. But the real cause of failure often lay in characteristics of building shape, planning, nonstructural components, or loading, that created torsion or stress concentrations that the structural members or connections could not withstand. It is in these areas that architectural design decisions play their part.

In looking at building failure in Mexico City it is useful to categorize the four characteristic patterns of failure: top floors collapsed, middle floors collapsed, bottom floors collapsed, or total collapse (Figure 5).

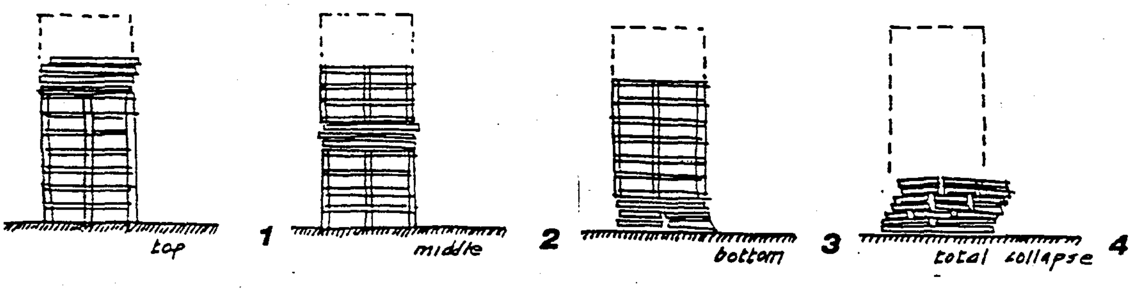


Figure 5. Patterns of Failure

Of the seriously damaged buildings, engineering investigators from Mexico City University found that 38% suffered an upper story failure (Figure 6). This can be attributed to 'whipping' action as the earthquake motion amplified in the upper stories of the building. In some cases, architectural or structural irregularities contributed to the failure: a change of column size, or the introduction of irregular framing or unusually flexible columns in some locations. Modern U.S. seismic codes distribute a larger percentage of the seismic forces to the upper stories of a tall building in the effort to recognize this problem, but this does not deal with the problem of architectural irregularities.

Figure 6. Upper story failure.

The Mexican engineers found that 40% of the seriously damaged buildings suffered a mid-story failure (Figure 7). In some cases failure could be attributed to a construction change, but most frequently the failure was caused by 'pounding' from an adjoining building, vibrating out of phase, so that the buildings impacted one another. While pounding has long been recognized as a problem, the extent of pounding failures in Mexico City confirmed this as a major issue. Current codes impose 'drift' limits - the extent to which lateral deflections are permitted. In theory this should protect against pounding, but in practice the code drift limits do not represent possible actual motion. To separate buildings to the extent necessary to protect against pounding the space between buildings needs to be very great (of the order of 5 feet for a 12-story building) and this presents real estate and urban problems.

Figure 7. Mid-story failure.

At the same time, many buildings in Mexico City were clearly protected from collapse because they were erected hard up against the adjoining buildings on both sides, so that whole blocks of buildings acted as a unit; and the group of buildings was stronger than the individual building. Realization that closely spaced buildings act as a unit - a 'super building' - was slow to materialize, and much analysis of buildings - even existing buildings - still focuses on their individual characteristics.

An interesting specific instance of the support phenomenon is shown in Figure 8. In this instance (towards the center of the intense damage zone in the city) the slender eight story building has a tall first floor and clear span between its outside walls: shear walls or bracing along the plane parallel to the street appear non-existent. Yet this building, that would be very suspect as a free-standing building, suffered little damage and clearly was braced by the lower buildings alongside, whose response to the ground motion would be minimal. This building group, then, responded as a large short period structure with a setback tower, rather than as a set of individual masonry buildings and an eight story tower.

Figure 8.
Tall building supported by low masonry buildings on either side.

Most significant as evidence of the support effect, Mexican studies show that 42% of heavily damaged buildings were corner buildings, lacking the protection of adjoining buildings. Clearly, in this instance, the earthquake sees not the building but the entire block. This finding necessitates serious thinking on the subject of allowable drift, pounding, and the design and analysis of closely spaced buildings: the solutions are not simple.

Weak first stories accounted for 8% of building failures. The percentage is probably much greater because many of the total collapses were also precipitated by this characteristic. But in buildings with weak first floors and stiff upper floors - created generally by open planning in the first floor to accommodate stores or lobbys - often the upper floors retained enough integrity to survive (Figure 9). The Mexico City experience reinforced the risks of this configuration, particularly for heavy frame structures lacking in resisting walls.

Figure 9. Weak first floor failure

It is harder to diagnose the failures of those buildings that totally collapse (Figure 10). Often, however, no single cause predominates. Irregularities in plan or loading may combine with a weak first floor, with inadequate connections, or with construction deficiencies, to produce collapse. When the total collapse occurs to an occupied building heavy loss of life is inevitable, and the niceties of structural or nonstructural damage cease to be of concern.

Figure 10. Total collapse.

Many damaged buildings that were inspected can trace their failures, at least in part, to characteristics of assymetry in plan, whether of overall form or in location of stiff elements such as stairs or walls. One characteristic example of this explicitly shows the relation between architectural form and the form of the city - in its street pattern. Buildings that were triangular or 'wedge' shape in plan suffered badly. Typically these would be the result of designing buildings on tight urban sites created by streets intersecting at an acute angle. This form is typical for U.S. cities, where our rectangular grids are intersected by diagonal streets. The wedge shape building often has a solid party wall and two open sides, which is a prescription for torsion (Figure 11).

Figure 11. Distortion of a wedge shape building at a corner. This building was later demolished.

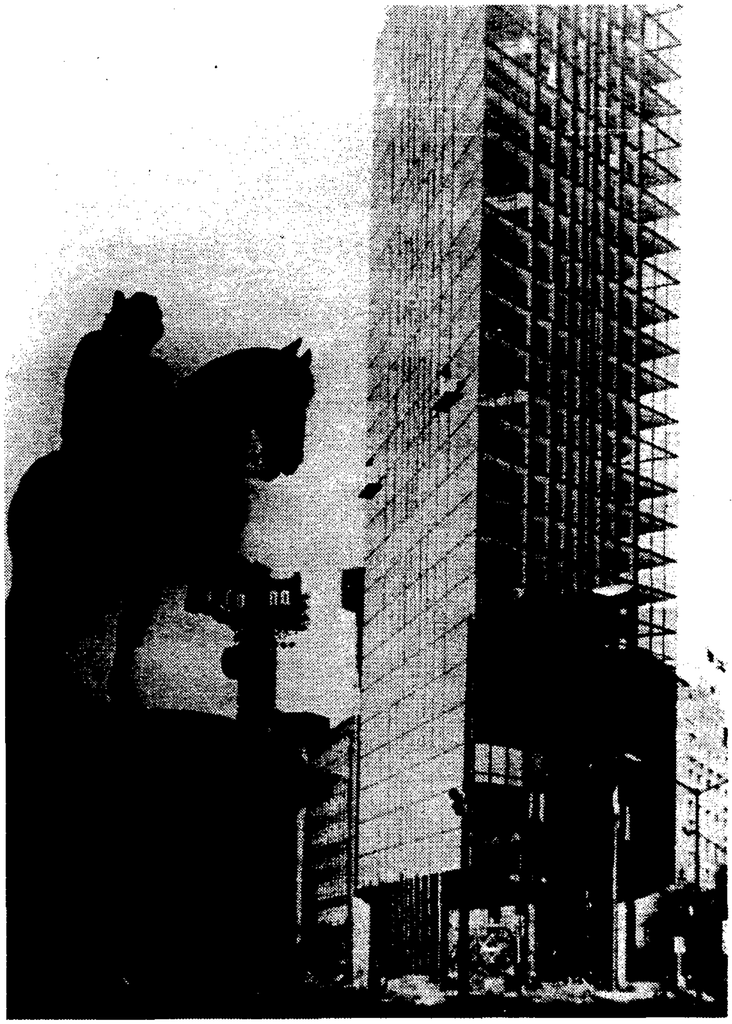
Thus building performance in Mexico City has confirmed the importance of building configuration as a performance determinant, but its exact influence remains difficult to determine with any certainty. While a number of failures have shown the effects of weak first floors, asymmetry, and other configurational irregularities, the information so far is not systematic enough to send a clear message. Many buildings that exhibit, at least superficially, poor configuration characteristics, seem to have performed well. Conversely, many buildings with apparently good configuration characteristics performed badly: i.e. no apparent irregularities are present. The question remains as to the extent that good construction and structural design can compensate for a poor configuration, or vice versa. The issue is important because to the extent that configuration is less important than non-architectural characteristics in determining seismic performance, the more difficult it is to convince the architect that his configuration decisions are critical.

But while analysis of the huge stock of damaged buildings is instructive, the successes must not be forgotten. One of these was the Torre Latino Americano, a 48-story building designed in 1948, as the tallest structure in Mexico City. Its size and design make this a very early metal and glass curtain wall structure in the Americas, almost contemporary with the United Nations Building in New York City, the first really large curtain wall structure in the U.S. The performance of the Mexico City structure is famous: surviving the 1957 and 1978 earthquakes without damage it rode comfortably through the 1985 event also, suffering five broken windows, minor damage to contents, minor cracking to some partitions, and the elevators had to be checked but were back in service in two hours.

One of the most interesting examples of the performance of a potentially poor configuration shows the positive effect of good structural design. The new National Lottery Building (about 1970) is a 25-story building of triangular plan form. It has a very tall first story - a conscious piece of urban design that opens up the public space at an important corner -

and an offset core in plan (Figure 12). The building also uses a complete floor to ceiling glass curtain wall of great delicacy. This building, a block and a half from the totally collapsed Regis Hotel, one of the worst single disasters in the event, was undamaged. The importance of this example is to show that knowledgeable engineering can make completely safe an otherwise questionable configuration. The period of this building is probably well above that of the critical number for this earthquake: the extent to which this was consciously designed is not known.

Figure 12.
The new National Lottery Building.
This steel frame building with a tall first floor was undamaged.



There are so many examples of both good and bad performance in Mexico City that only a systematic study of a large building inventory, in which configuration characteristics are accurately identified and correlated to degrees of damage, will isolate its importance. Meanwhile, the architect must realize that his conceptual decisions do effect, perhaps decisively, the building performance, and that building codes in the U.S. and in Mexico do not protect them from the consequences of bad judgment in this area.

ARCHITECTURAL AND STRUCTURAL DESIGN

The earthquake 'sees' and tests the whole building: it does not distinguish between the contributions of the architect, engineer, and builder. Since, under the U.S. contracting system, the builder is supposed to meticulously follow the plans and specifications, he plays no role in the conception of the design and uses no judgment in the execution of the work. The burden of seismic design and construction is placed squarely on the shoulders of the architect and the engineer.

It should be clear from the discussion in this article that seismic design is a shared architectural and engineering responsibility, that stems from the physical relationship between architectural forms and structural systems. An understanding of these relationships should be present in the mind of any designer working in a seismic area. Unfortunately, our methods of education and practice have tended to diminish such understanding, because we separate our architects and engineers during their education and for the most part, in U.S. practice the engineer is in an employee role to the architect, which tends to limit the force of his recommendations.

The interrelations between issues of engineering and architecture demand that architect and engineer work together from the inception of a project. The idea of engineers participating in early design concepts is not new, yet it often does not happen, for a variety of reasons, economic, cultural, and professional.

If they are to work effectively together, the architect and engineer must be able to communicate using a shared language within a common conceptual framework.

One of the traditional problems of communication has been - and continues to be - that designers tend to think visually and express themselves in sketches that are almost a form of shorthand, whereas engineers like the precise but abstract language of mathematics, and their visual language is that of curves and algebraic formulae. Because these two languages are almost completely incompatible, the architect and engineer may have little to say to one another.

In practice, the abstract idea of compatible architectural and seismic design comes down - as so often - to people. The issue becomes that of communication between the designer (not necessarily the architectural firm of record) and the project engineer (not necessarily the engineering firm of record). Traditionally, the engineer complains because the architect is ignorant of engineering concerns, is not interested in them, cares only for aesthetics, brings in the engineer when the design is already set, and then does not listen to him. Architects complain because the engineer does not understand concepts, can only react to design when it is presented to him, and cannot explain his concerns in a way that the architect will understand.

There is much truth in all these complaints, but the extent to which they are true will depend on the individuals concerned. Contrary to the stereotype some architects are knowledgeable about structure, interested in it, and respect it. Similarly, some engineers understand conceptual design, respect architectural needs, and are articulate about their concerns. Unfortunately, the stereotypes are based, as all stereotypes, on a preponderance of experience.

At this time, perhaps one can only give some advice, recognizing that many readers will not see him or herself as the audience to whom it addressed.

For architects, the lessons of experience seem to be:

- Acquire a better conceptual knowledge of engineering
- Acquire a feel for how structures respond to forces
- Talk often to your engineer in general, not just about the solutions to the project on hand
- Talk to your engineer before developing conceptual design of a project (i.e. when the program is known)
- Listen to your engineer when he talks to you
- Help the engineer to understand your objectives instead of trying to intimidate him

For the engineers, the lessons seem to be:

- Acquire a better conceptual knowledge of architecture

- Acquire a feel for how structures respond to forces
- Talk often to your architect in general, not just about the solutions to be project in hand
- Improve your explanations of engineering concepts
- When talking with architects, never explain concepts by use of curves or equations

It is important to realize that the relationship between structure and architecture (or engineers and architects) is much more critical for seismic design than for the vertical load design. To quote engineer Mete Sozen of the University of Illinois:

> "In resistance to gravity loads, architectural and structural decisions may be made independently of each other. But in resistance related to earthquake effects, separating the engineer from the architect is a formula for disaster."

THE ARCHITECT'S ROLE IN DECISION-MAKING

While in the design of the building the architectural-engineering relationship is critical, in the more general strategy of seismic design the architect plays a central role among all the other decision-makers. Before the detailed design of the building, seismic design issues are involved in site selection (is this a suitable site upon which to place a building?) and determination of the nature of the building (is it a suitable kind of building to place on this site?).

It is clear, for example, from the Mexico City experience, that the fundamental problems lay not with the detailed design of the buildings but in the fact that the kind of buildings constructed in the downtown area (i.e. slender concrete frame buildings between 6-20 stories in height) were inappropriate in relation to the site and its seismic history. Such buildings are only safe when designed and constructed with great care and understanding. We must recognize that in modern society there will always be a spectrum of professional performance from poor to excellent. Older buildings in Mexico City, because of material limitations (and stylistic fashion) were limited in height and span, their materials were not highly stressed, and they performed well. It is important to realize that structure, soil and ground motion interactions have become a serious problem for Mexico City because modern, and fundamentally inappropriate, buildings have been constructed since the great post-World War II expansion of the City started.

At the same time, to suggest that all buildings in Mexico City be limited to four stories, or be of shear wall design, or be only of first class design and construction, is unrealistic: many other factors than seismic issues determine what is built.

But major 'formulae for disaster' must be avoided, and the architect plays a key role in this. He is the source of information to the building owner, he may assist in site selection, and he certainly assists in determining the general type of building to be constructed. If serious conceptual errors in building type for seismic resistance are to be avoided the architect has a responsibility on the one hand to become better informed, and on the other to communicate his concerns to the developer, owner, or builder.

In the U.S. the architect's range of responsibilities vary greatly. For governmental work and major private work he will have full design responsibility and will employ engineering and other consultants to assist him. In large jobs, interior design is increasingly becoming a separate design responsibility, though many of the larger architectural firms have an interiors division that can handle such work as well. Many private office, industrial and retail buildings are designed as exterior shells only, with interior 'fitting out' done by tenants. Under these circumstances there is no relationship between the designer of the building shell and the design of interior nonstructural components.

The architect's responsibilities for inspection of the building while under construction are tending to reduce. At the lower end, architects will provide no inspection services, and the owner will rely on the contractor. At the upper end the owner will have his own inspection staff who will be present at the site on a full-time basis. In private development work the architect is often employed by a developer who is also a contractor, and provides limited design services only. In these cases, detailed engineering design, such as mechanical or even structural, will be provided by the mechanical contractor or the steel fabricator.

This variety of patterns means that the architect's role in seismic decision-making may be severely limited in the broad strategies of site selection and general building type, and may even be quite limited in the detailed aspects of the building design and construction. These trends towards limitations of the architect's role must be of concern in respect to seismic decision-making, because they are not automatically being assumed by other members of the building community.

In the detailed selection of appropriate systems for construction, the available systems tend to be responses to market conditions - in competition between the structural steel and reinforced concrete industries for example - and also are strongly influenced by the seismic code. High quality buildings will be designed above minimum code standards, with the exercise of considerable engineering judgment and control of all details. Lower quality buildings will be designed to the threshold of the code (i.e. code forces are a maximum) and engineering judgment and control may be lacking, primarily because of fee cutting and competition.

The architect tends to leave responsibility for seismic design to the engineering consultant. Since, for the most part, structural engineers are hired by architects, their position may be weak as far as demanding design cooperation, in such issues as configuration, from the architect.

Some of the problems discussed above are clearly present in the Mexico City experience, and requirements in the new Mexican seismic regulations are attempting to address these issues by mandating certain responsibilities for seismic design and construction which are presently not typical in the Mexican design and construction process. The U.S. should watch these trends with interest.

CONCLUSION

Mexico City remains as a living laboratory of a disaster; initiated by nature but made real by man's construction. The problems, the lessons, and the solutions are so complex, affecting all aspects of the physical, social, economic, and political environment, that we have no experience and clear rules upon which to base our activities. The possibility of a disaster on the scale of Mexico City certainly exists for an American City: it would be different in its details, but the same in its gross impact.

Where does the architect stand? Currently worried about his role, beset by issues of liability and unsure of the scope and force of his decisions, perhaps the last thing needed is an added concern. But Mexico City has made clear that the architect's responsibility for disaster is shared with his colleagues in the design and construction industry and cannot be delegated. To the extent that he wishes to lead the building team he must understand the forces of disaster and work towards reducing them.

ACKNOWLEDGEMENTS

All figures are by the author except for:

Figure 10	National Bureau of Standards
Figure 12	Process Architecture, Tokyo, July 1983

Information on damage in Mexico City is from Emilio Rosenblueth, Roberto Meli, and Enrique del Valle, but the opinions expressed are those of the author.

LAND USE AND PLANNING LESSONS OF THE 1985 MEXICO CITY EARTHQUAKE

Richard K. Eisner, AIA, AICP

GROWTH OF A MEGALOPOLIS

In examining the impact of planning and land use decisions on the seismic vulnerability of a city, it is impossible to separate current development patterns from historical determinants of settlement location, cultural values and traditions of the inhabitants, and external forces that influence development. Mexico City has a complex history that has molded its development and determined its seismic vulnerability.

Cities develop on sites where commerce can flourish or in response to tradition and religious imperatives. In the first category are those cities located near valuable natural or energy sources such as minerals, potable water or water power, those adjacent to natural harbors where the mode of transportation changes (between water and rail, rail and truck, etc.) or at the intersection of trade routes. Access and the availability of land for development or agriculture were primary considerations. Other communities develop on sites of religious significance or on the basis of tradition, myth, or pronouncements of secular or religious leaders. In selecting a settlement site, earthquakes, floods or other geological hazards if considered at all, were of a lessor concern.

Mexico City evolved from a combination of influences including both commerce and religious origins, with little attention paid to the geologic hazards of the region.

Origins of Tenochtitlan

Mexico City is located in the Valley of *Anahuac* (Mexico), a 96 by 48 kilometer basin bounded by mountains. The valley ranges in elevation between 1,500 and 2,500 meters above sea level (4,900 to 8,000 feet). Surrounded on three sides by mountains, the valley is underlain with clay and sedimentary soils of volcanic origins. Archaeological sites in the Valley of Anahuac suggest that the region was occupied by tribal agricultural communities as early as 1500 B.C. Mexico City is possibly the oldest continuously occupied city in the Americas. Tlatilco near the present site of Mexico City was an important community to the Olmec culture. The fall of *Toltec Tollan* in the 13th century brought a number of tribes into the Valley of Anahuac, including the *Tepanecs*, *Acolhua*, *Chichimecs* and the *Toltecs*. However, the region was dominated during this pre-Spanish period by the *Aztecs* who had, by legend migrated from their island home of *Aztatlan* (*Nahuatl* or "place of herons") under the leadership of their god-chief *Huitzilopochtli*. By 1299 this tribe, now calling themselves the *Mexica*, reached *Chapultepec*. After nearly a century of oppression by the *Tepanecs*, the *Mexica* fled *Culhuacan* and established *Tenochtitlan* ("place of the cactus fruit") on an island in Lake Texcoco. It is said that *Huitzilopochtli* had instructed his people to settle on the site where they saw an eagle sitting on a cactus eating a snake. This scene appeared to the *Mexica* at *Tenochtitlan* and is symbolically depicted on the modern flag of Mexico as illustrated in Figure 1.

The *Mexica* by using artificial islands ("*chinampas*") were able to develop a thriving agricultural community on the lake, and by the 14th century had expanded northward to include *Tlatelolco* (See Figure 2).

Figure 1 -- Coat of Arms of Mexico

The Mexican Coat of Arms depicts Huitzilopochtli's instructions to the Aztecs to settle where they find *an eagle sitting on a cactus while eating a snake*. The eagle symbolizes the sun and Huitzilopochtli, and the red cactus fruit the human heart which is consumed by the sun. Basing the decision on where to build the worlds largest city on these criteria has left Mexico City at risk to earthquakes, subsidence, and other geologic phenomenon.

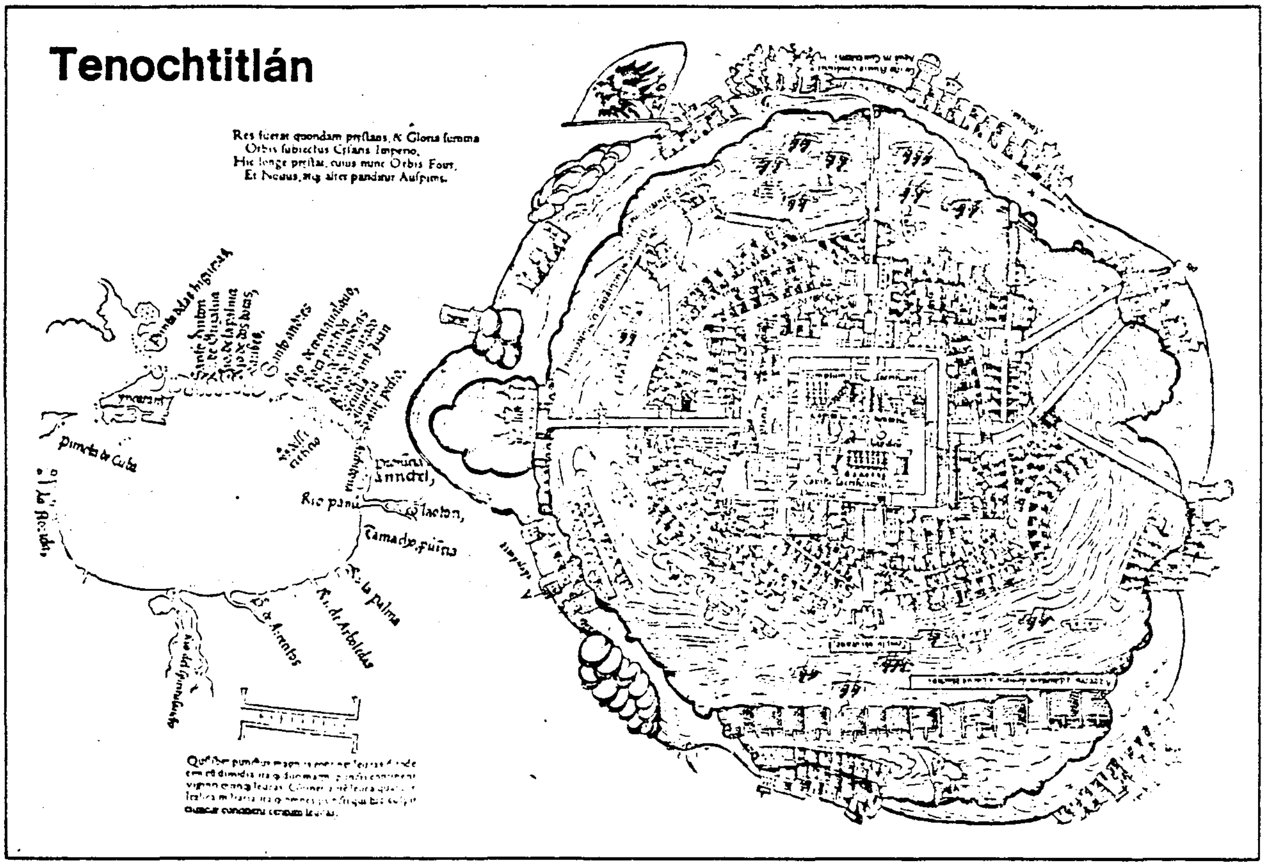


Figure 2 -- Map of Tenochtitlan in Lake Texcoco (From Baedeker)

The town plan of Tenochtitlan (1564 Nurnberg) illustrates the temple city's location in Lake Texcoco.

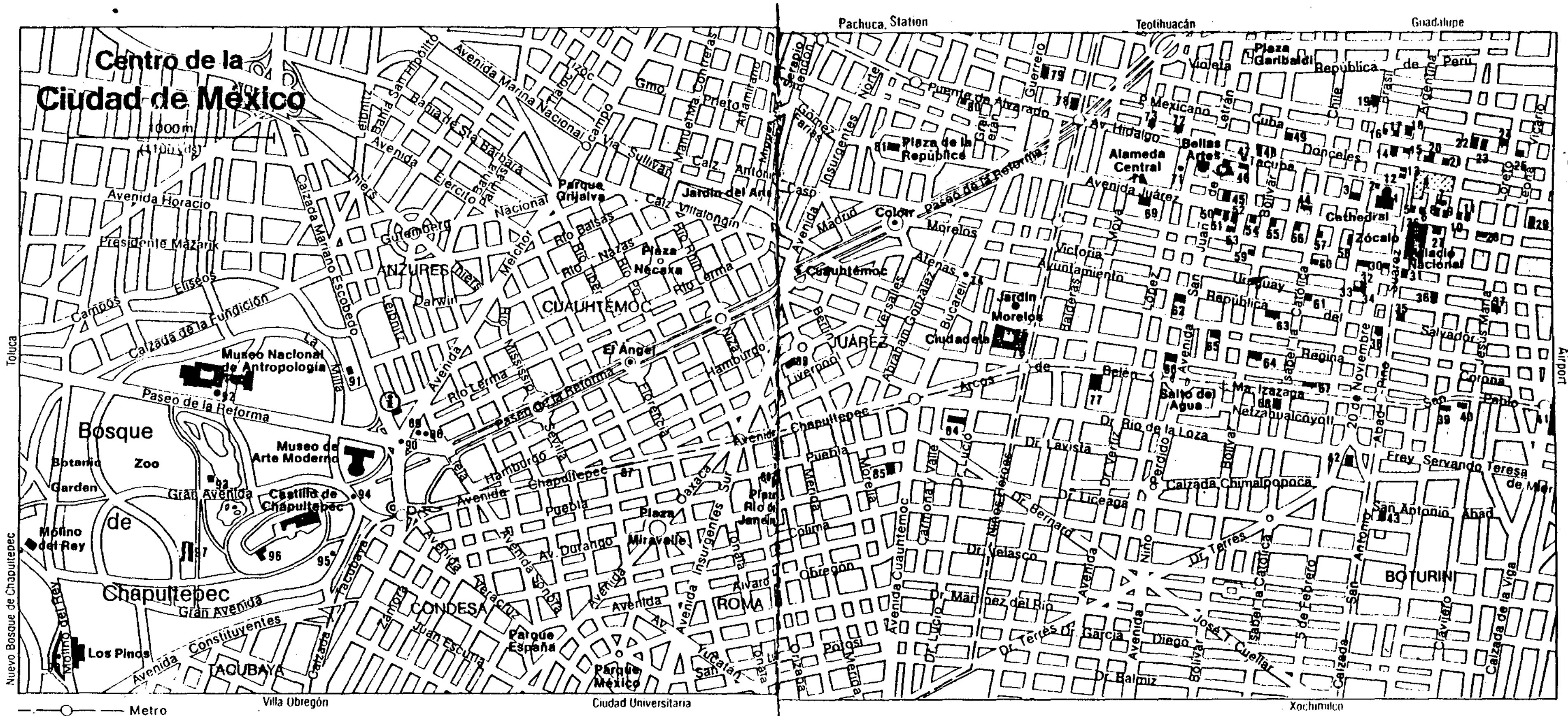
Influences on the Development of Modern Mexico City

In the early 16th Century the Spanish, under Hernan Córtes invaded Mexico and through alliances with the *Tlaxcalans* conquered the Aztecs and destroyed *Tenochtitlan*. At the time of the Spanish invasion, the population of *Tenochtitlan* was estimated to be 300,000 and the city was the center of trade in the region.

On the ruins of *Tenochtitlan*, the Spaniards built Mexico City (Mejico) in the pattern of a Spanish colonial city, using materials from the demolished Aztec monuments. The 240 meter square *Zocalo* (Plaza) was created over a portion of the Aztec temple precinct (*Teocalli*). Streets were laid out to connect the many elements of Spanish occupation; the plaza, embarcadero, mission and presidio.

Three hundred years of Spanish colonial rule resulted in the expansion of Mexico City by draining and filling the Valley's lakes to permit construction contiguous to the original settlement. As will be noted in this report, this development process directly increased the City's vulnerability to seismic damage in two ways: first by causing wide areas of the city to subside as ground water was lowered; and secondly, by placing new development on unconsolidated fills that were placed over layers of sedimentary sands and clay, materials prone to violent shaking during earthquakes.

The brief French rule of Mexico by Archduke Maximilian I (1863 to 1867) resulted in the construction of the Paseo de la Reforma, connecting the



1	Sagrario Metropolitano
2	Museo de Arte Religioso
3	Monte de Piedad
4	Zona Arqueológica (Gran Teocalli)
5	Primer Edificio de la Universidad
6	Casa del Arzobispado
7	Santa Teresa la Antigua
8	Primera Imprenta de América
9	Mayorazgo de Guerrero
10	Mayorazgo de Guerrero
11	Santa Inés
12	Casa del Siglo XVII
13	Casa de los Marqueses del Apartado
14	La Enseñanza Antigua
15	Colegio Nacional
16	Antigua Aduana
17	Biblioteca Iberoamericana
18	Secretaría de Educación Pública
19	Santo Domingo
20	Escuela Nacional Preparatoria
21	Anfiteatro Bolívar
22	Hemeroteca Nacional
23	Colegio de San Pedro y San Pablo
24	Iglesia de Loreto
25	Santa Teresa la Nueva
26	Museo Juárez
27	Antigua Casa de Moneda
28	Academia de San Carlos
29	La Santísima
30	Departamento del Distrito Federal
31	Suprema Corte de Justicia
32	San Bernardo
33	Casa de Don Juan Manuel
34	Casa de los Condes de la Cortina
35	Museo de la Ciudad de México
36	Iglesia de Valvanera
37	Convento de la Merced
38	Hospital de Jesús Nazareno
39	San Pablo el Viejo
40	San Pablo el Nuevo
41	Mercado de la Merced
42	Concepción Tlaxcoaque
43	Santa Cruz Acatlán
44	La Profesa
45	Casa de los Azulejos
46	Palacio de Minería
47	'El Caballito' (Monumento a Carlos IV)
48	Cámara de Senadores
49	Cámara de Diputados
50	Torre Latinoamericana
51	San Francisco
52	San Felipe de Jesús
53	Claustro de San Francisco el Grande
54	Palacio de Iturbide
55	Casa de Don José de la Borda
56	Casa del Marqués de Prado Alegre
57	Casa de los Condes de Miravalle
58	Portales de Mercaderes
59	Colegio de Niñas
60	Casa de los Condes de San Mateo de Valparaíso
61	Biblioteca Nacional
62	Mercado de Curiosidades
63	San Felipe Neri
64	Iglesia de Regina
65	Colegio de las Vizcaínas
66	Mercado San Juan
67	San Jerónimo
68	Capilla de Monserrat
69	Museo de Artes e Industrias Populares
70	Hemiciclo Juárez
71	Monumento a Beethoven
72	Santa Veracruz
73	San Juan de Dios
74	Reloj Chino
75	Exposición de Artesanías
76	Escuela de Artesanías
77	Templo de Belén
78	San Hipólito
79	San Fernando
80	Palacio de Buenavista (Pinacoteca)
81	Monumento a la Revolución
82	Monumento a la Madre
83	Librería Benjamín Franklin
84	Arena México
85	Iglesia de Romita
86	Sagrada Familia
87	Restos del Acueducto Azteca
88	Monumento a Venustiano Carranza
89	Diana Cazadora
90	Monumento a Simón Bolívar
91	Deportivo Chapultepec
92	Monolito Tláloc
93	Casa del Lago
94	Monumento a los Niños Héroes
95	Baño de Moctezuma
96	Galería de Historia
97	Fuente de Netzahualcóyotl
98	Monumento a Madero

Figure 3 -- Map of El Centro de la Ciudad de Mexico (From Baedeker)

The map illustrates the irregular street pattern in the central district of Mexico City. The Paseo de la Reforma crosses diagonally, connecting the Castillo de Chapultepec to the Zocalo. The pattern is a result of the superimposition of many cultural influences including the Axtec, Spanish, French and 20th Century town planning .

emperor's residence in Chapultepec Castle with the seat of government in the Zocalo. This 60 meter wide grand avenue now extends nearly 15 kilometers (9 miles) from Tlatelolco to the western boundary of the City (See Figure 3).

With the overthrow and execution of Maximilian, Benito Juarez returned from exile to restore the Republic. With Restoration came reforms in both government and physical development of Mexico City. Streets and avenues were cut through the city to expedite the flow of traffic and residential development was encouraged.

The Twentieth Century Metropolis

The dictatorship of Profirio Diaz (1876-1911) brought additional modernization and expansion of the City. Radial streets, exhibiting the French influence of Haussmann's Paris and L'Enfant's Washington, were constructed across many *colonia* during this period to facilitate the flow of traffic. The program of modernization was short lived as the revolution that toppled Diaz brought years of conflict to Mexico. It was only after this revolutionary period that Mexico City once again became the focus of development.

With political and economic stability during the post World War II period came economic growth and industrialization to Mexico. A central tenant of Mexico's industrial growth in the 20th century was the focusing of development in the Mexico City. Capital as well as population were channeled into the Valley of Mexico to fuel industrialization, fostered by a policy of centralization and flow of rural in migration that remains unabated to this day.

The population of Mexico City is currently over 18,000,000 and increasing at approximately 700,000 per year (split approximately equally between in-migration and birth rate), making it the most populous city in the world. Recent efforts to mitigate the problems resulting from the growth of the City have included development of the subsidized metropolitan subway system (the Metro fare of 1 peso barely provides for ticket printing), development of the limited access circumferential highway system to remove through traffic from surface streets, and the initiation of a less than successful national policy of decentralization of major industries, government ministries, and population from the capital. The following chart illustrates the continued growth in the City's population.

POPULATION GROWTH OF MEXICO CITY (From Baedeker)

1910	.8 MILLION
1920	1.0 mILLION
1950	3.0 MILLION
1970	7.5 MILLION
1980	15.0 MILLION
1986	18.1 MILLION
2000(Projected)	31.2 MILLION

Growth has outstripped the ability of Mexico City to provide housing and services, and has resulted in congestion, air pollution, an estimated shortage of 1.0 million housing units, and 100,000 homeless in the City before the earthquake.

In an attempt to address the critical shortage of housing in the 1960s, the Federal District developed a "new town in town" adjacent to the site of the pre-Columbian plaza of *Tlatelolco*. The *Conjunto Urbano Nonoalco-Tlatelolco*, designed by Arq. Mario Pani covered a 250 acre site and contained over 100 major structures including highrise apartments, schools, shops, recreation facilities, hospitals and theaters. Designed by Pani as a component of the *Plaza de las Tres Culturas* (Square of the Three Cultures -- Aztec, Spanish, and modern housing blocks) the project was to house 70,000. It was rumored to be occupied by over 100,000 people at the time of the earthquake.

By 1985, one-quarter of the nation's population and one-half of Mexico's industrial capacity were located in the Mexico City metropolitan area, a result of four decades of national policy that encouraged growth of the City.

Government of Mexico City

The Federal District of Mexico (*Distrito Federal*) was created in the early 1800s to serve as the seat of government and to ensure that the central government was not influenced by any of the surrounding federal states. The City is administered as a cabinet level Department of the national government, the *Departamento del Distrito Federal* (*DDF*). The President appoints the *Regente* or mayor to administer the *DDF*, and he, in turn appoints four secretaries-general responsible for developing plans and policies for the City, and sixteen district managers who preside over the City's sixteen *delegaciones*, or administrative districts. There are no direct elections for city officials and nearly eighty percent of the City's budget is provided by the Federal government.

Historic Preservation in the Central District

In 1980, the central district surrounding the *Zocalo* was designated *El Centro Historico de la Ciudad*, an historic district to provide protection of the historic monuments. A four story height limit was imposed on the area and plans for the restoration of 1,436 buildings initiated. Many of the structures in the district had over the years been converted from their original uses to serve as housing. In one case, a centuries old convent had been taken over as a tenement. The restoration efforts provided strengthening of the building's structure, relocation of the building's occupants to public housing, and the restoration of the historic character of the convent as a museum. Many of the restored historic structures are now used to house offices of the *delegacion* or other public entities.

OBSERVATIONS ON THE OCTOBER 1985 EARTHQUAKE

Many factors influenced Mexico City's vulnerability to the earthquake of September 1985: the geology of the region, the selection of Tenochtitlan as a building site, the influences of Spanish and French colonial rule, pressures for industrialization, and previous seismic activity. These factors combined and interacted on the morning of September 19, 1985 with devastating consequences.

The earthquake of September 19, 1985 and its aftershock of September 20 jolted a wide area of Mexico damaging structures in the states of Mexico, Jalisco, Guerrero, Colima and Michoacan. In the coastal resort of Ixtapa highrise structures were evacuated. In Ciudad Guzman most of the town's unreinforced masonry housing was destroyed. However, the greatest damage and loss of life occurred 250 miles from the epicenter in the central sections of Mexico City, areas that had been developed on a drained bed of Lake Texcoco (See Figures 3 and 4) and significantly, areas that were extensively damaged during a 1957 Mexico City earthquake. *Colonia Roma*, the *Zona Rosa*, and the area adjacent to

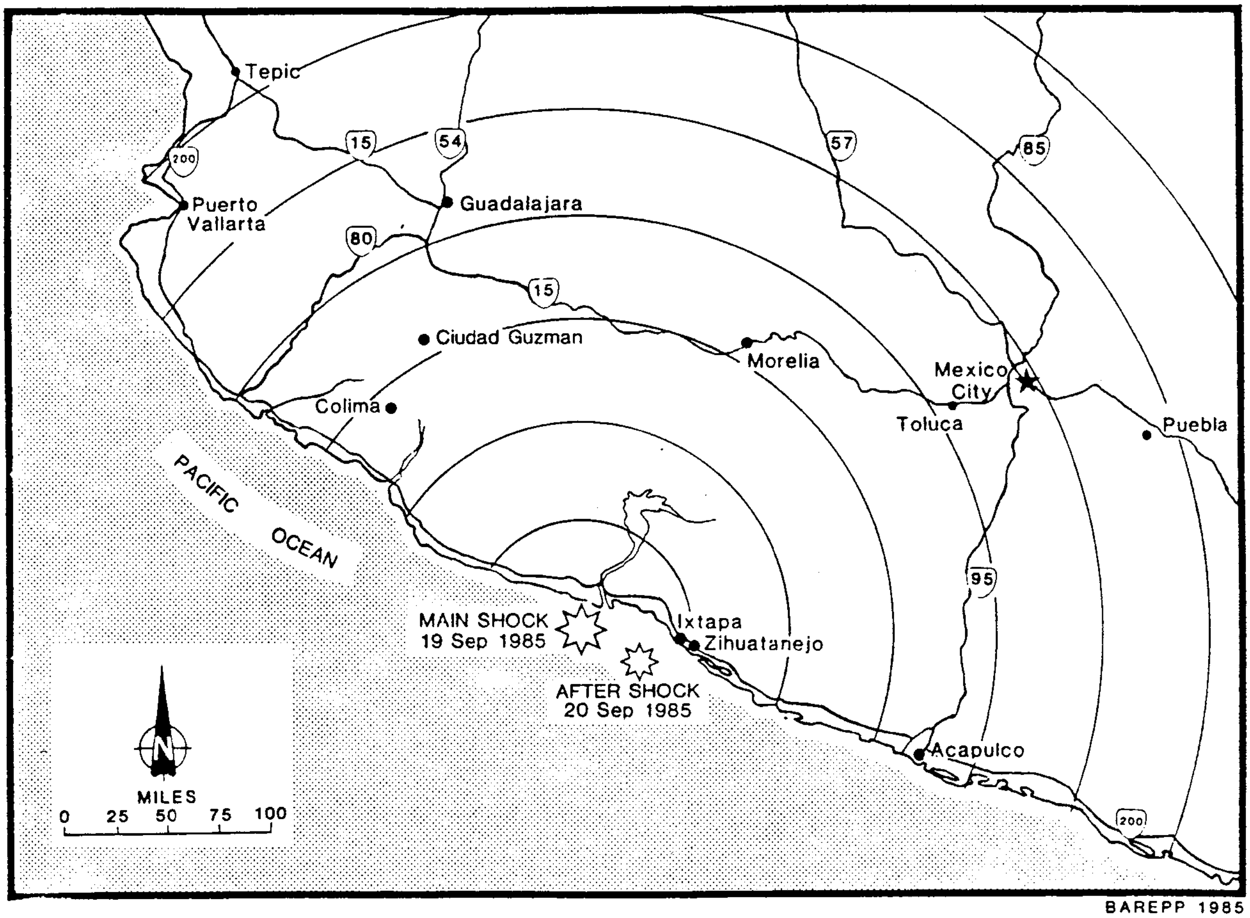
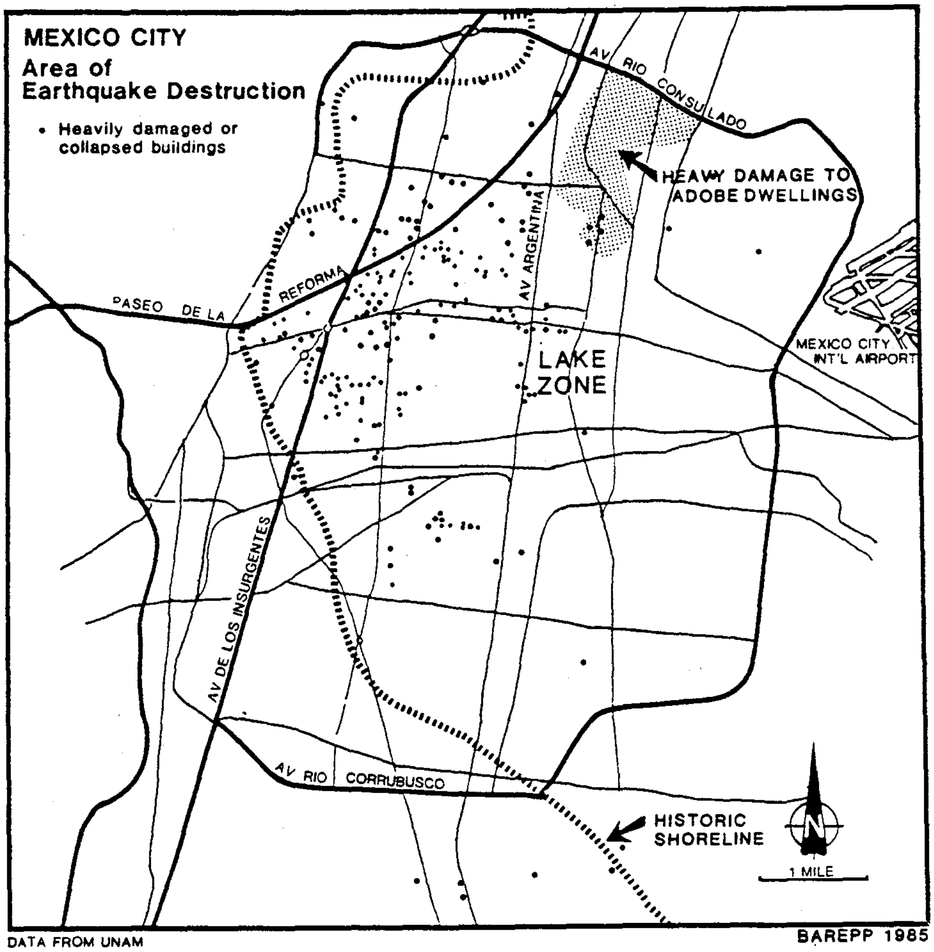


Figure 4 -- Epicenters of the 1985 Earthquake and Aftershock

Epicenters of the September 19 earthquake and the September 20 aftershock, located along the west coast of Mexico where the Cocos Plate strikes the Mexican mainland (250 miles from Mexico City). The earthquakes occurred at what was referred to as the Michoacan Gap. Scientists have forecast similar earthquakes on the nearby Guerrero Gap within the next decade, that could again cause damage in Mexico City.



DATA FROM UNAM

BAREPP 1985

Figure 5 -- Area of Earthquake Damage

Mexico City lies on a plateau at 7,300 above sea level. This plateau is surrounded by ancient volcanic peaks creating a basin in which layer upon layer of soft sediments are trapped. When the Aztecs first visited this site, the basin was partly filled by Lake Texcoco. Spaniards later drained the lake and placed fill materials on the lake sediments to provide flat building sites. The lake was never properly drained, and the fill never engineered properly. As seen on the map, damage in Mexico City drops off sharply as one moves away from the shoreline to areas where soils are compacted and water content is low.

the *Alameda* were the most heavily damaged. Several factors explain the concentration of damage in these older sections of the capital:

- *Building location was a critical factor in determining damage*

  The areas of greatest damage are located on a historic lake bed containing sandy soils and clay deposits which appear to have amplified the intensity of the ground shaking and increased the duration of the shaking. The area, drained by the Spaniards in the 16th century and filled over the lake sediments to provide flat building sites was never properly engineered.

- *Street pattern and building configuration may have affected building performance.*

  The evolution of city design through four centuries provided Mexico City with a complex street pattern. Linear Spanish schemes overlain by French radial and "surveyor's grid" systems result in an unusually large number of non-rectangular, asymmetrical triangular corner lots. The high rate of damage to corner structures, 42 percent of severely damaged buildings were located on corners, may have resulted from the inadequate performance of buildings with non-symmetrical configuration originating from site constraints.

- *Draining of the lakes, pumping of ground water, and centuries of subsidence increased the potential for earthquake damage.*

  Many of the structures in the area of greatest damage had subsided over the years, possibly "prestressing" their structures and making them predisposed to damage. The weight of buildings combined with the continuous pumping of ground water from under the city has resulted in as much as 4 meters of settlement to buildings near the *Alameda* and along the *Reforma*.

- *Previous earthquake damage may not have been properly repaired.*

  Older buildings appeared to be more vulnerable to damage. Most of the larger buildings damaged appear to have been built before 1976, many prior to 1972, before the upgrading of concrete design building code provisions. Many structures in the area had been damaged in the 1957 earthquake (M_s = 7.5) and were rumored to have been hastily repaired with stucco or "structural paint." There had not been a comprehensive survey of damage or supervision of repairs after the 1957 earthquake. The cumulative effect of the two earthquakes could have caused many of the structural failures.

- *Land use regulations were not uniformly enforced*

  Many of the damaged buildings had been designed for residential or light office occupancies. Over the years, a number had been converted for use in textile and garment manufacturing. Equipment and storage of materials greatly exceeded the weight that the floors were designed to withstand. This could have resulted in the frequent examples of "pancake type failure" of these structures.

- *Planning and urban design regulations did not provide adequate separation between structures or openspace for the City's inhabitants.*

  Decades of development in the city resulted in a mix of structures of varying age, height, stiffness, and setback. Many adjacent structures battered each other during the earthquake and settled out of plumb into their neighbors. Damage was especially devastating when newer, tall, flexible buildings struck older, shorter, stiffer structures, fracturing columns and masonry in-fill property line walls.

A lack of public open space and the narrow streets of the historic districts provided little space within which people could take refuge during and after the quake. Often debris from collapsed buildings filled the narrow streets, blocking thoroughfares and limiting rescue vehicle access.

- *Lifeline vulnerability can greatly expand the area affected by moderate or larger earthquakes.*

  Urban concentrations have become increasing dependent on maintenance of lifelines, especially those that supply information, electricity, water, and fuels; and those that remove waste. These networks often must cross fault rupture zones, or soils that are subject to subsidence. They have proved vulnerable during moderate and larger earthquakes in both Mexico and the United States. Loss of power, communications and portions of the water supply system compounded the problems of response and recovery in Mexico City. Loss of telephone communications cut Mexico off from the outside world for days after the earthquake.

AFTERMATH OF THE EARTHQUAKE

Management of the Immediate Disaster

The Mexico City Earthquake posed significant problems for government response. Damage to the power and communications systems made it difficult to gather information in the hours immediately after the temblor. The lack of "disaster intelligence" was compounded by the complexity of the required response.

Disaster response planning in Mexico was the responsibility of the military. There was no civilian agency with assigned roles or responsibilities for disaster management. The National Disaster Plan, *DN-III-E* gave full power to the military in the stricken area, and while appropriate for use elsewhere in the country, the plan was inappropriate for application in the Federal District where the military's role might be politically suspect. After a brief military response, control was transferred to the civilian government. The resulting response was "coordinated improvisation" as *delegaciones*, safety agencies, thousands of volunteers, and the national government attempted to assess the impact of the disaster and respond accordingly.

On the second day after the quake, the President placed the *Regente* of Mexico City in charge of the response, creating an Emergency Operations Center in the National Palace. Coordination of the response was difficult, however, because of the transition of responsibility from military to civilians, and the number of government buildings damaged. Individual public agencies acted independently and responded as best they could.

In the immediate aftermath of the earthquake, the government lacked a uniform system of damage assessment and documentation. This resulted in confusing and often contradictory reports on the number of buildings damaged and persons killed or injured. Information was collected from a variety of sources through individuals, voluntary organizations, and government agencies. The government often relied on media broadcasts for their situation reports. The single radio frequency available to police and fire agencies quickly became overloaded, adding to the difficulties of response.

Helicopters, which are generally thought to be a primary source of disaster intelligence, were not only ineffective in Mexico City, but may have posed a threat to public safety. Damage assessment from the air proved extremely difficult and unreliable as it was often impossible to determine from above the extent of damage to a structure. In addition, the noise and propwash of the helicopter blades posed a threat to already seriously damaged buildings and trapped victims.

Volunteers mounted a massive, spontaneous search and rescue effort within minutes of the earthquake. More than 7,000 volunteers reported to fire stations to assist in the rescue efforts. Thousands of others appeared spontaneously at disaster sites with shovels and buckets in hand to help dig through the debris. It is estimated that in the first 24 hours after the earthquake nearly 1 million of these "emergent volunteers" pulled over 3,200 survivors from the rubble of collapsed buildings. In the ensuing ten days, after which the rescue efforts were finally called off, a massive, organized, international, "high tech" effort located and rescued an additional 100 live victims. During the same period, it is estimated that nearly 100 rescuers were killed in the collapse of damaged buildings. **Lost in the media coverage of this effort was the message that while search and rescue is a critical element of earthquake response, and in Mexico a massive international effort recovered as many as 600 victims, <u>mitigation</u> is even more important as an estimated 20,000 persons died within twenty four hours of the earthquake in the collapse of buildings that were <u>not capable of withstanding earthquake forces</u>!**

Nearly 2% of the City's population lost their homes in the earthquake, creating a massive demand for emergency shelters. However, the earthquake confirmed a lesson learned in previous disasters, people use the extended family and networks of friends as much as possible and under utilize official shelters. An estimated 50% of those displaced found their own shelter, often camping on vacant property or in parks near their destroyed homes so that they could maintain neighborhood and community ties.

THE RECOVERY AND RECONSTRUCTION PROGRAM

Within a month of the earthquake Mexico initiated the difficult task of rebuilding. The President, in October 1985 established a National Reconstruction Commission to plan the recovery effort. The Commission with nine subcommittees comprised of both public and private members, was charged with making recommendations on all aspects of reconstruction. For many groups, the Commission provided their first opportunity to participate in the planning of their communities.

Damage Assessment

In order to take control of the damage assessment and reconstruction activities and prevent the unregulated and unsupervised repair that occurred after the 1957 earthquake, The *DDF* Department of Public Works developed standardized procedures for assessment of damage to structures. They first divided responsibility between the *DDF* and the *delegaciones* for monitoring damage assessment and reconstruction, with Public Works in charge of the approximately 600 damaged structures over 4 stories in height. The remaining 2,000 structures were the responsibility of the *delegaciones*. To ensure integrity of the damage assessment process, Public Works complied a list of approved structural engineers and architects that could be used by building owners to inspect damaged structures, and with a team of Japanese experts, developed a standard evaluation process and form.

Rebuilding

By mid-December, 7,400 damaged buildings had been identified with 775 in a state of partial or complete collapse. Demolition techniques ranged from the use of explosives where entire buildings were to be brought down to hand labor where structures were to be modified or strengthened. In one case, a building adjacent to *Pino Suarez* was shortened from 14 to 10 stories to reduce the weight on the foundations and change the building's frequency response.

On the sites of several buildings, mini parks replaced demolished buildings, complete with landscaping, paths, benches and lighting, providing much needed open space in the central district. The site of the collapsed *Hotel Regis* adjacent to the *Alameda* was redeveloped for use as a park and monument to those killed in the earthquake.

Debris Removal

Debris removal was a monumental task that had to be performed without further disrupting already congested traffic. Sites within the central district where damaged buildings had been leveled were designated as interim debris storage locations. Demolition debris was stored on these lots during the day and removed to outlying land fills during the night. Materials that were recyclable were salvaged for reuse, including masonry, reinforcing steel, and architectural finishes.

Seismic Microzonation

A critical part of the reconstruction planning effort is the completion of microzonation studies of the central part of the city. It is hoped that these studies will provide planners and engineers vital information about the soils underlying the city and their relative potential for violent shaking during earthquakes. It is also hoped that this new data will improve the quality of reconstruction decision making through strengthened building code application and planning regulations established for relative risk levels across the City.

Critical Housing Needs

To provide sites for critically need housing after the earthquake, the President of Mexico in early October issued an expropriation order for 7,000 properties in the damaged areas. The properties were primarily housing units that had been damaged in the earthquake; many being covered by the pre-war rent control act which had limited rents to as little as $3.00 per month. In a participatory planning process involving residents, planners, social workers, and architects the decision was made to replace damaged structures with scattered site housing that would permit residents to remain in their old neighborhoods. Temporary housing units, first of cardboard and later of corrugated sheet metal, provided shelter in closed off streets adjacent to construction sites. Displaced residents could thus remain in their neighborhoods and participate in the reconstruction of their homes. Within a year of the earthquake 34,500 housing units had been built using construction techniques that fostered owner participation. Financing schemes permitted former renters to purchase their new dwellings.

In *Tlatelolco*, several structures in the *Conjunto Urbano Nonoalco-Tlatelolco* housing complex were severely damaged. Two of the three sections of the *Nuevo Leon* housing block collapsed with a devastating loss of life. Thousands of displaced residents camped for weeks in the adjacent archaeological site rather than be relocated to government shelters. The mid-sixties experiment in community building which had accompanied construction of the housing complex proved successful. The residents were united in their insistence that the damaged buildings be repaired and pressured the *DDF* to undertake a project that is estimated to cost over 1 million dollars a day and 15 months to complete.

The problems facing Mexico in solving its combined pre-earthquake shortage of housing and simultaneously providing for those displaced by the temblor appear overwhelming, but they have embarked on a housing reconstruction effort that may be equal to the task. It is massive in scale, being characterized as one of the "largest housing reconstruction programs since the end of World War II."

LESSONS FROM THE MEXICO CITY EARTHQUAKE

I. Lessons for Land Use Planning and Urban Design

※ **Proximity to seismic faults is not the sole determinant of earthquake risk**

The 1985 Mexico City Earthquake occurred on a fault along the Pacific Coast of the country, over 250 miles from the Mexico City. In many areas of this country geologists have completed extensive research to map active faults in urban areas. In California the Alquist-Priolo Special Studies Zone limits development in proximity to such faults. Unfortunately, similar programs for determining ground shaking potential have not been initiated.

- **Microzonation studies can assist in determining relative risk of sites for development.**

  Land use and development patterns should be determined by using land capability analysis, including microzonation of expected ground shaking intensity; potential for ground failure, including liquefaction, subsidence, and land sliding; and inundation, to determine appropriate land uses and densities of development in a community. The land determined to have the lowest risk to earthquake damage should be permitted the least restricted land uses and highest densities. Development should be limited in areas with the highest level of risk.

- **Development and land use patterns will have an impact on the extent of damage and life loss from moderate or larger earthquakes**

  Areas of natural or manmade fill along bay margins, river courses and other areas of unconsolidated soils are likely to shake violently for a prolonged period of time during an earthquake, increasing the probability of structural damage. Land use policy, development regulations and building code provisions should recognize the increased risks to buildings in these areas.

- **Historical buildings may be more vulnerable to earthquake damage.**

  Older structures, particularly unreinforced masonry buildings and those constructed prior to the adoption of upgraded seismic code provisions (1973) are particularly vulnerable to earthquake damage. These structures should be identified and inventoried; their owners and occupants notified of their seismic vulnerability; and mitigation programs initiated to strengthen their seismic resistance or reduce their occupancy.

- **City Planning and Urban Design criteria can improve a city's capability to respond to an earthquake.**

In the aftermath of the Mexico City Earthquakes access to damaged areas was restricted as a result of debris in the streets. In addition, displaced residents used school sites, parks, parkways, and landscaped median strips along highways as sites for emergency shelters. Designers and architects in preparing their development plans should recognize the need for open space as a separation between land use activities, as buffers between older, collapse prone structures and circulation, and as sites for emergency shelters.

Urban Design schemes for historic districts should be particularly mindful of the potential for debris from unreinforced masonry structures to fall on pedestrian areas, and the need to separate adjacent structures to prevent battering.

II. Lessons for Local Government Preparedness

- **Rapid Damage Assessment is critical to an effective response**

The Mexico City Earthquake pointed to the importance of rapid and accurate damage assessments. The lack of accurate damage data hindered the early response and obscured the true magnitude of the disaster during the first several days after the earthquake. In Mexico it took several days to identify and assign architects and engineers to assess damage and assist in the search and rescue effort. Accurate information during this period is critical. If information is to be obtained quickly, trained engineers and architects must be fielded to the damaged areas to survey and assess the collapse hazard of damaged buildings and collect and report data on the extent of destruction. Architecture and engineering societies should therefore work closely with local and state governments to organize and train their members to assist in damage assessment and evaluation of damaged buildings.

- **Volunteer resources will be available to those governments capable of utilizing them**

  In the hours after the Mexico City earthquake, an estimated one million volunteers spontaneously appeared to assist in the rescue efforts. This pattern of convergence on disasters of emergent volunteer resources is common after disasters. Local government can be either overwhelmed by the number of volunteers, or prepared for their utilization. Volunteer skills range from doctors, engineers and architects, radio amateurs, and heavy equipment operations to laborers. An effective response can be dependent on a local governments ability to utilize the volunteers that appear at disaster sites, and to identify and recruit additional volunteers with desired skills. It is therefore essential that local governments develop effective techniques for coordination, training, and use of volunteer resources.

- **Pre-Earthquake Preparedness Planning is the Key to Reducing Damage and Life Loss**

  The 1957 Mexico City Earthquake (M_S = 7.5, epicenter on the Pacific Subduction Zone near Acapulco) was a harbinger of things to come. The pattern of damage in that earthquake was mirrored in the 1985 event with the focus of destruction in the area of the drained and filled bed of Lake Texcoco. The lack of damage assessment and the uncertain quality of repair and reconstruction left many structures predisposed to damage in future earthquakes. The events of 1985 were not isolated incidents in the history of Mexico City and forecasts of future seismic activity on the Guerrero Gap are warnings for the need to prepare for future earthquakes by identifying collapse prone structural types and instituting mitigations programs that will ensure their strengthening. Education of the public will also be a critical element of earthquake preparedness in Mexico. The population is being taught how to strengthen their homes using "self-help" techniques, and how to protect themselves and their families during future earthquakes.

The Mexico City Earthquakes clearly illustrate the need for pre-event preparedness. Earthquakes are one of the few natural hazards that occur without warning, therefore preparedness planning must proceed under the assumption that the earthquake can occur at any time; before training is complete, before hazardous buildings are identified and strengthened, and before local governments are ready.

The first and most critical step in preparedness is the determination of a community's vulnerability by identification of the hazardous areas where faulting might occur, shaking will be the most intense, and ground failure is likely. Development planning regulations and building codes can help to mitigate damage potential in these areas.

The second element of preparedness is the identification and mitigation of existing hazardous structures. Of particular concern should be unreinforced masonry structures, non-ductile concrete frame buildings, concrete tilt-up structures, and all buildings housing essential services.

The last preparedness element should address preparing to deal with what cannot be mitigated: street closures and route recovery; damaged assessment; demolition, search and rescue and debris removal; emergency shelter and housing; and, recovery and reconstruction. By knowing what to expect, planners can be ready for the unexpected. It is essential that decisions that can be made in advance of the disaster be made and promulgated so that they do not have to be made during the crisis atmosphere of the disaster. For example, recovery and reconstruction planning can be initiated before the earthquake if planners know what areas of the community are the most prone to damage and economic disruption and which buildings are likely to be damaged.

The elements of preparedness described above should be incorporated into the normal operations of the planning, public works, and managers offices of all local governments. The single most important lesson from the earthquake disaster in Mexico City was that comprehensive preparedness which addresses reduction of hazards can reduce the potential for life loss and economic disruption in future earthquakes.

CONCLUSION (But not the final chapter)

Scientists are now forecasting another major earthquake on the Guerrero Gap along the coast of Mexico. The quality of the post earthquake response and recovery planning in Mexico will surely be tested in the near future. We will be adding to the tragedy of Mexico City if we do not also learn from this disaster and prepare for the earthquakes that will inevitably strike our communities.

ACKNOWLEDGEMENTS

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- **PROCEEDINGS:** *1er Simposium International Los Seismos y sus Efectos en las Ciudades*, Mexico City, September 8-11, 1986
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26 September 1987

LESSONS LEARNED FROM THE 1985 MEXICO CITY EARTHQUAKE: PERFORMANCE OF EXISTING BUILDINGS AND NONSTRUCTURAL ELEMENTS

Henry J. Lagorio, AIA

INTRODUCTION

As indicated in several previous publications, Mexico City has become a natural "seismic laboratory" for the testing of existing buildings after the 1985 Michoacan earthquake which had its epicenter in a subduction zone along the west coast of Mexico. An interesting aspect of this disaster was that major damage and life loss, due to long period motions from this earthquake, occurred in Mexico City even though the city is located 230 miles from the epicenter. Approximately 5,700 existing buildings located in the central city were severely damaged or destroyed. This image of destruction tends to be counter to the public's normal interpretation of seismic events wherein it is perceived that maximum damage occurs in the epicentral region.

This is one of the first lessons to be learned: Depending on the set of circumstances involved, distant earthquakes can and do cause major damage in metropolitan centers whose location is not even remotely near the epicenter. This is a very important aspect of earthquake engineering which all architects must realize.

Because of the widespread damage caused by the 1985 Mexico earthquake, there are many other diverse lessons to be learned. However, in an attempt to filter out the complexities of all the data collected on this earthquake, this part of the report purposefully emphasizes two fundamental aspects of the study: the seismic performance of (1) existing buildings, and (2) nonstructural building elements.

EXISTING BUILDINGS

Background

First, it is well-known that geologic conditions underlying a building site have a direct bearing on how and what seismic ground motions are induced into a structural system. On this point, therefore, it is important to realize that over the years, following typical growth patterns for a modern city due to population pressures, industrialization, and urban spread, Mexico City has expanded from its historic lake bed center into surrounding areas with diverse topographies. Because of this growth, Mexico City today is built partly on rock in some locations but mostly on alluvial deposits and other geologic strata formed at the bottom or along the shores of a lake. The latter are about 30 to 50 meters thick in their uppermost sections. This layer is highly montmorillonitic. (See Figure 1.)

Second, any contemporary metropolitan center similar to Mexico City typically contains many building types and classes of diverse construction and age, including some historic monuments built prior to the promulgation of seismic code provisions as we know them today. It is also a reality that these diverse building types and classes of construction have very different performance characteristics in reaction to lateral load input motions induced by earthquakes. Each building type and class of construction will perform differently according to its age, size, mass, configuration, structure, materials, site conditions, and code provisions in force at the time of construction.

As a result of these two variables, the seismic performance of these different building types and classes combined with the behavior of diverse geologic conditions underlying each site is not expected to be uniform throughout a metropolitan center such as Mexico City. Anticipated damage patterns resulting from a severe earthquake in such an urban environment will change according to the number and types of buildings at risk and the geologic characteristics underlying their construction site locations.

The mix of buildings found in Mexico City does not establish an exception to this basic rule. In 1592 the Spanish started to build the colonial city with unreinforced stone masonry structures of two or three floors. Many churches were found in the city during that period including the Cathedral with its two towers about 52 meters high, see Figure 2. At that time it was the tallest structure in the Mexico City. During the 1930's, buildings of modern construction up to 17 stories started to appear. These were mainly analyzed statically but had no flexibility considered in their design. In 1956, the tallest building in Mexico City was completed, the Latinoamericana Tower with 44 floors. Since then, many other multi-story reinforced

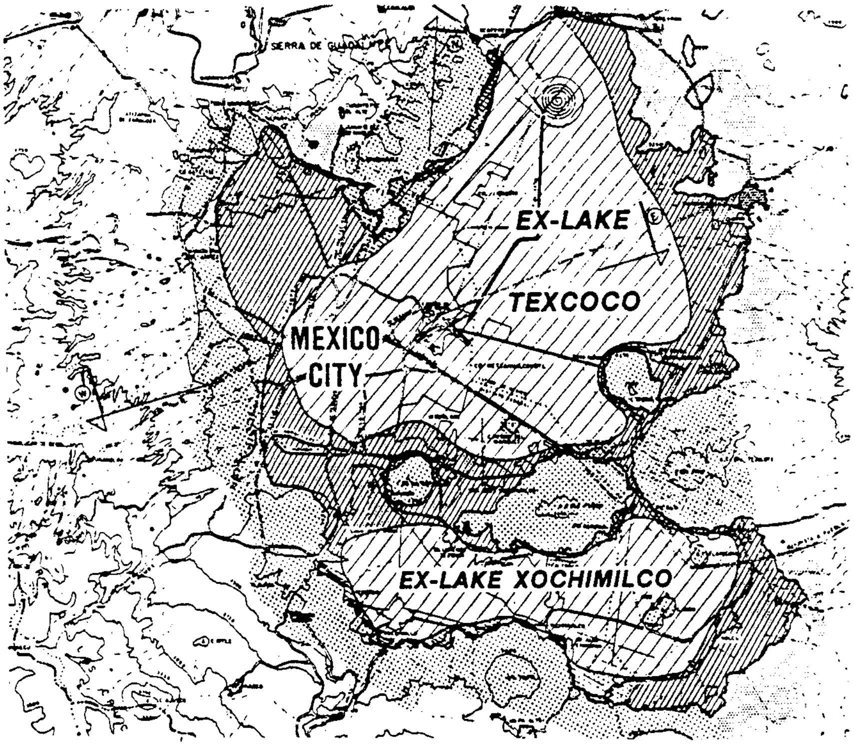


FIGURE 1 Geology of Mexico City

Source: EERI Newsletter, April 1986, Volume 20, No.4
"More on Mexico City's Local Geology"

FIGURE 2 Mexico City Cathedral

concrete and steel frame buildings of different sizes, configurations, and construction types were completed to produce Mexico City as seen today. It is important to remember this mix of building types when some lessons learned from the performance of the existing building stock in Mexico City are presented later.

SEISMICALLY VULNERABLE TYPES OF CONSTRUCTION

It is acknowledged that after each major earthquake new lessons are learned through field investigation concerning the performance of specific building types. These lessons learned, including those derived from the 1985 Mexico earthquake, result in the advancement of new seismic standards in building code performance requirements. Accordingly, over the years with progressive adoption of new seismic code standards based on new lessons learned, a greater number of existing structures face the possibility of being identified as technically hazardous to some degree or another when subjected to the forces generated by a maximum credible earthquake.

It is clear that the anticipated seismic performance of a building system is therefore generally classified according to its date of construction (building age) and quality of construction comparative to the year of adoption of seismic code standards currently in use. For example, modern reinforced earthquake resistant design for masonry systems was an unknown type of construction prior to the 1933 Long Beach, California, earthquake from which the first seismic code requirements were promulgated in California. It was exactly this building type that was severely damaged, with many collapses in evidence, at the time of the 1933 earthquake. Logically, therefore, the seismic performance of any unreinforced masonry bearing wall building (URM) constructed before 1933 in the United States would be immediately suspect upon technical review and automatically subject to further analysis.

In the same way, subsequent code changes, or major additions to code provisions, will impact the perceived seismic vulnerability of other types of building systems when compared to the levels of performance and construction practice expected by prior code standards in effect when they were originally designed. Obviously, any such deficiencies would vary widely in severity depending again on: (a) the age of the building and adequacy of code provisions at the time of construction, (b) building type and class, (c) design and construction practices, and (d) building size and configuration.

Seismic Risk Analysis and Existing Buildings

Generally, in seismic risk analysis, risk is often defined as a combination of our factors: (a) hazard, (b) exposure, (c) vulnerability, and (d) location. Hazard includes all possible geological hazards such as strong ground shaking potential, fault rupture, liquefaction, and landslides, among others. Exposure refers to public health and safety in face of the hazard. It includes the occupancy and function of a building. Vulnerability is associated with the expected performance of the building system. Location is the proximity of the building to a potential earthquake source. To identify high risk buildings, all four of these factors must be considered. Buildings of potentially vulnerable construction types, thus, may not all be of high risk such as those for example located in an area not even remotely exposed to an earthquake source. Nevertheless, the establishment of characteristics identified with potentially vulnerable building types of high risk is necessary as a first step toward developing an earthquake hazards reduction program.

It must be realized, however, that even representative vulnerable structures do not necessarily or automatically produce a high life-loss seismic risk since life loss is also associated with the use, or occupancy, of the building. A classic example is found in the case of a warehouse. If a warehouse, in which relatively low occupancy levels only occur during working hours, is extremely vulnerable to "collapse" in an earthquake, it still may be less of a seismic risk to its occupants than a hospital, with high occupancy levels around the clock 24 hours a day, vulnerable to "less serious damage." Accordingly, it is not the intent of this section to imply that all buildings identified as potentially hazardous construction types are extremely vulnerable structures, or to conclude that all buildings included in this category are of high risk, but rather to emphasize that there are many variables present in these building which may render their anticipated seismic performance potentially hazardous, and that as a consequence they merit detailed examination and analysis to determine their level of performance.

Potentially High Risk Buildings

Architects must realize that while the unreinforced masonry bearing wall building (URM) has gained much notoriety, other specific construction types are currently being postulated as presenting a potentially equal or even greater hazard to public safety. One of the others most frequently cited is found in nonductile-reinforced concrete frame type buildings constructed during the early 1940s to the early 1970s prior to the development of ductile concrete theory. As another example, since the advent of precast, prestressed reinforced concrete systems in the late 1960s, deficiencies in the early types of this building system have also appeared in contrast to currently defined earthquake-resistant design standards.

As a result of recent research activities in the earthquake engineering community, such as the California Seismic Safety Commission (CSSC), the Earthquake Engineering Research Institute (EERI), and the Center for Environmental Design Research (CEDR), a minimum of seven (7) classes of older, existing hazardous building types of construction and more recent building types have been identified as potentially dangerous under earthquake loads. These seven (7) classes of potentially hazardous building types are listed below in Table 1.

TABLE 1
POTENTIALLY VULNERABLE CONSTRUCTION TYPES

A. Unreinforced Masonry Bearing Walls
    A1. URM 2 stories and under
    A2. URM 3 and 4 stories
    A3. URM over 4 stories.

B. Nonductile Concrete Frame
    B1. Nonductile Concrete Frame 3 stories and under
    B2. Nonductile Concrete Frame over 3 stories

C. Precast, Tilt-Up and Reinforced Masonry
    C1. Liftslab Construction
    C2. Tilt-Up Construction, pre-1973
    C3. Tilt-Up Construction, post-1973
    C4. Reinforced Masonry
    C5. Precast Concrete
    C6. Prestressed Concrete

D. Pre-1940 Reinforced Concrete Systems
    D1. Under 4 stories
    D2. Over 4 stories

E. Wood Construction
    E1. Wood Stud Bearing Wall, pre-1940
    E2. Post and Beam Construction, pre-1940

F. Mixed Construction (wood, masonry, concrete, steel)
    F1. Under 4 stories
    F2. Over 4 stories

G. Steel Frame Systems
    G1. Steel Frame with Masonry Infill, pre-1940
    G2. Steel Frame with Concrete Cover, pre-1940
    G3. Steel Braced Frame, early systems

Source: "Issues for Seismic Strengthening of Existing Buildings: A Practical Guide for Architects," H. J. Lagorio, H. Friedman, K. M. Wong. CEDR, 1986

Relative Earthquake Safety of Buildings

Most current seismic building codes are intended to protect life and reduce (not eliminate) property damage. Even though we can not now predict earthquakes with respect to specific time, location and magnitude, it is clear from past experience that the existing building stock in major population centers located in a region of high seismic risk will be subjected to a major earthquake at one time or another. The potential of death and injury to people living in or working in potentially hazardous building types is a major concern. By establishing 1933 in California as an applicable base, prior to the promulgation of seismic codes and the development of earthquake resistive design, it is possible to derive the extent of maximum probable deaths in representative building types due to a major earthquake without consideration of external geological effects on structures such as landslides, liquefaction, subsidence, flooding or tsunami.

By focusing on building performance alone without the consequential effects of such other external geological impacts, a technical analysis of the maximum probable deaths per building type per 10,000 occupants in a typical urban center located in a high risk area can be developed. Table 2, below, indicates the results of this analysis as a function of the relative earthquake safety of buildings.

FIGURE 3 Collapsed Upper Floors, Reinforced Concrete High-Rise Building

TABLE 2
RELATIVE SAFETY OF BUILDING TYPES

	Probable Life Loss/10,000 Occupants	
Building Type	EQ-Resistant Building	Non-EQ Resistant Building
Small Wood Frame	2	4
Large Wood Frame	5	10
Small All-Metal	2	4
Large All-Metal	8	15
Steel Frame, Superior	5	10
Steel Frame, Intermediate	10	25
Steel Frame, Ordinary	15	40
Steel Frame, Mixed (wood floors)	25	50

	Ductile Concrete	Nonductile Concrete	
Reinf. Conc., Superior	25	50	100
Reinf. Conc., Intermediate	50	200	500
Reinf. Conc., Ordinary	75	300	1000
Reinf. Conc. Precast	75	500	1500
Reinf. Conc., Mixed (wood floors)	100	800	2000
Mixed Constr., Superior	15		800
Mixed Constr., Intermediate	20		1000
Mixed Constr., Ordinary	40		2000
Mixed Constr., Unreinf. Masonry	--		4000
Mixed Constr., Adobe Hollow Tile	--		5000

Source: "Existing Hazardous Buildings:
Assessing Direct Post-Earthquake Impacts."
K. V. Steinbrugge, et al, 1979, Seismic Safety
Commission. SSC 79-01

It is important to realize that the figures listed in Table 2 indicate general projections of life loss due to the relative safety of a simplified classification of typical structural systems generally found in the existing building stock and do not include collateral seismic impacts, such as soil failures and other geological effects indicated previously. In this regard the figures are useful as a general measure in identifying the relative safety of representative building types in the form of a life safety ratio.

LESSONS LEARNED

In Mexico City a total of about 5,700 buildings of the existing stock were recorded as damaged. Of these, 950 were destroyed and 2,300 severely damaged. Damage to the remaining 2,450 was listed from moderate to minor. The total number of damaged buildings represents approximately 14% of the building stock in central Mexico City. This indicates that the overwhelming majority of existing buildings in Mexico City performed well. Again this is quite a contrast to the image which the public has after a major 8.1 magnitude seismic event has occurred, wherein total destruction is mistakenly projected.

The following sections on lessons learned in Mexico City from the 1985 Michoacan earthquake are divided into two principal headings: (1) Existing Building Damage Patterns, and (2) Nonstructural Building Elements.

EXISTING BUILDING DAMAGE PATTERNS: LESSONS LEARNED

Long Period Motions and Soil/Structure Interaction

What is interesting about Mexico City during the 1985 Michoacan earthquake is the fact that building damage patterns did not follow precisely the expected norm charted in Table 2 due to four earthquake characteristics experienced in the city: (1) long period motions, (2) soil/structure resonance, (3) lake bed soil amplification of ground motions, and (4) duration of the ground shaking. A combination of these four characteristics produced lateral loads that proved to be critical to medium-rise buildings of reinforced concrete frame design with minimal or no shear walls, mostly of waffle slab or flat slab construction.

Table 2 implies that the most vulnerable building class is mixed construction of adobe and unreinforced masonry, the latter typical of the colonial buildings completed by the Spaniards in the 1520's. Yet in Mexico City only about 1% of the one or two-story low-rise structures of the unreinforced masonry class were severely damaged compared to an 11% damage rate for medium-rise reinforced concrete building types of six to twelve stories in height. It has been said that the long period lake bed soil deposits became a relative base isolator for the generally stiffer low-rise structures.

From observations of building damage in the center of Mexico City, inattentive conclusions could easily be drawn that adobe and unreinforced masonry buildings are more earthquake resistant than reinforced concrete structures. Yet, it is well-known that this is not necessarily true. A different type of an earthquake, even with the same 8.1 Richter magnitude but with diverse characteristics (shallow depths and/or short period motions), would have produced another completely diverse set of damage patterns. So, another lesson for architects to be learned from Mexico City is that different types of earthquakes with diverse characteristics will produce contrasting damage patterns.

If you are lulled into expecting the same damage patterns to appear in existing buildings after each and every earthquake, be prepared for a surprise and a rude awakening. When dealing with earthquakes and existing buildings, all design professionals should be well prepared for the unexpected to happen.

The collapse of many medium-rise facilities six to twenty stories high in Mexico City was clearly indicated by geophysicists to be the result of the natural frequency of this structural height becoming synchronized with the natural period of the underlying lake bed soil, a combination in which the latter amplified the shaking of the ground and set into motion a dynamic set of cyclical and progressively excessive lateral load inputs into the building. As many as 40 cycles of extreme reversal were recorded. This was exacerbated by the long duration of the ground motions (over one minute) and the long period of the motions caused by the energy released at the distant epicenter of the earthquake. This combination of effects may not happen after each earthquake, but when it does occur the results can be disastrous for a particular building type as seen in Mexico City.

Dynamic Pounding of Adjacent Buildings in the Urban Context

In a high-density, congested urban center, the proximity of adjacent existing buildings of diverse rigidity, typified by high-rise, medium-rise, and low-rise structures of different construction types and configuration has long been suspected to be a potential source of major "pounding" damage during severe earthquakes. In extreme cases, effects of this pounding have been known to be the cause of a building's collapse.

Prior to the 1985 Michoacan earthquake, however, little if any data was available to effectively document this phenomenon. For example in 1956, according to Professor Rosenblueth of UNAM, " . . . in Mexico City, there are only five buildings over 18 stories in height, two of them under construction, one of 43 stories tall. Previous to 1948 there were none." The building damage which occurred in Mexico City in 1985 has now changed all that and decisively shown that this is indeed an important factor to be considered in the analysis of potential hazards.

The period of oscillations of a building, in general depends on a building's mass and rigidity. The more rigid the building, the shorter its period of oscillation: the time it takes the top of the building to swing back and forth in one cycle. Even without lateral input loads from earthquakes, excessive movements have given rise to accelerations sufficient to give the building's occupants nausea. Building code performance standards address this problem of excessive movements by placing limits on the story-to-story drift of multi-story structures. For example, it is not uncommon for a building code to designate standards to limit interstory drift between two floors to specific numbers. Accordingly, under critical conditions, it is possible for a contemporary 50 story flexible, slender multi-story frame building to sway over 3.5 feet at the top in each direction under conditions severe enough to produce maximum drift. When dealing with earthquake loads such as those experienced in Mexico City, all of this has a direct bearing on the: (1) appropriate distance between adjacent buildings, (2) potential of dynamic pounding between buildings, and (3) severe damage which could result to either building.

In Mexico City, pounding between buildings contributed to damages in more than 40% of the damaged structures. Some of the damage patterns in Mexico City described by Professor S. Mahin, U.C. Berkeley, in a recent technical paper are extremely interesting:

> "Several modes of damage associated with pounding can be identified. Buildings of similar total and interstory heights can degrade due to successive impacts resulting in local collapse. Where one of the structures has substantially different mass, stiffness or strength, global collapse was also observed. In many cases, interstory heights differed so that at some locations the floor of one structure bisected the column of the adjacent structure. Impact in this case resulted in the cutting (guillotining) of the column." (See Figure 4.)
>
> "Other instances involved buildings of differing heights. Pounding was observed to result in the collapse of the upper stories of the taller structure, and it would fling itself over the lower building. Even more complex behavior has been observed when impact occurs between portions of buildings, thereby inducing torsional responses. There are significant instances where buildings have been observed to support adjacent weaker structures. It has been observed that buildings on the interior of a block (thus supported on both sides by adjacent buildings) performed well while those at the corners (and supported on only one side) are substantially damaged."

Research results in support of Professor Mahin's study indicate that in Mexico City 42% of heavily damaged buildings were corner buildings which lacked the protection of adjoining buildings. Damage patterns from Mexico City clearly indicate that when dealing with high-density, congested metropolitan centers located in areas of high seismic risk, serious consideration must be given to: (1) the potential of pounding between adjacent structures, (2) separations, or seismic joints, between buildings, (3) interstory drift limitations, and (4) the planning of entire urban blocks as a unit.

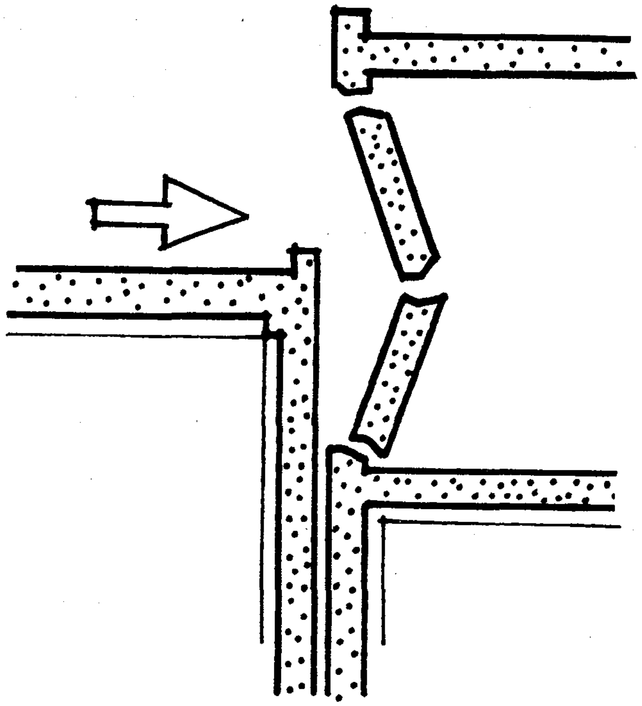


FIGURE 4 Diagram Indicating Effects of Pounding of Adjacent Buildings

Example of Pounding Damage Between Adjoining Buildings

Torsional Damage at Corner Buildings in the Urban Fabric

Another lesson to be learned is that city planning can inadvertently lead to extensive damage of existing buildings in the urban fabric. As Mexico City grew from the Colonial Period into the 20th Century, many changes occurred in its street patterns. The original center of the city during the Colonial Period in the Zocalo area was basically a grid system. From there the city spread in all directions, and to facilitate traffic movements, diagonal streets which cut across the grid system were added. The boulevard Insurgentes, or Oaxaca, is an example of this manifestation. The intersection of the diagonals with the grid system produced triangular shaped lots at the corners. In Mexico City today, therefore, a combination of triangular lots (pie-shaped) and rectangular lots are found at the street intersections.

It is not surprising to find that this city planning strategy has directly influenced the architectural design of buildings constructed to fit on these lots. In the center of Mexico City, two types of commercial buildings are typical on these corner lots: (1) a pie-shaped building, referred to as a flat iron building, with a solid structural wall at the base of the triangle and more flexible frame systems along the two street sides filled in with window/wall assemblies, and (2) a rectangular or square-shaped building with solid structural walls along the two back walls butting against adjacent, neighboring buildings and more flexible frame systems filled in with window/wall assemblies along the two street sides. See Figure 8 for an illustration of a plan view of these two systems.

As indicated earlier 42% of the heavily damaged buildings were corner buildings. It is not by accident that the percentage of damage in these buildings was so high. The damage patterns identified have been directly attributed to unforeseen high stress, torsional effects acting on these building types as a result of their shapes and the location of their solid structural walls in relationship to the flexible frames. In addition, there is evidence of pounding from adjacent buildings on the block as indicated earlier.

Failure of Foundation Piles and Overturning of Buildings

Another practical lesson to be learned for Mexico City was in the observed failure of friction supported foundation piles. Prior to the earthquake, it was generally assumed that friction piles would fail due to their severe settlement or subsidence of the surrounding soil. This was particularly expected in Mexico City because of inconsistencies in the lake bed soils.

But, although subsidence did occur in several instances as anticipated above, the surprise lesson was that totally destructive damage occurred when friction piles pulled completely out of the soil during the earthquake and the building overturned. During the more than 40 cycles of extreme reversals experienced by structures at the upper levels, the dynamic cyclical action was severe enough to pull the friction piles entirely out of the ground on one side of the building. In an extreme case, a four story building overturned when it pulled out the friction piles and collapsed across the street onto a previously undamaged apartment house on the next block.

Post-Earthquake Repair and Strengthening of Damaged Buildings

If Mexico City has been identified as a natural testing laboratory for seismic effects on buildings, it can also be correctly identified as a veritable and practical laboratory for the study of post-earthquake repair and strengthening methods of damaged buildings. Not all buildings suffered total collapse or severe damage during the earthquake so that they had to be removed or demolished. Many remain standing but are unoccupied waiting for rehabilitation.

Damage to structures in Mexico City resulted in many building deficiencies which are being identified and assessed by the architect and engineer prior to the development of final retrofit methods. Each damaged building is to be carefully evaluated since in some cases consideration for a specially complex set of damage characteristics has already led to the economic decision that new construction is the only choice.

Repair and Strengthening Methods

Basic methods for the seismic repair and strengthening of damaged buildings being utilized in Mexico City after the 1985 earthquake include, among others, the following strategies:

1. Replacing or restoring damaged materials and/or faulty components of structures.

2. Increasing the thickness or size of, adding reinforcement to, and/or increasing the strength of connections and joints of individual structural components.

3. Providing additional shear walls or vertical bracing to increase capacity of lateral resistance.

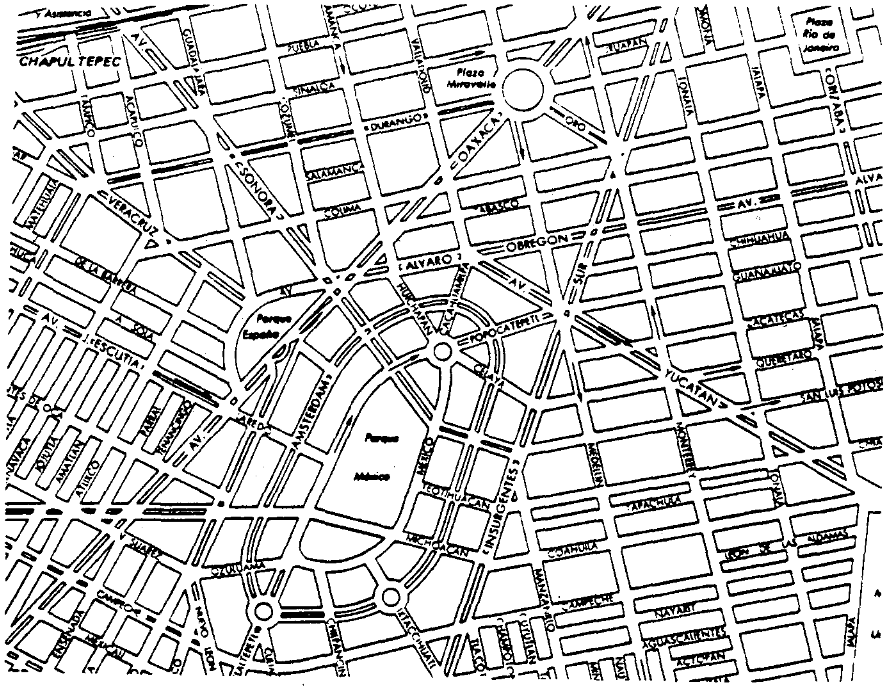
4. Removing upper stories to reduce mass of the building.

5. Shortening the period of the modified structure and increasing its response characteristics.

See Figures 5-7 for representative examples of repair and strengthening methods which are currently being used on damaged buildings considered economically viable for post-earthquake rehabilitation. Although, base isolation is a possible option when proven to be economically viable over more traditional repair methods, the author is not aware of any base isolation system currently being utilized in Mexico City as a rehabilitation strategy.

An Option to Repair: Creation of Open Space

In several instances when dealing with collapsed or severely damaged buildings, a most creative choice was made not to rebuild, but rather to treat the property as open space. Several large parks and mini-parks have appeared throughout Mexico City as an amenity to the immediate neighborhood. The most prominent park is a large permanent one which occupies the property of what was once the site of the Regis Hotel completely gutted by a fire following the earthquake. This is an interesting lesson to be learned since the creation of open spaces is also an integral part of a program attempting to deal with the post-earthquake decentralization of Mexico City.



Map of Diagonal Streets in Mexico City

FIGURE 5 Post-Earthquake Repair of Damaged Building

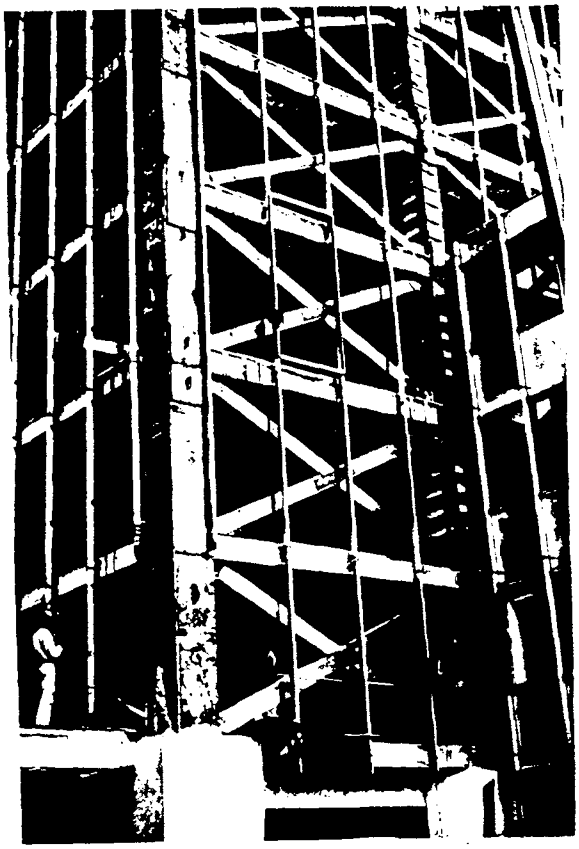


FIGURE 6 Post-Earthquake Repair of Damaged Building

FIGURE 7 Post-Earthquake Repair of Damaged Building

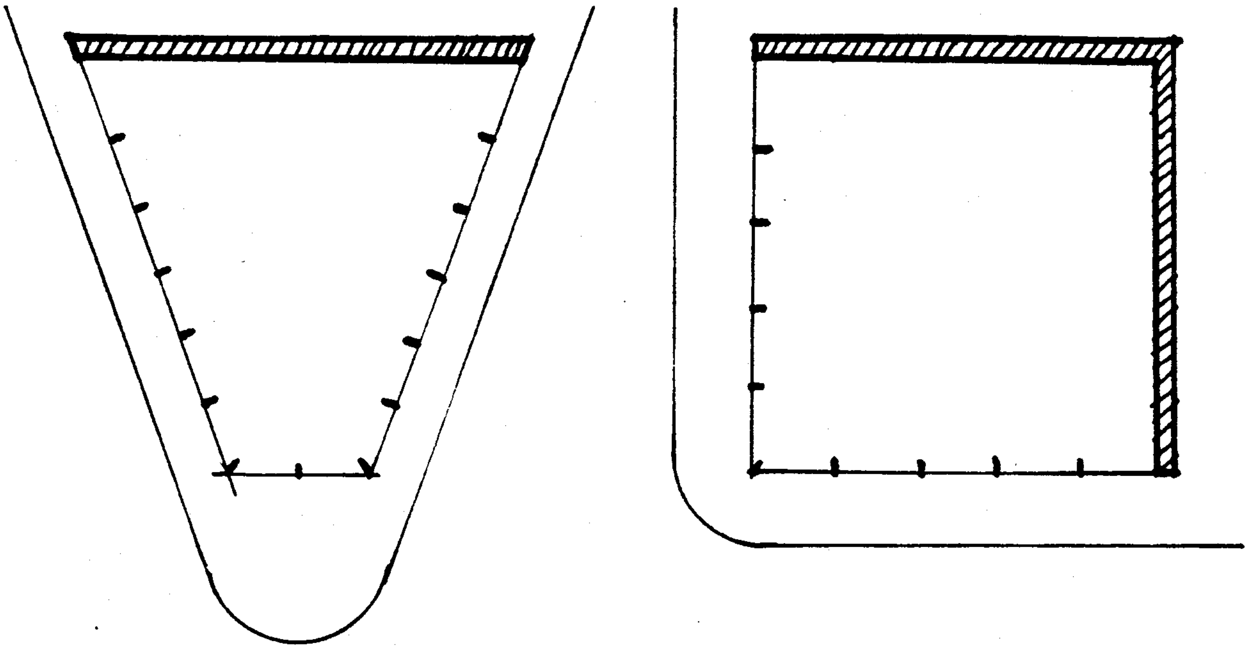
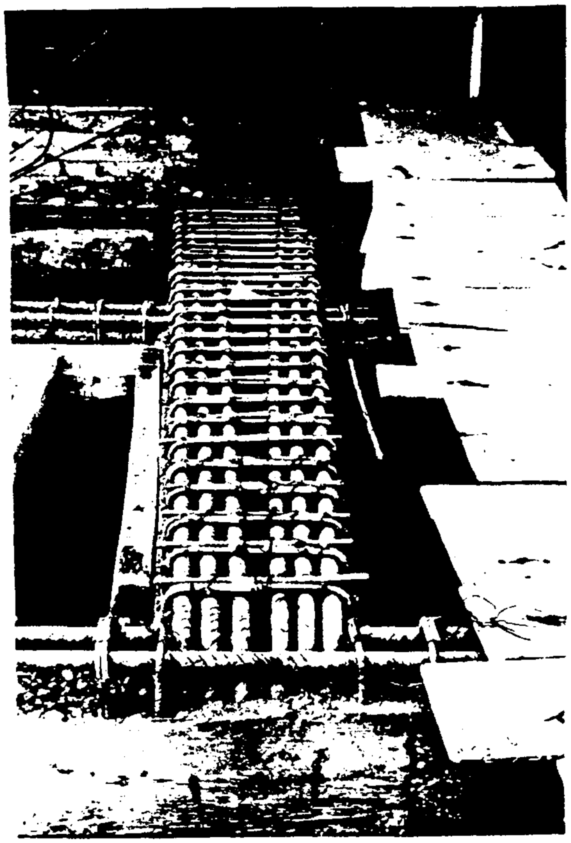


FIGURE 8 Drawing of Flat Iron and Corner Buildings, Plan View

Abandoned Flat Iron Building After Earthquake
Still Unoccupied in February 1987



Repair and Strengthening of Existing Foundation System on High-Rise Building at Tlateloco

NONSTRUCTURAL BUILDING ELEMENTS: LESSONS LEARNED

General Definition of Nonstructural Elements

Nonstructural elements of a building include all parts of the total building system and its contents which are not part of the fundamental structural system with its: (1) vertical support components (columns, piers, bearing walls, foundations, etc.), (2) horizontal span members (floor slabs, beams, girders, rafters, truss, space frames, etc.), and (3) any other structural element used for supporting the building's basic live loads and dead loads. The basic structural system of a building is designed to withstand all static live and dead loads, as well as all dynamic loads such as winds and earthquakes, without any assistance from the nonstructural elements which are predominantly inserted into the building during the final stages of construction.

Nonstructural elements include all the architectural components found in a building system such as cladding, ceilings, partitions, doors/windows, stairs, furnishings and equipment, contents, parapets, canopies, etc., in addition to all mechanical electrical, and plumbing components such as elevators, lights, piping, ducts, HVAC systems, escalators, security systems, fire protection systems, telephone and communication systems, computer equipment, etc., whether on the exterior or interior. A more thorough sampling of the principal categories of nonstructural elements is indicated in Table 3 below.

TABLE 3

REPRESENTATIVE CATEGORIES OF NONSTRUCTURAL ELEMENTS

1. Exterior Elements:
   Cladding, Veneers, Glazing, Infill Walls, Canopies, Parapets, Cornices, Appendages, Ornamentation, Roofing, Louvers, Doors, Signs, Detached Planters, etc.

2. Interior Elements:
   Partitions, Ceilings, Stairways, Storage Racks, Shelves, Doors, Glass, Furnishings (File Cabinets, Bookcases, Library Stacks, Display Cases, Desks, Chairs, Tables, Lockers, etc.), Ornamentation, Detached Planters, Art Work, etc.

3. Mechanical/Electrical/Plumbing Elements:
   HVAC Equipment, Elevators, Piping, Ducts, Electric Panel Boards, Life Support Systems, Fire Protection Systems, Telephone/Communications Systems, Motors/Power Control Systems, Emergency Generators, Tanks, Pumps, Escalators, Boilers, Chillers, Fire Extinguishers, Controls, Light Fixtures, etc.

4. Contents:
   Electronic Equipment, Data Processing Facilities, Medical Supplies, Blood Bank Inventories, High-Tech Equipment, Hazardous & Toxic Materials, Antiques/Fine Arts (Museums and Art Galleries), Office Equipment, Radios, Life Support Equipment, etc.

Source: "Architectural and Nonstructural Aspects of Earthquake Engineering," U.C. Berkeley, Continuing Education in Engineering, University Extension, July 1987

Damage to Nonstructural Elements

Damage to nonstructural elements of a building is generally caused in two ways:

1. Damage related to differential movement and distortion of the primary structure, and

2. Damage related to the shaking and overstressing of the elements themselves, either in-plane or out-of-plane.

Distortion related damage may occur to any nonstructural element forced to undergo, but not able to take, the same deformations and deflections as the basic structure. Stiff, brittle infill walls, curtain window/walls rigidly fixed between structural components, continuous stairways, or inflexible pipe risers between two or more floors. Or the element can be crushed between floors due to the interstory drift of the basic structural system.

Shaking-related damage is basically caused by the inability of an element to respond well to overall general shaking or the vibratory-induced motions of the primary structure. Failure will occur when stressed to over capacity while vibrating internally, overturning, sliding, or oscillating/swinging back and forth.

Relationship of Nonstructural Elements to Basic Structure

Fundamental engineering principles basically indicate that buildings are horizontally flexible under lateral loads. This flexibility is defined as interstory drift wherein one floor deflects horizontally in relation to the other. Generally speaking, a tall, multistory building is therefore more flexible by definition than a short, squat one, but it is important to know that both will deflect laterally to one degree or another. In addition to its own capacity to resist seismic forces without shattering or its anchorage pulling out, each nonstructural element, particularly exterior cladding and curtain walls, must also accommodate to this flexible interstory drift or be seriously damaged. Herein, of course, lies one crux of the problem. This becomes of critical concern when dealing with typically slender high-rise contemporary multistory buildings with 30, 50, or, as in recent buildings, more stories. It is one of the reasons that building codes are conscious about the need to establish drift controls even though they are not specifically detailed about nonstructural damage except for emergency critical facilities.

As indicated in the previous paragraph, drift control is one of the essential components in damage control of nonstructural building elements. This is especially true for more flexible, moment frame buildings in contrast to structural frame systems made more rigid by the addition of shear walls throughout the entire building. In Mexico City, excessive building movements induced by earthquake forces in more flexible framing systems, whether of reinforced concrete or steel, gave rise to accelerations sufficient enough to: (1) damage interior partitions, (2) peel off portions of the exterior cladding, (3) damage window frames and pop out glazing, (4) overturn office furniture and equipment, (6) cause electric power outages, and (7) result in other building impairments.

The amount of nonstructural damage, as well as the vulnerable aspects of construction and architectural designs indicated in other sections of this report, follow patterns observed in previous earthquakes which affected Mexico City in 1957 and 1979. In 1985 it was only the duration of ground shaking and larger magnitude combined with a higher concentration of population and buildings at risk that resulted in a more pronounced effect.

In the case of the 1985 Mexico earthquake, more nonstructural damage occurred in Mexico City as a result of the numerous cyclical oscillations and flexibility of multi-story frame buildings, previously alluded to, rather than the basic ground accelerations caused by earthquake induced long period motions. Accordingly, less nonstructural damage occurred in low-rise, one to three story buildings than in the multi-story frame buildings in Mexico City. In fact, as an indication of the slow, long period motions which occurred, many products and items stored on shelves in low-rise retail stores were not even knocked off their shelving. Exactly the opposite would have been true if the ground motions had resulted in high frequency accelerations.

Performance Model: Latinoamericana Building

One exception to the general damage patterns observed in multi-story buildings in Mexico City is found in the Latinoamericana Tower, a 44 story building finished in

1956, which is well-known for the careful attention paid to the integration of its structural and architectural design. The seismic performance of this building was excellent in every respect including damage control of its nonstructural elements.

Reports on the design of the building can be found in the Proceedings of 1956 and 1960 World Conferences on Earthquake Engineering. In general, precautions were taken in its design to avoid severe damage during an earthquake including concerns for nonstructural elements. For example, partition walls were not anchored to the floor above, window frames were designed to permit floor displacements without overstressing the glass, a simple symmetrical plan shape was selected to avoid excessive torsional stresses, and a pile foundation system was extended through the poor lake bed soils so that the building's natural period of vibration would be different from that of the subsoil.

The performance of nonstructural elements in this building during the 1985 Mexico earthquake clearly indicates that the precautions taken were very effective for the type of seismic event which took place. Quoting the building's engineer, A. Zeevaert, who inspected the building floor by floor after the earthquake, "Two windows broke on the second floor, one window broke on the third floor, two windows broke on the east facade and the north facade, ten windows were loosened from the structure on the 24th floor; two aquariums were broken and 30% of their water spilled on the 38th floor; on the 43rd floor a refrigerator turned over. No other damage was reported." "The elevators needed to be checked and a couple of hours later were back in service."

It is interesting to note that according to Zeevaert, a total of "2,500 window frames" made up the exterior curtain wall cladding the building. A total of five broken windows out of 2,500 isn't bad, even when taking into account the characteristics of the long period motions which took place.

Stairways: Building Access/Egress

The performance of stairways in the buildings of Mexico City once again indicated an important lesson dealing with access/egress problems. The Uniform Building Code generally treats an exit as a critical building element offering a continuous and unobstructed means of egress to a public way. By definition it includes intervening doors, corridors, ramps, stairways, smokeproof enclosures, exit passageways, exit courts and yards. In many buildings damage occurred to these elements making exiting very difficult from the upper floors.

In several cases in Mexico City, many stairways were blocked when their infill walls collapsed and the stairways became extremely hazardous. In other damage patterns investigated, reinforced concrete stairways completely collapsed with stairway landings and runs left suspended in midair dangling from steel reinforcing bars. The stairways were completely unusable as exits. In such cases, elevators were also found to be severely damaged and nonfunctional as a result of the seismic forces. They too had to be discounted as a means of exiting from or providing access to the upper floors of a multi-story building. Analysis of such damage patterns strongly indicate that exits are a critical building element which requires careful seismic treatment.

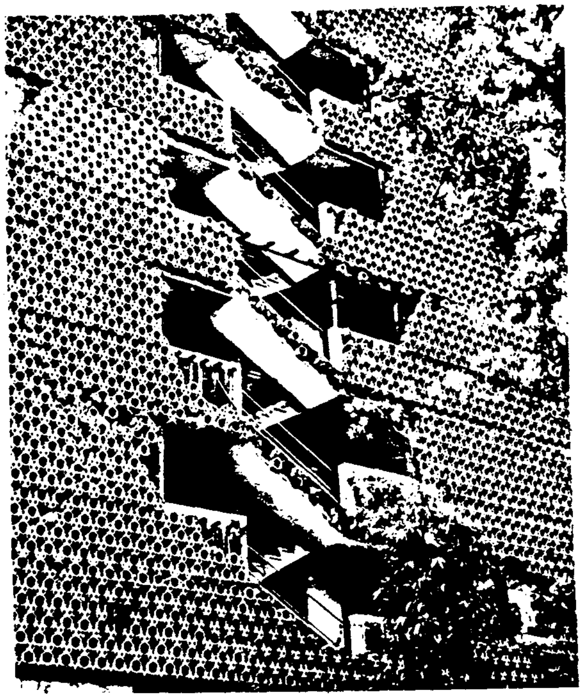
Window Wall, Curtain Wall Assemblies

The earthquake-produced contrasting damage patterns in Mexico City which ranged from severe damage to little, or no damage, to curtain wall assemblies on the exterior of buildings. Well-designed window wall assemblies with precautions taken to allow for movement performed well. Those which were not designed to accommodate interstory drift caused by the oscillations of the upper floors in multi-story buildings were severely damaged and failed. There were many examples of inadequate attention to the detailing and anchorage of curtain walls with no provisions made for extended movement of clips.

In several cases, damage to window wall assemblies was caused by pounding from adjacent buildings. Severe pounding led to the complete failure of curtain wall systems, while moderate pounding resulted in local failure of elements directly in line with the horizontal level of pounding. (See Figure 9.)

Change of Building Use/Occupancy and Contents

A very interesting lesson occurred in Mexico City wherein representative buildings changed their use or occupancy from their original function over the years. When this change of occupancy also required a change in the building's contents, it



Damage of Nonstructural Masonry Screen at Stairway

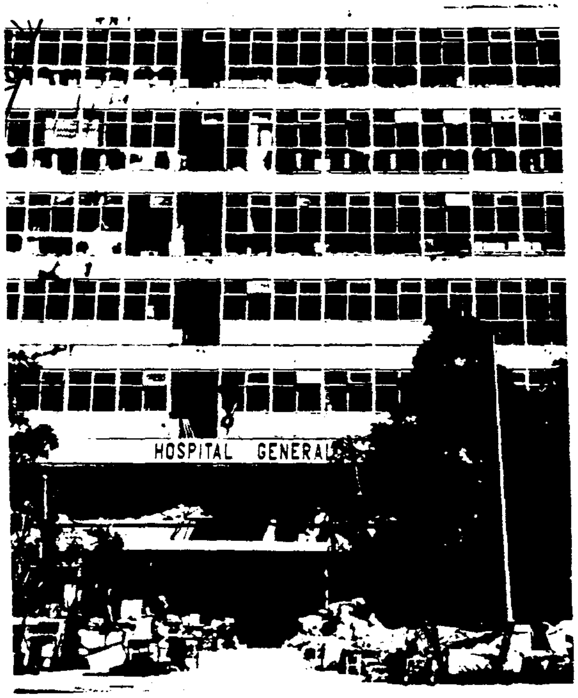


FIGURE 9 Damaged Window Wall Assembly

became a critical performance factor by also changing the building's capacity to respond to earthquake forces.

Specific examples occurred in Mexico City whereby buildings originally designed as housing units with relatively small live load requirements were changed into office buildings or commercial units with heavy live loads resulting from the furnishings and equipment needed in office or commercial operations. In a specifically critical case, a building was changed into a newspaper printing facility with heavy loads from a lesser function with light loads. The heavy mass of newspaper rolls and printing equipment on the upper floors of the building, for which the structural system was not originally designed, led to total collapse when the original structural system designed for lesser live loads was clearly overstressed.

The lesson learned here is that a relatively innocent nonstructural decision, such as what might appear to be a passive, innocuous change in occupancy or use, can lead to a building's collapse. In considering an alteration to or remodelling of a building, architects must be aware of the extent to which a change in occupancy or use will affect a building's seismic performance in comparison to its original design loads.

Exterior Veneers

Generally speaking, there were extensive examples of inadequately anchored veneers on the exterior of buildings. Approximately 30% of the damaged multi-story buildings had heavy veneer elements peel off of their street facades to one degree or another and fall onto the pedestrian walkways below. In several cases, the veneer was inadequately held in place by brittle mortared connections rather than a ductile hanger or anchor blocked back to a structural element. In other cases, veneers were also knocked loose or damaged by pounding from adjacent buildings.

In cases where multi-story buildings utilized a heavy, brittle stucco coating as finish material on property line walls, slabs of stucco were shattered and broke loose from the flexible frame to cascade down onto the roofs of adjoining lower buildings. The lesson here is that continuous brittle materials like trowelled stucco should not be used as a finish material on flexible buildings, especially at the upper floors.

Building Contents

Damage patterns to building contents were a direct result of the long period motions experienced during the 1985 earthquake. Excluding total building collapse which completely destroyed building contents, some interesting, but typical, patterns emerged.

As referenced in prior sections of this report, one to three story buildings survived the earthquake quite well, and, accordingly, there was little damage to contents. Items on shelves or tables were not overturned or jolted off shelving. File cabinets, furnishings, and equipment survived quite well. For example, stone sculpture, bas reliefs, figurines and ceramics in the two story Anthropology Museum in Chapultepec Park were not damaged, except for three or five pieces in the entire collection. The same was true for the Folk Art Museum, located off the Alameda, where clay pots and figurines were not disturbed or toppled over. Even free-standing art pieces were able to ride out the earthquake successfully. It must be indicated, however, that while the Folk Art Museum did not employ any nonstructural aseismic devices, the Anthropology Museum had made effective use of extensive aseismic systems to protect their collection.

Exactly the opposite was true in the multi-story buildings which experienced cycles of increased oscillations at the upper floors. Substantial damage to building contents occurred where ceiling panels and/or infill walls cascaded onto equipment and furnishings below causing considerable damage. Objects rotated off shelves and cabinets overturned in several buildings inspected.

The lesson learned, and repeated here for emphasis, is that different earthquakes with different motions will affect nonstructural elements and building contents in diverse ways. Architects must realize that different damage patterns will occur depending on the type and location of the earthquake. It is unrealistic to design nonstructural building elements to perform well under a single earthquake's ground motion while ignoring other potential motions within the realm of reality.

Building Impairment

Because of the poor lake bed soils under central Mexico City, many examples of building impairment were identified. Several well-designed buildings which performed well structurally and architecturally with minor damage, were functionally impaired and out of service when their underground utility services were severed due to extreme settlement. In an extreme case, a nine story office building settled 3 - 1/2 feet below the original sidewalk/street level, destroying all utility connections.

The lesson here is that no matter how well a building is designed architecturally and no matter how well it performs structurally under seismic loads, careful attention must still be given to electrical/mechanical connections to outside utility services. Today, a multi-story building would be placed out of service quite easily if any of its utilities were cut off (even if limited to a damaged sewerage connection, for example) for an extended period of time.

In Mexico City, major buildings in this category were still out of service when reinspected 18 months after the 1985 earthquake. A monumental effort would be required to restore functionality, which in all probability would not necessarily be that cost-effective. In such cases the economic impact in lost income would be quite severe.

FIGURE 10 Building Impairment Due to Severed Utility Service Connection Entering Below Street Level

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ARCHITECTURAL EDUCATION AT MAJOR UNIVERSITIES IN THE U.S.A.

Henry J. Lagorio, AIA

INTRODUCTION

In order to understand the relationship between architects and engineers in the United States, it is necessary to understand that the two are considered separate professions distinct from each other in education and practice.

At university levels, accordingly, the educational component of architects typically exists independently at a College or School level under which the architectural curriculum is housed. On a typical campus, the College of Engineering is also a distinct entity, separate from architecture, where curricula in civil engineering, with courses in structural engineering and structural mechanics, are found.

There are a few schools in the United States which offer a degree in Architectural Engineering, but they are rare and atypical.

Architects have their own primary national professional organizations, the American Institute of Architects (AIA) as a distinct institution, as do the engineers, the American Society of Civil Engineers (ASCE). There are also regional state organizations of each, such as the California Council of the American Institute of Architects (CCAIA) and the Structural Engineers Association of California (SEAOC).

Both have been active in the promulgation of the technical aspects and policy considerations of seismic safety standards, although the engineering professions are more advanced in their earthquake-oriented research efforts and practice, having started sooner.

As a profession, the architect's initial interest in earthquake hazards reduction programs first became publicly evident in the 1960's and advanced perceptibly by the middle of the 1970's. A few isolated individual efforts by some architects with interests in seismic safety started in the early 1950's. On the other hand the engineering professions started much earlier in developing research, structural analysis, and design of earthquake resistant buildings.

Recently, the two professions have actively entered into cooperative interdisciplinary research efforts addressing the complex issues found in joint seismic safety concerns. It is clear that this trend will continue to expand as the two professions work together in advancing earthquake hazards mitigation programs.

History of Schools of Architecture

The first official offering of a professional architecture curriculum at the university level started 125 years ago. The American architect-president, Thomas Jefferson, was the first to propose that a professional curriculum in architecture be established in the School of Mathematics at the University of Virginia in Charlottesville in 1814. Unfortunately the development of the school in Virginia was postponed due to organizational problems, so that the first formal program in architecture was offered at the Massachusetts Institute of Technology in 1862. This action was followed in 1867 by the University of Illinois at Urbana, and in 1871 by Cornell University.

Through the years, as architecture schools expanded the curriculum beyond the art of rendering to include practical and professional courses such as mechanical equipment, structural analysis, and the physical properties of materials, the standard four-year program was no longer able to contain all courses required. The first school to adopt a five-year professional program of study was Cornell University in 1922. By 1940 almost all schools offered a standard program of five years leading to a Bachelor of Architecture Degree.

During the 1960's, the "four plus two" architectural program became a model for expanding the professional curriculum into six years. The first such program to be offered was developed at the University of California, Berkeley, and Washington University in St. Louis. This program typically includes a four-year course of study in environmental design followed by two years of a strong concentration in architecture. However, many schools still offer the five-year Bachelor of Architecture Degree as the first professional degree.

Today, over 100 schools in the U.S. and Canada offer professional degrees in architecture, and about 200-300 more offer nonprofessional one-or-two year programs in architectural studies or technology. Schools that offer a professional degree are referred to as "professional schools of architecture." Generally, a professional degree is a five-year Bachelor of Architecture or a six-year Master of Architecture Degree, although variations to these models exist in some areas. It is important to note that the Doctor of Philosophy Degree (Ph.D.) offered by many schools is not considered a professional recommending degree.

EDUCATIONAL OBJECTIVES IN ARCHITECTURE

Typically in the United States, major universities have identified several general but fundamental objectives at three levels in the education of architects:

1. First Level - Undergraduate Education:

    (a) A basic education in the skills, professional knowledge, and values common to the several branches of the field.

    (b) An opportunity to develop a broad understanding of the cultural, social and technological contexts of the field.

    (c) The option for students to start independently the formulation of a particular emphasis for themselves as future practitioners, researchers, or specialists equipped with a pre-professional command of one subject field as a major.

    (d) An education sufficiently sound in its general outlines to provide a basis for work in other subfields enhanced by an architectural background.

2. Second Level - Professional Graduate Education:

    (a) Impart a high degree of professional skill in specific areas of study.

    (b) Develop attitudes of responsibility for leadership in society through the profession.

(c) Develop a capacity for decision making under conditions of uncertainty which characterize all professions, and at the same time to develop those scientific attitudes that will lead to the advancement of knowledge of the profession.

(d) A general opportunity for specialization in focused study if so desired.

3. Third Level - Professional Post-Graduate Doctoral Education:

(a) Provide the capacity to engage in creative research, or explicit specialization in a specific topic area which adds to a clearly identified body of knowledge, and/or the development of academic roles in higher education.

(b) Pursue research study related to the development of basic architectural theory in an environment not regarded as preparation for an advanced degree in professional practice.

UNDERGRADUATE AND GRADUATE ARCHITECTURE DEGREE PROGRAMS:

Bachelor of Arts Degree with a Architecture Major (4 year), and Bachelor of Architecture Major (5 year)

At the undergraduate level, students enroll in a four-year program leading to a Bachelor of Arts (A.B.) degree with a major in architecture. The A.B. degree is a nonprofessional accredited program. Students may terminate their studies at this level, but for the majority who graduate it serves as preparation and entry to graduate study.

In the Bachelor of Architecture program, the student enrolls in a five-year curriculum leading to a professional recommending degree when completed. Completion of this program is generally followed by entry into the profession after a period of practical experience in a licensed architect's office.

Master of Architecture Professional Recommending Degree (M.Arch)

At the professional degree level, students enroll in a two-year program leading to the Master of Architecture (M.Arch) degree which is the accredited professional recommending degree for entry into the practice of architecture. completion of the M.Arch degree typically takes a minimum of six years (a four-year undergraduate degree as an architecture major and a two-year graduate masters degree).

At the University of California, Berkeley, advanced graduate classes and seminars in architectural design for seismic forces exist at this level.

Doctor of Philosophy in Architecture Degree (Ph.D.)

At the Ph.D. degree level, students are required to formulate a two-year program of courses related to their area of specialization and research. Upon completion of the program of courses, and after having indicated a comprehensive understanding of their field of study, a qualifying examination is required before preparation of a thesis dissertation on a focused topic. Upon completion of the thesis and passage of the dissertation examination, the Ph.D. degree is awarded. The maximum time allowed for completion of the Ph.D. degree is five years: two years of course work and three years for the thesis and dissertation requirements.

At the University of California, Berkeley, research specialization in architectural and planning considerations of seismic safety by individual students occurs at this level.

Joint Degree Programs at the Graduate Level:

At the Master of Architecture level, opportunities exist for entering joint degree programs between architecture and other allied departments.

For example, among others, at some universities it is possible to obtain a joint Master's degree in architecture and engineering by completing a set of courses required for the Master of Architecture degree (M.Arch) and the Master of Science degree (M.Sci.) in civil engineering.

Other joint degree programs are found between departments of architecture and departments of city and regional planning leading to separate but joint M.Arch and MCP degrees, or a Master Degree in Urban Design.

STATE BOARD REQUIREMENTS FOR LICENSING TO PRACTICE ARCHITECTURE

To receive a license to practice architecture in specific regions, it is typically first necessary to either, (a) obtain a professional recommending degree (in California six years for the M.Arch degree) from an accredited university and complete an additional required apprenticeship period of practical experience, or (b) complete an equivalent period of time in a licensed architect's office, sufficient to exhibit on-site practical experience, in order to qualify for the State Board Examination.

After satisfaction of state requirements for licensing, which typically requires specific periods of practical experience (minimum of two years in several cases) and successful completion of a State Board Examination, the candidate is conferred full legal rights to practice in the region as a licensed architect.

ISSUES AND CONCERNS

With the addition of many new course materials over the years, expanded requirements in architecture schools are perceived by many to be causing standard programs to bulge at the seams. More and more demands are being placed on the student to complete new courses required for professional recommending degrees. The institutional arrangements in architectural programs are becoming most complex even as urban environments and societal needs become more complex. Yet, it is clear that the education of an architect must meet these challenges in practice. Some of the issues and concerns which fall out of this developing situation are easy to identify but difficult to solve.

1. The 1985 Mexico earthquake sent a clear signal that architects must become involved in seismic resistant design at all levels. yet only a few schools offer courses in architectural design for seismic forces, not only in building design but also in urban planning and design disciplines. the issue in question is how to introduce the subject appropriately into a curriculum already bulging at the seams?

2. Since, in actual practice, seismic safety in the urban environment is a shared responsibility of all the design professions, more interdisciplinary collaboration between schools of architecture, engineering, planning and urban design must be achieved. How can joint programs supported equally by engineering and architecture be developed?

3. Traditionally, the majority of faculty in schools of architecture are not technically oriented toward earthquake hazards reduction. How can symposiums, seminars and/or training sessions be developed to familiarize faculty with the subject, collectively and individually?

4. As seen in Mexico, the architecture profession must realize that seismic safety is not limited to the field of engineering. The earthquake resistant design of new buildings, rehabilitation of existing buildings, and the seismic performance of nonstructural building elements all fall into the responsibility of architects. How is this information transferred early on to the student through the educational process, and at what level? How can the architecture student be informed about the importance of earthquake property damage mitigation?

5. Clients must be educated, too. How can university extension courses be structured to disseminate technical information on seismic safety of buildings to prospective clients, broadly and generally, so that they thoroughly understand the problems faced by architects?

6. The 1985 Mexico earthquake clearly indicated that many new lessons are learned after each major, damaging event. Yet many architects with well-established offices never had the opportunity to complete course work in seismic safety simply because it was not offered during the time they went to school. How can continuing education courses at the university level be developed for the well-established, practicing architect to complete? Or, rather than at the university level, is this more appropriately done by the profession?

7. At the graduate level, more basic and applied research in earthquake hazards reduction must occur in schools of architecture, and such research must be recognized as a legitimate area for investigation. It is only in this way that a greater basic knowledge is introduced into the profession.

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Architectural Lessons
From the 1985 Mexico City Earthquake

What Have We Learned From the Mexico City Earthquake
Structural Engineering Issues

By Eric Elsesser, SE
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San Francisco, California

The information gained about earthquake response was substantial, especially in the area of structural behavior and related architectural component performance. The behavior of buildings in Mexico City clearly demonstrated the dynamic response of structures to earthquake motions. The observations also provided insight about soils effects, materials, building configuration, and the problems associated with dense urban sites.

A brief summary of what was observed follows, the lessons are applicable to many seismic areas in the world:

1. We observed the importance of structural dynamic behavior:
    1) dynamic resonnance of structures,
    2) amplification of structural motion,
    3) the effective "Base" Isolation of rigid structures on soft soils (dynamic decoupling of soil and structure), and
    4) the importance of regional and local geology on response.
2. We observed that critical or damage level structural response can be caused by:
    1) large amplitude motion or rocking,
    2) degradation of the structural members with a resultant softening of the system,
    3) pounding of adjacent structures,
    4) "Soft" stories with discontinuous lateral stiffness,
    5) unbalanced strength and stiffness of structural resisting elements with resulting torsional behavior,
    6) weak structural members,
    7) non-ductile structural members,
    8) unintentional resistance (infill walls, etc) and
    9) lack of continuity. We have seen some or all of these patterns in other earthquakes.
3. We observed some unexpected beneficial structural behavior:
    1) Rocking of structures which may have successfully dissipated seismic energy and prevented collapse,
    2) The energy dissipation effect of non-structural infill walls, which though sacrificed, probably prevented serious structural damage or collapse.
    3) The undamaged old unreinforced masonry buildings which were probably decoupled from the ground motion.

4. We observed some expected good structural behavior from:
   1) Well designed steel frame structures,
   2) new ductile reinforced concrete frame buildings and 3) old massive masonry or concrete buildings.

5. We learned about performance of various types of construction and configurations:
   1) Buildings which vibrated at resonant levels or which degraded (softened) to resonant levels failed or were badly damaged.
   2) Buildings which were in the resonant range, but which were either ductile or had sufficient energy dissipation capacity did not fail, and generally were not damaged.
   3) Open frame concrete buildings (in the resonance range) without, significant infill walls frequently failed.
   4) Open frame concrete buildings with symmetrical infill walls (which could dissipate energy) did not usually fail, although they may have been damaged.
   5) Large reinforced concrete shear walls without discontinuities at the base, generally performed well.
   6) The performance of previously damaged and repaired buildings.

6. We learned that building size, configuration and architectural layout can be critical issues in performance:
   1) Size and height as related to dynamic properties (period of vibration) can be critical for response at a specific site.
   2) Discontinuities of either structure or infill can produce hazardous conditions.
   3) Buildings with "open" stories either at the base or above, in contrast to "closed" stories, produce structural response problems.
   4) Random infill walls (unplaned stiffness) can result in structural distress.
   5) Use of non-ductile concrete framing for architectural expression without regard to the structural issues of strength, stiffness, ductility, etc. can create unanticipated problems.

7. We observed the variable performance of the following non-structural elements and of architectural finishes:
   1) Cladding panels and tile finish applied directly over masonry infill walls.
   2) Glass cladding.
   3) Open screen masonry grillwork.
   4) Interior unreinforced masonry partition walls.

Beyond the physical observations after the 1985 earthquake, we could not learn by casual observation about other important issues in the design-build process. Some issues which this joint Mexican-U.S. effort may expose for our mutual benefit are:

1) How both architectural design and construction engineering decisions are usually made for particular projects.
2) The effect of budget, code, and administrative constraints.
3) The problems with and resolution of quality control during construction,
4) The limitations placed on the service of the Architect and Engineer by convention, contracts and fees.

All of these are significant issues in California with regard to the Architect/Engineer trying to provide seismically safe buildings which meet both the owner's goals and the public's expectations. Insight into Mexican practice will help both of us learn from the recent earthquake.

The observations from the Mexico City Earthquake can provide the data for upgrading our codes and practice, and as with each earthquake experience, the impetus to improve our designs and our construction.

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Architectual Lessons
From the 1985 Mexico City Earthquake

What Are Our Concerns About Seismic Safety

Structural Engineering Issues

By Eric Elsesser, SE
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There are basic concerns about seismic safety of buildings which are common to people throughout the seismic regions of the world. They center first on our approach to new building design and second on our concern for how existing structures will perform. We are concerned about loss of life in collapsing buildings, and also about serious damage to buildings and the resulting social displacements and economic losses.

From the architectural and engineering perspective we are concerned about the following issues:

1. Discrepancy between knowledge and practice:

   Recent observations and laboratory tests have provided substantial insight into building system behavior. However, this data is not rapidly absorbed into practice, and may take decades. Education is first required, then code revisions, then practice - a long process.

2. A lack of consistency between goals and expectations for seismic behavior of structures. The issue is life safety vs. property protection:

   Governments are usually empowered to protect the public safety and are not directly concerned with the protection of property in natural disasters. The public, however, usually expects some degree of property protection provided in the form of codes, building permits, licensing of professionals, and certification of products.

3. The lack of acceptable performance criteria which reflects our goals and expectations:

   Our only formalized criteria for expected seismic response of buildings is our Building Codes. Our codes do not state the goals to be realized by compliance with the code. Is it life safety, that is performance without collapse, but with substantial damage, or is it protection of property with minimum damage?

4. The lack of consistent practice between various Architects and Engineers:

   Lack of consistency is due, in part, to 1) differences in education and experience, 2) inadequate technical references 3) different professional attitudes (reflected by adequate designs vs. minimal code designs) and 4) lack of understanding of the technical issues, which may be known but not yet codified.

5. The rapid adoption into practice of recent earthquake experience:

   Earthquake observations can be considered similar to uncontrolled laboratory experiments. We gain significant but fragmented insight about our buildings after each earthquake experience, but we must act to avoid the painful experience again. We should adopt into practice rapidly the lessons learned so as not to continue with past mistakes. This requires discussions, workshops, research and determined effort by Architects and Engineers.

6. Lessons from the Mexico City Earthquake which can help improve world-wide seismic-resistant construction:

   a) Dynamic performance of structures must be taken into account, considering site response and degrading or "softening" of the system.
   b) The potential of site "tuning" of a structure should be considered.
   c) Unintentional building elements can govern the seismic response; and they must be considered in the design, or avoided.
   d) Energy dissipation is critical for proper seismic response and the entire building system should be considered. Rocking modes and sacrificial infill elements can be used to advantage.
   e) Pounding of adjacent structures, especially in an urban environment, must be considered and the problem solved.
   f) Building configuration does play an important role in seismic response, and should be positively acknowledged.
   g) Base Isolation or decoupling of the structure from the site appears to be a significant design approach.
   h) Non-structural elements must be positively designed to be appropriately attached to the primary structure.

Architectural Lessons
From the 1985 Mexico City Earthquake

How Architects and Engineers Practice in California

Structural Engineering Issues

By Eric Elsesser, SE
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It is useful to understand the workings of professional design practice to be able to comprehend how decisions are made and which methods are used in the creation of buildings. The relationships between the creators of buildings (owners, architect, engineers, contractors, and government regulatory officials) are important and are usually governed by laws, contracts, and the conventions of practice.

Discussions of how architects and engineers practice in California may illustrate both positive and negative aspects of the actual process of providing seismic resistance for buildings. This may also provide some insight as to how architectural and engineering practice in seismic regions may be improved.

Working Relationships - Contracts

For building design and construction normally the owner retains an Architect for full design services (this includes architectural and engineering service). The Architect provides the engineering portion of the service as part of his contract either with in-house staff or by retaining outside consultants. These relationships between parties are generally covered by contracts, which are usually standard contracts such as those of the American Institute of Architects (AIA). For construction the Owner retains the Contractor under separate contract which frequently is related to the Owner-Architect contract in regard to the Architect's obligations.

For engineering structures which do not involve architectural design, the design is usually provided by the Engineer with direct contract with the Owner. The Owner, in turn, retains the Contractor for construction.

There are exceptions, with single package design-build contracts with owners wherein a Architect-Engineer-Contractor team will provide all services necessary to create and build the building.

In all of the above relationships, normal contracts do not make specific reference to seismic design or construction issues. These are only addressed in contracts for special projects or with owners who have special concerns or seismic experience.

Scope of Structural Engineering Services

In an attempt to define the complex and varied relationships which have evolved between architects and structural engineers, the Structural Engineers Association of California and Consulting Engineers Association of California jointly published a "Guide For Consulting Structural Engineering Services" in June 1979.

The seismic design of the primary structural system is included as a basic service to be provided by the Structural Engineer to the Architect (Prime Design Professional). The seismic design of non-structural elements (such as architectural and mechanical/electrical components) may be considered as a special design service to the Architect. These items are defined in Part II of the GUIDE; along with information to be furnished to the Structural Engineer; and a discussion of responsibility for design, shop drawing review, contractor design drawings, and performance or certification clauses.

Structural engineering services are actually provided in a variety of ways. Some contracts have a tight definition of services, others are loose and ambiguous.

Building Code Requirements

Most design work in California is governed by the Uniform Building Code (UBC) and its variations. The seismic requirements in the UBC (Chapter 23) have been developed over the past 30 years by The Structural Engineers Association of California. There has been little or no input by architects to the UBC seismic provisions.

Aside from the primary structural engineering issues covered by the UBC, there is only a nominal discussion of building configuration, an issue related directly to architectural planning. Only a horizontal load factor table providing design loads covers the seismic design for all architectural and mechanical/electrical systems.

Design of public schools and all hospitals in California are covered by special state codes (Title 24), but with very little guidance as to seismic design for architectural issues and non-structural components, except for horizontal load factors (design loads).

Review of designs for building permits is variable, the quality of review depending on the competence of the individual jurisdiction. Only school and hospital design review is consistently thorough and complete, covering non-structural elements as well as structural.

Construction Quality Control

The degree of construction review and inspection varies with the type of project and the individual contract provisions.

The Uniform Building Code requires special inspections (and tests) for certain types of constructions:

1) Concrete strength specimens and tests
2) Ductile reinforced concrete frames
3) Reinforcing steel and prestressing steel placement

4) Welding
5) High strength bolting
6) Structural masonry
7) Reinforced gypsum concrete
8) Insulating concrete fill
9) Spray applied fireproofing
10) Piling and drilled piers
11) Special grading and excavation
12) Special cases, which involve hazards

Enforcement of these inspections is not always consistent between the various local building departments.

School and hospital construction is closely monitored by project inspectors together with tests and inspections required by the State of California. Enforcement of these requirements is generally good.

Individual architects and engineers specify tests and inspections on private and public projects (other than schools and hospitals) depending on several factors:

1) Building department and code requirements,
2) Owner preferences,
3) Architect and Engineer experience and attitudes

Materials and assemblies, when required to be tested, are generally tested by private independent testing laboratories in accordance with standard test procedures. These laboratories are hired and paid by either the owner or by the contractor, depending upon the construction contract requirements.

The Architect and Structural Engineer usually, but not always, provide construction administration services as part of the Owner-Architect contract requirements.

This service includes:

1) Review of contractor shop drawings,
2) Review of contractor designs, if required by the specifications,
3) Periodic visits to the construction site for general review of the work,
4) Monitoring of the Testing Laboratory test results, and
5) Clarification of design details as required by the construction.

Some projects, with adequate budgets, receive this full service. Others with marginal budgets receive little or no service by the Architect and Engineer during construction.

Periodic inspection of the project is usually provided by the Local Building Inspector. The quality of this inspection varies with jurisdiction, and with the complexity of the work. Simple construction, such as wood frame residential buildings, can generally be inspected adequately by the Building Inspector. Complex projects with structural steel, reinforced concrete, and other sophisticated systems generally may not be properly inspected by the Building Department. At this point, either a specially trained resident inspector or the Architect and/or Engineer is required. This work, if performed by the Architect or Engineer, is considered to be a special service.

GLASS DAMAGE DURING
THE 1985 MEXICO CITY EARTHQUAKE

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GLASS DAMAGE DURING THE 1985 MEXICO EARTHQUAKE

Deane Evans Earle Kennett

INTRODUCTION

On the morning of September 19, 1985, at 7:19 a.m., a great earthquake registering 8.1 on the richter scale, struck the west coast of Mexico and traveled over 200 miles to cause serious damage and loss of life to sections of Mexico City.

In the early evening of September 20, 1985, at 7:38 p.m., another earthquake, with a Richter rating of 7.5, struck the city. Buildings that were still standing but heavily damaged now collapsed, causing additional casualties and death, and a large number of addtional buildings were severely damaged.

Mexico City has a population of approximately 18 million people. Due to the tragic earthquake, over 9,000 people lost their lives and another 10,000 people were injured. The earthquake also caused the displacement of about 40,000 people who lost their homes, places of employment and their possessions.

Of the 700,000 to 800,000 buildings in the city, a survey by the Institute of Engineering at the National University of Mexico showed that approximately 180 buildings completely collapsed and 85 were in serious danger of collapsing.

It is believed that much of the damage to the Mexico City built environment has direct application to the design and construction of buildings in the United States. The last major earthquake the United States experienced was in 1964 in Anchorage, Alaska. A far less destructive earthquake occurred in 1971 in San Fernando, California; however, our experience in terms of what we can expect from the next great earthquake is limited to knowledge gained over twenty years ago.

This nation has historically assumed that earthquakes are primarily confined to the West Coast, and the great San Francisco earthquake of 1906 is our most familiar event. About 40 of the 50 states as well as many U.S. territories are at some risk from earthquakes. Twenty-eight states have been identified as having major or moderate risk to earthquakes in the United States. In fact, three of the more severe earthquakes in the United States did not happen on the West Coast, but in the East and Midwest. One of these was in Charleston, South Carolina in 1886; another in 1755 at Cape Anne, Massachusetts; and the third in New Madrid, Missouri in 1811 and 1812. The "felt area" of this last earthquake was 2 million square miles, encompassing an area from Memphis, Tennessee to St. Louis, Missouri.

Although earthquake provisions and codes, through appropriate design requirements, promote <u>structural</u> safety during earthquakes, much less has been done to protect nonstructural systems in the building. These systems windows, mechanical/electrical systems, stairs, elevators, partitions, and other interior systems.

The primary reason for this lack of attention has been the minor life safety threat posed by these systems. Building codes and standards deal primarily with public safety and do not attempt to regulate property damage exclusive of its effect on life safety. For those buildings which remain standing (the vast majority in any earthquake), large amounts of property damage can come from the nonstructural systems and elements. An understanding of the components of construction costs illustrate this point. The structural system generally accounts for only 20-25 percent of the construction costs, while the mechanical/electrical systems account for approximately 35 percent, leaving the architectural systems (including envelope systems, glazing systems, partitions, elevators, etc.) to make up the final 40 percent.

The potential for nonstructural property damage is important to building owners, the public and our government for a number of reasons. First, there is a life safety issue with nonstructural damage, especially from secondary effects such as fires and explosions. Second, excessive property damage can be extremely costly, costs that must be borne by the building owners and their customers in private buildings, and by the public directly in public buildings. Third, nonstructural damage can easily cause the closing of even buildings whose structure remains undamaged. Damaged plumbing, mechanical systems (especially due to our standard hermitically sealed envelopes), electrical systems (no lighting or power), elevators (no access), and glazing systems (debris, hazardous (critical facilities, work environments, schools, multifamily housing, etc.) for long periods of time. Finally, the economic disruption caused by the down time and disruption of commercial and institutional services can effect a community directly, not only in terms of service delivery but also economically.

Very little research has been done on what to expect from nonstructural damage during earthquakes. Most of the information and data gathered to date has been the result of individual investigations and in no case has the data been gathered or analysed sysematically to identify the causes of damage, understand the damage potential, and define the level of risk.

This project analyzes information on damage to nonstructural glazing systems during the Mexico City earthquake, which effected primarily larger scale commercial buildings with similar structural and construction systems (primarily reinforced concrete frame) to those found in the United States. The study was undertaken in order to better understand the risk to glazing components in the case of future U.S. earthquakes and what can be done to mitigate that risk.

PROJECT APPROACH

The primary objective of this project was to gather detailed damage information on a valid subset of buildings damaged in the Mexico City Earthquake and determine the amount of nonstructural damage, the larger risks, and the causes of such damage.

During the project glass damage was singled out as the predominant nonstructural element in terms of numbers of incidents.

The project used building evaluations performed by the Mexico Department of Public Works (SEDUE) on buildings both owned and leased by the federal government. These evaluations, undertaken immediately after the earthquake, are impressively thorough and detailed. The data base includes over 500 buildings located in Mexico City. Of this number approximately 175 were completely undamaged, while 25 partially or completely collapsed, leaving 300 buildings with some degree (minor to major) of structural or envelope damage. Because the primary focus of this research effort was on the threat of glass damage in the absence of total building collapse, the study ignored both the 25 collapsed structures and the 175 without any damage at all to concentrate on the remaining 300.The data base is therefore meant to give a valid picture of the extent of nonstructural damage that can be expected in those buildings which receive some degree of structural or envelope damage during an earthquake.

The researchers are confident that this data base approximates the general damage to Mexico City because the federal buildings surveyed encompass a large number of building types, locations, and systems reflecting the general building conditions of Mexico City. The following data was developed for each of the 300 buildings evaluated, based on the original damage report data and a follow-up visit to each building by the research team.

- Location of the Building
- Building Type

- Structural System Type
- Exterior System Type
- Configuration
- Length and Width of the Building
- Height of the Building
- Structural Damage and Extent
- Structural Elements Damaged
- Nonstructural Damage and Extent
- Nonstructural Elements Damaged
- Relative Drift or Displacement of the Building
- Corner Location
- Heights and Location of Adjoining Buildings
- Amount of Glass Damage
- Amount of Glass Frame Damage
- Window Dimensions
- Shape of Window
- Glazing System
- Glazing Type

- Glazing Connections Analysis of this data base resulted in the final conclusions found in this report.

RESEARCH RESULTS

In the research glass damage was recorded as none (0 percent damage), limited (1-10 percent damage), minor (10-25 percent), partial (25-50 percent), substantial (50-75 percent), major (75-90 percent), and total (90-100 percent). Serious glass damage was considered any glass damage above 25 percent.

1. Of the nonstructural components (excluding infill walls) glass was the most likely nonstructural element to receive damage. In 42 percent of the buildings, inspectors recorded glass damage as one of the primary damages of the building. This appears to correspond to the percentage of glass damage recorded above 10 percent. Stairs and elevators were the next most recorded damaged components with 20 percent and 27 percent respectively.

2. In the data base (buildings with some structural or envelope damage), serious glass damage (above 25 percent) was recorded in 24 percent of the buildings. Glass damage, in general (over 10 percent), was reported in 42 percent of the cases. Any glass damage (including all glass damage above 1 percent) was recorded in 63 percent of the buildings.

3. More serious glass damage (above 25 percent) appeared to be closely associated with the amount of total building drift or displacement the building experienced. In the data base 23

percent of the buildings had no information on building drift, 33 percent appeared to have no drift or displacement, 39 percent had some degree of minor drift or displacement, and 5 percent appeared to receive major amount of drift or displacement. Of the building receiving no drift only 9 percent received serious glass damage, while with those buildings receiving minor drift 28 percent were recorded with serious glass damage, and of those buildings with major drift a very high 43 percent received serious glass damage.

4. The seriousness of glass damage appears to be closely associated with the severity of structural damage caused in the building. Of those buildings with no structural damage only 2 percent reported serious glass damage, with buildings reporting in minor cracks and deflections 10 percent recorded serious glass damage, of those buildings with major cracks and deflections a larger 28 percent recorded serious glass damage, and of those buildings with limited collapses a very high 74 percent reported serious glass damage.

5. A similar relationship appears to exist between serious glass damage and the extent of nonstructural damage. In the data base 26 percent of the buildings reported no nonstructural damage, 26 percent reported minor nonstructural damage, 38 percent reported major nonstructural damage, while in the remaining 9 percent the extent of nonstructural damage was unknown. Of the buildings reporting no nonstructural damage no

serious glass damage was reported. In those buildings reporting minor nonstructural damage only 6 percent also reported serious glass damage, while in those buildings reporting major nonstructural damage 46 percent also reported serious glass damage.

6. Serious glass damage appears to be associated with the complexity of the building configuration. In the data base 15 percent had unknown configurations, while 68 percent were considered having regular shapes, and 17 percent were considered irregular. Of the regular buildings 23 percent had serious glass damage, while 36 percent of the irregular buildings had serious glass damage.

7. There is apparently no relationship between serious glass damage and the size of the overall plan of the buildings. Although only 40 percent of the data base had plan dimensions, small plans (less than 500 square meters), medium plans (500-1500 square meters), and large plans (over 1500 square meters) had 21 percent, 28 percent, and 26 percent serious glass damage respectively.

8. Because the period of the earthquake coincided with the natural period of midrise buildings (approximately 10 stories), most of the damage occurred in these buildings during the Mexico City Earthquake. This data base included 21 percent low rise, 48 percent mid rise, 23 percent high rise, and 8 percent unknown. The analysis confirms that for mid rise height buildings (5-12

stories) 30 percent reported serious glass damage. Lower rise buildings (below 5 stories) reported only serious glass damage in only 6 percent of the cases, while for high rise buildings (over 12 stories) the reported incidents of serious glass damage was only 17 percent.

9. There appears to be no relationship between whether the building was a corner building (adjacent sides confined) or a noncorner building (opposite sides confined) and the extent of serious glass damage. Buildings with a corner location reported serious glass damage in 21 percent of the cases, while those buildings with a noncorner location reported serious glass 23 percent of the time.

10. There does appear to be a strong relationship between serious glass damage and the existence and height of adjoining buildings. Of those buildings with adjoining buildings of partial height (25-75 percent of the damaged building) 34 percent experience serious glass damage. This is in contrast to those buildings with adjoining buildings of excess heights (over 75 percent of the damaged building) which reported serious glass damage in only 16 percent of the cases, and those buildings with adjoining buildings of limited heights (below 25 percent of the damaged building) which reported serious glass damage in only 15 percent of the cases.

11. In the data base 37 percent of the building had no glass nor window frame damage, 38 percent recorded some degree of glass

damage but no frame damage, while 22 percent recorded some degree of glass and window frame damage. Of those buildings without any window frame damage only 13 percent received serious glass damage, while of those buildings with some degree of window frame damage, a much larger 58 percent recorded serious glass damage.

12. There appears to be a relationship between the larger glass areas and more serious amounts of glass damage. In the data base 33 percent of the buildings had small windows (less than 2 square meters), 26 percent had medium windows (2-4 square meters), 15 percent had large windows (over 4 square meters), and 26 percent were unknown. Of those buildings with smaller windows only 14 percent experienced serious glass damage, those buildings with medium windows reported a larger 21 percent, while of those buildings with large windows a higher 34 percent reported serious glass damage.

13. The shape of the window appears to be associated with the extent of glass damage. In the data base 30 percent of the windows were square, 17 percent were vertical, 26 percent were horizontal, while 26 percent were unknown. Horizontal shaped windows appeared to experience the lowest serious glass damage at 15 percent. Square windows appeared to be the next most successful with serious glass damage in 20 percent of the cases. Vertical window shapes suffered the highest proportion of serious glass damage at 30 percent of the time.

14. Individual widths and heights of the window pane also appear to be associated with serious glass damage. Short panes (less than 1.5 meters in either direction) experienced serious glass damage in only 15 percent of the cases, while medium panes (1.5-3 meters in either direction) recorded serious glass damage 21 percent of the time. The longer panes (over 3 meters in either direction) experienced serious glass damage in much larger 54 percent of the time.

15. The type of glazing system in the building (metal curtainwall, metal frame, placed directly into the structural frame, and precast curtainwall/panel systems) appeared to have some association with the amount of serious glass damage. In the data base 8 percent of the buildings had metal curtainwalls, 21 percent had metal frame sytems, 29 percent had windows framed directly into the structure, 14 percent had precast curtainwall or panel systems, and 26 percent were unknown. It appears that metal curtainwall systems and metal frame systems have a higher amount of serious glass damage in 26 and 27 percent of their cases. Windows set directly into the structural frame serious glass damage 18 percent of the time, while precast curtainwall or panel systems experienced serious glass damage only 12 percent of the time.

16. There appears to be no association between the various operating types of glass and serious glass damage. Fixed (non-operable) glass systems reported serious glass damage 20 percent of the time, pivoted windows 17 percent of the time,

casement windows 23 percent of the time, and sliding windows 18 percent of the time.

17. The placement of a resilient gasket between the glass and frame did not appear to be associated to any degree with serious glass damage. In the data base 23 percent of the windows used gaskets, 34 percent did not use gaskets, while 41 percent were unknown. Those glazing systems with no gaskets experienced serious glass damage only 12 percent of the time, while those systems with gaskets experienced serious glass damage 17 percent of the time.

CONCLUSIONS

The following conclusions were developed based on the research analysis results and further corroboration with a detailed examination of a selected subset of buildings.

1. A large number (over half) of those commercial buildings receiving some sort of structural or envelope damage during an earthquake can expect some glass damage. Approximately one-quarter of these buildings can expect serious glass damage.

2. Those buildings experiencing larger amounts of drift or displacement (more flexible buildings) received three to four times as much serious glass damage as buildings not experiencing large amounts of drift or displacement. Those buildings experiencing large enough lateral forces and/or drifts to cause major structural/nonstructural damage received higher chances of serious glass damage.

3. Buildings with complex or irregular configurations received almost twice as much structural damage and serious glass damage as regular configurations.

4. Buildings with partial height (25-75 percent) adjoining buildings received twice as much serious glass damage as buildings with much lower or higher adjoining buildings due to pounding between the buildings.

5. Smaller window glass areas received less serious glass damage than larger glass areas. As the window glass area or either dimension increases the amount of serious glass damage goes up to three times as much as for the smaller areas. Window glass dimensions on the order of 1.5 meters and window areas less than 2 square meters appear to receive the least amount of serious glass damage.

6. Vertical glass shapes received twice as much serious glass damag as horizontal or square shapes.

7. The more flexible glazing systems (metal frames) received twice as much serious glass damage as the more rigid systems.

PHOTO TITLES:

1. Buildings which experienced large drifts or displacements tended to experience higher levels of serious glass damage.

2. Buildings which experienced larger amounts of structural or envelope damage tended to experience higher levels of serious glass damage.

3. Those building with irregular configurations experienced higher amounts of serious glass damage.

4. Buildings with partial height adjoining buildings experienced higher amounts of serious glass damage through pounding.

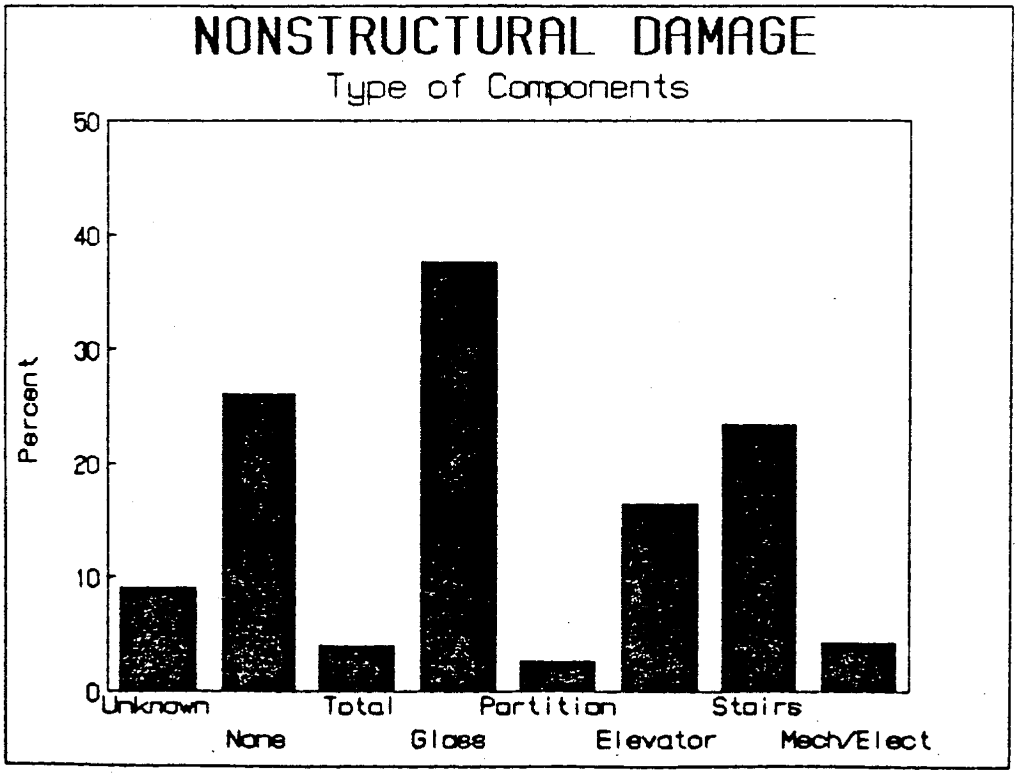
5. The larger glass panels tended to experience the more serious glass damage.

6. Vertical glass shapes tended to receive the highest amounts of serious glass damage.

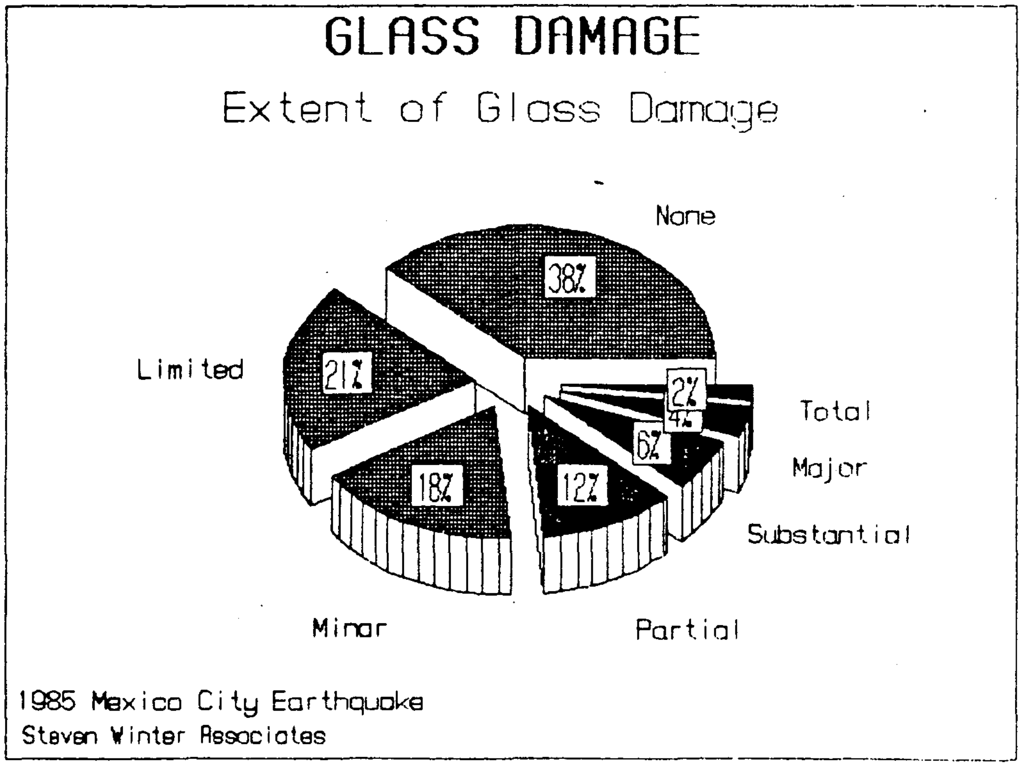
7. Glass panes with long sides tended to receive a higher shape of serious glass damage.

8-9. Metal frame glazing systems tended to receive higher amounts of serious glass damage than the more rigid systems.

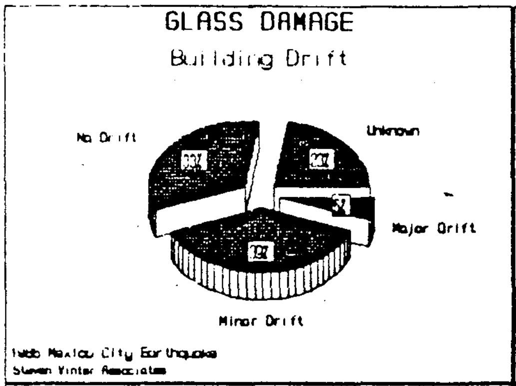
Of all nonstructural components (excluding infill walls) glass was the most likely nonstructural element to receive damage. In 42 percent of the buildings, inspectors recorded glass damage as one of the primary damages of the building. This appears to correspond to the percentage of glass damage recorded above 10 percent. Stairs and elevators were the next most damaged components with 20 percent and 27 percent respectively.



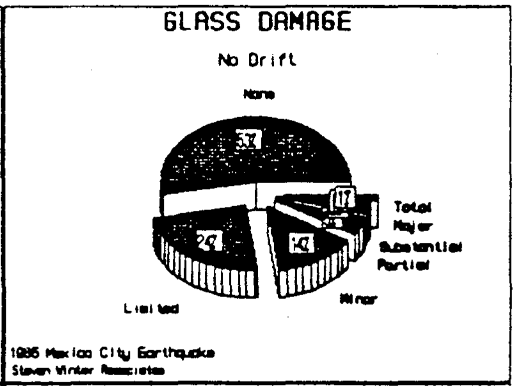
In the data base (buildings with some structural or envelope damage), serious glass damage (above 25 percent) was recorded in 24 percent of the buildings. Glass damage in general (over 10 percent), was reported in 42 percent of the cases. Any glass damage (including all glass damage above 1 percent) was recorded in 63 percent of the buildings.



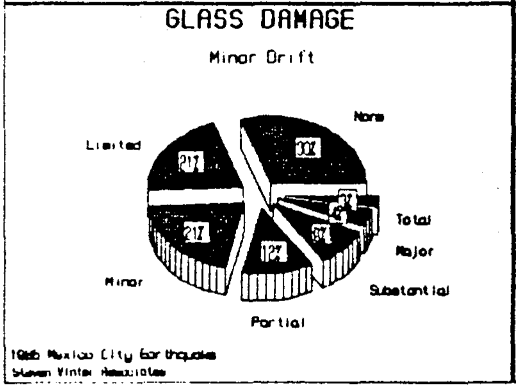
Serious glass damage (above 25 percent) appears to be closely associated with the amount of total drift or displacement the building experienced. In the data base, 23 percent of the buildings had no information on building drift, 33 percent appeared to have no drift or displacement, 39 percent had some degree of minor drift or displacement, and 5 percent appeared to receive major amount of drift or displacement. Of the building receiving no drift only 9 percent received serious glass damage, while with those buildings receiving minor drift 28 percent were recorded with serious glass damage, and of those buildings with major drift a very high 43 percent received serious glass damage.


GLASS DAMAGE
Building Drift

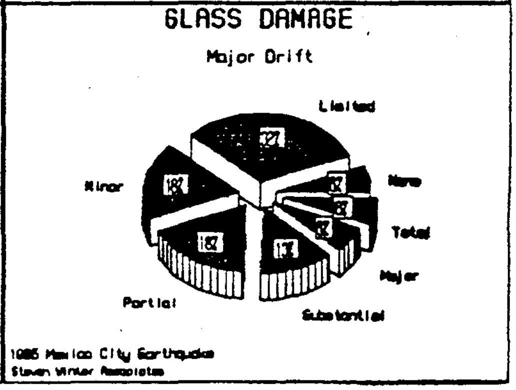
1986 Mexico City Earthquake
Steven Winter Associates


GLASS DAMAGE
No Drift

1986 Mexico City Earthquake
Steven Winter Associates


GLASS DAMAGE
Minor Drift

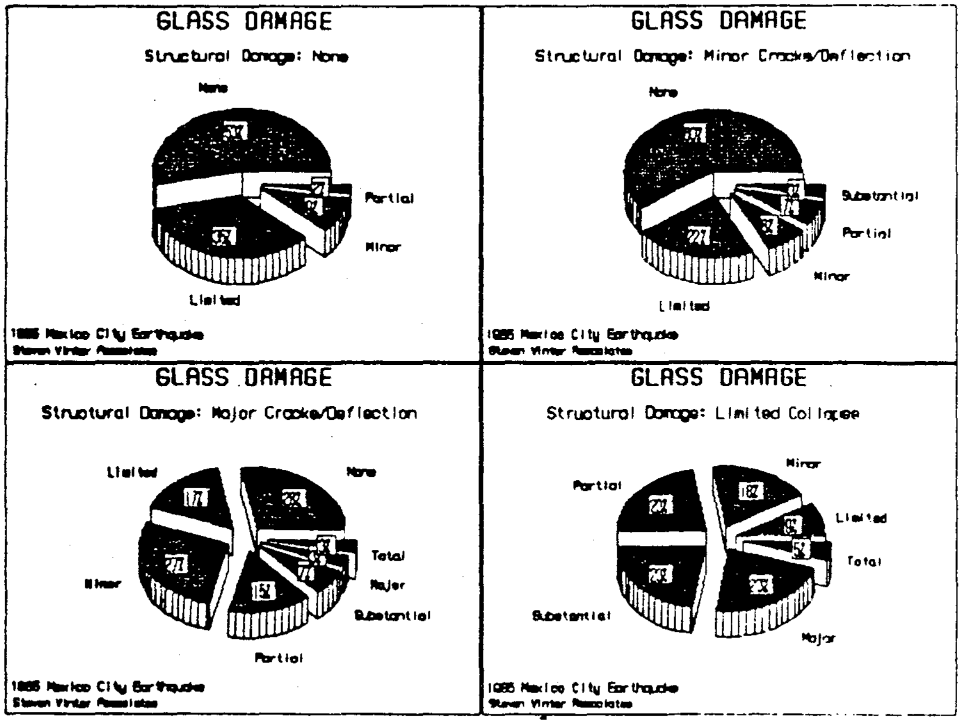
1986 Mexico City Earthquake
Steven Winter Associates


GLASS DAMAGE
Major Drift

1986 Mexico City Earthquake
Steven Winter Associates

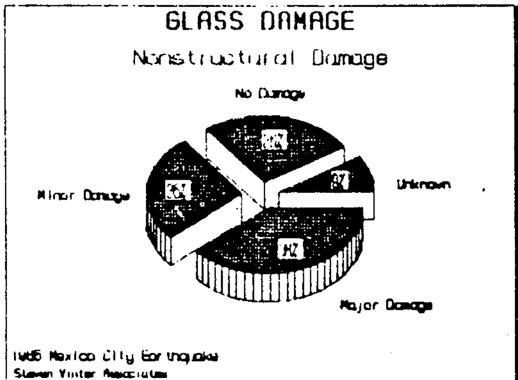
Buildings which experienced large drifts or displacements tended to experience higher levels of serious glass damage.

The seriousness of glass damage appears to be closely associated with the severity of structural damage caused in the building. Of those buildings with no structural damage only 2 percent reported serious glass damage, of those reporting minor cracks and deflections 10 percent recorded serious glass damage, of those buildings with major cracks and deflections a larger 28 percent recorded serious glass damage, and of those buildings with limited collapses a very high 74 percent reported serious glass damage.



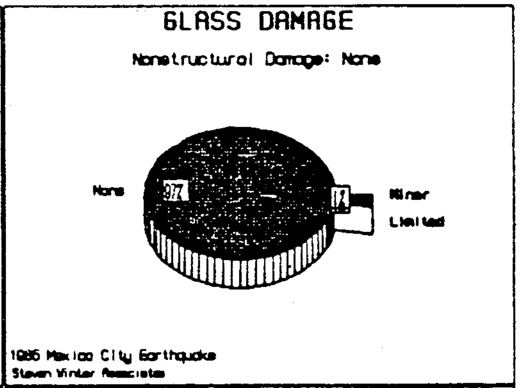
Buildings which experienced larger amounts of structural or envelope damage tended to experience higher levels of serious glass damage.

A similar relationship appears to exist between serious glass damage and the extent of nonstructural damage. In the data base, 26 percent of the buildings reported no nonstructural damage, 26 percent reported minor nonstructural damage, 38 percent reported major nonstructural damage, while in the remaining 9 percent the extent of nonstructural damage was unknown. Of the buildings reporting no nonstructural damage no serious glass damage was reported. In those buildings reporting minor nonstructural damage only 6 percent also reported serious glass damage, while in those buildings reporting major nonstructural damage 46 percent also reported serious glass damage.


GLASS DAMAGE

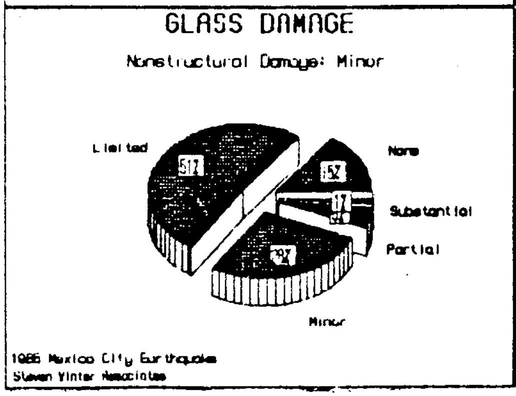
Nonstructural Damage

1985 Mexico City Earthquake
Steven Winter Associates


GLASS DAMAGE

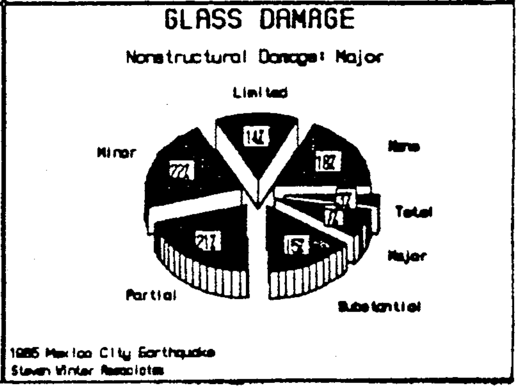
Nonstructural Damage: None

1985 Mexico City Earthquake
Steven Winter Associates


GLASS DAMAGE

Nonstructural Damage: Minor

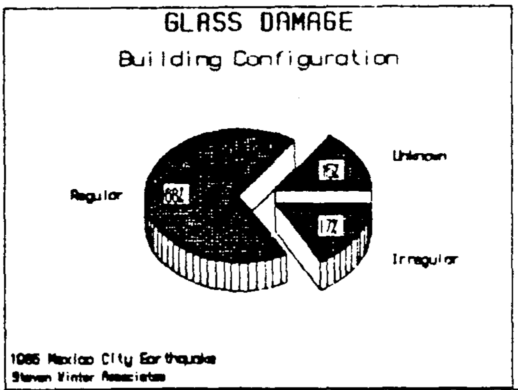
1985 Mexico City Earthquake
Steven Winter Associates


GLASS DAMAGE

Nonstructural Damage: Major

1985 Mexico City Earthquake
Steven Winter Associates

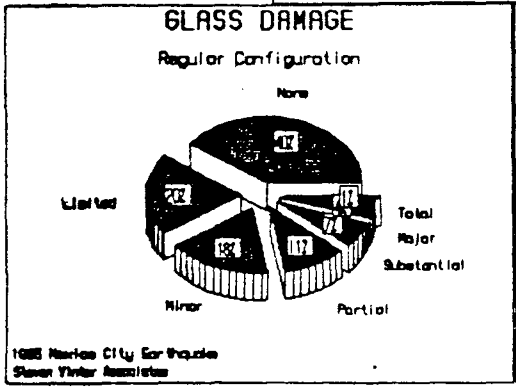
Serious glass damage appears to be associated with the complexity of the building configuration. In the data base, 15 percent had unknown configurations, while 68 percent were considered having regular shapes, and 17 percent were considered irregular. Of the regular buildings 23 percent had serious glass damage, while 36 percent of the irregular buildings had serious glass damage.



GLASS DAMAGE

Building Configuration

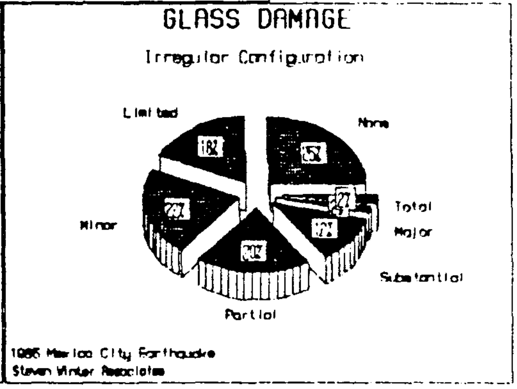
1985 Mexico City Earthquake
Steven Winter Associates



GLASS DAMAGE

Regular Configuration

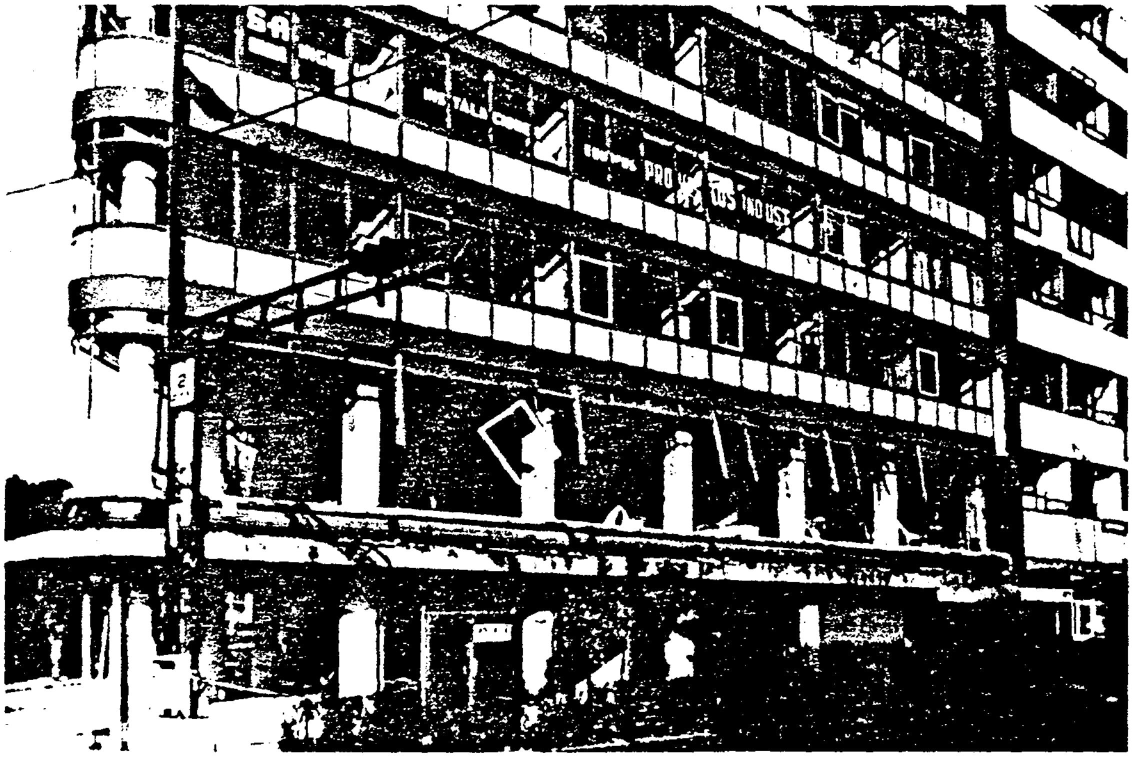
1985 Mexico City Earthquake
Steven Winter Associates



GLASS DAMAGE

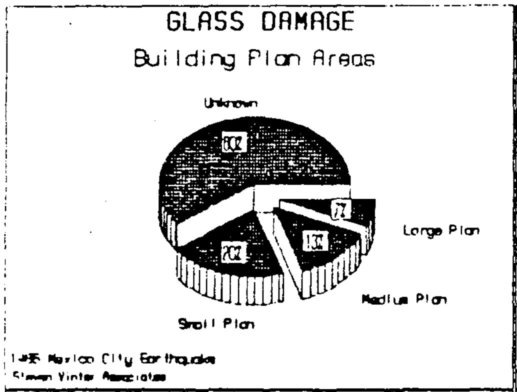
Irregular Configuration

1985 Mexico City Earthquake
Steven Winter Associates



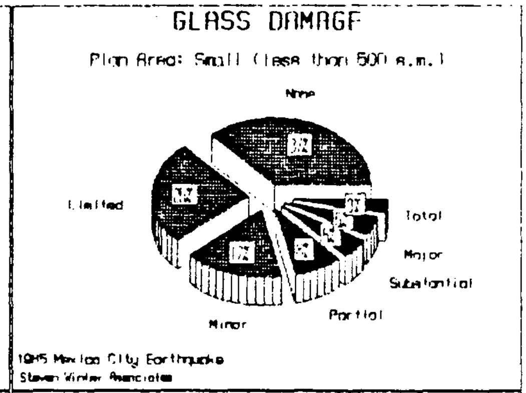
Those buildings with irregular configurations experienced higher amounts of serious glass damage.

There is apparently no relationship between serious glass damage and the size of the overall plan of the buildings. Although only 40 percent of the data base had plan dimensions, small plans (less than 500 square meters), medium plans (500-1500 square meters), and large plans (over 1500 square meters) had 21 percent, 28 percent, and 26 percent serious glass damage respectively.


GLASS DAMAGE

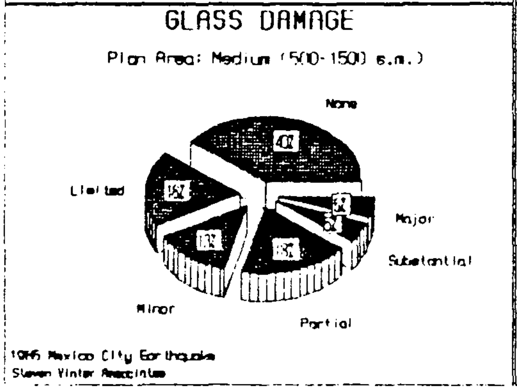
Building Plan Areas

1985 Mexico City Earthquake
Steven Winter Associates


GLASS DAMAGE

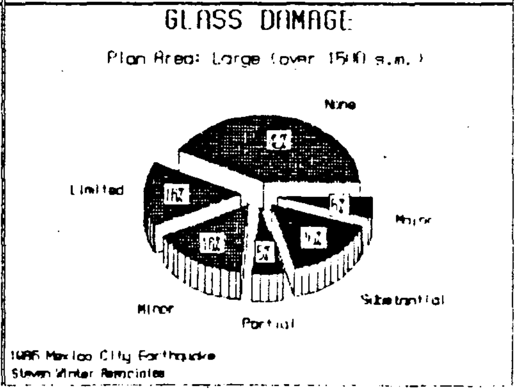
Plan Area: Small (less than 500 s.m.)

1985 Mexico City Earthquake
Steven Winter Associates


GLASS DAMAGE

Plan Area: Medium (500-1500 s.m.)

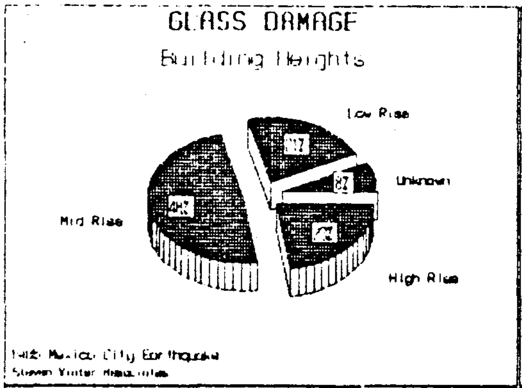
1985 Mexico City Earthquake
Steven Winter Associates


GLASS DAMAGE

Plan Area: Large (over 1500 s.m.)

1985 Mexico City Earthquake
Steven Winter Associates

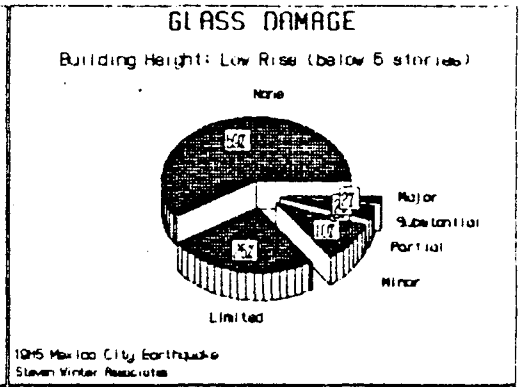
Because the period of the earthquake coincided with the natural period of midrise buildings (approximately 10 stories), most of the damage occurred in these buildings during the Mexico City Earthquake. This data base included 21 percent low rise, 48 percent mid rise, 23 percent high rise, and 8 percent unknown. The analysis confirms that for mid rise height buildings (5-12 stories) 30 percent reported serious glass damage. Lower rise buildings (below 5 stories) reported serious glass damage in only 6 percent of the cases, while for high rise buildings (over 12 stories) the reported incidents of serious glass damage was only 17 percent.



GLASS DAMAGE

Building Heights

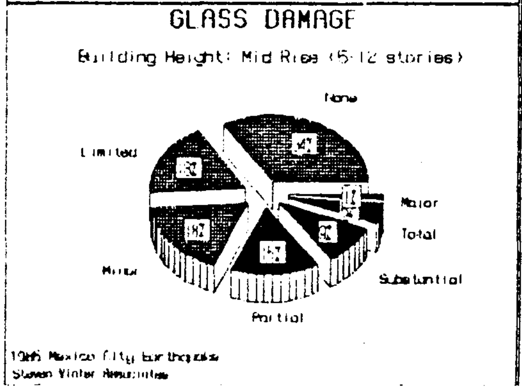
1985 Mexico City Earthquake
Steven Winter Associates



GLASS DAMAGE

Building Height: Low Rise (below 5 stories)

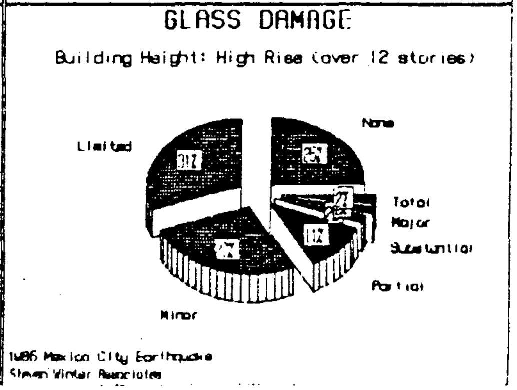
1985 Mexico City Earthquake
Steven Winter Associates



GLASS DAMAGE

Building Height: Mid Rise (5-12 stories)

1985 Mexico City Earthquake
Steven Winter Associates

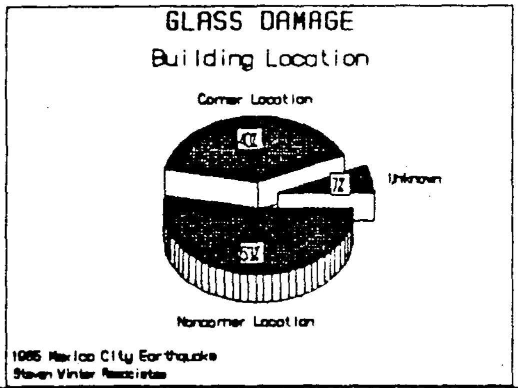


GLASS DAMAGE

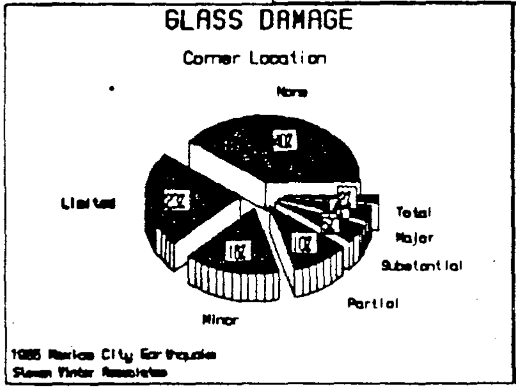
Building Height: High Rise (over 12 stories)

1986 Mexico City Earthquake
Steven Winter Associates

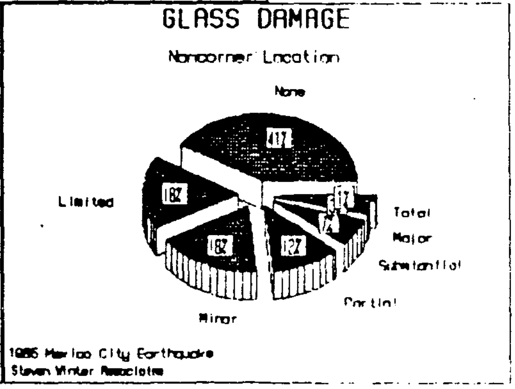
There appears to be no relationship between whether the building was a corner building (adjacent sides confined) or a noncorner building (opposite sides confined) and the extent of serious glass damage. Buildings with a corner location reported serious glass damage in 21 percent of the cases, while those buildings with a noncorner location reported serious glass damage 23 percent of the time.



1985 Mexico City Earthquake
Steven Winter Associates

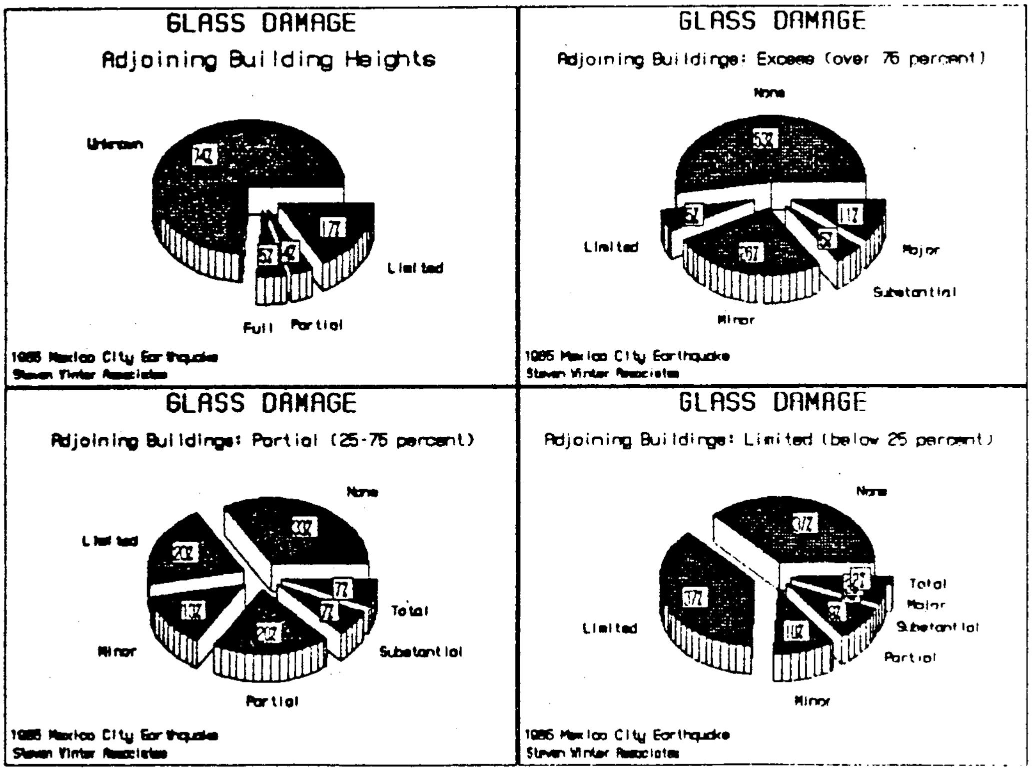


1985 Mexico City Earthquake
Steven Winter Associates



1985 Mexico City Earthquake
Steven Winter Associates

There does appear to be a strong relationship between serious glass damage and the existence and height of adjoining buildings. Of those buildings with adjoining buildings of partial height (25-75 percent of the damaged building) 34 percent experienced serious glass damage. This is in contrast to those buildings with adjoining buildings of excess heights (over 75 percent of the damaged building) which reported serious glass damage in only 16 percent of the cases, and those buildings with adjoining buildings of limited heights (below 25 percent of the damaged building) which reported serious glass damage in only 15 percent of the cases.



GLASS DAMAGE

Adjoining Building Heights

1985 Mexico City Earthquake
Steven Winter Associates

GLASS DAMAGE

Adjoining Buildings: Excess (over 75 percent)

1985 Mexico City Earthquake
Steven Winter Associates

GLASS DAMAGE

Adjoining Buildings: Partial (25-75 percent)

1985 Mexico City Earthquake
Steven Winter Associates

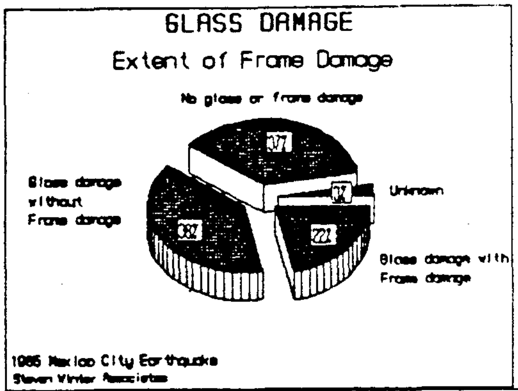
GLASS DAMAGE

Adjoining Buildings: Limited (below 25 percent)

1985 Mexico City Earthquake
Steven Winter Associates

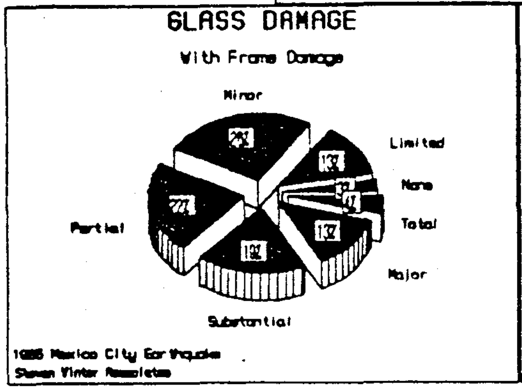
Buildings with partial height adjoining buildings experienced higher amounts of serious glass damage through pounding.

There appears to be a relationship between the design of window frame damage and the amount of glass damage. In the data base, 37 percent of the buildings had no glass or window frame damage, 38 percent recorded some degree of glass damage but no frame damage, while 22 percent recorded some degree of glass and window frame damage. Of those buildings without any window frame damage only 13 percent received serious glass damage, while of those buildings with some degree of window frame damage, a much larger 58 percent recorded serious glass damage.


GLASS DAMAGE

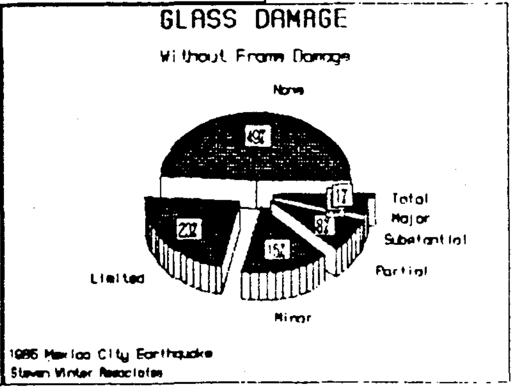
Extent of Frame Damage

1985 Mexico City Earthquake
Steven Winter Associates


GLASS DAMAGE

With Frame Damage

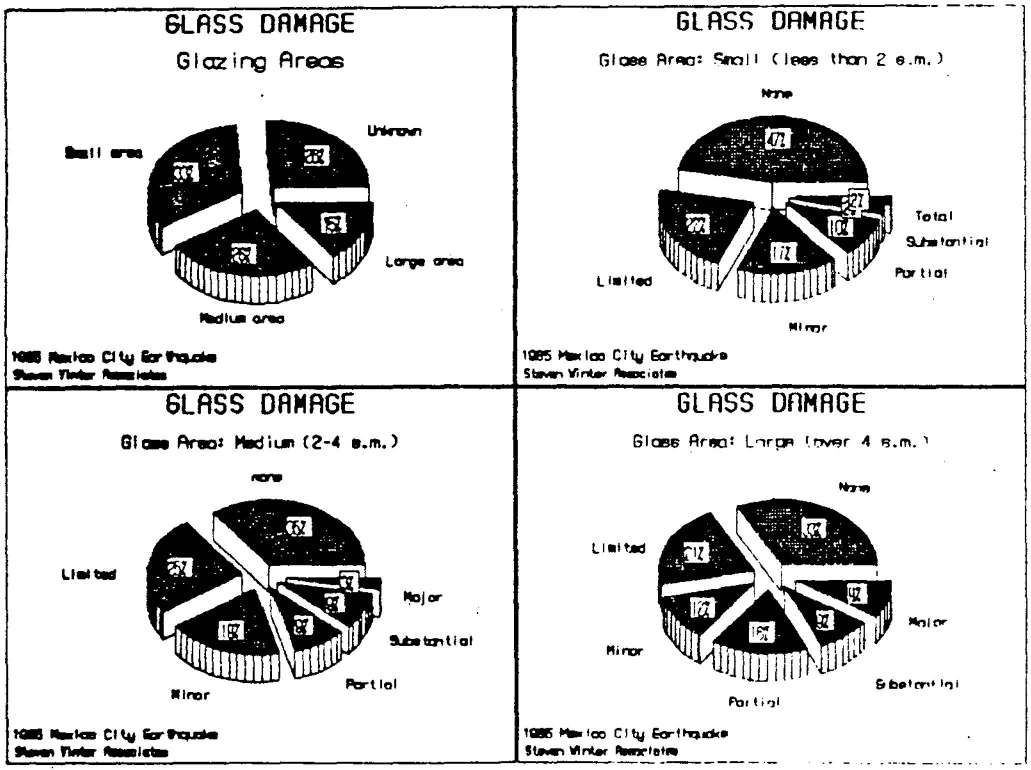
1985 Mexico City Earthquake
Steven Winter Associates


GLASS DAMAGE

Without Frame Damage

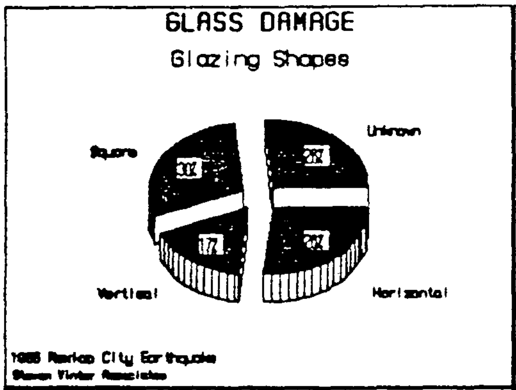
1985 Mexico City Earthquake
Steven Winter Associates

There appears to be a relationship between larger glass areas and serious glass damage. In the data base, 33 percent of the buildings had small windows (less than 2 square meters), 26 percent had medium windows (2-4 square meters), 15 percent had large windows (over 4 square meters), and 26 percent were unknown. Of those buildings with smaller windows only 14 percent experienced serious glass damage, those buildings with medium windows reported a larger 21 percent, while of those buildings with large windows an even larger 34 percent reported serious glass damage.

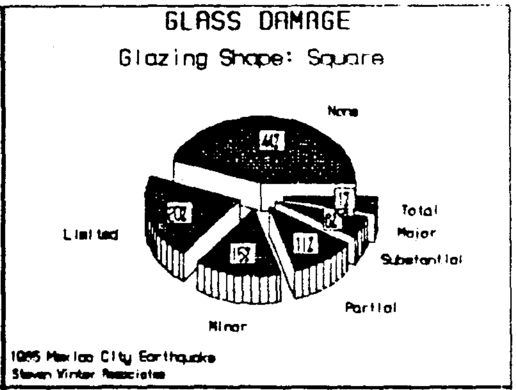


The larger glass panels tended to experience the more serious glass damage.

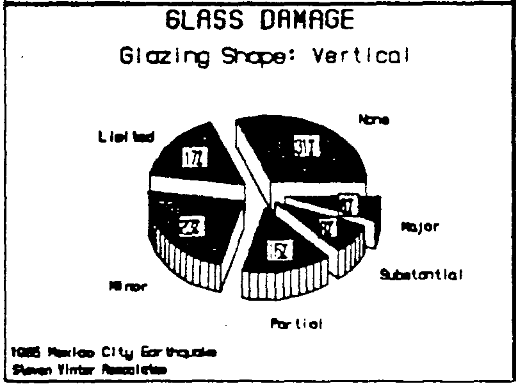
The shape of the window appears to be associated with the extent of glass damage. In the data base, 30 percent of the windows were square, 17 percent were vertical, 26 percent were horizontal, while 26 percent were unknown. Horizontal shaped windows appeared to experience the lowest serious glass damage at 15 percent. Square windows appeared to be the next most successful with serious glass damage in 20 percent of the cases. Vertical window shapes suffered the highest proportion of serious glass damage at 30 percent of the time.


GLASS DAMAGE
Glazing Shapes

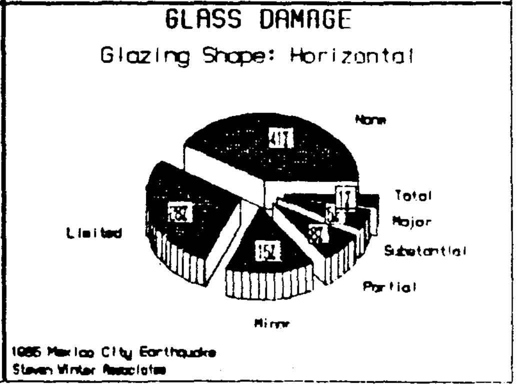
1985 Mexico City Earthquake
Steven Winter Associates


GLASS DAMAGE
Glazing Shape: Square

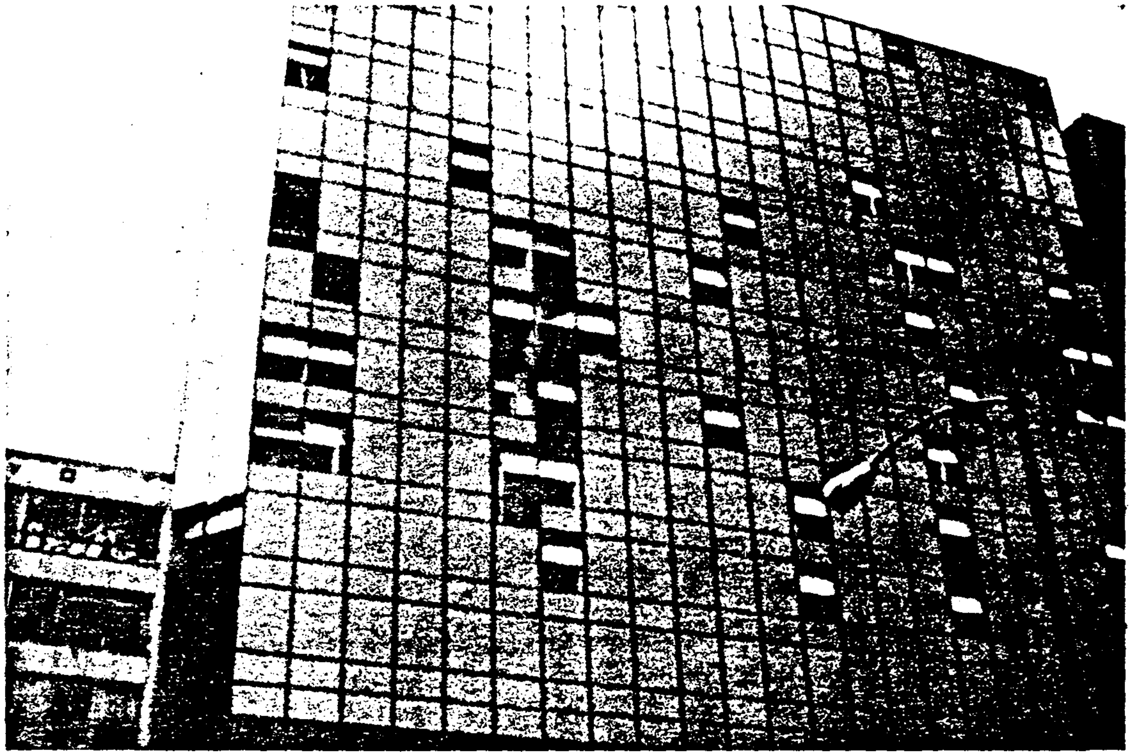
1985 Mexico City Earthquake
Steven Winter Associates


GLASS DAMAGE
Glazing Shape: Vertical

1985 Mexico City Earthquake
Steven Winter Associates

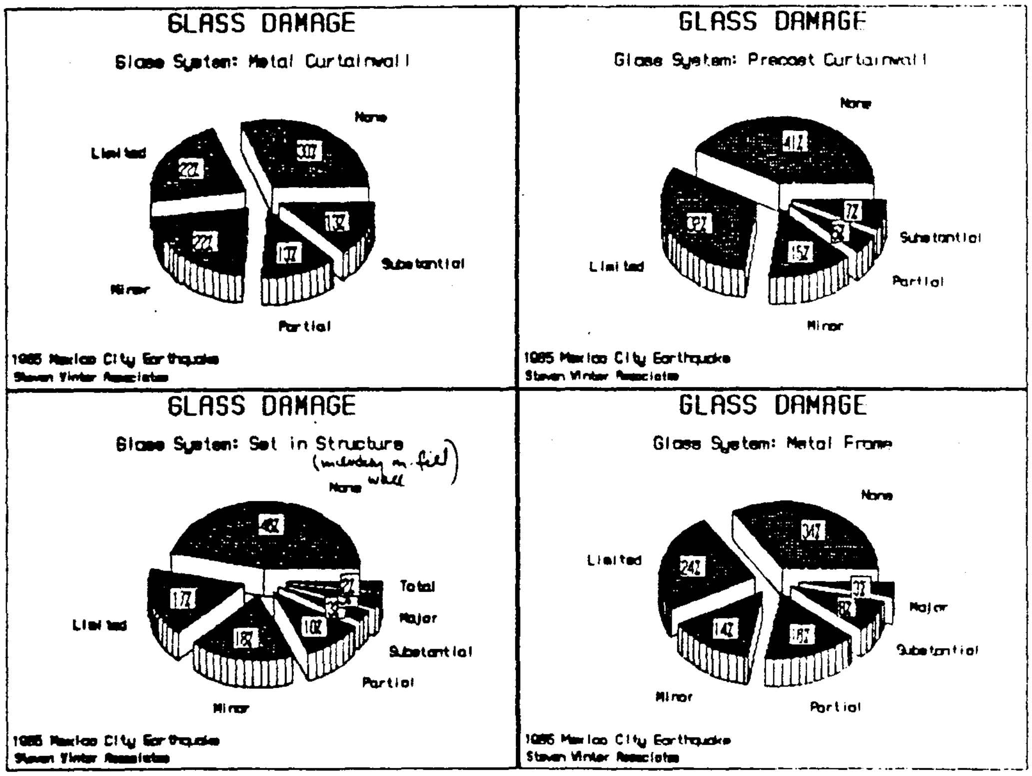

GLASS DAMAGE
Glazing Shape: Horizontal

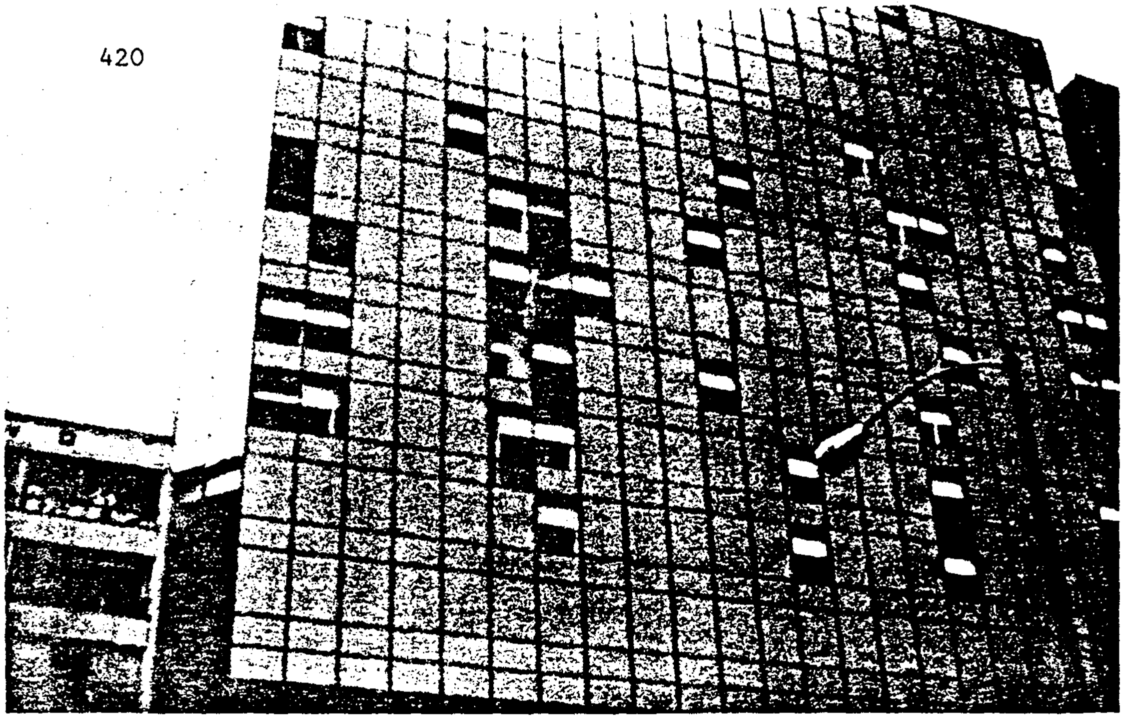
1985 Mexico City Earthquake
Steven Winter Associates



Vertical glass shapes tended to receive the highest amounts of serious glass damage.

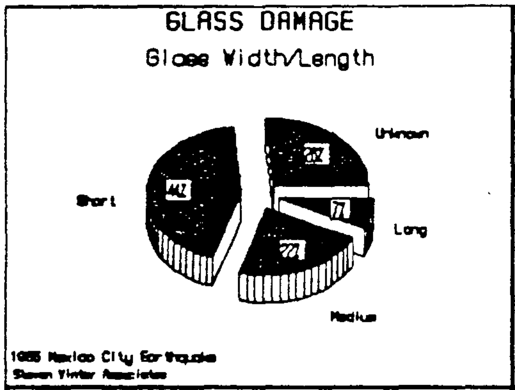
The type of glazing system used (metal curtainwall, metal frame, glass framed directly into the structure, and precast curtainwall/panel systems) appeared to have some association with the amount of serious glass damage. In the data base 8 percent of the buildings had metal curtainwalls, 21 percent had metal frame sytems, 29 percent had windows framed directly into the structure, 14 percent had precast curtainwall or panel systems, and 26 percent were unknown. It appears that metal curtainwall systems and metal frame systems have a higher incidence of serious glass damage (26 and 27 percent respectively). Windows set directly into the structural frame experienced serious glass damage 18 percent of the time, while precast curtainwall or panel systems experienced serious glass damage only 12 percent of the time.

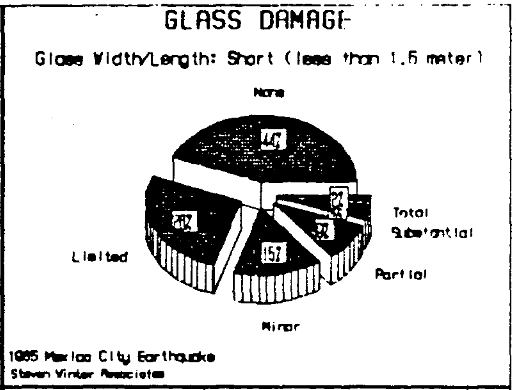


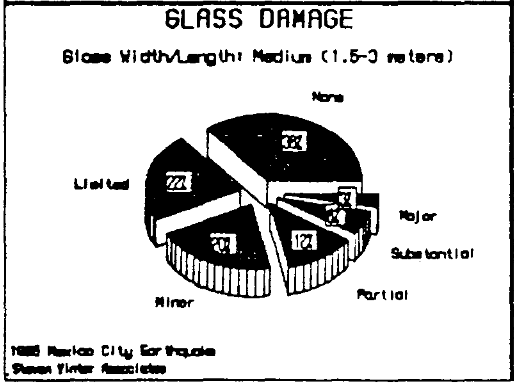


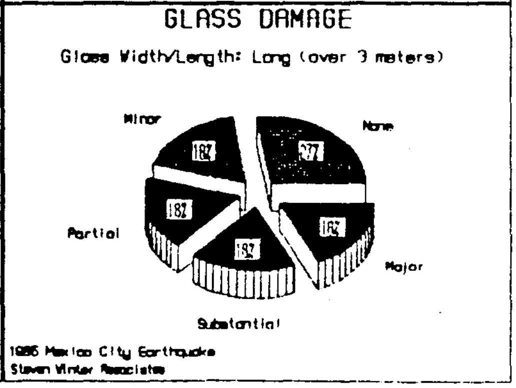
Metal frame glazing systems tended to receive higher amounts of serious glass damage than the more rigid systems.

Individual widths and heights of the window pane also appear to be associated with serious glass damage. Short panes (less than 1.5 meters in either direction) experienced serious glass damage in only 15 percent of the cases, while medium panes (1.5-3 meters in either direction) recorded serious glass damage 21 percent of the time. The longer panes (over 3 meters in either direction) experienced serious glass damage in a much larger 54 percent of the time.

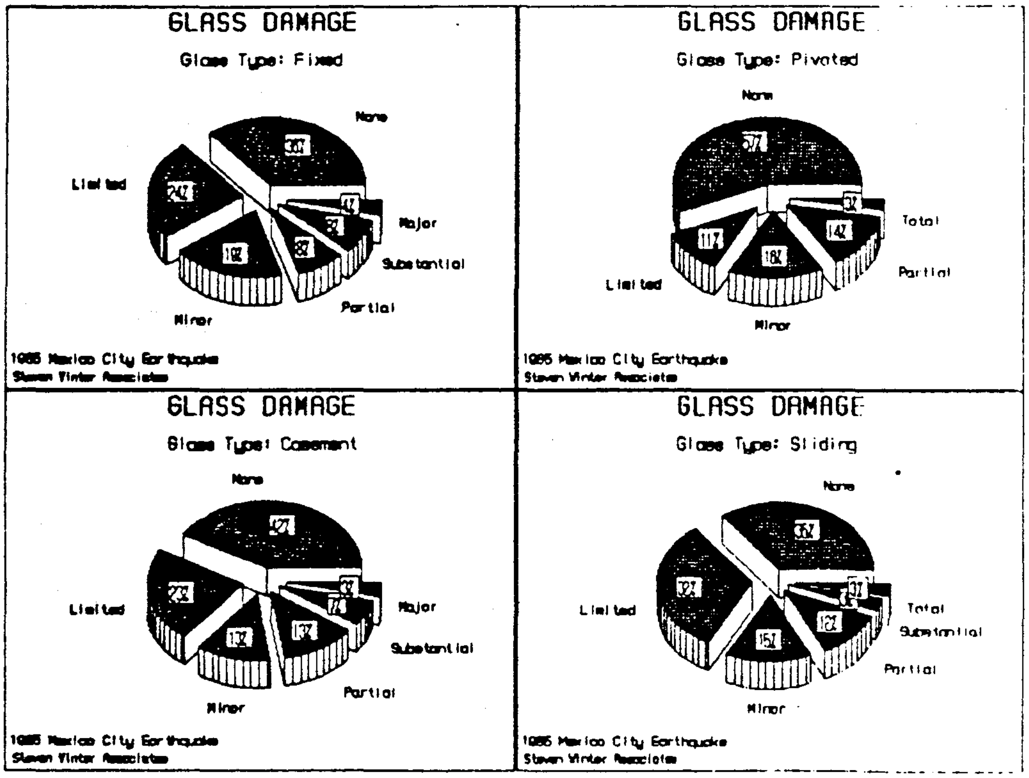




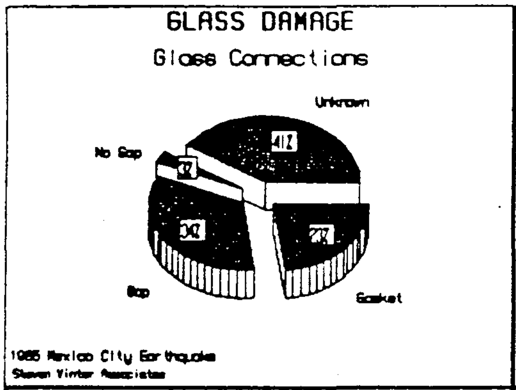




There appears to be no association between the various window operating systems and serious glass damage. Fixed (non-operable) glass systems reported serious glass damage 20 percent of the time, pivoted windows 17 percent of the time, casement windows 23 percent of the time, and sliding windows 18 percent of the time.

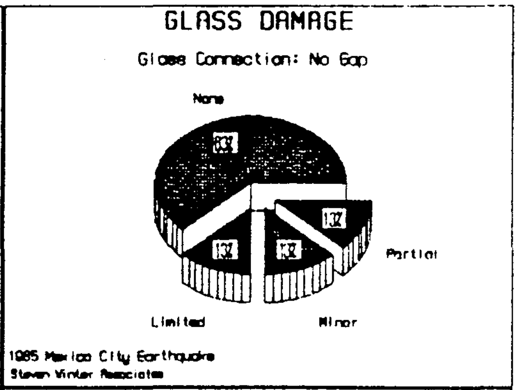


The placement of a resilient gasket between the glass and frame did not appear to be associated to any degree with serious glass damage. In the data base, 23 percent of the windows used gaskets, 34 percent did not use gaskets, while 41 percent were unknown. Those glazing systems with no gaskets experienced serious glass damage only 12 percent of the time, while those systems with gaskets experienced serious glass damage 17 percent of the time.


GLASS DAMAGE

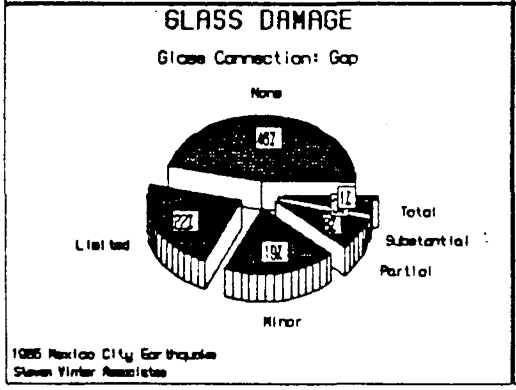
Glass Connections

1985 Mexico City Earthquake
Steven Winter Associates


GLASS DAMAGE

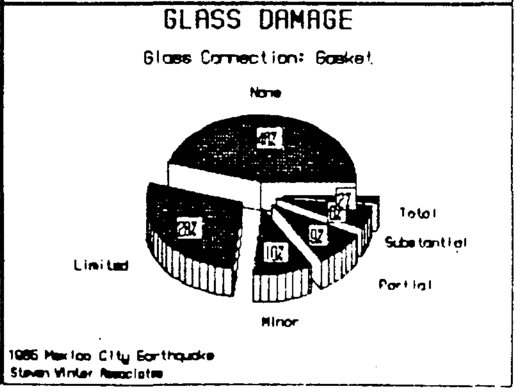
Glass Connection: No Gap

1985 Mexico City Earthquake
Steven Winter Associates


GLASS DAMAGE

Glass Connection: Gap

1985 Mexico City Earthquake
Steven Winter Associates


GLASS DAMAGE

Glass Connection: Gasket

1985 Mexico City Earthquake
Steven Winter Associates