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Paper No. 1065. (quote when citing this article)
Eleventh World Conference on Earthquake Engineering
ISBN: 0 08 042822 3

SOFT FIRST STORIES TREATMENT IN THE MUNICIPAL ORDINANCES OF A HAZARDOUS SECTOR OF CARACAS, VENEZUELA

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ABSTRACT

Caracas, Venezuela's capital city, was last damaged by a moderate magnitude 6.3 earthquake, on July 29, 1967. Since then Caracas has grown considerably in population and in area, being this growth accompanied by the construction of mid- and high-rise condominium type housing and office building complexes, in areas that were severely damaged in the last earthquake. Municipal urban ordinances encourage certain configurations such as "soft first stories", that according to worldwide experience affect considerably the ability of buildings to withstand earthquakes. This paper presents some architectural and structural recommendations to be included in Municipal urban ordinances.

INTRODUCTION

Venezuela is located on the northern-central part of South America, on the edge with the Caribbean Sea. The seismic activity of Venezuela, according to Quijada, P., E. Gajardo, et al. (1993) is considered as moderate to high. The northern part of this country is located at the boundaries of two tectonic plates that slide past each other. The main seismic activity of the country is related to a main fault system constituted by three subsystems: (a) Bocono, from the Andes bounding in the SW - NE direction to the Caribbean; (b) San Sebastian, parallel to, and about 10 kilometers north of the Venezuelan coast, in the E-W direction; and (c) El Pilar, eastwards to Trinidad.

Caracas is located in the northern-central region of the country, at an elevation of approximately 900 m. above sea level. The main economical and financial activities are located in the narrow valley of the Guaire river. The Serrania del Avila is the mountain range between Caracas and the Caribbean coast, with mountains as high as 2765 m. above sea level. Caracas is surrounded by fault zones that belong to the San Sebastian Fault subsystem. This fault system is considered as the origin of the earthquakes that affect the capital city. The seismicity of Caracas has been catalogued in the moderate range. The city, however, has had a series of significant earthquakes in the past, including three very destructive ones (1641, 1812, 1900).

Caracas is one of the oldest cities settled by the Spaniards in the American continent, in 1567; however, during the Colonial period it was a very modest town. Venezuela was not rich in gold or silver, as were other American countries of the Spanish Empire. Its main contribution to the Spanish Crown from the 16th to 18th centuries, were agricultural products such as tobacco, coffee and cocoa. During the 19th century the country was devastated by the Independence war, followed by a long period of federal wars. At the end of last century Caracas was a small provincial capital, surrounded by a rural environment. Caracas rapidly transformed during this century into a modern metropolis, as a result of : (a) the oil-boom on the 30's, that produced a fast economic growth and induced the migration of population, looking for better opportunities and a new way of life; (b) the European immigration after World War I and World War II; (c) the latest oil-boom, during the 70's and the 80's, which induced an increased immigration, mostly from other

Latin-American countries; and (d) from the 30's to the present, the policy of centralization, resulting in a concentration of the main Governmental and financial activities of the country in Caracas, which still attracts people to move in.

Under this pressures Caracas has grown quite rapidly in all directions without effective control. At present, the city is formed by the inner and the outer metropolitan areas. In the first, the urban area is mostly settled within the long, narrow, and more or less flat floored valley; topography limits its horizontal growth; in this area are located most of the financial and commercial activities. The expansion areas, which climb past the gentler slopes of the lower hills at the south, west and east of the city, together with the Litoral Central, constitute the outer metropolitan area. Caracas is at present a modern metropolis, containing a very high proportion of modern structures, but it is surrounded by large areas of slums.

On July 29, 1967, a moderate 6.3 Richter magnitude earthquake occurred in the Caribbean sea, northwest of Caracas. Four mid rise apartment buildings totally collapsed inside the city and many multi-storied buildings and single family houses were severely damaged. Since 1967, Caracas has grown considerably; the construction of very audacious mid- and high-rise condominium type housing and office building complexes in areas that were severely damaged in the 1967 earthquake characterizes this growth.

Municipal urban zonation ordinances regulating the structural and architectural configuration of new buildings have not considered the 1967 Caracas earthquake experience. According to worldwide experience, certain building configurations, such as "soft first-stories," affect considerably the ability of these buildings to withstand earthquakes. Some local ordinances encourage the use of these configurations in very hazardous areas, such as Los Palos Grandes - Altamira. It is very difficult to eliminate this irregular configuration from the architectural design activity; therefore, it is important to provide some recommendations in order to mitigate the undesirable consequences of this particular configuration.

This paper presents information pertaining to the soft first story condition induced by municipal ordinances in certain urban zones, already catalogued by initial seismic microzoning as prone to considerable ground amplifications. A study on soft first-stories reinforced concrete framed structures has been carried out, from the architectural and structural points of view. Architectural and structural recommendations are presented, as an initial step towards a comprehensive risk assessment project for Caracas. Conclusions are based on an overall research done by the authors and on the results of a series of Civil Engineering theses tutored by Prof. Paparoni both at the Universidad Metropolitana and at the Central University of Venezuela. To satisfy the objectives of this study, cooperation was required among engineers, urban planners and architects.

SEISMIC MICROZONING IN CARACAS

The magnitude 6.3 earthquake, on July 29, 1967, was the strongest earthquake that residents of Caracas have experienced in the last 90 years. While that earthquake resulted, officially, in approximately 350 death and 5 mid-rise (10 to 12 stories high) collapsed buildings in Caracas and Litoral Central, observers identified extensive structural damage within very well delimited areas. Experts attributed most of the damage to ground shaking and ground failure. Several authors suggested, at that time, anomalous ground amplifications in these areas (for details, consult related bibliography at the end).

In 1969 a geophysical study carried out by the Weston Geophysical Engineers International, Inc., produced a map of "Depth to bedrock in the Caracas Valley." In 1970, the Direccion de Cartografia Nacional, of the Ministerio de Obras Públicas, MOP (Ministry of Public Works), published a map containing the previously mentioned information and the information obtained from the study developed by the Seismograph Service Corp. of Delaware for the Instituto Nacional de Obras Sanitarias, INOS (National Institute for Water Treatment and Service). This study identified deep alluvial soils in the suburbs of: Country Club, Chacao, La Castellana, Bello Campo, La Floresta, La Carlota, Altamira., Los Palos Grandes, Santa Eduvigis, Sebucan y Los Dos Caminos (see Fig. 1).

Four of the collapsed buildings and most of the structurally damaged buildings were located in Los Palos Grandes and Altamira. In 1972, Espinosa, A.F. and Algermissen, S.T, presented an exhaustive report on this subject, entitled "A Study of Soil Amplification Factors in Earthquake Damage Areas, Caracas, Venezuela". In 1975., J.L. Alonso developed an incipient microzoning map for structural design purposes. Until today, this map has been considered mostly for academic purposes but not for land use or city planning.

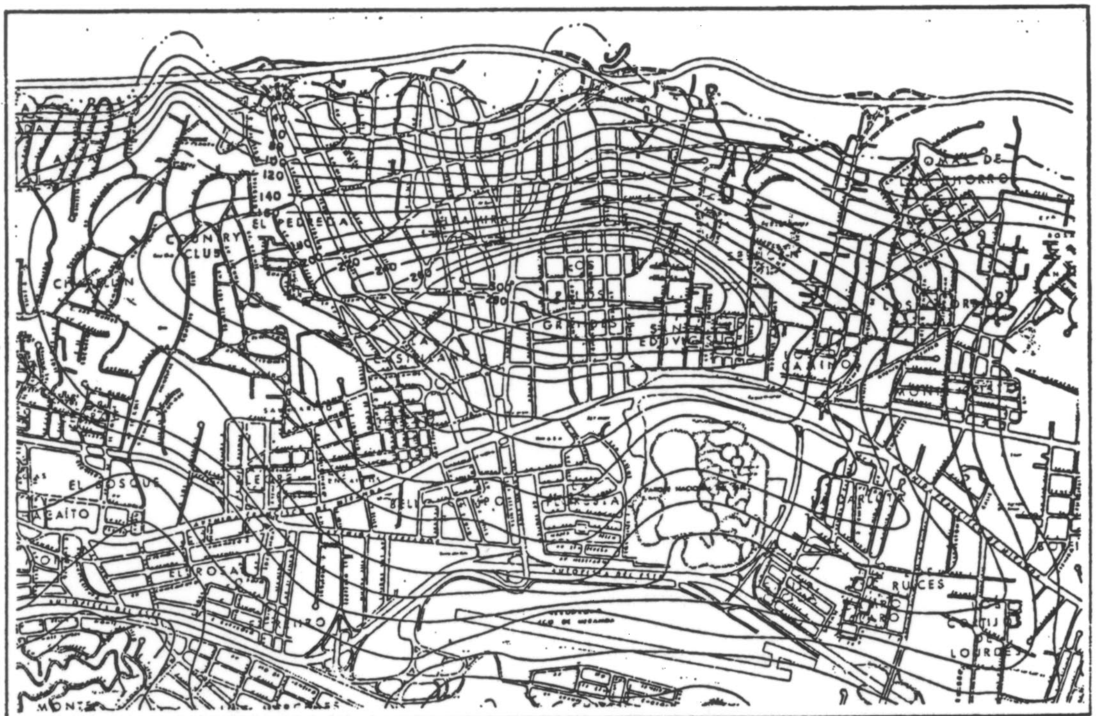

Fig. 1: Section from the Map of "Depth to Bedrock, Caracas Valley" published by Direccion de Cartografia Nacional (1970), Ministerio de Obras Publicas, MOP. Caracas, Venezuela.

There exists plenty of reliable knowledge related with the dynamic characteristics of the local soils. Local authorities, however, neglect the 1967 Caracas earthquake experience and the new research knowledge.

SOFT STORY

The "soft first story" configuration is present in a building when a significant change of strength and stiffness between the first lower floor and the upper floors exists. When an earthquake occurs, the resultant forces will tend to distribute along the building following uniform and continuous paths.

The earthquake shears increase towards the ground floor, therefore, when a more flexible portion of the building supports other rigid and more massive portions, the bulk of the energy will concentrate in the lower more flexible story while the small remainder will be distributed amongst the rigid upper stories. This zone of weakness in the path of force transmission at ground level may create a critical situation during an earthquake; the stiffness discontinuity between the first and the second stories might cause significant structural damage, or even the total collapse of the building.

In Venezuela when architects design mid- and high-rise framed buildings with the usual hollow masonry block walls, they do initial sketches establishing the main structural elements with their tentative location and dimensions. These initial sketches are sent to the structural engineer for doing the refined structural design and analysis. At this stage, the architect generally has not yet defined the location and characteristics of walls, assuming that these do not affect the structure. But the engineer does calculations assuming that in all the frames, the first and the upper floors, will have walls with the same characteristics. Therefore, the resulting design situation is a mutual missassumption. The soft first story configuration is widely used by architects in the whole world, specially stimulated by Modern Architecture..

It has been widely recognized by the specialists that when frames with an open first story are designed, ignoring that the upper stories have been stiffened by "non-intentionally-structural" walls, they can suffer severe structural damage and even cause the collapse of buildings when a earthquake occurs. The soft first story problem might also occur when shear walls are located only in the upper stories and they are not brought down to the foundations, but interrupted at the second floor. This design feature is typical of apartment buildings, hospitals and hotels. The areas at the first story are mostly used for social events, parking, and other activities that require free open spaces. Some examples of the dramatic collapse of buildings which had a soft first story, are: (a) Olive View Hospital (San Fernando, California, USA, 1971); (b) the Imperial County Services Building (El Centro, California, USA, 1979); and, (c) the east wing of

Palace Corvin apartment building (Caracas, Venezuela, 1967). The Caracas 1967 earthquake studies show a significant number of examples of structural damages in buildings with the soft first story pattern.

URBAN ZONING MUNICIPAL ORDINANCES

Caracas is administered by a "Gobernador" or mayor who is appointed by the President, but he metropolitan area is constituted by 14 Municipalities or administrative districts. Each one with an "Alcalde" or district manager, elected by each community. The main task of the alcaldes is to administer each municipality. Each of these municipalities has an Office of Municipal Engineering, responsible for the construction and maintenance of public works, for issuing construction and occupation permits and for controlling the enforcement of codes and regulations.

The Local Office of Urban Planning is responsible for developing plans and policies for the municipal district. The legal municipal instrument is the Municipal Ordinance and each municipality has its own ordinances. The inner Metropolitan area was, until 1989, constituted by 2 districts: Libertador (Distrito Federal, main federal entity) and Sucre (Estado Miranda). In 1989, with the enforcement of the new Law of Municipal Regime, the Legislative Assembly of the Estate of Miranda dissolved the Distrito Sucre and transformed it into two municipalities: Sucre and Baruta. The first one constituted by Chacao, Petare and Leoncio MartInez. In 1991, Chacao became an autonomous municipality. The most seismically hazardous areas of Caracas are Chacao and Leoncio MartInez, where the depth to bedrock are the largest in the city. The old urban zonation ordinance of the Distrito Sucre still regulates these areas, ignoring their deep alluvial deposits.

There are several questionable features within the text of this ordinance, which neglect the importance of seismic microzoning. As an example we have that the height of a buildingin Los Palos Grandes and Altamira, is regulated only by the width of the street on which it is located. The soil amplification factor and the resonance effect, are ignored. Regarding soft first stories, the zonation ordinances enforced in Caracas stimulate the use of soft first story configurations. The areas enclosed by these soft first stories are not computable for habitability and area limitations, neither for tax control, but they can be computable for selling purposes. The articles in the Urban Zonation Ordinance of the Distrito Sucre, Estado Miranda, that promote the use of soft first stories are: (a) Article 41(d), for 3-4 story department buildings; (b) Articles 95 and 247, for parking areas in mid- rise department buildings.

CONCLUSIONS

When the July 29, 1967, Caracas earthquake occurred, the structural damage was concentrated in very well delimited areas. The four mid-rise buildings that collapsed in Caracas were located on Altamira and Los Palos Grandes. A significant number of studies done after the earthquake, recognized in these areas the correlation between the pattern of structural damage, the depth to bedrock and the amplification of seismic waves. The map of "Depth to Bedrock" done by Weston Geophysical Engineers International, Inc. (1969), also identifies similar depths to bedrock in other neighboring suburbs such as Chacao, La Castellana, Bello Campo, La Floresta, Santa Eduvigis, Sebucan. When the earthquake occurred, mid-rise buildings were concentrated mostly in the southern parts of Altamira and Los Palos Grandes, while the other areas mainly had 1 or 2-story houses. From the time of the 1967 earthquake until the beginning of the 90's, these suburbs presented a very low rate of growth, so very few buildings were built. At present, however, this zone is going through a process of urban redevelopment with many new mid- and high-rise condominium type housing and office building complexes. It is imperative for the local authorities that regulate and control the land use and the structural and architectural rules for new buildings, to include in the new urban Zonation ordinances special considerations to reduce seismic risk in these zones.

The soft first story is an architectural design feature that cannot be eliminated from the architects design repertory, because It brings with it a series of functional and aesthetic advantages. In the case of Caracas, urban Zonation ordinances encourage economically the use of this configuration scheme; therefore, almost all new buildings will be built with this configuration . But, it has been recognized by worldwide specialists that a soft first story, when not treated in a special way, can produce severe structural damage and even the collapse of buildings when an earthquake occurs. Therefore, it is necessary to include in urban Zonation ordinances, recommendations for designers aimed at reducing the vulnerability of buildings in the already identified seismically hazardous zones . "Prescriptive," instead of "restrictive," recommendations should be considered in urban regulations for those areas of Caracas where local soils represent a seismic hazard.

A series of Civil Engineering theses tutored by M. Paparoni both at the Universidad Metropolitana (UniMet) and at the Central University of Venezuela (UCV) with a reasonable number of frame structures with variable location of soft stories (bottom, intermediate and top floors), were studied. See bibliography at the end. The following conclusions were reached:
When the "soft first story" irregularity is present, two-situations arise: (a) total absence of walls in the first story, because they were interrupted at the second story, with no drastic changes in framing schemes; (b) a consequence of Modern and Post-Modern Architecture, which many times impose the partial or total destruction of connectivities at the lower stories (some beams and/or columns are suppressed) .

The first situation can be dealt with: (1) using strong and stiff complete elevator and staircase cores, which can take all but the total base shear, leaving the first story columns almost only with axial loads; (2) by using diagonals to stiffen the first story; (3) by specifically designing the first story for much larger loads and smaller induced displacements than the rest of the structure, keeping the overall framed character of the building; (4) by making "transitions" where the "softness" is distributed in several stories (this procedure is very delicate and needs careful tuning).

The second situation, related but not equal to the former, arises when the architect wants to modify the façade frames only, be it with higher apparent story heights, be it by suppressing connectivities only at the façades but leaving the inside frames untouched. In this case the situation can be tolerated, if the inner frames are complete, regular and sufficiently strong to dampen the local peaks created by the introduced framing irregularities (the regular frames must constitute at least a 60% proportion of the total amount of framing.)

In a totally framed structure, if we keep the value of the following parameter k as constant as possible between successive floors, by careful member proportionings, the effects of the irregularities will be minimized: (k=Total sum of sectional Rigidities of all the columns/Total sum of Floor Shear Rigidity)

Solutions based on the use of diagonal members in the soft first stories are also feasible.

All the foregoing assertions can be considered as reliable under the condition of having very weak walls in the upper stories, that is, that walls will not increase sensibly the rigidity of the structural subsystems. When we go to solid brick walls, or rigid walls, most of these rules cease to be valid.

One influence which in many instances tends to be ignored is the large increase of the member forces in the first stories of buildings due to torsional effects. Besides the dynamic influences, the simple fact that most of the first stories of buildings are designed as if they had built-in columns and theoretically rigid foundations gives rise to very high concentrations of design forces there. In the case of seismic torsion, we have the additional effect of warping, due to the particular nature of most of the framing schemes in current use. When we add to that the sudden change in rigidities caused by the disappearance of relatively rigid claddings over the soft story level, then large force concentrations appear, which can be attributed especially to the torsional effects.

These comments, based on some of the results of our studies (UCV, UniMet), want to call the attention that there are in this case two undesirable effects which add together at the same place (Mutilations+Torsion), making the soft story case even more difficult to treat. Especially prone to these effects are the increasingly frequent framing schemes using mutually disconnected façade frames or façades which are drastically altered in the bottom stories for architectural purposes.

Perhaps the only practical advice that can be offered here is the necessary complementation of these façade frames with internal frames of sufficient strength and rigidity. We can also recommend the use of true space frames as structural schemes to determine member forces. Many commercial computer programs still use plane frames which are treated as independent from each other. This situation generally gives rise to very high axial loads for corner columns which are not necessarily true. It is not our intention to go into too much detail in this area, we simply want to point out that any imposition of the soft story schemes in building ordinances is in itself an invitation to trouble, if it is not accompanied by very explicit recommendations on the actions to be taken at the project level.

The available information on the location of seismically hazardous areas gives reliable justification in order to request the Caracas Local Authorities concerned to incorporate in their Zonation Ordinances, as soon as possible, "prescriptive" recommendations on the design and analysis of buildings which present any of the soft first story configurations.

At present, there is sufficient reliable knowledge and available data allowing local authorities to initiate in Caracas a "Seismic Risk Assessment Project", based on a "Grade 1 Zonation" (according to The Technical Committee for Earthquake Geotechnical Engineering, TC4, of the International Society for Soil Mechanics and Foundation Engineering,. 1993) in order to reduce seismic risk.

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