THE CARACAS EARTHQUAKE
OF JULY 29, 1967

By

VENEZUELAN OFFICIAL SEISMIC COMMISSION

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SUMMARY

This work is a general approach to the seism action in the North Central Region of Venezuela, seat of the country's capital and its most important population center.

The characteristics and effects of the more severe earthquakes causing destruction subsequent to 1641, are herein summarized.

The Valley of Caracas and the Central Coastal Region, divided by the Avila Range, are described under the heading Physiography of the Valley of Caracas. An explanation is given of the formation process of the alluvial layers or beds covering a good part of the bed rock.

Based on available geologic information, a description is given, by order of discovery, of the principal faults crossing areas on the main land and in the sea.

The characteristics of the most recent earthquake - July 29, 1967 - are presented as estimated and computed by "Observatorio Cagigal", on the basis of data furnished by several seismographic stations in neighboring countries. The earthquake, considered of moderate intensity, is especially important because it destroyed or damaged a good number of modern buildings. It is believed that subsoil conditions in given areas played an important role in adding to the destructive power of the earthquake.

An analysis is made of design and layout of the structural units most commonly used in the country.

Included is a summary of the general concepts about the legal effects and the application of aeseismic Codes in Venezuela as of 1939.

A summary is given of the studies made by the Commission in connection with the buildings razed by the earthquake, with an explanation of the general characteristics of those buildings, the procedures for structural analysis and the interpretations of the Codes.

Included also are some results of the investigations made in the rubble and of the examination and testing of samples of structural members.

In connection with damaged buildings, a description is given of the characteristic types of failure observed in the structures and of the influence of partitions.

Based on studies made so far, some hypotheses and conclusions are advanced about possible causes of building collapse or damage.

Reference is made to the outstanding points contemplated in the Interim Code issued after the earthquake by the Commission on Standards of the Ministry of Public Works.

Finally, a summary is given of the studies and investigations scheduled by the Presidential Commission for Studying the Earthquake of July 29, 1967.

THE CARACAS EARTHQUAKE OF JULY 29, 1967.

1) Historic Introduction

The importance that seismic studies has for Venezuela is evidenced by the fact that a good part of the country has been affected more or less severely by earthquakes, and may be subject to further seismic action.

Earthquakes in Venezuela have been reported since colonnial times, and recorded for the first time in 1530.

The following list shows the seism that have caused destruction (except in 1915) in Caracas: (5) (6)

Year	Richter Scale	Coordinates of Epicenter Longitude	Latitude	Intensity at epicenter M.C.S.	Approx.dist. from Caracas Km.
1641	6.0	66°.7 W	10°.9 N	7.5	50
1812	7.1	66°.9 W	10°.8 N	9.0	25
1837	5.6	66°.6 W	10°.3 N	7.0	45
1878	6.1	66°.9 W	10°.2 N	7.5-8.0	35
1900	6.3	66°.8 W	10°.9 N	8.0	50
1915	5.1	66°.8 W	10°.9 N	6.0	50
1967	6.3	67°.25 W	11°.0 N	8.0	60

The approximated focal depths lies between 6 and 28 Km..

On the basis of the foregoing information and publications of the Caracas Seismologic Observatory (1) (8), the attached map (N° 1) was prepared and it shows that three of the epicenters are in the sea, spaced relatively close to each other.

The one for 1812 is north of La Guaira, in the fault zone near the coast; two other epicenters are in the mainland, in a east-west fault zone; and finally, the epicenter of the 1967 earthquake, is located in the sea, the same region that gave rise to the earthquakes of 1641 and 1900.

The history of the earthquakes causing destruction in Caracas, shows the following:

The 1641 earthquake ruined several houses and churches in the city. The one of 1812, considered the most severe in the city's history destroyed completely all houses in the northern districts, and La Trinidad and Altagracia churches whose high towers were distinguishing land marks. About ten thousand people out of a population of 50.000 where killed (7). A severe earthquake struck the city in 1837, but no damage of consequence was reported.

Another severe shock was felt in 1878 cracking the walls of several houses. The earthquake of 1900 cracked walls and levelled to the ground some houses; considerable damage was caused in the nearby towns of Macuto, Guarenas and Guatire. Some 250 aftershocks were felt in Caracas during the following three years.

The most destructive earthquakes felt in Caracas heretofore, reaching an intensity of 6 or more, have had their epicenters located in the sea, approximately between longitudes67°25' W - 66 8' N - 11°0'N. The four earthquakes so identified - 1641, 1812, 1900 and 1967 - ocurred at intervals of 71, 88 and 67 years, respectively, with an average of 75 years.

The region to the south, source of the epicenters of the 1837 and 1878 earthquakes, seems to have become stabilized, as their effects were less intense in the Capital.

Many microseims have been originated in the faults near Caracas, but none of them has reached an intensity of 5.0.

The attached map (N° 2) shows the intensity curves for the last earthquake that struck Caracas on July 29, 1967.

2) Physiography of the Caracas Valley. (4) (11)

With a population of 1.800.000 inhabitants (Metropolitan Area), Caracas lies in a narrow valley of tectonic origin, 4 Km. at its widest point, extending 25 Km. from east to west. The altitude is 900 m. above sea level. The city is bound on the north by the Avila Range (with some peaks reaching 2650 m.) which separates it from the Caribbean Sea; and on the south by low hills. At its southern end, the valley is crossed from west to east by the Guaire River and its tributaries: the Valle River and two streams known as La Vega and Baruta. Originally, the Guaire must have run more toward the north of the Valley, near to the fault zone at the south of the Avila Range and more or less parallel to it. At the north, several streams run down from the Avila Mountain, forming alluvials cones at the foot of the mountain and gradually intermixing their sediments with those from the Guaire River. Rock outcroppings have closed off the east end, forming a kind of large reservoir that has been filled by the sediments transported by rivers and streams. The Guaire River cuts these outcroppings at Petare in a kind of natural spillway, which at the same time controls the sedimentation in the valley. As shown by the studies being made by the Commission, and other sources of information (8), the sedimentary deposition is very heterogeneous, its texture varying from boulders to fine clay-silt soils, with a prevalence of granular soils of varying densities. The thickness of the deposition varies, showing a depth of 120 m. in some places. These are young sediments and therefore their density is rather low, specially where the coarse material (boulders) prevails at the east of the Valley. However, the borings made so far show a marked change in density in the deposits at depths between 50 to 60 m., where the material consists of alternating sandy and clayey layers. The coarse and fine materials have been transported and deposited in the valley by the rivers and streams running through it.

North of Caracas, across the Avila Range, lies Caraballeda, more or less on the same meridiam. This zone is formed by the alluvial cone of the Caraballeda River (also known as the Quebrada San Julián), and the material deposited in some places is more than 70 m. thick. The materials are predominantly medium to fine sands of varying texture, with interbedded layers of silt and clay. Seepage water is sometimes trapped, as evidenced by artesian wells with piezometric heights of more than 5 m. above ground level. Large boulders, from the steep foothills of the northern part of the Avila, are also found embedded in the sand layer.

3) Geology of the Caracas Valley. (4) (8) (11)

The Avila Range is made up mainly of gneiss and bounded north and south by fault zones. It has been established that this is not a fault block or horst, because the faults to the north differ in character and age from those in the south.

The foundation of the valley of Caracas is made up mainly of schists which crop out in the hills to the south. A fault, running east to west, lies between the schist and the Avila rocks, there are other cross faults in the schist, running north to south, which, on being crossed by other faults, running approximately east to west, form a series of blocks in the foundation. See map N° 1.

Three main types of faults have been found in the Caracas region, which are listed in relative chronological order: a) Reversed faults dipping to the south, belonging to the Curucutí fault system; b) faults running approximately 60° north and dipping in a southwesterly direction which characterizes the fault zone south of the Avila; c) faults running east-west and dipping north in sharp angles, typical of the Macuto fault zone, north of the Avila.

To the south and west of Caracas there are three large folds: the Junquito anticlinal, the Cementerio sinclinal and the Baruta anticlinal. There are some minor structures associated with these folds. It may be assumed that these folds are the result of compression forces acting in a NNW-SSE direction. These forces may have also originated the inverse faults such as those at Curucutí.

4) Characteristics and Effects of the Earthquake of July 29, 1967.

At 8:05 p.m. (local time), on July 29, 1967, an earthquake began to be felt in Caracas and surrounding areas, lasting approximately 35 seconds, of which 20 seconds were of maximum intensity. The earth trembled twice, in two separate quakes, with an interval of almost total interruption of about 6 seconds, the two successive earthquakes reached two maximum intensities, the second lasting longer with shorter periods of greater intensity. The earthquake was accompanied by apparent undulations on the surface of the ground, as witnessed by several persons in the streets of Caracas and Caraballeda, as well as a loud underground rumble, as if by thunder or the overflow of torrenttial waters. The earthquake was also felt with great intensity along the Central Coast Region, between Naiguatá and La Guaira, especially in the area of Caraballeda.

A short time after the first major shock, some persons felt minor shocks, approximately at 8:40 and 9:00 p.m.

The table on page 1 gives the characteristics of the earthquake, based on data compiled by several seismografic stations from neighboring countries and estimations made by the Observatorio Cagigal.

Intensity: (5) The intensity varied considerably from one city district to another. From inspections made of damaged buildings located on the natural rock as well as on the schist, the intensity reached was 6.5 M.C.S. In the area of Los Palos Grandes (Metropolitan Zone) and Caraballeda, (Caribbean Coast) which rest on fill about 100 meters thick, the intensity was 7 to 8. In the fill area in the northern part of the San Bernardino district, as well as in the San José and Catia district (all within the city of Caracas) the intensit was very near the same. Map. N° 2, showing isoseismic curves, gives a general idea of the areas of intensity and their relation to depth of fill. The map shows, in the area east of Caracas, the influence of the transition from fill to schist south of the Guaire River which runs approximately where the schist crops. To reach more definite conclusions would require more detailed studies, which are now being undertaken.

Damages: The earthquake destroyed 4 buildings in Caracas, about eleven stories high; other buildings of varying heights suffered structural damage, classified as major or serious. Some 200 persons were killed in Caracas alone.

In the area of Caraballeda, in the Central Coastal Region, three small buildings (2 to 3 stories) were destroyed, and one 11-story building lost the upper four floors. Two other 14-story buildings suffered serious structural damage. Some 60 people were killed.

A large number of one and two story houses were seriously damaged in Caracas, Caraballeda and in the neighboring towns of Guarenas, Guatir Los Teques, Antímano, Maiquetía and La Guaira.

No damages were reported to tunnels or bridges; only minor damage ocurred in the water utility pipes in the coastal region, at Caraballeda and Naiguatá.

The Mareografhic Station at La Guaira of the Cartografía Nacional recorded a small Tsunami at the time of the earthquake, classified as a Micro-Tsunami.

Influence of Alluvial Fill: The buildings that suffered major damage are located in a distinctly limited area, mostly residential, in the eastern part of Caracas, precisely on alluvial soils resulting from the alluvial cones of neighboring streams. Borings made after the earthquake, to a dept of 115 m., did not reach foundation rock. This alluvial fill is estimated to be more than 150 m. thick. The greatest damage was suffered by buildings of 9 to 12 stories, and three of the buildings destroyed were on an almost straight line running east to west. The buildings damages in Caraballeda are on the coast and very close to each other.

Scattered damages were also reported from other areas.

The relation between the predominating periods of the soils in the various zones and that of the buildings is being investigated. Based on data compiled from the recent earthquake, and studies made in other countries, the following preliminary information can be given: (6)

In the stable or weathered schist the vibration periods were between 0.20 to 0.25 second, and with an acceleration of approximately 0.75 $m/sec.^2$

In the area of Los Palos Grandes,according to estimations, the ground vibrations periods ranges between 0.20 and 1.00 second.

The natural vibration period of the buildings located in los Palos Grandes is somewhere between 0.90 and 1.50 seconds.

Serious damages to several buildings,as well as the collapse of others,can be partially explained,by the situation at the moment when the ground's period approached that of these buildings; neighboring buildings with similar characteristics suffered minor damage.

5) Structural Design.

In current practice in Venezuela, buildings are designed to resist vertical loads and horizontal forces (seism) through the use of reinforced concrete frames. Very few buildings are designed with shear walls.

Most of the floor structures are ribbed concrete slabs,reinforced in one direction and filled in with hollow tile; blocks reinforced slabs ribbed in two directions are also used, filled with hollow concrete blocks that form part of the supporting structure.

Must of the inner partitions and outer walls are of hollow tile blocks, but its resistance is not taken into account in the structural design. Partitions are not anchored to the structure.

Foundations: The type of foundation ussually employed in Caracas, are direct foundation of piles. Foundation mats have been used only in isolated cases.

Piles most commonly used are of concrete cast in place 10 to 15 m. long and 40 to 80 cm. in diameter, reinforced in the upper 5 or 6 meters.

Behaviour of fundations under seismic action has been satisfactory, no settlements or lateral displacements has been reported.

6) Building Codes.

Since 1939 Venezuela has had a building code for seismic design, that required designing in two directions, perpendicular to the fronts of the buildings (paralel to the axes). The Code was established by the Ministry of Public Works, for application to Ministry construction, and followed the general outlines of the Uniform Building Code of California, in force at the time. The Code was gradually applied to private construction and became part of the building codes of Caracas and other cities.

This Code was revised in 1947. In this revision the country was considered as divided into three seismic zones. The values of the horizontal forces were computed with the formula:

$$F = C \times Q$$

where horizontal force factor "C" was constant for all floors,varying only with the type of structure and the subsoil conditions. The value of this factor in the "A" Zone of medium intensity, comprising Caracas and covering cases of buildings structures, was C= 0.05, which could be reduced to 0.025 when the bearing soil capacity exceeded 2 Kg/cm^2. The value of Q was taken as the dead load plus half the live load for each floor.

This Code was modified again in 1955 by the Ministry of Public Works, and since then the "C" factor is obtained by the formula of the Uniform Building Code:

$$C = \frac{0.3}{N+4.5}$$

where N is the number of floors above the level under consideration. The result is a variable factor that contrasts with the previous fixed one. Q is the total dead load for each floor.

As officially interpreted by the Ministry, the Code under discussi is applied as follows : The value of the force, F, is taken as the product of the total dead load for each floor multiplied by the corresponding factor, the sum of these forces giving the total shearing force

Outside the Ministry, in some instances, the Code was given a different interpretation because of the doubtful wording about the load Q requirement. There were cases where the value of the shearing forces were taken as the product of the cumulative dead loads multiplied by the force factor, for the floor under consideration.

The values of the shearing forces, computed under the first of the two interpretations, were higher and more in agreement with the previous Code, when applied to the more generalized cases where the coefficient 0.05 was reduced to half its value because of subsoil conditions. This interpretation gave rise, for example, to the adoption of base shearing force somewhere between 3.9% and 3.4% for buildings of 9 to 12 stories.

As a result of the second interpretation, the base shearing force for these same buildings varies from 2.4% to 1.9%. This is dangerously low for buildings of more than 12 stories.

On the other hand, the 1955 standards required checking for overturning and torsion.

7) Study of the Collapsed Buildings. (2) (3)

A. Structural Design

A rewiew of the structural designs of the fallen buildings, revealed omissions and erroneous interpretations of the standards, to wit:

1) In buildings with concrete frames in one direction, and ribbed slabs functioning as frame beams in the other direction, the following was observed:

   a) The upper reinforcement of the slabs extended only 25 per cent of the span length, giving rise to a possible break by flexion induced tension in the concrete in that area, initiating the formation of plastic hinges.

   b) The supporting beams for the slabs were not sufficiently reinforced to resist the torsion introduced by them on bending under earthquake action.

2) In one case, where the flat beams were wider than the columns, particularly with the end columns, defective joints were found, resulting insufficient bond of beam reinforcing bars framing into the columns, and the bond stresses of the lower reinforcement exceeding the allowable limits.

3) In unsymetrical buildings, the torsion was not taken into account, and a subsequent check revealed a considerable increase in the torsion effect on certain columns.

4) In one of the four buildings that collapsed in Caracas, the value of the shearing forces were erroneously taken, as the difference of the forces between consecutive floors. As a result the building was designed with very low seismic forces.

Another one of the buildings was designed under the 1947 Code. The other two were designed using the least conservative interpretation of the 1955 Code discussed in parragraph 6.

On the four buildings that collapsed in Caraballeda, one of them (partially collapsed) was designed under the 1947 Code; the other three (2 and 3 stories) were designed without any antiseismic features because they were not required by the Code, which exempt buildings less than five stories high.

As a result of studies made in damaged buildings, close to the ones that collapsed in Caraballeda, it is estimated that the intensity of the earthquake exceeded the provisions of the Code, and therefore the possibility of initiating the formation of plastic hinges in the structures, even if Code requirements had been complied with.

B. Investigation of Rubble. Examination and Testing of Samples. (2)

1) An inspection of rubble of the fallen buildings, revealed the following:

   a) Defficient arrangement of reinforcement steel column ties and beam stirrups.

   b) Concretes showing a resistance lower than that specified in the design, according to results from core-drilled samples.

In this connection, the investigations now under way show a weakening tendency of the resistance of the structural members, especially in columns, due to the dynamic action of the earthquake, spurred by a certain number of repeating forces. It should be pointed out that when using the results of the core-drill samples it was taken into account the uncertainity regarding the validity of such tests.

8) Damaged Buildings. (3)

Listed below are the most common damages observed:

1) Broken columns - Fig. 1 to 6. In some cases, breakage may be attributed to defficient column ties; in others, to slender columns (double height) in lower floors.

2) Broken beams - Fig. N° 7.

   a) By shearing stress

   b) By torsion

   c) By bending. This failure ocurred especially at the fourth or fifth point of the span where there was insufficient upper reinforcement.

3) Broken stairs: Damages ocurred to stair members integrated to

the building structure, because the rigidity of these members was not taken into account in the design of the structure, provoking failure of the members themselves, as well as of the surrounding building structure when unforeseen rigidity was introduced.

4) Failure of Roof Water Tanks: Broken supporting members caused the failure of several water tanks contructed atop buildings and residential homes.

5) Broken and destroyed walls partitions - Fig. 8.

Quite a number of buildings suffered damaged front walls and interior partitions. Generally, walls and partitions are constructed with hollow tile blocks, which are very rigid but brittle. Front walls are built with tile 15 to 20 cm. thick; and interior partitions use tile 8 to 15 cm. thick.

Q5 – Shear Wall

The energy absorbed by walls and partitions, possibly contributed in some cases to keeping the building from collapsing; this is evidenced by cracked and broken walls and almost total lack of damage to the structures.

In other cases, the front walls acted jointly with the frames as shear walls, producing a considerable concentration of forces on outside columns of open ground floors, provoking failure by compression or combined bending and compression.

9) Assumptions and Conclusions

An examination of drawings and calculations, and field inspections of the fallen buildings and many others damaged buildings leads to the conclusion, for now, that, in general, failure and even collapse may have been due to the following causes:

1) The structural systems were inadecuate in many cases.

2) The use of beams in one direction and ribbed slabs acting as beams in the other direction:

    a) The lack of adequate reinforcing in the upper part of beams, beyond a fourth of the span length, to resist the bending moments.

    b) The lack of reinforcing in the upper part of the slabs ribbs, beyond a fourth point of the span, to resist the bending moments.

    c) Torsional stress by slab action, not taken into account in the beams, and, consequently, exceeding allowable stresses.

3) Failure to take into consideration the torsional and overturning effects of the building.

4) Inadecuate joints between beams and columns.

5) The lack of partitions in the ground floor may have increased the shearing effect at that level because of the existence of partition that stiffed the frames at the upper floors.

6) In some cases involving ribbed slabs, the floor structure cracked

near the partitions resting on it, leading to the assumption that the concentrated forces transmitted by the partition itself, produced tensions in the slabs that they were not prepared to support.

7) Poor construction practices.

8) Inadequate expansion joints or lack of them.

It is assumed that the deep alluvial fill played an importan role in the intensity of the vibrations transmitted to the structures, thus produced greater damage in certain areas.

Future studies may prove, -and this is an assumption that ought not be discarded,- that the periods of many buildings were very near the ground period.

10) Temporary Standards (9)

After the earthquake, the Code Comission of the Ministry of Public Works, prepared a set of Interim Standards for Aesismic Constructions, which were published in November, 1967. The standards will be revoked when definite standards are published, based on the experience derived from the last earthquake.

The Interim Code is much more exacting than those in force at the time (1955) of the earthquake. This was partly due to the Commission's desire to be conservative during the transition period, and to the lack of accurate information.

The Interim Code has changed the country's seismic zoning, putting Caracas and surrounding area in the zone of greater intensity. Seismic coefficients were increased, and two criteria were adopted according to the classification of the soil.

Structures were classified in three types, and the uses of the buildings fall within two groups.

Emphasis is given to torsion and overturning forces as well as construction details.

The standards require the checking of the relative maximum displacements between two points in a building, spedifying a rather restricted limit.

For the first time, the dynamic analysis is a requirement for buildings more than 60 m. high or having more than 20 stories.

11) Program of Studies and Investigations. The Commission appointed by the National Government to study the earthquake of July 29, 1967, has prepared a work schedule, comprising the following points:

1) Investigation of the subsoil in the Valley of Caracas and the Central Coastal Region.

   a) Soil mechanics studies to determine the physical properties and the dynamic characteristics of the soil and the depths to foundation rock.

   b) Geophysic and seismologic investigations to complete the structural geology study of the zone.

2) Study of damaged and undamaged buildings, representative of the construction in the city

   a) Evaluation of aesismic contruction design and practice.

   b) Structural check analysis, static and dynamic.

   c) Model testing, material examination and testing.

   d) Measurement of natural periods of building being studied.

Preliminary observations indicates a noted variation of damages in buildings located in certains areas of the Valley of Caracas, and the Central Coast; this can be partially explained by the influence of the "sediments characteristics" in the trasmission of seisme waves.

With the result of these and other investigations, an attempt will be made to determine the influence of the subsoil on the various types of buildings. The results would be used as the basis for improving the aesismic design standards and construction practices.

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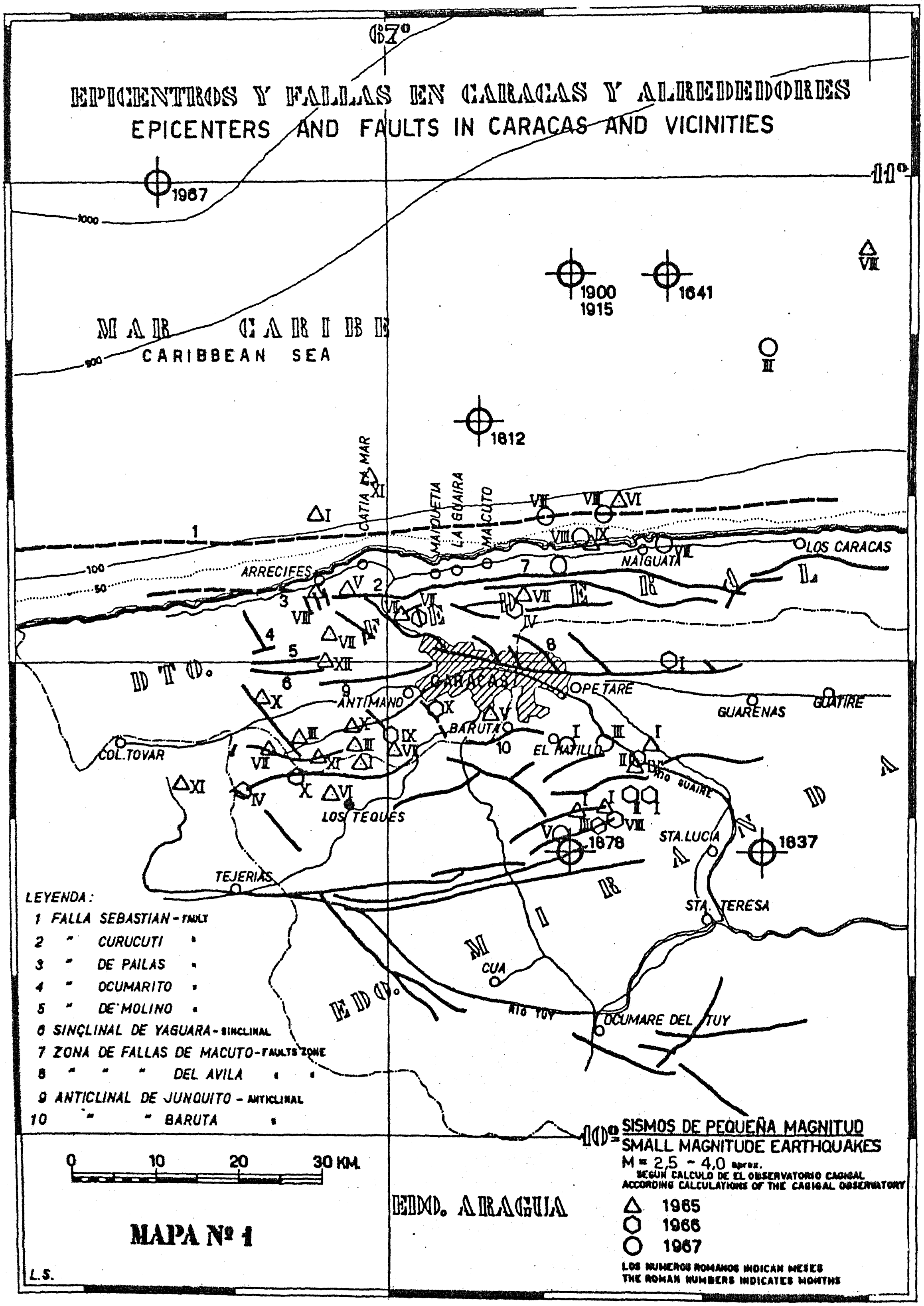
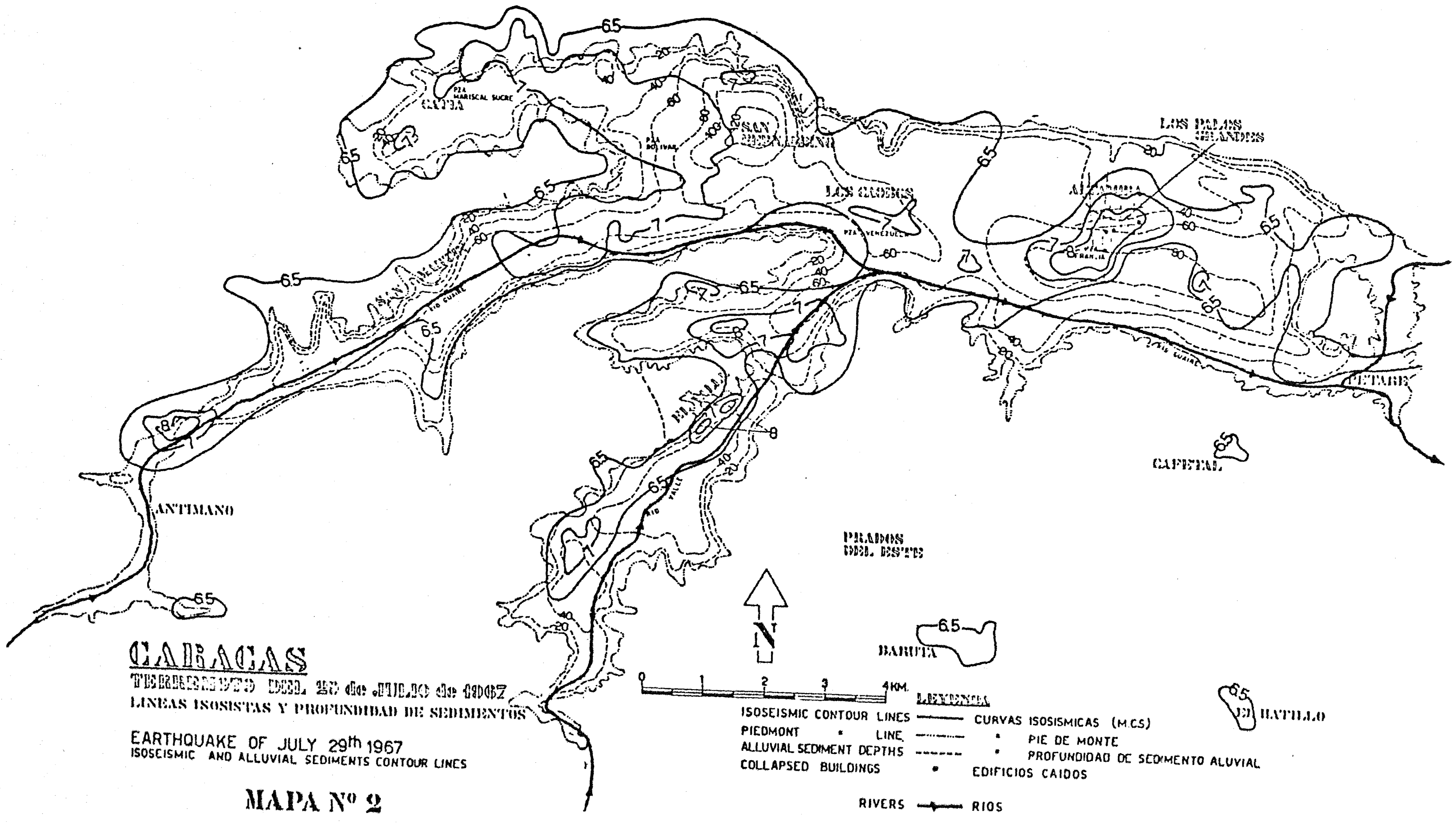


EPICENTROS Y FALLAS EN CARACAS Y ALREDEDORES
EPICENTERS AND FAULTS IN CARACAS AND VICINITIES



CARACAS

TERREMOTO DEL 29 de JULIO de 1967

LINEAS ISOSISTAS Y PROFUNDIDAD DE SEDIMENTOS

EARTHQUAKE OF JULY 29th 1967

ISOSCISMIC AND ALLUVIAL SEDIMENTS CONTOUR LINES

MAPA Nº 2

Fig. 1. Petunia II, N-W corner column. Column with combined axial and bending damage.

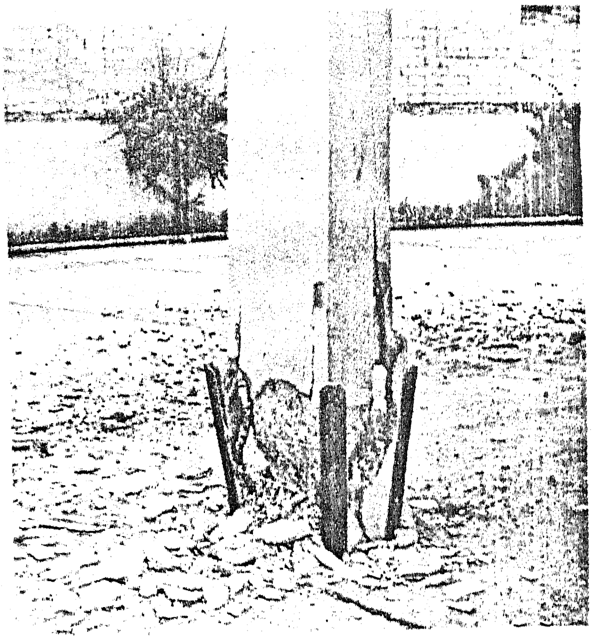


Fig.2. San Bosco building. Damaged column at ground level. Compression failure.

Fig. 3. La Pinta building. Damaged column at ground level. Combined stress failure.

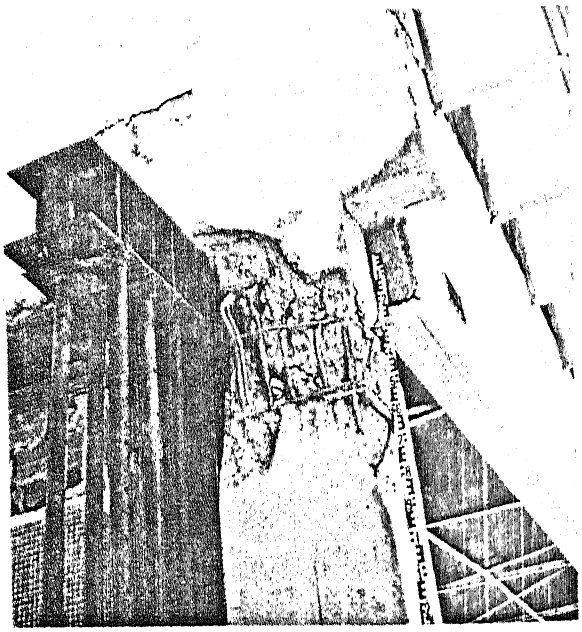


Fig. 4. Mene Grande building. S-W corner column. Combined stress failure.

Fig. 5. Macuto Sheraton's mezzanina damaged columns.

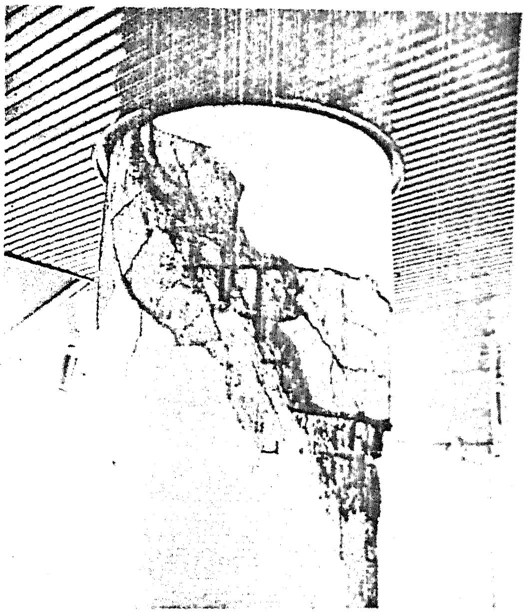


Fig. 6. Macuto Sheraton's mezzanina damaged column.

Fig. 7. Petunia I, South front. Beam with shear damage.

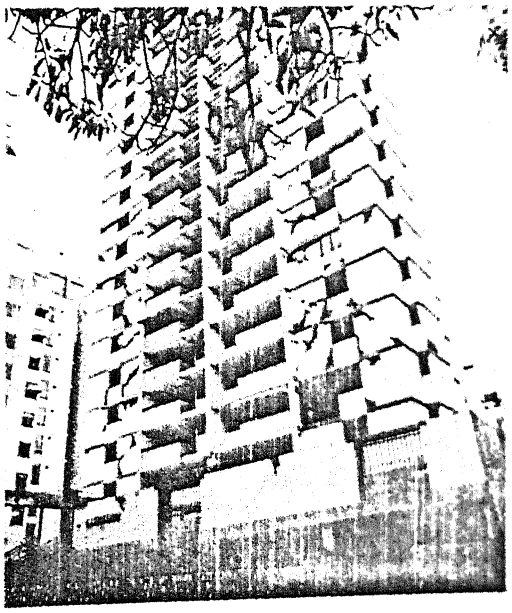


Fig. 8. Castillete building. West front. Damage of hollow brick walls.