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SEISMIC MICROREGIONALIZATION OF MEXICO CITY AFTER THE 1985 EARTHQUAKE

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SUMMARY

Using a simplified method for the evaluation of the seismic capacity of medium rise concrete structures, it was possible to obtain the base shear coefficients corresponding to failure for 90 structures associated to severe damage, and use them to elaborate a map of intensities for the 1985 Mexico City earthquake. This map shows the strong interaction of neighboring zones of firm soil or rock that amplify the ground motion in the soft soil between them as much as 100%, this being the main reason for the high intensities observed in some districts of the city. Based on these results, a new seismic microregionalization was proposed for the chapter of the 1987 Mexico City Building Code.

INTRODUCTION

The lack of adequate seismic instrumentation in Mexico City during the 1985 earthquake made it necessary to study the distribution of damage, considering the seismic capacity of the affected structures, in order to interpret the different intensities observed in the city. Initial studies were made on the basis of the density distribution of the damage, without taking into account the seismic capacity of the damaged buildings. This led to very general zonings of the damage or to the association of the higher intensities with poor quality construction zones. The map of intensities presented in this paper is based on the quantitative evaluation of the damage, which resulted in a new interpretation of the seismicity of the city.

SIMPLIFIED METHOD FOR THE EVALUATION OF CONCRETE STRUCTURES

A simplified method for the evaluation of the seismic capacity of medium rise concrete structures was developed in order to evaluate the number of buildings needed for the elaboration of the map of intensities for the 1985 Mexico City earthquake (Ref. 1). The method is an adaptation of the first level procedure of the Japan Building Disaster Association guideline (Ref. 2). It is based on the consideration that, for the failure condition, the ratio of the resistant shear force to the acting shear force in a given floor is equal to unity:

$$\frac{VRi\ Si}{Ki\ Ai\ W} = 1 \tag{1}$$

V_{Ri}: resistant shear force in ith floor
S_i : reduction factor for structural configuration and deterioration
K_i : shear base coefficient reduced by ductility, corresponding to ith floor's failure
A_i : shear force distribution with height for static analysis
W : total weight of the structure

Using the hypothesis that failure occurs in the vertical structural elements of a floor, the resistant shear force is obtained from the combination of the resistance of the different groups of structural elements, according to their stiffness. The reduction factor S considers the irregularities of the structural shape and the degree of deterioration present in the building.

From Eq. (1), it is possible to equate the shear base coefficient K corresponding to the failure condition of the critical floor (resistance coefficient), which is adopted as an index of the seismic capacity of the structure. In particular, for the purpose of this work, the resistance coefficient of a severely damaged building is identified as a measure of the seismic intensity at the site of the building.

MAP OF INTENSITIES FOR THE 1985 EARTHQUAKE

A total of 865 concrete buildings in Mexico City was studied. Only in 296 of them was it possible to obtain the information needed for the simplified evaluation of their seismic capacity. Some of the evaluated structures were disregarded: those where the damage was not concentrated in the vertical structural elements; those without damage but with more than ten floors and those where the critical floor, according to the evaluation, did not coincide with the damage observed. In this manner, the original group of buildings was reduced to 162: 74 with severe damage; 16 with medium damage and 72 with ligth or non damage. In order to use the 16 buildings with medium damage in addition to the 74 with severe damage, a preliminary zoning of the city was done. In each one of the six resulting zones, the ratio of the mean resistance coefficient for severe damage to that for medium damage was used as a conversion factor between both types of damage (Ref. 1). Finally, the map of intensities was obtained from the plot of the 90 resistance coefficients associated with severe damage. In this map (Fig. 1), besides the three geotechnical zones (hill, transition and lake bed), it is possible to distinguish six zones of different intensities according to the classification of Table 1.

Table 1 Zones of Different Intensity

Zone	Intensity	Zone	Intensity
I	$K \leq 0.05$	IV	$0.08 < K \leq 0.09$
II	$0.05 < K \leq 0.06$	V	$0.09 < K \leq 0.11$
III	$0.06 < K \leq 0.08$	VI	$0.11 < K \leq 0.15$

Zones I and II coincide with the oldest districts of the city, where building has been concentrated since the time of the Aztec Empire until the end of the XIX century (Fig. 2). These zones, though having been considered for a long time as part of the lake bed zone, have a different stratigraphy with historic fills more than 10 m in depth and 20 to 30 m of consolidated clay below.

Zone III covers the main part of the lake bed zone. It spreads over the transition zone according to the 1976 Building Code, at Lindavista district in the North and at Escandón district below Chapultepec.

The highest intensity zones IV, V and VI are located between the firm soil

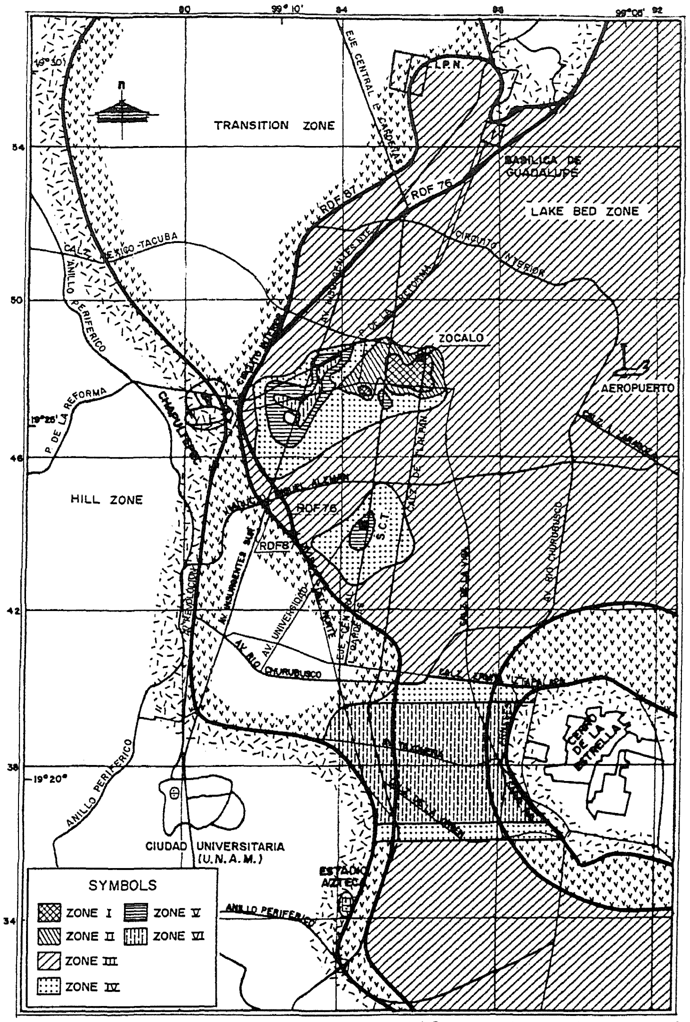

Fig. 1 Map of Intensities for the 1985 Mexico City Earthquake

of the old town and Chapultepec hill in the North, and between "Cerro de la Estrella" (Star Hill) and the hill zone in the South. This shows the strong interaction between neighboring zones of firm soil or rock that emit and reflect the seismic waves through the soft soil between them, amplifying the seismic intensity 100% from zone III to VI.

Finally, the central area of zones IV and V at Secretaría de Comunicaciones y Transportes SCT, appears surrounded by three former islands inhabited since Aztec times (Fig. 2), which again suggest the influence of the lateral interaction of zones of firm soil on the amplification of the ground motion.

SEISMIC MICROREGIONALIZATION OF MEXICO CITY

Following the procedure proposed by Ref. 3, the intersection of the cumulative frequency curves Ko for severe and medium damaged buildings and light or non-damaged buildings was adopted as the resistance coefficient recommended for design in each one of the zones of the map of intensities. In

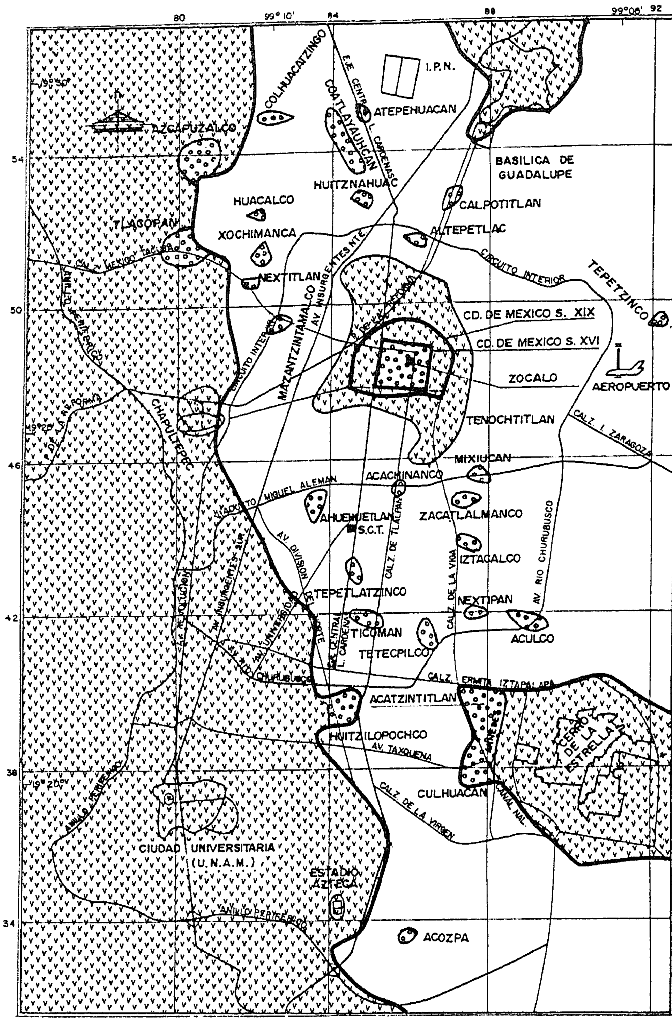

Fig. 2 Map of Mexico City in the XVI Century

Fig. 3, the cumulative frequency curve for seriously damaged structures in zone VI-South is drawn from left to right, while that for ligth or non-damaged structures is drawn from right to left. The recommended value for design corresponds to the intersection of the two curves: Ko = 0.15, with a discrepancy of 5%. The resistance coefficients Ko for all zones are presented in Table 2, together with the base shear coefficients obtained by multiplying by Ko the ductility factors (Q) for ductile concrete structures of the new 1987 building Code.

Based on these results, a new seismic microregionalization of Mexico City was proposed for the chapter of the 1987 Mexico City Building Code. As shown in Fig. 4, this included two new zones of high seismicity, mainly with lake bed stratigraphy, that cover in a conservative way zones IV, V and VI of the map of intensities. The recommended resistance coefficient for design in these zones was Ko = 0.15, which is equivalent to the design spectrum of Fig. 5, with a base shear coefficient c = 0.6 and an ordinate at the origin ao = 0.15 for a ductility factor Q = 4. The response spectrum at SCT and the design spectrum finally accepted by the 1987 code are also presented in the same figure.

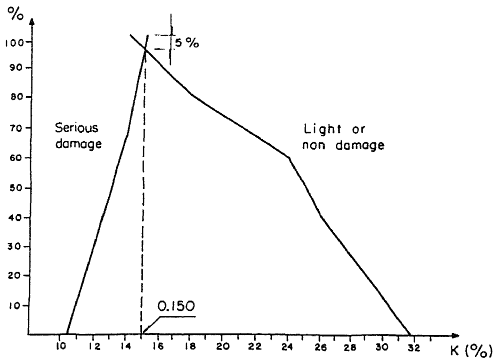

Fig. 3 Cumulative Frequency Curves for Zone VI-South

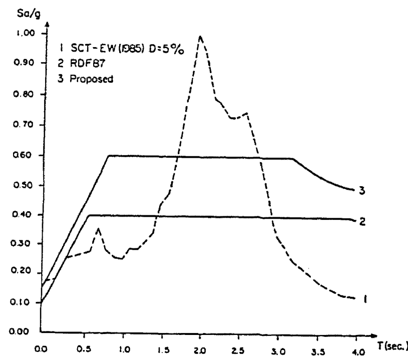

Fig. 5 Design Spectra

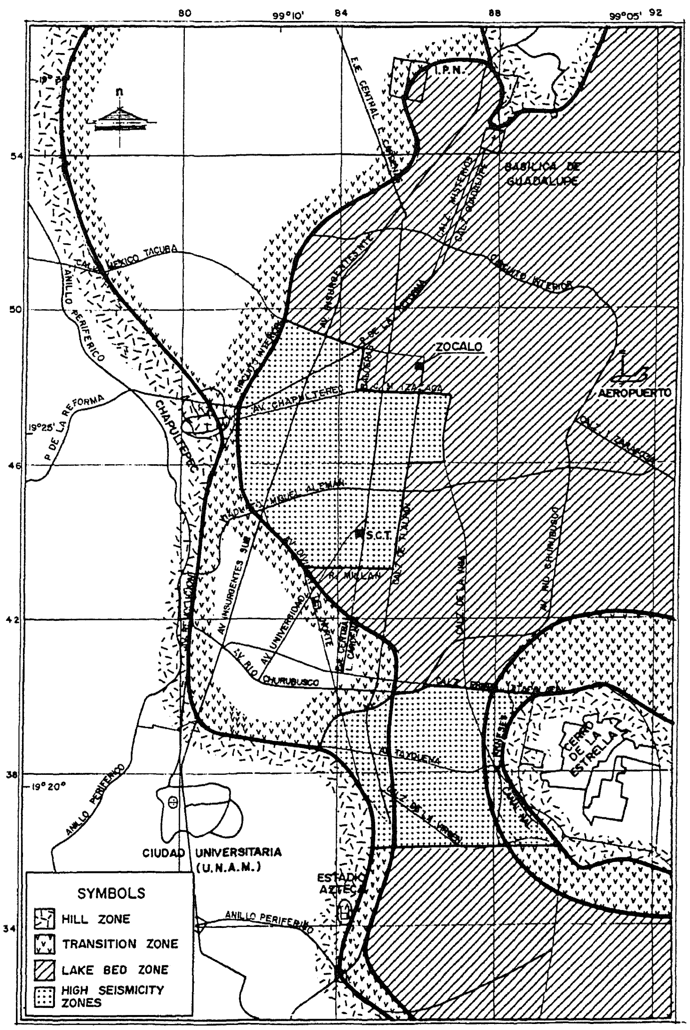

Fig. 4 Seismic Microregionalization of Mexico City

Table 2 Resistance Coefficients for Design in Mexico City

Zone	Ko	%Discrepancy	c (Q=4)	c (Q=3)
I+II	0.070	7	0.28	0.21
III	0.093	9	0.37	0.28
IV	0.120	7	0.48	0.36
V	0.138	6	0.55	0.41
VI-Total	0.149	10	0.60	0.45
VI-North	0.148	7	0.60	0.44
VI-South	0.150	5	0.60	0.45
All	0.122	14	0.49	0.37

The final version of the new code has been approved adopting the proposed microregionalization, but without changing the seismic coefficient c = 0.4 of the 1985 Emergency Code, considering it safe enough when used with the design specifications of the new code. In this manner, the high seismicity zones are only used to extend the use of the shear base coefficient of the lake bed zone to some parts of the transition zone in the South.

CONCLUSIONS

Based on the evaluation of the seismic capacity of damaged buildings in the 1985 Mexico City earthquake, a new interpretation of the seismicity of the city was formulated. The most important conclusion is the evidence of the strong interaction of neighboring zones of firm soil or rock, which can amplify the ground motion in the soft soil between them as much as 100%, this being the main reason for the high intensities observed in some districts of the city. As a direct consequence of this, a new seismic microregionalization for Mexico City was proposed and it was partially adopted by the new code without changing the base shear coefficient of the Emergency Code c = 0.4 in the high seismicity zones. It would be expected that future versions of the code recognize the quantitative difference in seismicity inside the lake bed zone, avoiding the use of a single base shear coefficient with design specifications that try to justify its low value for the high seismicity zones.

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