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## EVALUATION OF THE SEISMIC CAPACITY OF REINFORCED CONCRETE BUILDINGS IN MEXICO CITY AFTER THE 1985 EARTHQUAKE

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### SUMMARY

As a consequence of the 1985 Mexico City earthquake, the authorities of the city have decided to evaluate the seismic capacity of the buildings without damage with the purpose of detecting those with the most vulnerability, in order to take the preventive actions necessary to improve the security of the citizens in future earthquakes. Based on the census of the structures of the city, the procedure of evaluation used considers three levels of increasing precision permitting a progressive selection of the buildings in bad condition. Work is now under process in the main districts of the city with good results.

### INTRODUCTION

The 1985 Mexico City earthquake left several thousand damaged buildings (Ref. 1) and concern with regard to the seismic capacity of those apparently without damage. For structures of group A (very important buildings) it is compulsory to satisfy the new building code (Ref. 2), even if they had suffered no damage, at the cost of repair or strengthening when necessary. For the remaining buildings, the authorities of the city decided to proceed to their massive evaluation with the purpose of classifying them according to their seismic capacity. Based on this classification, it will be possible to focus preventive actions on the buildings in the worst condition.

### METHOD

Fig. 1 summarizes the methodology proposed for the evaluation of the seismic capacity of the buildings in Mexico City (Ref. 3). The first step is the census of the structures, which allows an initial classification by number of floors and use. Beginning with the more vulnerable buildings according to this classification, two levels of simplified evaluation and increasing precision are applied. If the building do not fulfill the appropriate requirements, then it is necessary to make a detailed evaluation with conventional procedures to decide the repair or strengthening of the structure.

### CENSUS OF BUILDINGS

In order to proceed with the massive evaluation of buildings, it was necessary to begin making an actualized census of the buildings in Mexico City.

The information of the census contains the address of the building, the number of floors, the use, and the damage it presents. The work was begun in the Cuauhtēmoc District, that was the most affected by the 1985 Mexico City earthquake. With the results of the census it has been possible to elaborate statistics of the incidence of damage in relation to the number of floors and the use of the structures. Table 1 shows that collapses and severe damage were concentrated in the buildings with more than five floors, reaching a frequency greater than 35% in those with more than nine floors.

Table 2 shows that from the point of view of use, the buildings with high density use were the most affected.

Based on these results, it was possible to make a first classification of the buildings with more than four floors, which according to Table 1 were the most damaged, into four groups according to importance:

1. High density use and more than five floors
2. High density use and five floors
3. Low density use and more than five floors
4. Low density use and five floors

#### FIRST LEVEL EVALUATION

This level of evaluation is based on a visual inspection of the building, which gives information about the structural configuration, the behavior of the foundation, the location, and the degree of deterioration it presents (Ref. 3). From this data, it is possible to judge each one of five indexes related to the main seismic characteristics of the structure, in order to obtain its security level (S) and to decide whether a second level evaluation is required:

- I Structural configuration in plan. Considers the distribution of the structural elements and the geometry in the plan of the building.
- II Structural configuration in elevation. Considers the distribution of stiffness and the geometry in elevation of the building.
- III Foundation. Identifies the different problems of foundation which influence over the structure stability.
- VI Location. Takes into account the geographical location of the structure in relation to the seismic zoning of the city.
- V Deterioration. Reflects the deterioration of the seismic capacity of the building by previous earthquakes or age.

#### SECOND LEVEL EVALUATION

This level of evaluation is based on the simplified method of Ref. 4 for the evaluation of the seismic capacity of medium rise concrete buildings. In this stage, it is necessary to complete the information of the first level evaluation with a more detailed inspection, focused on the detection of damage or previous repair work, and on the determination of the dimensions of the basic geometry of the buildings and of the cross sectional area of the structural elements.

This method of evaluation adopts the shear base coefficient corresponding to the failure of the structure (resistance coefficient K) as an index of its seismic capacity. The value of K is compared with the intensity index  $K_S$ ,

defined according to the seismic zoning of the city, in order to obtain the security level of the building and to decide whether a detailed evaluation (third level) is required (Ref. 3). In structures with more than ten floors it is necessary to complement this method of evaluation with measurements of the natural periods of the structures and with an approximate evaluation of their displacements.

#### DETAILED EVALUATION

The purpose of the two first evaluation levels is the massive evaluation of buildings with simplified methods, quick and economical, that permits detecting those structures for which a detailed evaluation is justified. In these cases, the seismic capacity of the building is obtained following the analysis and design procedures of the building code (Ref. 2). The result may conclude with recommendations for the repair or strengthening of the structure.

#### RESULTS

The work proceeded simultaneously in the three districts most affected by the 1985 Mexico City earthquake: Cuauhtémoc, Benito Juárez and Coyoacán. The census has been finished in all of them, and the first and second level evaluations of the buildings of the first group are now being carried out: high density use and more than five floors. Fig. 2 shows the progress in the Cuauhtémoc District. It should be noted that after the census, the structures of group A (important buildings) have been put aside, and that some of the buildings that qualified for the first level evaluation were ignored because they were actually under the control of the authorities.

#### CONCLUSIONS

The massive evaluation of the seismic capacity of non damaged buildings is now in process in some of the more affected districts of Mexico City. The results that have been obtained so far will enable the city authorities to detect the buildings where it is justified to invest in detailed studies and possibly in the repair and strengthening of the structure. This will make it possible to take the preventive actions required to increase the security level of the city in the event of future earthquakes.

#### REFERENCES

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Table 1 Damaged Buildings in the Cuauhtémoc District

Floors	Damaged Buildings		Total Bldgs. Cuauh. D.	%Damaged Bldgs Cuauh. D.
	City Total	Cuauh. D.		
0	0	0	1 275	0.00
1-2	1 160	617	30 299	2.00
3-5	577	342	11 975	2.86
6-8	268	206	1 439	14.32
9-12	215	168	456	36.84
>12	83	64	181	35.36
Totals	2 303	1 397	45 625	

Table 2 Use of Damaged Buildings in the Cuauhtémoc District

Use	Damaged Buildings Cuauhtémoc D.	Total Bldgs. Cuauh. D.	%Damaged Bldgs Cuauh. D.
hospitals	94	389	24.16
offices	265	2 333	11.36
schools	51	619	8.24
housing	833	30 887	2.70
entertainment	3	138	2.17
commercial	138	6 756	2.04
tourism	7	837	0.84
no use	6	2 832	0.21
services	0	108	0.00
others	0	726	0.00
Totals	1 397	45 625	

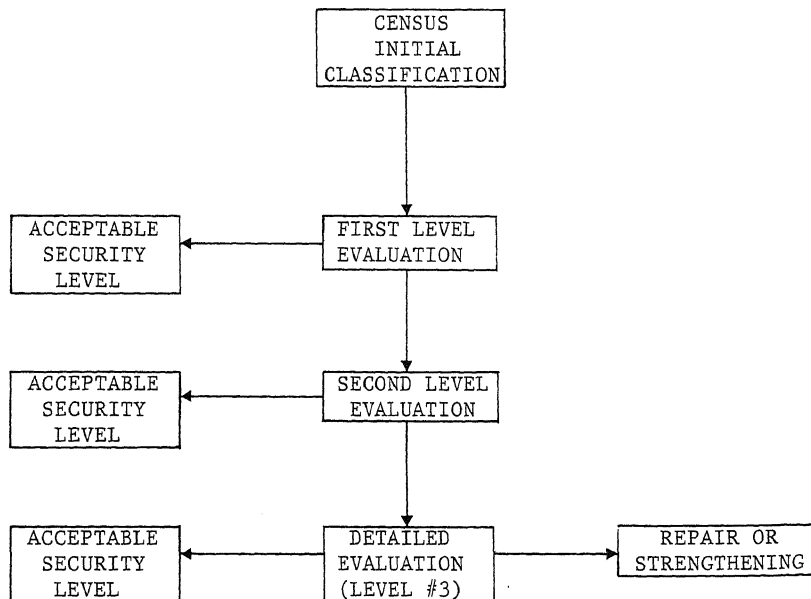


Fig. 1 Methodology for the Seismic Evaluation of Buildings in Mexico City

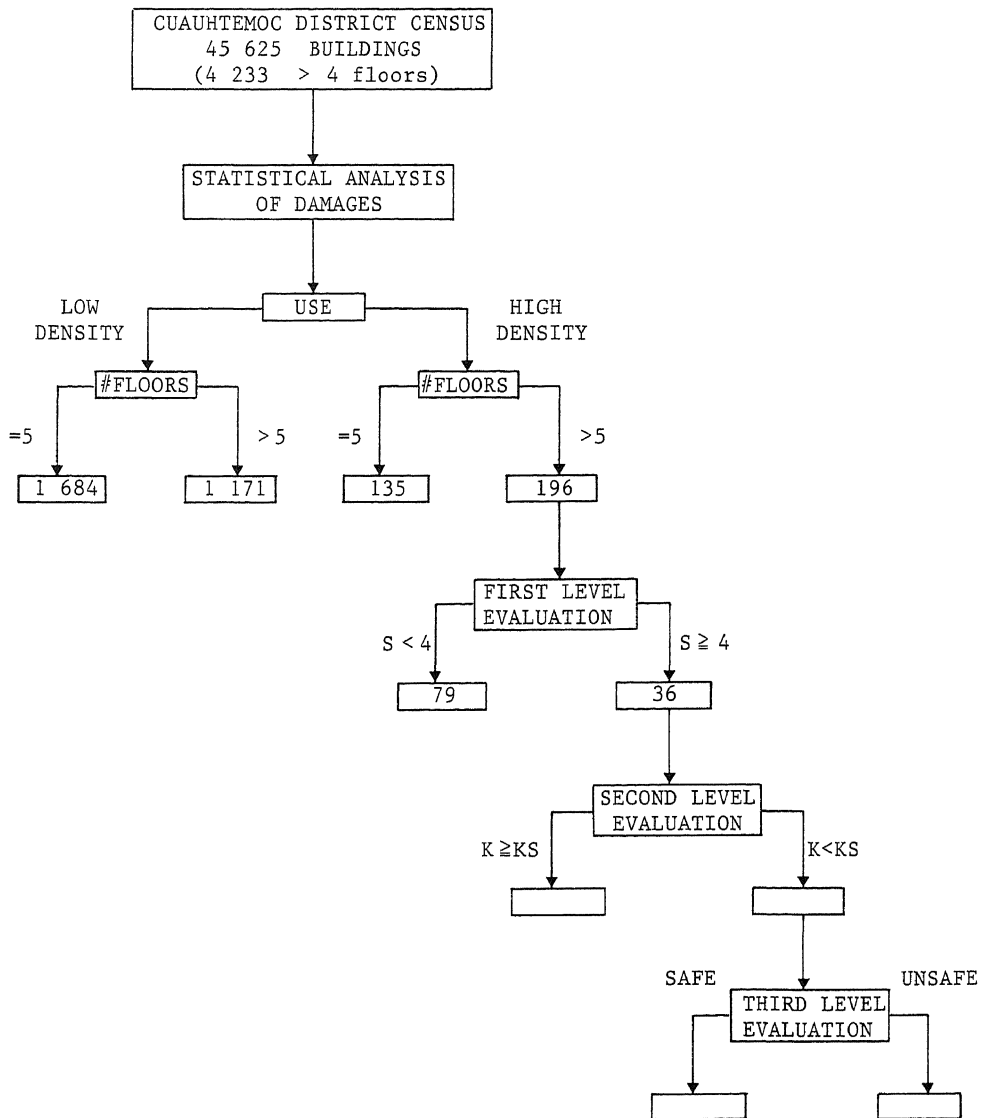


Fig. 2 Progress of the Evaluation of the Seismic Capacity of the Buildings in the Cuauhtémoc District