

Analysis of damages and its relations with seismic intensity

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ABSTRACT: This paper presents a study of the buildings behaviour in the zone that resulted most affected ($I_{MM} = IX$) by the November 23, 1977 earthquake ($M = 7.4$) in San Juan, Argentina. The buildings were classified according to their functions and architectural design. At each group, the damages are analyzed in relation to the shaking level produced by this earthquake and that produced by the January 15, 1944 earthquake ($M = 7.8$) in San Juan city.

1 INTRODUCTION

The November 23, 1977, Caucete Earthquake ($M=7.4$) that hit San Juan Province, in the west region of Argentina Republic, caused serious damage, from collapse to minor ones, among others to schools, hospitals and industrial buildings.

These buildings were built according to seismic resistant regulations, using elastic method with admissible stress.

2 ANALYSIS OF THE DAMAGES

The damage took place mainly in San Juan city (I_{MM} near VIII) and Caucete city (I_{MM} near IX) (Fig.1). San Juan city was totally devastated by another quake in 1944 ($M=7.8$) which caused in this city seismic intensity similar to that of Caucete city in 1977 earthquake (Fig. 2).

San Juan city had natural period measurements of several buildings before the earthquake. After it, they were measured again and, in general, a 30% average increase in the natural period due to structural and non-structural damages was found (Table 1).

By classifying the building according to their function, the more damage were Educational ones. Most of them are confined masonry structures of one storey and some of two or more, which have frame structure with bays filled with masonry walls.

From a general of point of view, the damages were due to: short column, torsional effect, cantilever fault, difference of stiffness and strength at different structural plane for the same storey and between different storeys (Fig. 3). They were produced by deficiency in the Architectural Design and the Structural solutions.

In the Industrial Buildings which are in general Vineries, the damages were mainly produced by anchor faults, shell bulging of the cylindrical metallic tanks used to store wine. Some of them collapsed. This depended on its slenderness and the volume contained (Fig. 6).

A three-storey vinery seismo-resistant designed and reinforced concrete built fell down because of the damage concentration at the first storey as a consequence of having been designed as a free floor storey.

Hospitals: The hospital in Caucete city was completely destroyed by the quake. It brought as consequence the lack of hospital attention just in the city that suffered more damage and had more injured people.

Housing: They were one or two-storeyed buildings, with a high density of confined masonry walls. Their behaviour was, in general terms, excellent.

3 RELATIONSHIP BETWEEN DAMAGES AND GROUND SHAKING

Considering the damage description in buildings with different functions and structural-architectural designs, though few in number, they were important for their functions and structural-architectural features, the question whether this damage level is compatible to the shaking ground produced by the earthquake.

In order to find an answer to this question, the Earthquake Research Institute Building (I.D.I.A.) of the National University of San Juan, was analyzed. It consists of two storeys and a basement (Fig.7). Some columns in the basement and the masonry walls covering all the building suffered shear damages.

The total energy induced by an earthquake is absorbed by a structure according to

$$W_e + W_p + W_d = E$$

where

E : energy exerted by an earthquake that depends on the earthquake and building characteristics.

W_e : elastic vibration energy.

W_d : energy absorbed by damping effect.

W_p : energy absorbed by the frame due to inelastic strain.

W_e , W_d and W_p depend on the building characteristic.

Assuming that for the most severe earthquake that could occur in the considered zone, the structure should have inelastic strains, and designating W_u to be the energy absorbed by the structure by inelastic strains, E_u energy released by the earthquake, the condition upon which the structure would survive without collapsing will be:

$$W_u + W_p = E_u - W_e - W_d$$

To quantify this equation, the method proposed by Ohkubo (2) is used. It is based on ultimate resistance theories to calculate the column capacity and the relationship between the elastic and elastoplastic responses according to Newmark to calculate the ductility of the building.

The inelastic absorbed energy is represented by

$$I_s = E_0 \cdot S_d \cdot T$$

where

E_0 stands for a kind of energy equivalent to the maximum elastic response of the structure; S_d and T modify the basic seismic behaviour considering both the influence of the structural properties (symmetry and height regularity) and the deterioration condition produced by the weather.

I_s must be greater than I_{s0} . The latter represents the requirements the structure should have for the severest earthquake and it depends on the structure characteristics, function of the building, soil-structure interaction and macroseismic conditions and, therefore, on the region where the building is placed at; so it should not be applicable to the analysis.

Being $I_s = 0.6$ and considering the amount of damage observed in this building, it can be assumed that I_{s0} will approximately be equal to I_s .

Taking into account that a measurement of the energy introduced by an earthquake is given by the destructive potential, as defined Saragoni Huerta (3)

$$P_d = \frac{I_A}{V_0^2}$$

where

I_A : Arias intensity

V_0 : Zero crossing intensity that depends on the ind of earthquake produced.

If we consider that the earthquakes of 1944 and 1977 have the same characteristics (V_0) and, if we take for San Juan city $I_{MM} = IX$ in 1944 and $I_{MM} = VIII$ in 1977, then the former one has almost three times more the destructive power or its equivalent exerted energy (Fig.8) (1) than the 1977 earthquake which would make I_{s0} greater than I_s . Therefore, following Ohkubo's definitions, we have that, from the seismic resistant point of view, this building would have badly-behaved.

4 CONCLUSIONS

Despite its good behaviour, even at the epicentral zone in which there are low-rise buildings with high density walls, damage in non-conventional structures could be observed. It was mainly due to the damage concentration effects occurred as a consequence of an incorrect structural - architectural design. Such structures in San Juan city could have had serious consequences if they would have been hit by an earthquake like that of 1944.

Therefore, it is essential -for this type of buildings- to carry out a detailed study of the energy distribution exerted by the earthquake; bearing in mind that the building responses as an earthquake resistant whole through its structural and non-structural elements.

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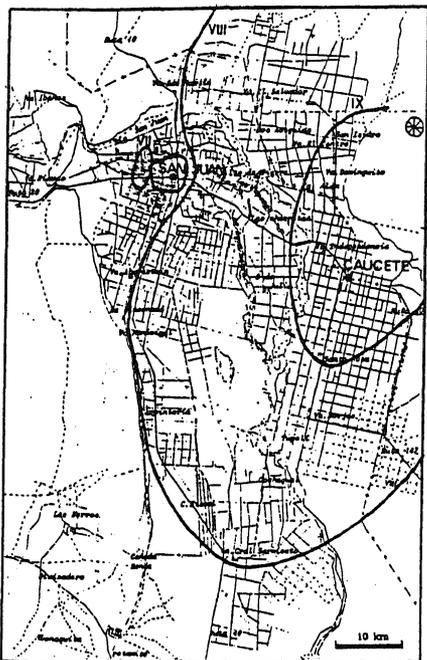


FIGURE 1 - 1977 CAUCETE EARTHQUAKE ISOSEISMALS

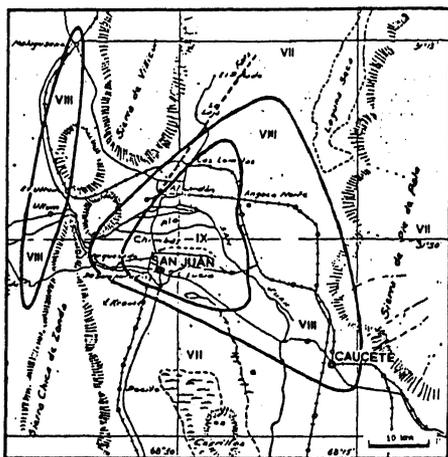


FIGURE 2 : 1944 SAN JUAN EARTHQUAKE ISOSEISMALS

TABLE 1 - NATURAL PERIOD OF SAN JUAN BUILDINGS

BUILDING	N° STORY	DIRECTION	NATURAL PERIOD	
			BEFORE	AFTER
San Miguel	6	N-S	0.35	0.44
Boo Hipotecario	7	E-O	0.42	0.60
Sta Fe y Mendoza	5	N-S	0.32	0.41
I.D.I.A.	3	N-S	0.14	0.18

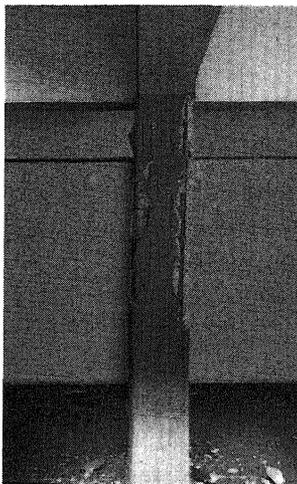


FIGURE 3 - SHEAR FAILURES IN SCHOOL BUILDING'S COLUMNS

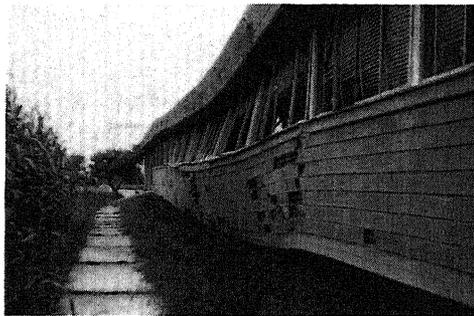


FIGURE 4 - CANTILEVER AND SHORT COLUMNS IN SCHOOLS BUILDING

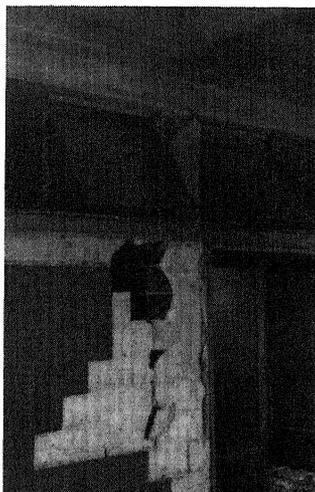


FIGURE 5 - SHORT COLUMNS IN SCHOOL BUILDING

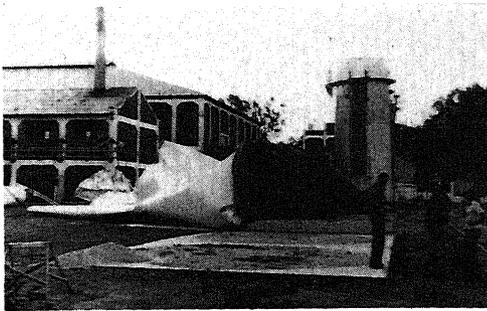


FIGURE 6 - ANCHOR FAULT IN CILINDRICAL METALLIC TANKS

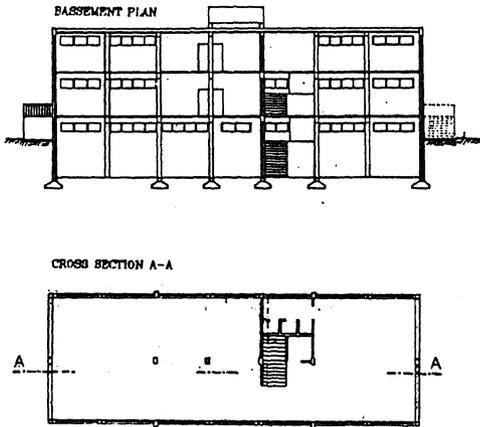


FIGURE 7 - LD.I.A. BUILDING

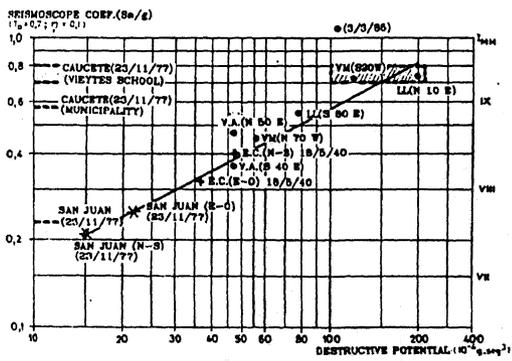


FIGURE 8 - SEISMOSCOPE - DESTRUCTIVE POTENTIAL (IMM)