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OBTENTION OF BASIC PARAMETERS FOR INTRAPLATE EARTHQUAKES AND COMPARISON OF THEIR DAMAGE POTENCIALITY IN THE WEST OF ARGENTINA

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SUMMARY

In this paper it is compared the seismic potential damages of two kinds of strong ground motions that represent earthquakes with extreme possible characteristics that may take place in the central western area of Argentina.

They represent earthquakes with long strong motion duration, typical of multiple event phenomenon, which require structures to dispel continuous energy over a long period of time, producing numerous hysteresis cycles (a). On the other hand, the quakes that stand for almost impulsive earthquakes, produce a sudden release of energy which should be immediately dispelled by one large yield excursion with few yield reversals.(b).

Once the parameters normally used to classify the ground motion severity in an earthquakes have been obtained, it is possible to determine that type (a) earthquakes may cause a superior structural demand even for great distances to origin (D) than the ones observed in (b). Then, it may be established that the ductility concept is not an accurate parameter to define seismic structural performance.

INTRODUCTION

The central western region of the Argentinean Republic is situated on the greatest seismic area of the country. It is about 350 kilometers to the east of the Nazca and South American convergence line, which extends along the Peruvian – Chilean trench, subducing the first to the second one (fig Nº 1) (1).

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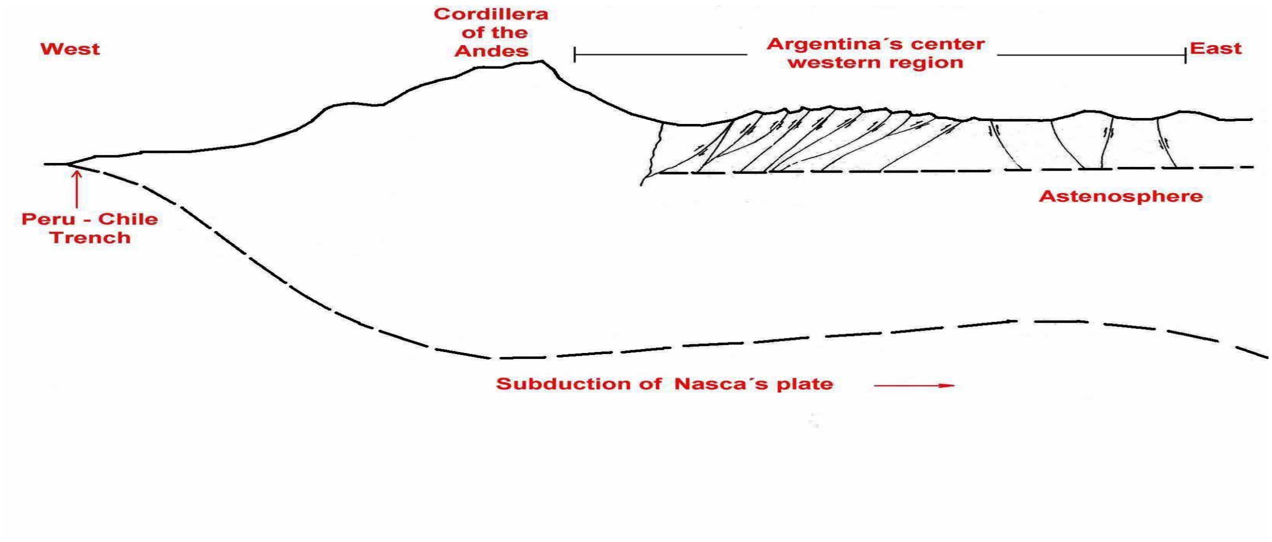


fig Nº 1

Such convergence generates a compression effort régime in the South American plate responsible for the Andean orogeny. Firstly this regional tectonic produces two seismic areas (fig Nº 2,3) (2):

- crust area with superficial tremors (H< 70 km)
- subduction area, nearly horizontal in the west of Argentina, with deep quakes (H>70km) known as Benioff's zone

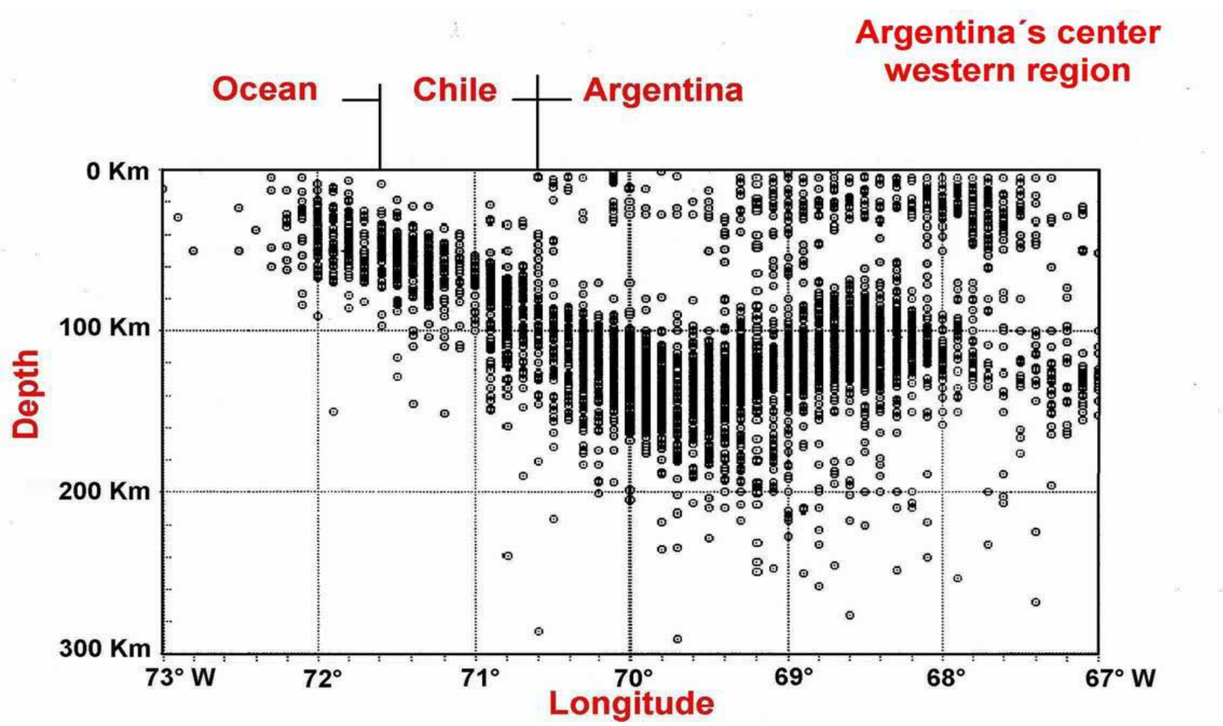


fig Nº 2

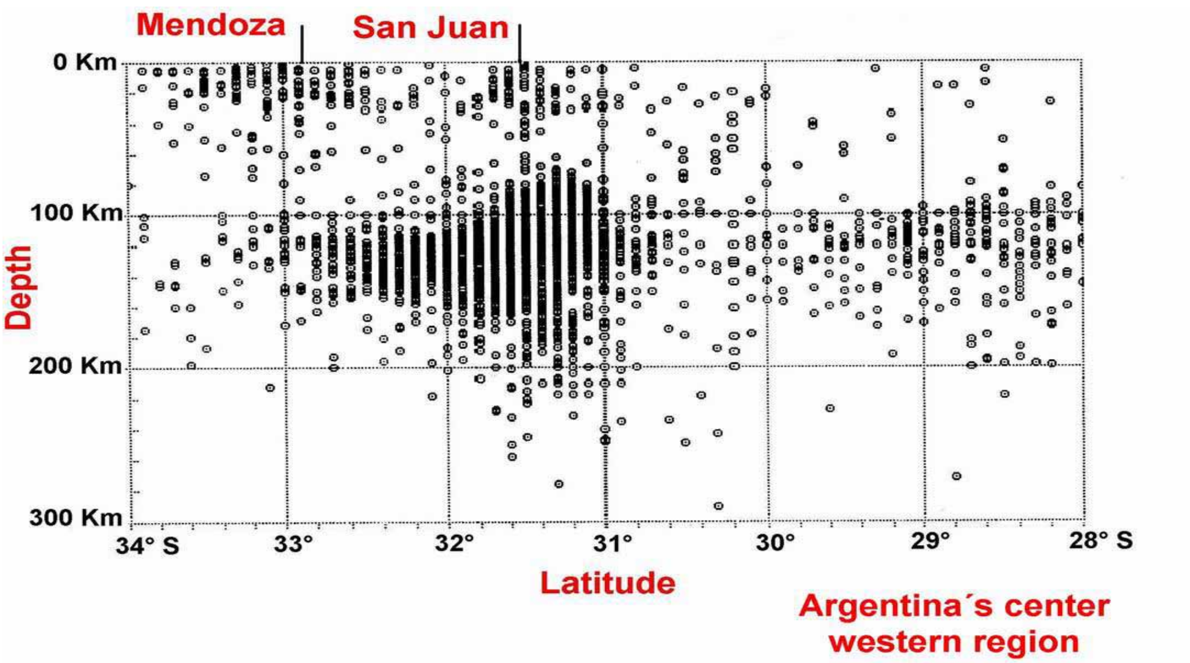
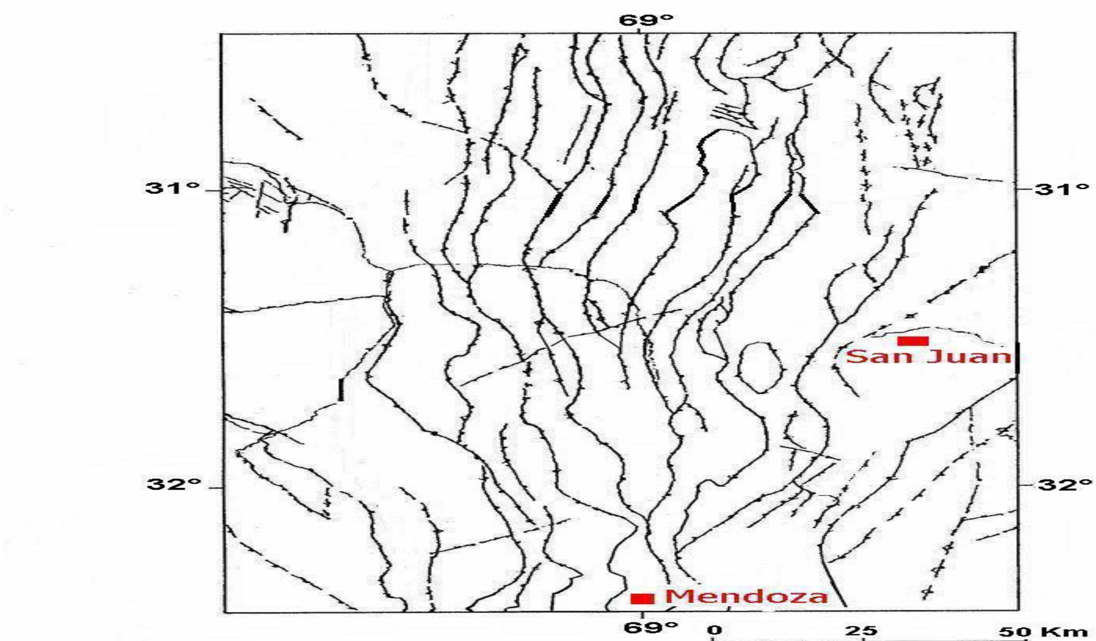


fig Nº 3

This regional tense regimen originated a system of inverse active faults with a North - South orientation, connected by transversal secondary faults that form together a dense crack mesh where crust seismic activity takes place. In the last 221 years there have been one deep and six shallow earthquakes of a magnitude greater than or equal to 7, and 59 shallow ones of a magnitude between 6 and 7 (fig Nº 4,5).



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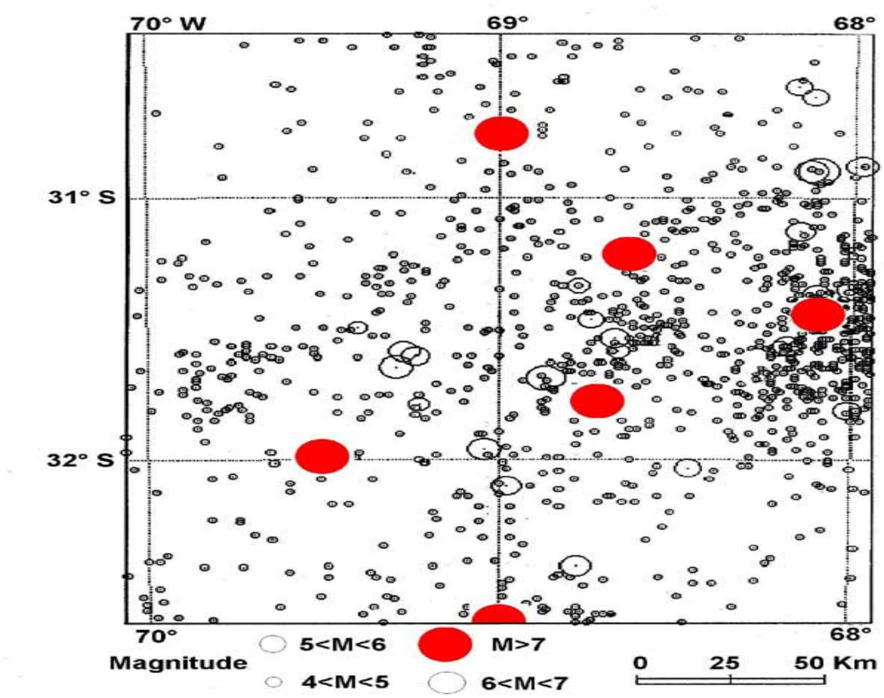

fig Nº 5

The first 7 earthquakes took place on the dates below and with the following characteristics:

- May 22, 1782: Ms= 7.0; H+ shallow; De (Mendoza) = 7km , I_M(Mendoza)= VIII
- March 20, 1861; Ms=7.0, Mw= 7.2; H= shallow; De (Mendoza)= 7km , I_M(Mendoza)= IX. It destroyed Mendoza capital city.
- October 27, 1894 ; Ms= 7.5, Mw= 7.7; H= shallow; De(San Juan)= 115km, I_M= VIII(San Juan), VI(Mendoza). It affected the whole central- eastern area of Argentina, being felt in an area over 3 million km^2.
- April 14, 1927 ; Ms= 7.1, Mw= 7,1; H= 110km; De= 69km (Mendoza), 121 (San Juan), I_M= VII (Mendoza), VI (San Juan). It affected Mendoza capital city
- January 15, 1944; Ms= 7.4, Mw= 7.4; H= shallow, De(San Juan)= 8km, I_M= X(San Juan), VI(Mendoza). It destroyed San Juan capital city, with similar characteristics to the one which occurred in 1894; regardless of magnitude and seismic origin.
- June 11, 1952: It damaged San Juan capital city.
- November 11, 1977; Ms= 7.0, Mw= 7.0; H=shallow; De= 8km (San Juan), 155km (Mendoza), I_M= VII (San Juan), V(Mendoza).
- November 11, 1977; Ms=7.4, Mw=7,4, H= 26km; De= 80 km (San Juan), 219 km (Mendoza), I_M= VII (San Juan), VI (Mendoza). It produced great damages in San Juan capital city. There are instrumental records due to the main event.

Only two of the 59 earthquakes of a magnitude between 6 and 7 should be especially considered:

- July 3, 1941; Ms= 6.3; H= shallow; De = 74 km (San Juan); I_M= VI (San Juan). Not only did it have the same characteristics to the one which occurred in 1977, regardless of their magnitude.

- January 26, 1985; m_B= 6.0; H= 5 km; De= 15 km; I_M= VIII (Mendoza). It had a similar nature to the quake that took place in 1861. There are records of earthquakes in different areas of the main event and resembling ones. This was the second greatest earthquake in Mendoza capital city

Of the comparison, through historical stories, of the characteristics that these earthquakes had, are observed among them two groups with similar properties, in spite of their different magnitudes. Those registered during the earthquakes of the 23/11/1977 in the San Juan city from to 80 Km of the epicenter with M_L=7.4 (a) and the 26/01/1985 in the Mendoza city from 20 Km of the epicenter with M_L=6.1 (b). (fig Nº 6,7)

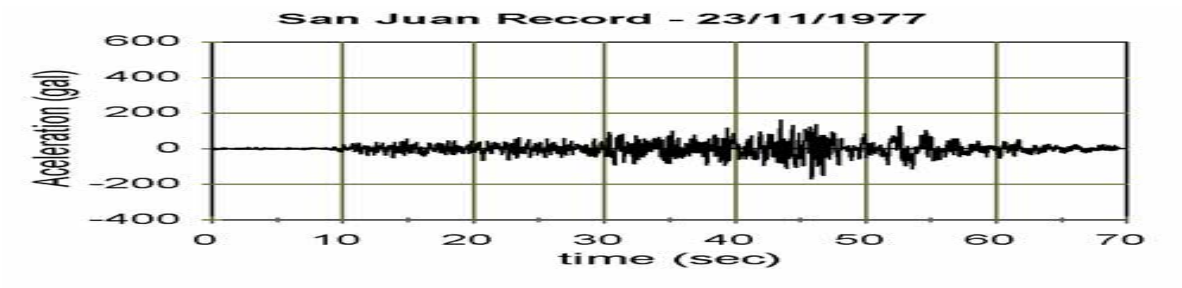

fig Nº 6

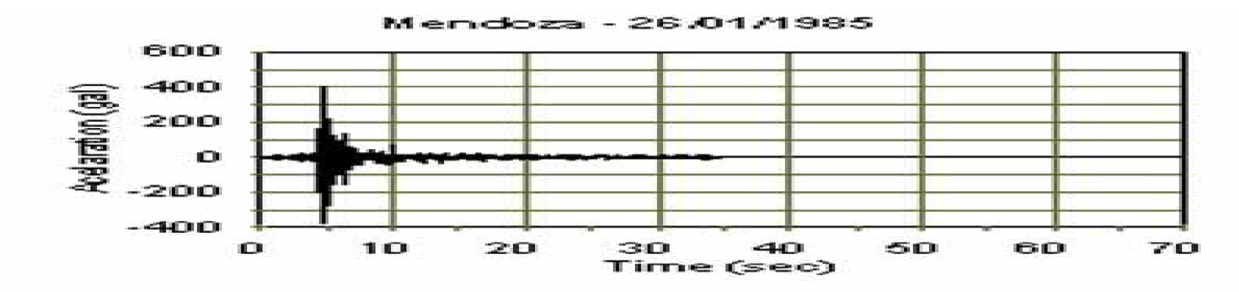

fig Nº 7

All records were obtained in building basements or in free - field conditions, generally in areas with similar types of local soil, causing I_{MM}=VIII in San Juan and Mendoza cities where resembling ground peak velocity and different peak accelerations and displacement were produced.

On the one hand, the first group is a multiple event phenomenon and represents long duration earthquakes; in this case with approximately 50 sec. of 0,05 g bracketed duration as defined by Bolt. Seismic of these characteristics require a steady dissipation of energy over a long period of time with numerous yield reversal.

On the other hand, the 1985 earthquake in Mendoza represents cases of the impulse type ground motion, which result in a sudden burst of energy into the structure, which must be dissipated immediately. This is usually characterized by one large yield excursion with few reversal.

POTENTIAL DAMAGE ANALYSIS

The most important characteristics of strong ground motions resulting from an earthquake, which may influence the structure's performance are

- Peak ground motion (peak ground acceleration, velocity and displacement) resulting from seismic wave generation mechanism and influencing the structure's vibration amplitudes
- Frequency content, associated to generated wave spreading, which influences the structure's resonance phenomena and, therefore the spectral shapes.
- Duration of strong motion, function of the seismic wave generation mechanism, which has a pronounced effect on the severity of shaking.

These parameters are commonly typified by two kinds of values (3) (4):

- Instrumental values obtained either directly or with some simple calculations from the accelerograms
- Spectral values obtained either from the decomposition of the movements in its harmonic or the parametric integration of equation or considering the energy balance equations for elastic and inelastic single degree of freedom systems.

The maximum ground motion recorded in 1977 and 1985 earthquake are:

- In San Juan city a=189.1 cm/sec^2, v=20.3 cm/sec., d= 18.9 cm
- In Mendoza city: a= 404.4 cm/sec^2, v=26.5 cm/sec., d= 7.5 cm

The contrast between them makes it possible to observe peak velocity values of the same range and different duration, acceleration and displacement, being the latter greater in San Juan than in Mendoza because of high period pulses in velocity. These characteristics in isolated form are considered not very representative of the potential of damage of an earthquake.

For the purpose of quantifying and comparing the frequency content of recorded ground motions, the Fourier Spectra (FS) of the movements in each city were obtained (fig Nº 8).

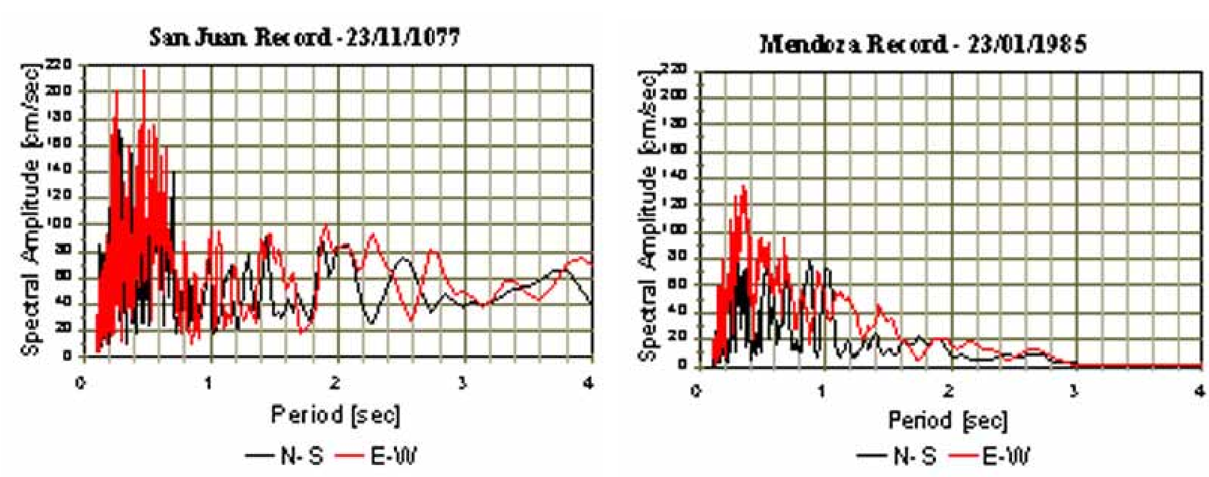

fig Nº 8

Fourier Spectra depend on three parameters: magnitude (M), distance to source of energy release (D) and the local soil conditions (S).

Great M indicates relatively larger energy contents in longer periods, D has a significant effect over spectral shapes due to geometrical relation of the energy spreading in the crust. This implies a substantial change of the frequency content of ground motion with the distance. S determines what frequencies amplifying more than others according to the type of local soil, considering its independence from M and D.
These general tendencies are observed, besides others as the influence of the directionality, in the FS of these movements, in which the high contents of frequency can be observed in (a) despite their epicentral distance and the concentration of higher energy supplies in low period range in (b).

These earthquakes show regional particular characteristics:

- When comparing spectral amplitude decrease in low periods with the distance, such decline is less than the amplitudes observed in other regions.
- There is a smaller dependence in the relations between the spectral amplitudes in low and high periods with M, than the ones found in other regions.

The tendencies above produce several effects, such as the fact that in the center of Mendoza city, located 200km away from the San Juan's earthquake epicenter, it produces higher energy supply in low periods than Mendoza's earthquake.

Considering not only the San Juan and Mendoza FS, but also the records obtained in both earthquakes in the same place in the downtown in Mendoza city, it possible to appreciate a higher frequency content that contributes to the total energy input in the first case that in the second (fig Nº 9)

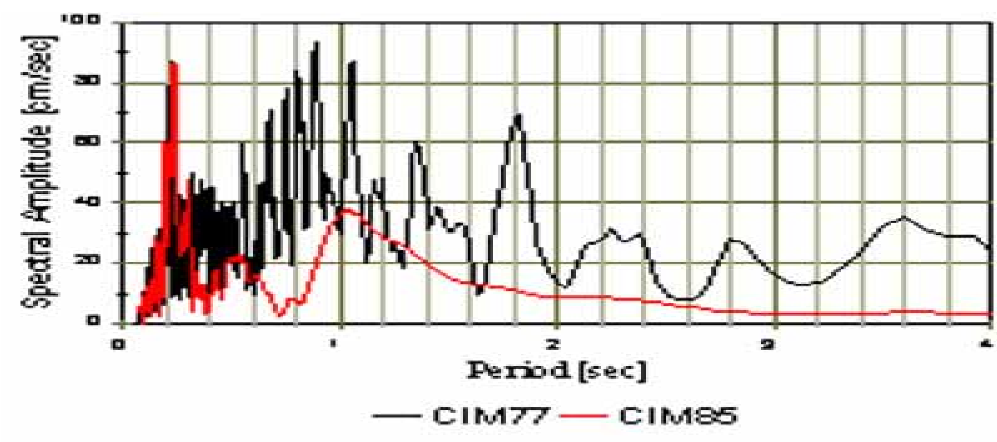

fig Nº 9

One of the first techniques used characterize the severity of the ground motion produced by an earthquake is the concept the elastic response spectrum (ERS), introduced by Biot y Hausner.

The ERS measures the maximum energy of elastic deformation stored in the structure during the earthquake which is a measure of the maximum displacement and therefore of the maximum tensions

ERS depends on M, D and S, being taken into account both first for the peaks values of the ground motion, affecting S the shape of the ERS.
The general characteristics that give the ERS these parameters are observed in these two cases showing much more excitement in short period buildings in both case, effect not corroborated by the observed damages (fig Nº10)

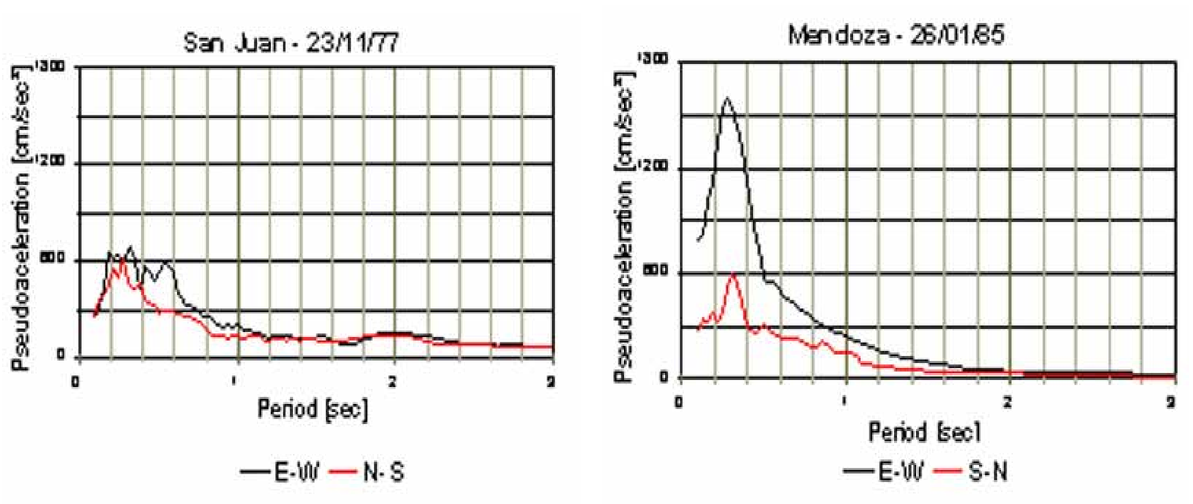

fig Nº10

Due to financial issues, normal structures may have inelastic deformations during an earthquake This deformation is usually defined according to the displacement ductility of an SDOF oscillator. It is commonly expressed as $\mu_d = \delta_{max} / \delta_y$, being δ_{max} the maximum displacement and δ_y the yield displacement.

Due to the ground motion cyclical nature during an earthquake, the structure's strength - displacement relation follows hysteric loops, whose shape and orientation depend on both the structural system and the constitutive materials being used. These hysteric' loops are a measure of the capacity of the structure to dissipate energy and often result in stiffness deterioration. Adopting for the relationship strength - displacement an elastic - perfectly plastic curve and constant yield strength (cy), it is possible to estimate the inelastic response spectra for a 5% viscose damping (η) in function of the demand of ductility (μ).(fig Nº11).

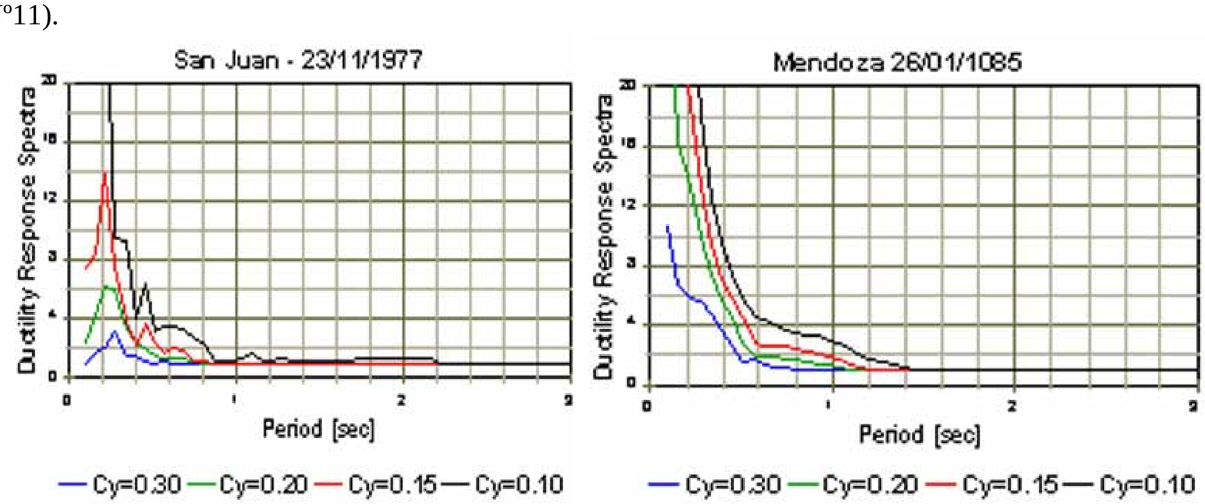

fig Nº 11

From these spectra it has been inferred that (b) causes grater ductility demand than (a) in shorter periods than one second. In both cases the ductility demand is too high in the structures, even for c_y values over 0.3, in periods of 0.6-0.3 seconds, which does not agree with the levels of damage observed in the buildings during these earthquakes.

All this may be observed in more detail when the c_y for μ =4 and η= 5% are contrasted in the case (a) with three different place of the Mendoza city in the case (b), in which case one observes the high cy values required by the buildings, even for constructions of great ductility (fig Nº 12).

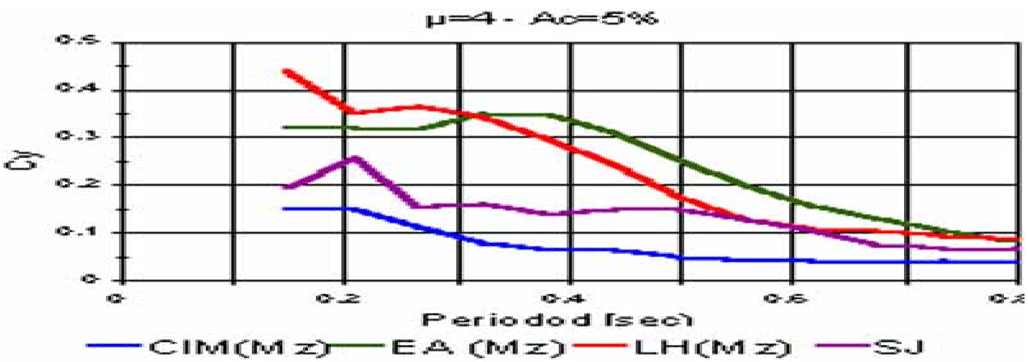

fig Nº 12

It is grateful that the structures with behavior elastic - plastic behavior are more sensitive to the duration of the earthquakes than the elastic structures, having the former a non constant behavior in the time and incremental damages regarding the effects of the plastic deformations.

If the evolution displacement - time of an SDOF with the inelastic behavior, η= 5% and 0.5 sec of the periods, is compared for (a) and (b), also indicating the times in which the system yields it is possible to see that, in (a) there are more yield six times cycles that take place than. (b), are these all distributed along its duration requiring a dissipation of continuous energy on a long period of time while in the case (b) in which the few yield cycles concentrate on the beginning of the movement, resulting in sudden burst of energy into the structure which should be dissipated immediately (fig Nº 13,14,15).

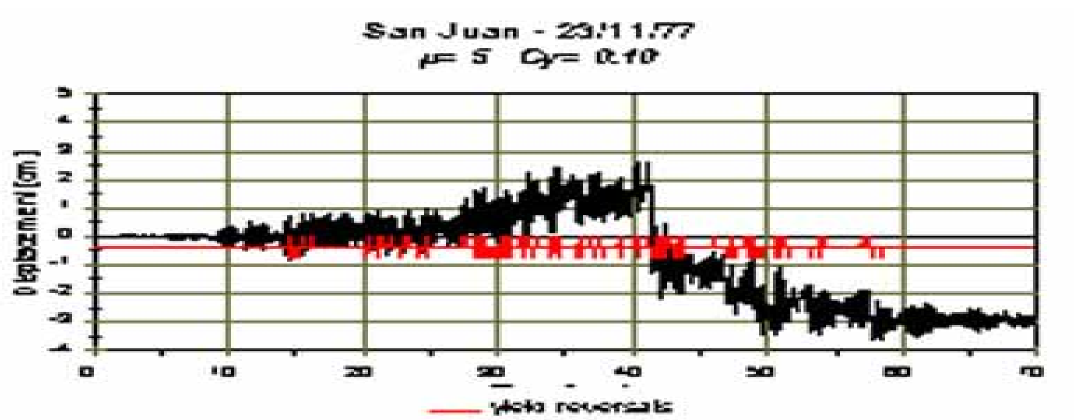

fig Nº 13

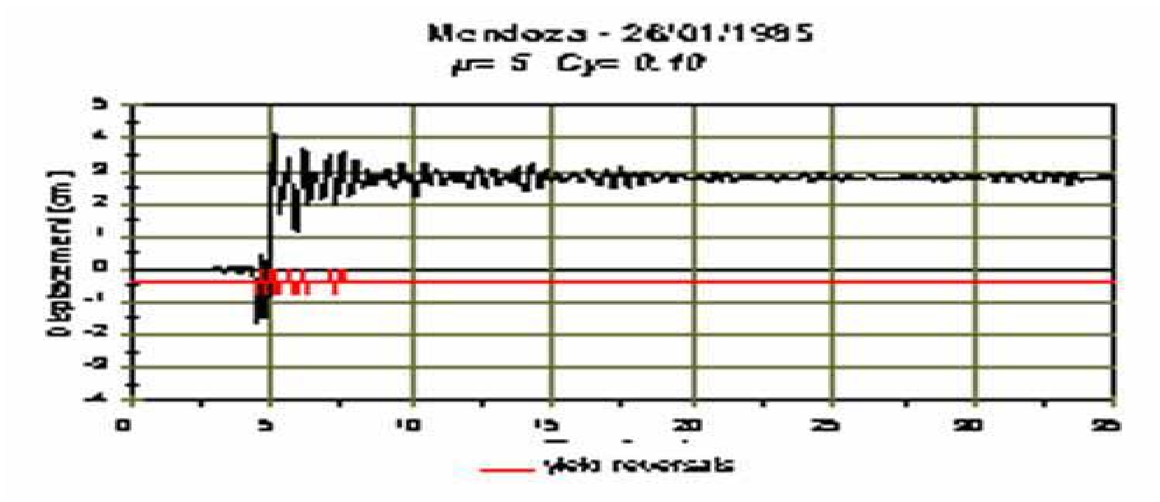

fig Nº 14

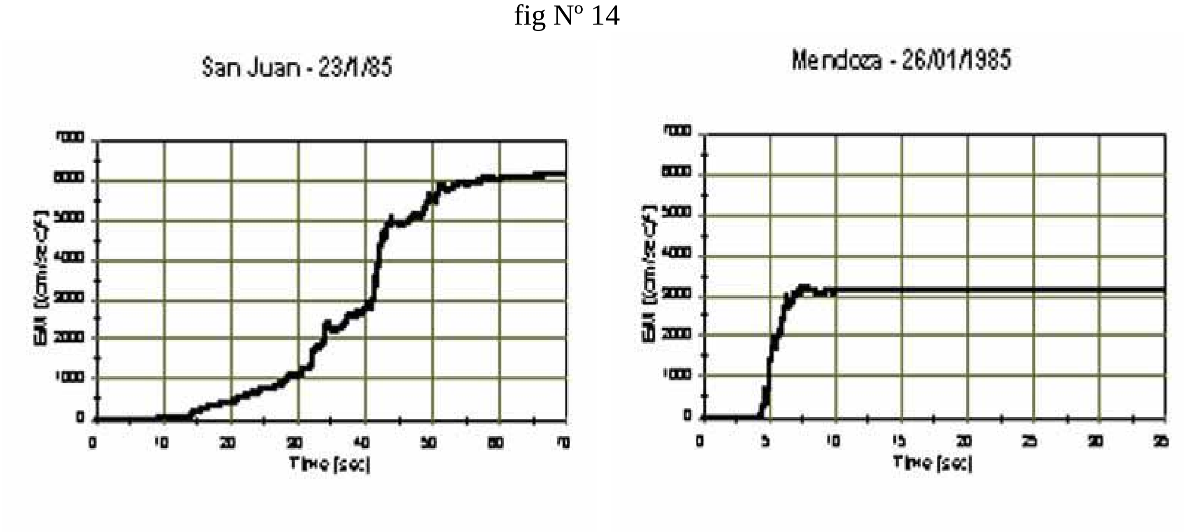

fig Nº 15

These considerations can be really kept in mind when it is considered that the effects of the ground motion on the structures are represented by the total energy input given by the earthquake, being this, therefore, one of the parameters more reliable to define the potential of damage of an earthquake.

Total energy input depends on ground motion, on particular period, on (c_y), and on the structure's accumulated ductility rate, and it is represented by the spectra of input energy.

Being the energy input the most suitable way to measure potential damage, the earthquake in Caucete was much more devastating than the one in Mendoza, except for very short period structures (fig Nº 16).

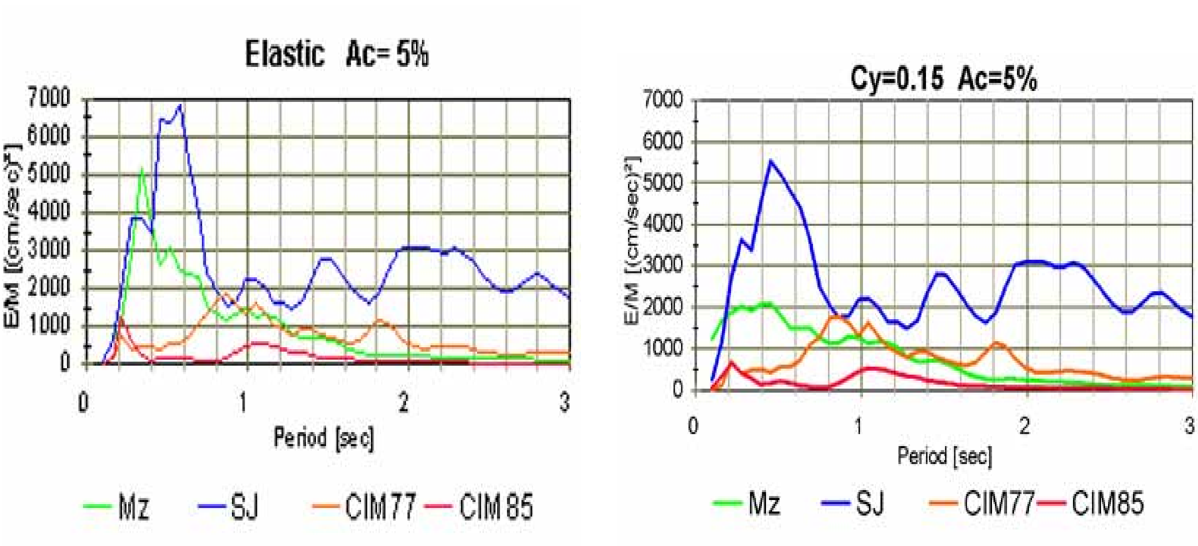

fig Nº16

CONCLUSIONS

San Juan and Mendoza, where the record data was compiled, are two of the most important capital cities in the west of Argentina. They are both in the same seismic macro-area, characterized by a compression effort régime that results from the convergence of the Nazca and South American plates. This tense régime has originated a north - south oriented active inverse fault system which is linked by other transversal secondary fault.

This seismic macro area may be divided according to shallow seismic activity associated to earthquakes that might affect, in a lesser or a greater degree, these two cities in three sub areas:

- a central area, in which earthquakes may affect both cities.
- northern and southern areas, in which earthquakes might affect only one of the cities.

Considering 200 year of the historical data, instrumental data in the last decades, as some available geologic studies, M>7 earthquakes may occur with features of (a) and (b) in the central area. However, in the northern area stronger earthquakes with (a)'s qualities may predominate, while in the south, (b)'s features are prone to be present.

Among the parameters normally used to classify ground motion severity in an earthquake, energy input spectra are considered to be the most illustrative. Nevertheless, FS and non-linear parameters provide important data about general characteristics, regardless from M and D.

In sum, it is possible to determine that type (a) earthquakes may cause greater potential damage due to their long duration of the strong ground motion, and to high energy content in range of low and high periods.
In San Juan it is possible to notice smaller energy attenuation in low periods than in other places, thus producing high values in short and long periods even for great D.

The structural ductility demands required, in these of earthquakes, is considerably elevated even for high yield resistance values. This does not match the levels of damages observed in the constructions during these earthquakes. All the information above indicates that the structures in this region present a high over strength given by non-structural elements not considered in seismic designs. It also brings to light that the ductility concept is a rather inaccurate parameter to define seismic structural behavior.

All the data presented in this paper show that not only the city center, but also the rest of San Juan province exhibit greater seismic risk than all Mendoza province.

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