SOME LESSONS TO BE DRAWN FROM THE EL ASNAM EARTHQUAKE OF 10 OCTOBER 1980

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SUMMARY

The shock which destroyed El Asnam (ALGERIE) on 10 October 1980 appears to have been of a rather unusual type, whith an extreme abruptness of the attack, a short duration and an abnormally large predominance of the vertical component. These specific conditions resulted in a number of typical failures bringing out some aspects of the seismic action generally disregarded in codes or current design practice. Indirect effects of vertical accelerations must be emphasized. The abruptness of shock may lead to responses larger than usually expected. Other problems are also mentionned.

INTRODUCTION

The two shocks of magnitudes 7.3 and 6.3 respectively which struck the region of El Asnam on 10 October 1980 may be considered to be the largest seismic event in the Maghreb for the last thousand years. The energy released in the main shock was about eight times that of the earthquake which destroyed Orléansville (the former name of El Asnam) in 1954.

One third of the city of El Asnam was composed of constructions built after the 1954 earthquake according to the provisional antiseismic code "Recommandations AS 55", or of constructions repaired and strengthened according to this code. The other two thirds were built between 1962 and 1980, but only a very small number of them were designed to resist earthquakes. The code applied to them was the French code "Règles Parasismiques PS 69" ; in a few cases other foreign codes were used.

Thus one would have thought that it would be possible to evaluate the efficiency of antiseismic codes by comparing the behaviour of the various structures. Unfortunately, it was not possible to learn as much from this experience as might have been hoped, the main reason being that the violence of the shock largely exceeded the intensity level usually taken into account in codes : the importance of the exceedance resulted in smoothing out the differences in the behaviour of the various structures with an increased degree of ramdomness. It also appears that independent of its violence the ground motion presented some specific features originating partly from the location of the town with respect to the focal zone and partly from the focal mechanism itself. We have no record of the motion in the macroseismic area, or even at larger distances, and this blank can hardly be filled. Nevertheless seismological and tectonical considerations, testimonies of witnesses and inspection of structures yield a cluster of converging indications which allowed the main features of the shock to be reconstructed. It thus becomes possible to draw some significant lessons for antiseismic construction from the El Asnam experience.

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CHARACTERISTICS OF THE MAIN SHOCK

General

It may be briefly recalled that the causative fault runs roughly from the south of El Asnam to the north of El Abadia (fig. 1) and that he contact surface is inclined at about 40° to 60° towards the NW. It worked as a compressive overthrust fault, forcing the north-western portion to creep over the south-eastern part. The length of the fault line involved in the earthquake is of about 40 km, showing displacements up to 200 and 180 cm in the vertical and horizontal directions respectively (ref. 1).

The microseismic epicenter lies at about 8 km south of El Asnam (36.09° N, 1.33° E). The macroseismic epicenter, i.e. the centre of the zone where the motion may be estimated to have reached its maximum intensity, may be located between Oum Drou and Ponteba. The focus itself was rather shallow. From studying the aftershocks, its depth may be estimated between 10 and 15 km. The compatibility of this figure with the observed magnitude implies that the energy must have been released rather uniformly all along the fault-line. In fact the isoseismal curve corresponding to the intensity X in the MMS scale appears as a very elongated ellipse sketching from El Asnam to Zeboudja (ref. 2).

From these topographic features, it may me inferred that a part of the energy has been released just below the city itself.

Predominance of vertical component and abruptness of shock

Witnesses generally described the shock as a sudden and violent vertical impulse with high frequency vibrations of a short duration, followed by a longer sequence of less intense horizontal motions of a lower frequency (ref. 1, 3).

The predominance of the vertical accelerations as compared to the horizontal accelerations was confirmed by the records of several aftershocks which show the same characteristic. It was also demonstrated by the behaviour of the structures. The inspection of buildings showed that some types of damage specific to the action of horizontal motions were found in a significantly smaller proportion than is usual, whereas there were many cases of failures which could be ascribed only to vertical forces. Case histories are discussed with more details in references 3 and 4.

This predominance does not imply that the horizontal components played a negligible part. In fact their contribution must have been quite decisive : due to the suddenness of the attack and the nearness of the focus, the maximum responses in the horizontal and vertical directions must have been separated by only a short time interval. There is practically no example of a failure obtained through the repetition of a number of cycles of an increasing amplitude, with plastic hinging. On the contrary collapses generally appear as the consequence of brittle failures favoured by the abruptness of the initial impetus.

The abruptness of the attack is also demonstrated by the behaviour of two masonry infill panels which remained visible in the ground floor of a school two storeys high which almost entirely collapsed. Under the effect of the shock a diagonal strut was formed in each panel as shown in figure 3 but the upper storey collapsed before the oscillation in the reverse direction could create a second strut along the other diagonal.

Discussion

In spite of their specificity, the characteristics described above do not contradict our knowledge of earthquake motion in general.

The release of the larger part of the energy in a shock of short duration with high peak accelerations seems to be a rather common feature of shallow earthquakes especially in the Maghreb (cf Orléansville - El Asnam 1954, Bougainville - Sanjas 1957, Bou Medfa 1959, Melouza 1960, Agadir 1960). In the present case the fact that the causative fault was a compressive overthrust fault with a largely inclined contact surface could only favour such a trend.

Short durations associated with high accelerations values are rather frequent in the West-Mediterranean area, even in the case of a rather deep focus (cf Friuli, Italy 1976:focal depth 24 km). In fact, for a given value on the intensity, the southern Europe earthquakes show peak ground accelerations substantially larger than the Pacific ones (ref. 5). The destructiveness of the first ones is a consequence the high level of accelerations they rapidly reach, while the second ones mainly act by sustaining their action for a rather long while. This may have consequences for the design of structures.

With regard to the vertical component, it is generally accepted on the basis of a global statistical estimate that its peak value is, as a mean, 55 to 65 % of the horizontal one. In fact, it has been recognized that the focal mechanism could strongly influence this ratio (ref. 6). The local tectonics seem to play also some part as suggested by the record obtained in Ulcinje (Montenegro 1977) which shows a vertical acceleration of 0.49 g against 0.30 g in the horizontal direction. In the case of El Asnam these trends may have been amplified due to the location of the city just above the zone of energy release. There are some hints that in El Asnam the vertical acceleration may have reached loccally values very close to 1 g, while the horizontal one is estimated to 0.20 - 0.25 g. These figures may be compared with those recorded in El Centro, array n° 6, at a distance of 1,25 km from the fault, during the Imperial Valley earthquake of 15 Octobre 1979, where the vertical component reached 1.75 g while the horizontal acceleration did not exceed 0.5 g.

BEHAVIOUR STRUCTURES AND CONSEQUENCES FOR DESIGN

Detailed damage reports can be found elsewhere (e. g. ref. 7). It is worth noting that, though they were designed for an intensity level much lower than the level actually reached on the site, most of the low-rise buildings built according to the old rules of 1955, or even repaired and strengthened after the 1954 earthquake, survived. Shear wall structures designed according to some antiseismic code resisted the shock pretty well, many often with no damage or with negligible damage. Structures with reinforced concrete frames showed a less satisfactory behaviour, especially through brittle failures. In fact, due to the special characteristics of the ground motion, they were in quite critical conditions.

On the importance of vertical component for structural behaviour

The part played by the vertical component is neglected in most codes. It is generally admitted that the margin of safety structures usually present with respect to normal vertical loads is sufficient to cover its effects. It seems that this simplification is not always permissible, even in the case of rather simple constructions.

It must be emphasized tha the vertical components an dangerous through their indirect effect, i.e. the unfavourable influence they have on the resistance and ductility of structural elements acted upon by lateral forces. In the case of a r.c. column for instance, it may easily be seen on the classical interaction diagram that the safety with respect to flexure may be affected by an increase or a decrease of the axial load. It is also recognized that an increase of this load adversely affects the ductility of the element. The most important point is perhaps that the reduction of the axial load may drastically reduce the shear strength. Due to the large values reached by the vertical accelerations, these effects have been made quite sensible in El Asnam, especially in buildings of the type described below.

Reinforced concrete frames with masonry infillings

Buildings composed of r.c. frames with masonry infillings are a type of construction widely used throughout the world. Infillings are generally taken into account in the resistance to lateral forces from wind or even earthquakes. The classical pattern used in this case is recalled in figure 2 a : it is generally admitted that the infill panels contribute to the resistance to lateral forces by developing diagonal struts which transform the concrete skeleton into a trussed vertical cantilever.

There was a large number of buildings of this type in El Asnam. Many of them systematically collapsed in the way shown in figures 4 and 5 : the ground floor columns failed in shear at their upper end and the block of the upper storeys fell down between the columns. Though they were not designed to resist earthquakes, much can be learnt from their behaviour, as it may be thought that usual aseismic design would not have prevented their collapse.

The reasons for such catastrophic behaviour were two :

a) The classical pattern described above implicitely pustulates the indeformability of panels. In fact the full reaction of a diagonal strut can be developed only through an important shortening of the strut and a non-negligible deflection of columns (fig. 2 b). This results in additional bending moments and a ductility demand much larger than expected in the design. Unfortunately the experimental data now available are insufficient for providing the designer with rules allowing for the calculation of deformations.

b) Each strut develops at its upper end i) a horizontal thrust tending to shear the column end ii) a vertical thrust tending to reduce the axial load. This vertical force is only partly compensated by the downwards thrust from the upper storey, so that there is a cumulative effect from top to bottom resulting in important uplifting forces. These forces may be very large in edge or corner columns, where no compensation exists. As these columns carry normal gravity loads much lower than the central ones, the intervention of additional uplifting forces coming from the vertical component of the ground motion, even if the maxima do not occur at the same time, is quite critical in their case : the residual axial load may be very small and the resistance to shear considerably reduced.

These effects are even more sensible in columns with panels at right angles. In this case the two horizontal components combine their action : the two shear forces are combined geometrically, but the uplifting forces are added arithmetically, so that the three-dimensional aspects of the ground motion cannot be ignored. This last remark raises also the problem of the evaluation of the resistance of r.c. members to bi-axial shear : due to insufficient experimental data, no satisfactory method can be proposed to the designer in this field.

Response of structures to motions with strong initial impetus

The response of structures is computed taking into account an equivalent viscous damping defined by some fraction of critical. This ratio, estimated as a mean value, is assumed to be a constant during the whole motion. In fact, damping varies with amplitude, so that the design damping is over-estimated in the very first phase of the motion. This over-estimation may have consequences when the amplitude, instead of reaching more or less progressively values large enough to allow the expected amount of energy dissipation to take place, immediatly reaches a high magnitude before complete significant cycles can be described.

In fact, it is very likely that in the case of short duration earthquakes with a strong initial impetus, the actual response is larger than computed on the basis of damping values normally used. Some research seems to be necessary to clarify this point.

Effects of local geology and topography

The commercial centre "Nasr" failed through frame-masonry interaction effects as described above. However in its case local geology and topography played some part through ground motion amplification. The site was bordered on one side with a very steep slope and retaining walls several meters high, and along a diagonal axis, soil layers had been altered by underground water circulation. From aerial pictures 6 and 7 taken before and after the quake, it may be seen that blocks located above altered layers or along the edge of the slope failed, whereas blocks located on firm ground away from the slope did not collapse, even during the second shock.

Construction joints

Codes specify rules for width of construction joints in order to avoid hammering of adjacent blocks. Figure 8 gives an unexpected illustration of the consequences of a deficiency with this respect : two blocks of a building were arranged in an L shape. Due to this special configuration, when the blocks hammered, the translational motion of the block B was transformed into a rotational motion resulting in the total collapse of the block. Larger joints widths should be provided when such consequences are possible.

CONCLUSIONS

The main conclusions which can be drawn from the experience of El Asnam are as follows :

1. Our knowledge of the characteristics of the West-Mediterranean earthquakes is insufficient. The existing network of strong-motion accelerographs should be densified.

2. Research should be performed in order to provide a better understanding of the behaviour of structures with respect to abrupt short duration shocks.

3. The three-dimensional aspects of the ground motion especially with respect to the vertical component should be considered.

4. The problem of interaction between masonry fillings and concrete frames, and especially their deformability properties should be more thoroughly investigated in order to provide the designer with appropriate data. The problem of the resistance of r.c. columns to bi-axial shear should also be clarified.

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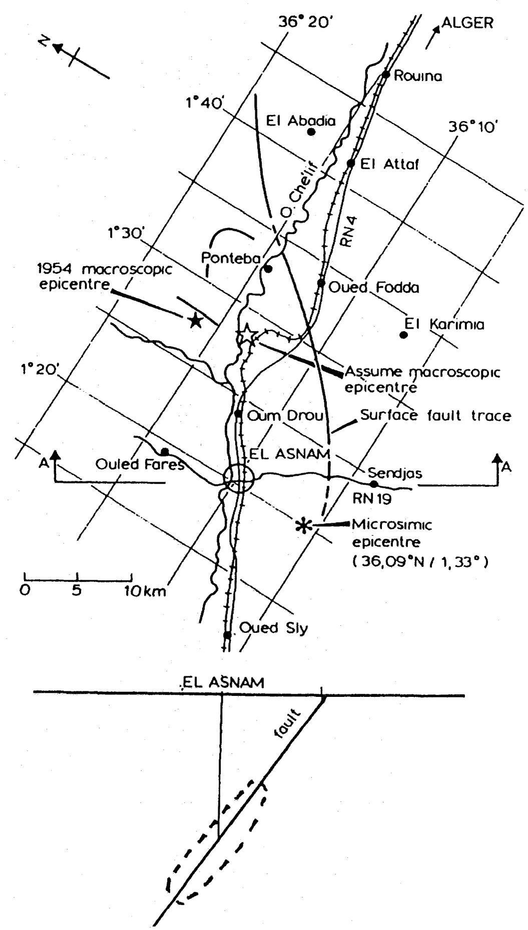
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Rouina
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El Attaf
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Surface fault trace
EL ASNAM
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Ouled Fares
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A
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(36,09°N / 1,33°)
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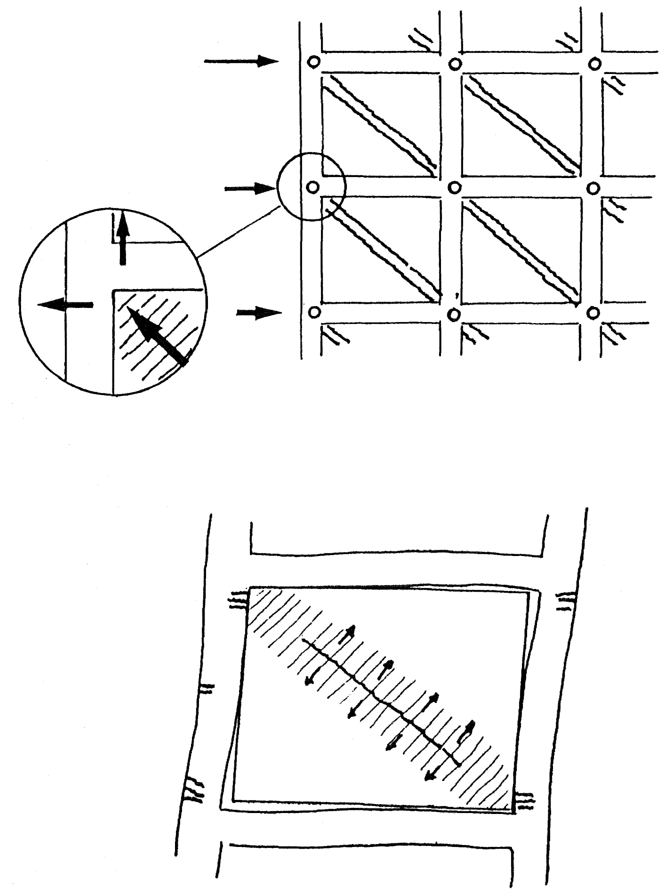
Fig. I



a

b

Fig. 2

Fig. 1

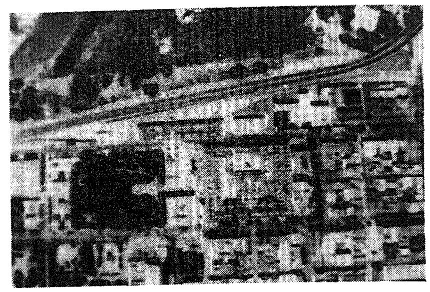
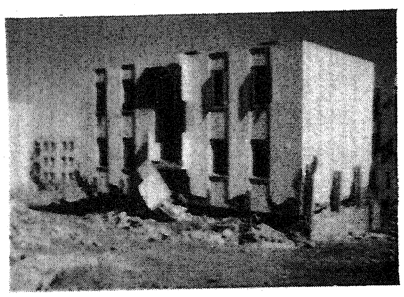


Fig. 4



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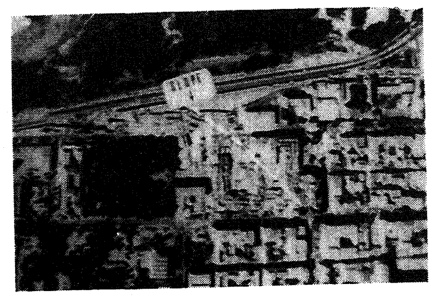

Fig. 5

Fig. 3

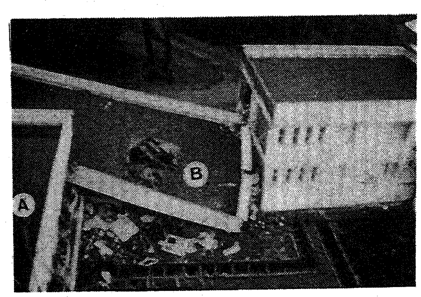

Fig 6