Chapter II

Macroseismic data from field studies

1. Extent of field studies

There is a great difference between macroseismic and instrumental seismology. Instrumental seismology deals with what happened during the shaking, whereas the macroseismic seismology is interested in the effects of what happened. Also, very often but depending on various factors, the instrumental data can be precise and accurate while the macroseismic information is able to make definite and exact measurements of the impact of the ground motion upon man-made structures, humans and on the ground itself. The impact of destructive earthquakes on the environment constitutes a multi-disciplinary model which may reveal important and useful findings in the respective domains of the geologists, seismologists, engineers, architects, archaeologists, sociologists as well as the emergency planners (administration, police, army, health organisations, ... etc.). The complexity and the multitude of effects produced by destructive events cannot be studied, at the present time, on the theoretical basis only. Thus, the necessity for efficient macroseismic observations to both theoretical and practical needs. The former arises from the fact that macroseismic field works permit one to collect spatial information which it is otherwise not possible to obtain from instrumental seismology. The latter need constitutes a direct measure of the interaction between the environment and damaging earthquakes. Various authors involved in the problems of field investigations of earthquakes for more than thirty years (Ambraseys, 1971, Vogt, 1979, Ambraseys and Melville, 1982 and Ambraseys *et al.*, 1990) have refined a multi-disciplinary data acquisition and analysis methodology.

The long experience of these scientists has shown that real progress in understanding the earthquake phenomena can only be achieved by the consideration of both instrumental and macroseismic data. For instance, it is only in this way that knowledge about liquefaction, faulting, earthquake-induced landslides and rockfalls as well as damage can progress. Also, the efficacy of new aseismic design and construction methods can be really effectively tested only after a destructive earthquake. For example, the earthquakes of El-Asnam (1980) and Chenoua Mount (1989) are among the best examples in the region showing the deficiency of the Algerian seismic protection measures. As elsewhere, the development of aseismic building codes has always been influenced after a destructive earthquake, and where the macroseismic observations have also played a very important role. Macroseismic studies are very useful for characterizing with a certain degree of efficiency and reliability the interaction between destructive earthquakes and the whole environment and thus seismicity, hazard and risk. Complete macroseismic and instrumental surveys of destructive events provide a fundamental tool for the mitigation of future seismic disasters by recommending ways of improving local construction procedures, building materials, layout and implantation of new urban and rural sites. As in other domains, the entire social and economic impact of the event may also be investigated directly in the field, in order to avoid any deformation of the true picture due to the prevailing circumstances in the region.

2. The impact of earthquakes on the Maghreb building stock

The distribution and characteristics of the building stock are considerably influenced by the historical development of the region. Therefore, the structures may be separated distinctively with respect to the different historical periods of the Maghreb region.

Field observations in destructive earthquakes in the region have shown the degree of fragility and facility with which the structures and particularly those of local traditional construction are damaged or simply destroyed. Because of their agricultural vocations, Maghreb countries are rather rural residential areas; even today, more than 60 percent of the population live in small scattered villages and douars. Figure 1 shows the evolution of rural housing up to 1970. For instance, in Algeria, the urban population represented only 13.9 percent of the whole population in 1886 and 49.67 percent in 1987 (Armature Urbaine 1987, 1988). Generally, apart from the official buildings, industrial plants, high rise apartment blocks and villas and public work constructions, most of the old housing units are of adobe, mud-straw, mud-reed, iron sheets, drystone or unreinforced masonry bearing walls structures. These buildings can be divided with respect to different historical periods of the Maghreb and to their type of structure into the following categories:

1) local traditional native housing (gourbis) which is still predominant in certain regions. Most of them were built during the colonization period (1830-1962);

2) non-engineered ordinary masonry and reinforced concrete structures were built during and after the colonization period, up to 1975. Many of them are 100 years old;

3) engineered modern structures are generally built from 1975 onwards.

Besides these distinctive types, there is a wide range of self-built residential constructions, very often of mixed materials, which are not easy to classify.

Constructions of the first category are mainly local traditional drystone, mud-sun-dried brick or mud-straw dwellings which were prevailing in the region up to 1970. These housing units are separated into gourbis and houses which may be permanent or temporary. The gourbi is a rough construction composed of one isolated rectangular room, whereas the house is constituted of 2, 3 or 4 rooms which generally open to a closed courtyard, and is built with more care (fig. 2.). Their walls, badly joined and not tied together by any means, present a very low strength to earthquake forces. The roofs of these constructions are generally built of mud layers of 10 to 15 cm thick which lie on a bed of branches of jumper, tamarisk, rose laurel, on reed and sometimes on straw or herbs. This roofing system is supported by a ceiling of beams which simply rest on the walls. Roofs are generally flat, because they are also used as additional space for sleeping in the summer season and for drying crops, but some of them have single or double panels covered either by diss (Ampelodesmos tenax), tiles, or iron sheets. This kind of building, which is characterized by low strength free walls and heavy roof, is highly vulnerable to earthquakes, and even to heavy rains. These gourbis or houses, built in clusters, form the so-called douar, and are separated by winding narrow alleys. Many of these douars have been seriously damaged during past earthquakes and thus have been repaired more than once. A large number of them collapse each year without the help of an earthquake. Heavy rain causes tremendous destruction to these local types of houses each year, even today, in Algeria (Cheliff region, 1991 and Guelma, 1992)

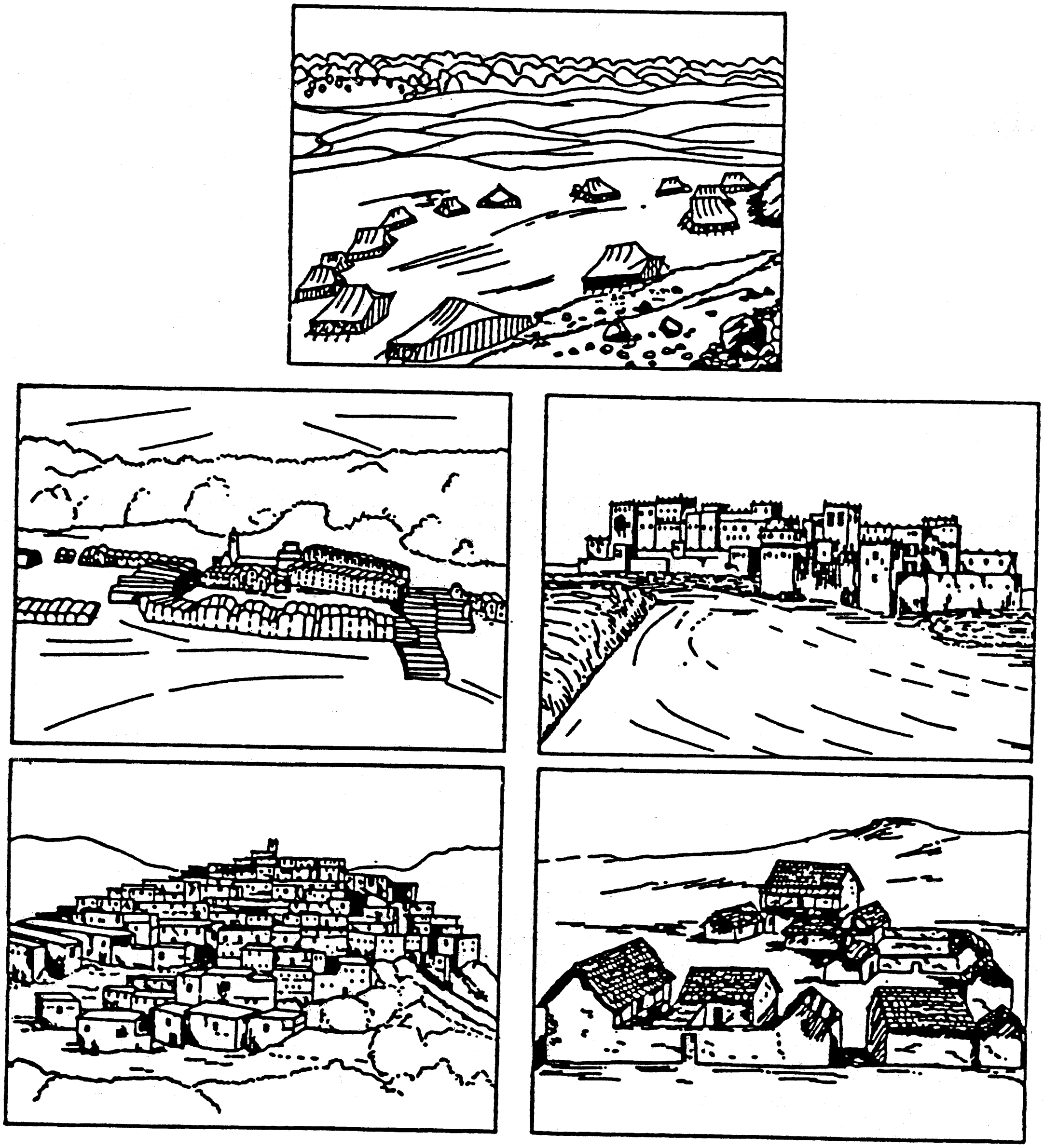

Fig. 1. The evolution of rural housing in the Maghreb region up to 1970.

and also in Tunisia (Sidi Bouzid region, 1990). The low resistance of these housing units to rain is evidence of the weakness of the structure. For instance, the heavy downpour that preceded the M'Sila (Algeria) earthquake of 1 January 1965 caused major damage to several dwellings in the region. Quite often, the association of earthquake with rain has influenced ground motions through saturation of foundations.

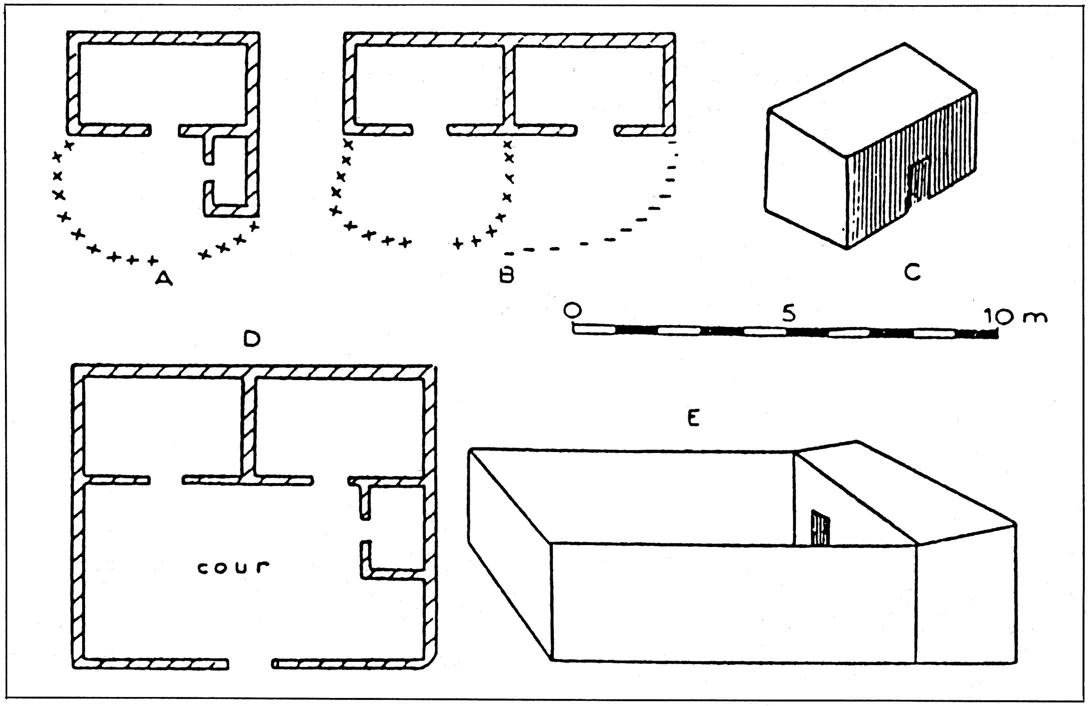

Fig. 2. Structures of gourbis and houses in the Maghreb region: A, B, C show different types of gourbis, and D and E show a house of two rooms opening in a courtyard.

The second category consists mainly of non-engineered masonry and reinforced concrete structures built during the French period and up to 1975. This type of building is characterized by thick walls of burned bricks or concrete blocks, heavy floors and tile roofs. Floors and roofs of stone or masonry structures rest on joists of timber, which in turn are simply embedded a few centimetres into the wall masonry, opposite walls were not tied to each other, which facilitated the destruction. Typical buildings consist generally of two way reinforced concrete frames with three metre modules. The floors are composed of hollow precast elements with a four to five centimetres thick overtopping reinforced concrete slab cast in-situ. The resulting slab of the floor is about twenty centimetres thick. Interior and exterior walls are generally built of hollow precast concrete blocks or burned brick infills. The main characteristic of these buildings is that they are commonly elevated from the ground floor on pilotis for official buildings, and sometimes housing, while apartment blocks are built upon a short «crawl space» supported by stubby columns. This «crawl space», which is used for water, gas, sewage pipes as well as vertical ventilation shafts, is called the sanitary void. On this typical structural configuration, lateral loads are transmitted by the first slab, which acts as a diaphragm to these one metre high columns, which are generally 25 × 25 cm in cross section. This method of construction, which is still widely used, is in many cases the direct cause of the destruction of numerous buildings.

Constructions of the third category, which represent only a small portion of the total building stock, are supposed to be built in conformity with the aseismic design and construction regulations (AS 55 and PS 69, France, RPA 81 and RPA 88, Algeria). Most of these buildings are built from 1975 onwards; they are reinforced concrete structure frames with hollow burned bricks, concrete blocks or reinforced concrete panel infills. Although, the first French seismic code was introduced in 1955, shortly after the Orléansville earthquake of 9 September 1954, only a few structures were really designed according to these regulations. Almost all buildings built in Orléansville after 1954, which were assumed earthquake resistant according to AS 55, were severely destroyed during El-Asnam 1980 earthquake (see El-Asnam 1980 earthquake study in Appendix B). It was only after 1980 that reinforced concrete shear walls were introduced in the Algerian buildings. The floors are either built with precast reinforced concrete shallow beams supporting hollow precast elements or with reinforced concrete slabs cast in-situ. The foundation systems consist of footings tied to beams of 45 to 55 cm deep or general raft. Constructions with «soft storey» and «sanitary void», which were proved to be the main cause of extensive damage in scores of buildings in past earthquakes, are still being built.

We should keep in mind that many constructions of the first two categories in the whole region have suffered considerable degradation through ageing, past earthquakes, rain and, particularly, neglect and lack of proper repairs. As a consequence of the weakness of the constructions in the Maghreb region, the degree of damage is an indication of the defects in design and construction rather than the severity of the ground motion, as experienced, for instance, during the Agadir 1960 earthquake. Even modern buildings newly and relatively better built have shown little extra resistance during the Constantine 1985 and Chenoua Mount 1989 earthquakes. In reality, introducing new construction materials and procedures without an adequate aseismic building code and the implementation of its regulations may only produce a new type of vulnerable structure.

3. Re-evaluation of intensity

Intensities are re-assessed anew with reference to the Medvedev-Sponheuer-Karnik – MSK – (1981) intensity scale, using standard criteria (Medvedev *et al.*, 1981) and macroseismic data retrieved from various sources mentioned in the previous chapter.

Destructive earthquakes in the Maghreb region and elsewhere have always caused substantial damage and/or total collapse to all adobe and unreinforced masonry bearing wall constructions. These structures have shown a high vulnerability and very low and variable resistance to seismic forces, and even to heavy rain. As a result of their weakness, maximum intensity in any destructive earthquake in the Maghreb countries seems to saturate; that is, at intensities IX or less on the MSK intensity scale, all adobe houses (gourbis) and unreinforced structures are destroyed and thus any douar or hamlet would be equally, but no more, devastated at higher intensities of the scale. Particularly, during the first half of this century, higher intensities can be adequately assessed only from the damage to colonial structures such as administrative centres, villages, military posts and European farms. From the 1960's, most new constructions in the so-called remote areas (douars) are built of burned bricks or concrete blocks, and in cities and villages the buildings are modern structures of reinforced concrete and steel. Because the building stock in the Maghreb countries has numerous variable characteristics such age, building materials and structural systems, an extensive investigation was carried out in order to reveal what type of constructions were exposed and what state they were in during each earthquake during the period under survey. The results of the building stock analysis were added to the macroseismic information already collected, thus allowing a re-assessment of intensities with an appreciable degree of reliability. It was found that the degree of destruction of a local traditional dwelling is generally associated with the weakness of the structure. Due to certain particularities in the construction materials and procedures in the Maghreb, as in the Middle East, the assessment of intensities poses some significant problems. Intensities re-assessed for many events in this study present some important differences compared to those assessed by other authors, particularly when intensities were assigned by seismologists from questionnaires and press reports, without field study. For example, the Carnot earthquake of 7 September 1934 has been considered one of the largest earthquakes in the Cheliff Valley this century. In a macroseismic study, Hée (1936 a,b) assigned a maximum intensity of IX on the Mercalli-Sieberg scale but, in reviewing the original source data (this work) combined with prevailing building stock characteristics, we find that the maximum intensity that can be attributed for Carnot does not exceed VII MSK.

Macroseismic data on recorded effects of past earthquakes in the region under study, used in re-evaluating intensities, were obtained from published and unpublished documentary sources, though only published materials are listed in the references. The main problems are the correct interpretation of the written accounts according to the historical context of the period concerned. Certainly exaggerations exist in the sources, usually made to attract more attention to documents, but these are not very difficult to discover, particularly when there is more than one source. The contribution of illustrative photographs in the damage survey is noteworthy. Also, the experience acquired in analyzing the historical information, the style of the statement, together with the predominant political and economic conditions, all cooperate in the reconstruction of a good descriptive picture of the event as a whole, and particularly the effects of interest in assessing intensities. For instance, reports such as «...the city was completely destroyed by a strong earthquake which made most of the inhabitants homeless» should be studied with great care. This statement suggests that the earthquake was not all that catastrophic. Therefore, written accounts should always be considered in their historical context and particularly concentrating on important factors such as the density of the population and building stock conditions.

In this study, the effects due to landslides, rockfalls and soil failures, which very often added to the damage observed, are often used as a criterion for the assessment of intensities. In fact, many douars in the region, built on steep slopes, have experienced almost complete destruction either by landslides of the flank of the mountain on which they were built, sliding of the ground under their foundations or from rockfalls (example: Kherrata earthquake 1949 in Appendix B). These secondary effects cannot be taken alone in assessing intensities since they may be produced by strong or slight shakings, or even by rain falls. Along the Atlas mountains, landslides and rockfalls occur, often in regions of unstable relief, with or without the assistance of earthquakes. In Algeria, landslides and rockfalls from the flanks of mountains in the regions of Kherrata, Blida and Medea, for instance, are frequently produced only by heavy rain.

4. Location of macroseismic epicentres

The location of macroseismic epicentres is of great value, in terms of tectonic feature determinations, particularly during the first half of this century when instrumental data were still unreliable.

Macroseismic information provided by the available source documentary materials usually allows a relatively accurate location of the epicentral area. It is noteworthy that even where there is no significant damage at any one of the diverse sites reported to have been touched, the location of the epicentral zone may be appraised quite well: as where a shock of small magnitude was felt within a relatively limited area, any instrumental location of the epicentre will give errors much larger than the average radius of the highest isoseismal. During the early 1900's, in some cases, the determination of epicentral location is less accurate from instrumental data than from macroseismic information (Ambraseys, 1978). For instance, using all the locations at which the Ben Chabane earthquake of 5 November 1924 caused damage (see report in Appendix B), the macroseismic epicentre has been determined at 36.64°N, 2.91°E compared with the International Seismological Summary (ISS) instrumental epicentre at 35.3°N, 3.5°E giving a location error of about 160 km. The same instrumental data processed by the present location procedure at the International Seismological Centre (ISC) give an epicentre at 36.6°N, 3.0°E which is only at 11 km away from the macroseismic epicentre. For events with relatively large felt areas, the identification of sites which experienced significant damage, and thus the delimitation of the epicentral zone, is generally determinable, except in remote or sparsely populated regions across the Atlas mountains. The determination of macroseismic epicentre locations has been carried out according to that developed for the investigation of the seismicity of Iran (Ambraseys and Melville, 1982).

5. Conclusions

Field studies constitute a fundamental mean for characterizing with a certain degree of reliability the interaction between destructive earthquakes and the whole environment and thus seismicity. They provide useful means for the reduction of future seismic disasters by improving local and regional aseismic building codes, land use management, emergency planning and advancing our theoretical knowledge about earthquake phenomena.