Seismic Vulnerability Assessment of the Old Casbah of Mostaganem City – Algeria-

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SUMMARY:
Located 320 km to the west of the Capital Algiers, Mostaganem city has witnessed during the last century several natural disasters, among them the flooding of the Ain Sefra River, a day of November 26 of 1927 that represents the most devastating event, with more than 150 dead and several destroyed houses
The city which encompasses two old casbahs constructed during the Othman era represent a valuable cultural, architectural and societal heritage. Not far from a well known seismotectonic active regions, the city of Mostaganem is a prone seismic region of moderate to high seismicity. In order to preserve the cultural heritage of the city, the vulnerability assessment of the old Casbahs of Tigditt and Derb Tobanna has been performed.
Based on a modified vulnerability index method using the Benedetti approach, the building damage assessment has been carried out on the most representative old masonry buildings, having the same constitutive materials, structural systems, and considered to be built during the same period.
The findings of this study showed than more than 75% of the buildings stock might experience a heavy damage during a moderate earthquake level. In this respect, it is necessary to take significant and practical steps to reinforce and rehabilitate this cultural heritage of the city in order to reduce the seismic risk in the city.

Key words: building damage assessment, vulnerability index method, Casbah of Mostaganem

1. INTRODUCTION

The city of Mostaganem is located about 320 km to the west of the Capital Algiers. The city is not only known by its magnificent sand beaches that attract hundred thousand of tourists and visitors yearly, but also by the old roman vestige and the historical and cultural monuments built during the whole history of the city.

When you visit Mostaganem, you may certainly come across Tigditt Casbah or Derb Tobbana Casbah, which are two urban nuclei that represent the heart of the ancient town. Both of the Casbahs were built along the Ain Sefra River. The Casbah of Tigditt built in the northern east along the river symbolizes the nevralgic centre of the ancient Capital Dahra, while the Casbah of Derb Tobbana whose name states for “Toppanna” which means “Canon” was built on the opposite side of the river and represents the garrison installed by the Ottoman to protect the town during the Spanish conquest, and prevent the terrestrial access to Algiers.

Both Casbahs encompass several historical, architectural and cultural heritages. The districts were urbanized according to a well known Islamic concept around three principal axes; 1-the great mosque, the central market, 2- residential area, public bathes, mausoleum and 3- the city rampart and donjons.
As an illustration, one may name the great mosque built during the Merinides era in the 13th century, the five old ramparts of the city built during the Medieval and the Ottoman era, or the old palace of Bey Mohamed El kebir built in 1752.

Because of its seismotectonic setting along the margin of the African plate, the northern part of the Algerian territory has experienced during the past century, a series of moderate to heavy earthquakes, which caused severe human losses and casualties, disruption and economic losses.

The city of Mostaganem located in the northern part is a prone seismic region of moderate to high seismic activity according to seismic zoning of the RPA 99-version 2003 as shown in Figure 1.1.

The city full of archaeological sites and historical monuments as illustrated in Figure 1.2, represent indeed, a valuable architectural, cultural and societal heritage, which should be preserved in order to maintain alive the memory of the region and of the ancient inhabitants.

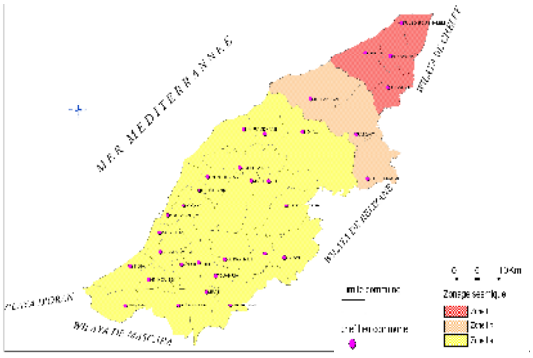

Figure 1.1: Seismic zoning of Mostaganem city

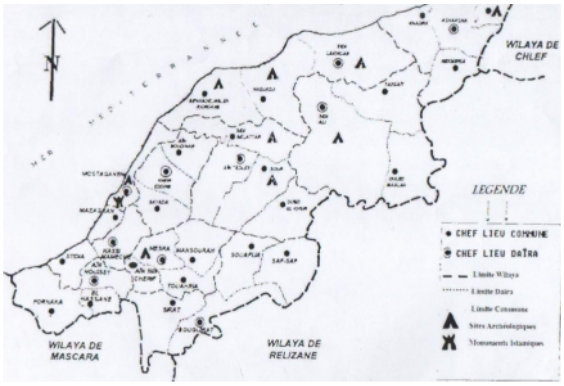

Figure 1.2: Archaeological and historical monuments in Mostaganem city.

In this respect, the seismic vulnerability assessment of the old Casbahs of Mostaganem city was carried out using the vulnerability index method. The study was mainly conducted on the most representative residential and cultural old masonry structures which represent the large building stock of the Casbahs, in order to assess the possible damage during the occurrence of a seismic event of moderate to high intensity.

2. METHODOLOGY FOR THE ASSESSMENT OF THE SEISMIC VULNERABILITY

Methods to assess the seismic vulnerability of an urban nuclei or buildings fall generally in to two categories; the empirical methods and the analytical/mechanical methods.
The seismic vulnerability assessment of buildings at large geographical scales has been first carried out, through the employment of empirical methods initially developed and calibrated as a function of macroseismic intensities. They are of two type based on the damage observed after the earthquakes, 1) the damage probability matrices (DPM), which express in a discrete form the conditional probability of obtaining a damage level j , due to a ground motion of intensity i , 2) the vulnerability functions, which are continuous functions expressing the probability of exceeding a given damage state, given a function of the earthquake intensity.

To overcome some of the drawbacks of the empirical methods, recent proposals have made use of computational analyses. It is not the scope of this paper to go through an extensive literature review of all available approaches, but one may name two as an illustration; 1- Singhal and Kiremidjian (1996) developed fragility curves and damage probability matrices for three categories of reinforced concrete frame structures using the Monte Carlo simulation. 2- Rossetto and Elnashai (2005) constructed adaptive pushover curves of European buildings and applied the capacity spectrum methodology to obtain the performance point which was then correlated to a damage state through a damage scale calibrated to experimental data.

In the framework of this study, the vulnerability index method developed by Benedetti and Pertini, 1984 is used in order to assess the seismic vulnerability of the two old Casbahs of Mostaganem city. The main features of this approach are described in detail in the next section.

3. VULNERABILITY INDEX METHOD

The "Vulnerability Index Method" developed by Benedetti and Petrini, 1984 has been used extensively in Italy in the past few decades. It is based on a large amount of damage survey data, where a relationship between the seismic action and the response is established through a 'vulnerability index'. The method uses a field survey form to collect information on the important parameters of the building which could affect its vulnerability: for example, plan and elevation configuration, type of foundation, structural and non-structural elements, state of conservation and type and quality of materials. There are eleven parameters in total, which are each identified as having one of the four qualifications coefficients K_i, in accordance with the quality conditions – from A (optimal) to D (unfavourable). Each parameter is then weighted with W_i to account for their relative importance. The global vulnerability index of each building is then evaluated using the following formula:

$$I_v = \sum_{i=1}^{11} K_i W_i \qquad 3.1$$

The vulnerability index ranges from 0 to 450, but is generally normalised from 0 to 100, where 0 represents the least vulnerable buildings and 100 the most vulnerable.

4. SEISMIC VULNERABILITY ASSESSMENT OF THE OLD CASBAHS

As stated above, the city of Mostaganem is full of archeological sites and monuments that bear witness of the important role played by the city over its long history.
The old Casbahs of Tigditt and Derb-Tobbana sit on a total area of 60 ha, where 50 ha are located in Tigditt and the remaining in Derb-Tobbana. According to the official statistical survey, the historical monuments sit on a non negligible area of 9.51 ha in Tigditt, which encompasses mosques, Islamic schools, public bathes, palaces, mausoleum, etc and an area of 2700 m^2 in Derb Tobbana. Some of these monuments depicted in Figures 4 are considered of an important cultural and societal heritage.

Figure 4.1: the Great Mosque

Figure 4.2: Mausoleum

Figure 4.3 : Public bath

Figure 4.4 : City rampart

Figure 4.5: Dar Laid Palace

Figure 4.6: Aïssaoua Zaouia

In order to assess the seismic vulnerability, a sample of 105 building houses was chosen in Tigditt and Derb-Tobbana Casbahs, most of them are of residential type. The two districts depict typical traditional Arabo-Mediterranean houses that reflect a total fusion between the ancient Arab lifestyle, the Islamic customs and the architectural traditions.

The classical structural system of the residential masonry houses consist of untied bearing untrimmed stones walls, with lime-stone mortar, as illustrated in Figures 4.8 and 4.9. The structural walls bear only the gravity load and do not offer any lateral resistance to the seismic force. The floor slab consists of a non rigid diaphragm made either with arch hollow brick masonry and metallic girders as in Figure 4.10, or wooden girders arranged in the longitudinal or transversal direction as shown in Figure 4.11.

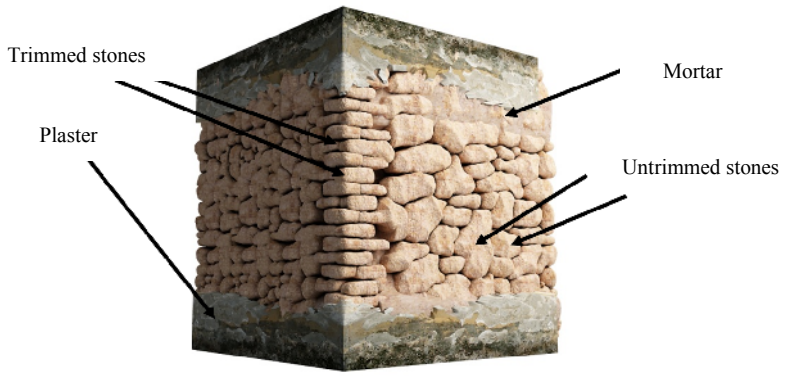

Figure 4.8: Corner tie of two walls

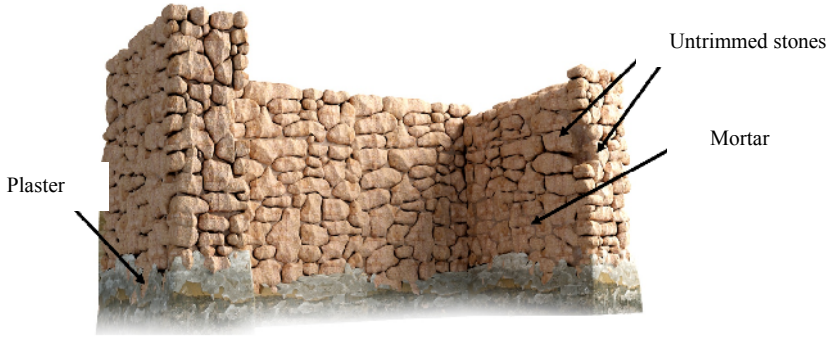

Figure 4.9: Typical external masonry wall

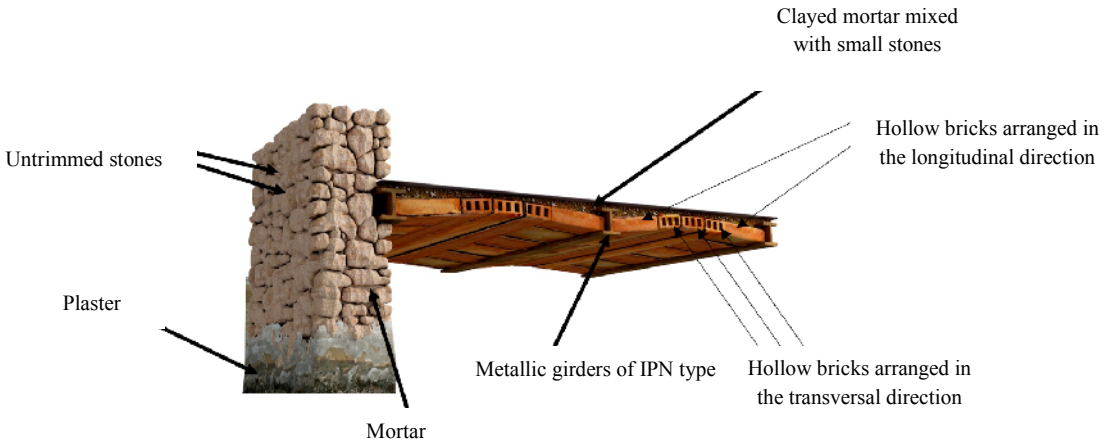

Figure 4.10: Arch brick masonry - metallic girder floor slab

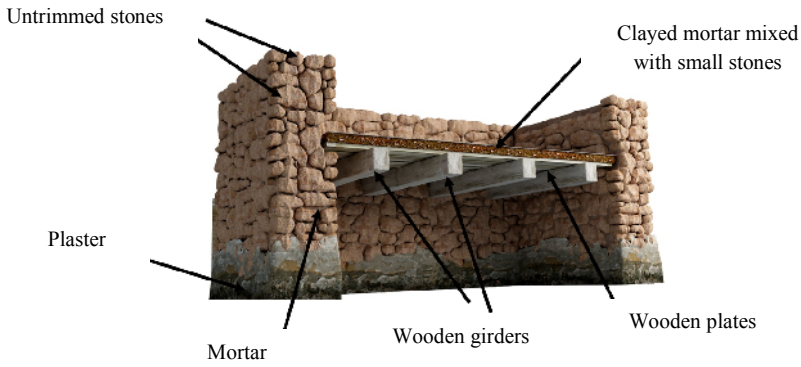

Figure 4.11: Wooden girder floor slab

To perform the seismic vulnerability assessment of the residential buildings, the data needed have been gathered using simplified forms based on the classical GNDT 2nd level, through an extensive field survey.

To adapt the data, the values of 11parameters were generated according to Table 3.1, as proposed by Benedetti and Petrini, 1988, and modified by Boukri and Bensaibi, 2007. Each parameter has been used to select a vulnerability class associated to it. Four classes have been used in increasing order of vulnerability from A to D. The complete list of the rules used is summarised in Table 3.1.
A weight '*W*' is assigned to each vulnerability parameter, ranging from 0.25 for the less important parameters up to 1.5 for the most important ones.

Table 4.1. Vulnerability index according to Benedetti and Petrini and modified by Boukri and Bensaibi., 2006.

Parameters	Classes				Weighted factors
	A	B	C	D	
1. Total Shear Strength	0	5	25	45	1.50
2. Regularity in Plan	0	5	25	45	0.50
3. Regularity in Elevation	0	5	25	45	0.50
4. Walls Connectivity	0	5	25	45	1.00
5. Walls Type	0	5	25	45	0.25
6. Floor Slab	0	5	25	45	0.25
7. Roof	0	15	25	45	0.25
8. Type of Foundations	0	5	25	45	0.75
9. Details	0	0	25	45	0.25
10. State of Conservation	0	5	25	45	1.00
11. Modifications	0	5	25	45	0.50

A qualification factor or a score 'K_i' is assigned to each vulnerability class of each parameter: from 0 (Class A – very low vulnerability) to 45 (Class D, high vulnerability). Most of the intermediate scores have values equal to 5 and 25 for classes B and C.
The building vulnerability index 'I_v' is calculated as the weighted sum of the vulnerability scores of the various elements using equation 3.1.

On the basis of the obtained vulnerability index ranging from 0 to 450, a clear picture can be drawn on the building vulnerability and practical measures can be taken whether the building should be reinforced or upgraded to sustain the prescribed lateral seismic force. Table 4.2 illustrated the main decision according to the obtained vulnerability index.

Table 4.2. Vulnerability classes according to the Vulnerability index

Vulnerability Index	[0 - 35]	[35 - 250]	[250 - 450]
colour			
State of the building	No intervention	It is necessary to reinforce the building	Low seismic quality. Should be replaced or upgraded to sustain the prescribed seismic force

5. MAIN RESULTS

The main results of the vulnerability assessment conducted on 105 residential buildings in Tigditt and Derb-Tobanna Casbah are illustrated in Figure 5.1

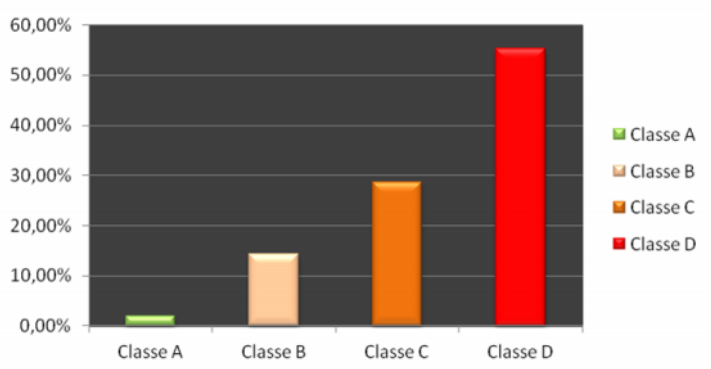

Figure 5.1: Total percentage of the buildings for each vulnerability class

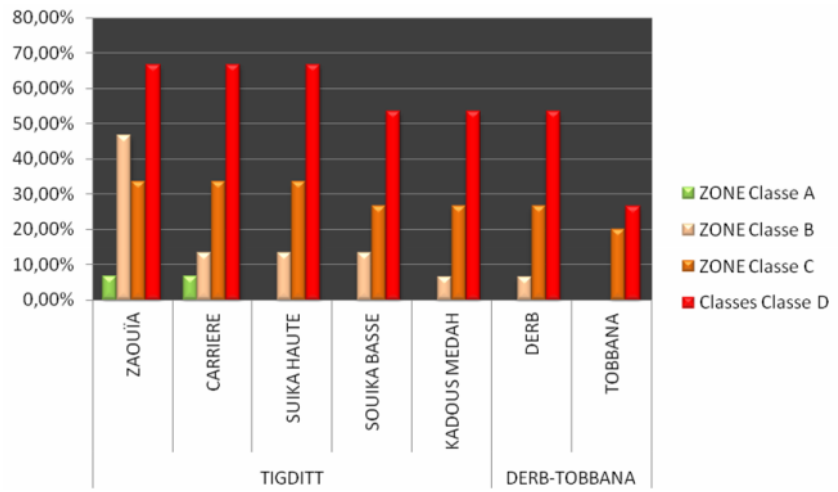

Figure 5.2: Vulnerability class in each district

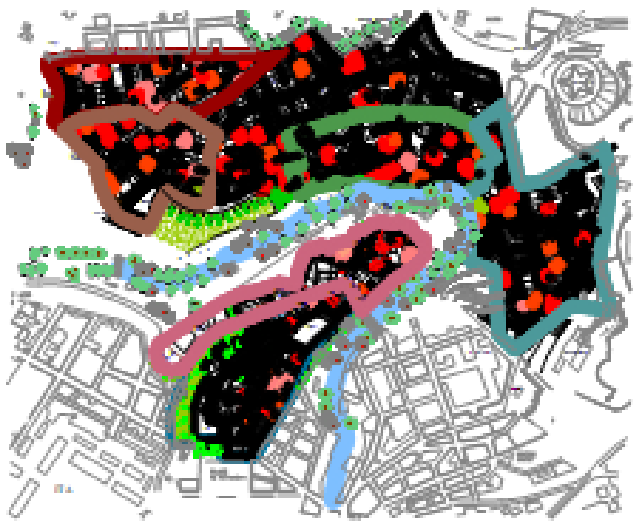

Figure 5.3: Vulnerability distribution in each district

Figure 5.1 shows that more than 50% of the analysed sample (58 buildings) belong to class D which is the most vulnerable and around 30% to class C. According to Table 4.2, most of these buildings need to be reinforced or upgraded. However, since most of these residential buildings are old, the awareness should be directed towards the reinforcement and the upgrading of the historical monuments that represent the memory of the town such as, the great mosque, the zaouia, some public bath, rampart and old palaces.

Figure 5.3 clearly illustrates that most of the vulnerable buildings are located in Tigditt district where most of the historical monument are located. The city dates back to the 14th century and needs in this regard, a particular attention should be paid from the local authorities in order to take practical measures to safeguard this cultural and societal heritage.

6. CONCLUSION

Mostaganem city located in a region of moderate to high seismicity is considered as a prone seismic area. The city which encompasses two old Casbahs constructed during the Othman era represent a valuable cultural, architectural and societal heritage. In order to preserve this cultural heritage, the vulnerability assessment of the two urban nuclei i.e. the old Casbahs of Tigditt and Derb Tobanna has been performed using the vulnerability index approach developed by Benedetti and Petrini.

The building damage assessment has been carried out on the most representative old masonry buildings, having the same constitutive materials, structural systems, and considered to be built during the same period. To this end, a sample of 105 building houses was selected from a field survey.

The findings of this study showed than more than 75% of the buildings stock might experience a heavy damage during a moderate earthquake level. In this respect, the local authorities should take significant and practical steps to reinforce and rehabilitate this cultural heritage of the city in order not only, to reduce the seismic risk, but to preserve this invaluable cultural heritage.

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