CLASSIFICATION OF BUILDINGS OF ORAN CITY (ALGERIA) BASED ON THEIR SEISMIC VULNERABILITY

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SUMMARY:
The exposition of Algerian towns to earthquakes raises a number of issues related to the urbanization of territories in earthquake-prone areas and also to the maintenance of the existent urban fabric. In particular, the assessment of the actual seismic risk and of the vulnerability of the existing building stock is a key information in view of setting up priorities in a long term prevention policy. The current standard method in the Euro-Mediterranean area is the RISK-EU approach, and more specifically its first "macroseismic" level, which is essentially based on the building typology. The aim of the present study is to provide the first elements in view of assessing the seismic risk in the city of Oran. This has been achieved through an investigation of the building typology inside a sample "intramural city" perimeter by exterior visual screening along itineraries. In addition to the identification of the main building types, it also allowed to gather information of the additional vulnerability parameters as listed in the RISK-EU method. The results indicate rather high vulnerability indexes for both masonry and RC buildings, due to a number of aggravating factors which could be identified for each building typology. This preliminary study lays the ground for further investigations both in the whole greater Oran area, and for damage estimates in the case of various scenario earthquakes.

Keywords: urban vulnerability , seismic risk, typology, pre-existent buildings.

1. INTRODUCTION

Several large scale vulnerability assessment methods are now available. These methods first appeared during the seventies in Japan and in the USA, then in the eighties in Italy. Since then, these methods have known a worldwide expansion that resulted in a multiplicity of methods and regional variants (CETE, 2008). The city of Oran in northern Algeria is exposed to moderate to strong seismic hazard, as witnessed by the 1790 earthquake, the strongest earthquake in the known history, with an estimated intensity between IX and X (Manuel López Marinas and Salord, 2001). A recent microzonation study (CGS, 2010) indicates peak acceleration levels from 0.34 to 0.48 g for return periods of 200 and 475 years, respectively, which significantly exceed the design values recommended by the RPA99/2003 seismic code, ranging between 0.15 and 0.25 g according to the building use. Though debated, such a high hazard level compels to address the issue of the seismic risk and the probable level of damages in case of a large nearby event. Large scale vulnerability evaluation methods, despite their high level of approximation and uncertainties, present the advantage to provide a first estimate at the city or urban district scale when only limited resources (manpower, funding) are available. In addition, any urban renewal project must incorporate the seismic constraint to ensure a sustainable development, .

2. THE CONCEPT OF TYPE IN VULNERABILITY EVALUATION METHODS

The use of building typology in the evaluation of seismic intensity has been implicitly endorsed since the beginning of the macroseismic scales. Intensity evaluation in post-seismic surveys refers to building damages. The ATC13 approach (ATC, 1985) was amongst the first ones to explicitly base the vulnerability assessment on the definition of a typology. In Western Europe, the first systematic approach was the Italian GNDT method, which proposed to evaluate a "vulnerability index" from a weighted combination of eleven parameters that have to be gathered for each building. GNDT did not make use of any explicit typological classification; it was however later adapted and modified for the 3-level VULNERALP approach by (Guéguen et al., 2007), who introduced the use of the EMS98 typology to replace some quantitative information on the structural system, by a more qualitative, but standardized one. Actually, the EMS98 macroseismic scale has been an important step as it contains a "qualitative" model of vulnerability which gave birth to the RISK-EU method.

The RISK-EU LM1 method, also known as macroseismic method, was elaborated to be an European standard (Milutinovic and Trendafiloski, 2003). Lagormasino and Giovinazzi made an essential contribution to the development of this method (Giovinazzi and Lagomarsino, 2004), by translating the implicit model contained in EMS98 into a vulnerability assessment model. It is based essentially on the typology through a basic index V* and its modulation by modifying factors (Vm) considering different aspects varying from one building to another (resisting system quality, regularity...etc). Although typological indices are estimated for all types of constructions, RISK-UE provides the values of the modifying factors only for masonry and reinforced concrete buildings, which are by far the most common construction types in the Euro-Mediterranean area. The value of a modifying factor Vm is negative for favorable elements that contribute to decrease the vulnerability, and positive for unfavorable elements. The final vulnerability index V is the sum of the base index V*, a regional vulnerability modification ΔV_r, and these modifying factors ΔVm. It should in addition remain in a range $[V^{min}; V^{max}]$ specified for each building typology (Milutinovic and Trendafiloski, 2003).

$$\mathbf{V_0 = V^* + \Delta V_r + \Delta V_m} \qquad (2.1)$$

3. TYPOLOGICAL CLASSIFICATION

The foundation of the city of Oran dates back officially to 902; rare however are the still existing housing buildings that are older than the French occupation starting in 1831 (Lespès, 2003). The old city, also called "the low city", leans against the West side of the Murdjadjo mountain and spreads in the small valley of Oued R'Hi. The urban area considered for the present study does not include this very old part, but includes buildings from both the French occupation area and the great urban extension which began in the early eighties of the 20th century (Lespès, 2003). This extension gave rise to the "upper city" on the vast and quasi-flat or only gently sloping area provided by the plateau of Oran. The older buildings in this urban sprawl use masonry bearing walls and metallic floor joists (steel-joists). The bearing walls are usually about 50 cm thick, and consist mainly of tuffo-limestone stones with variable degree of friability, and sometimes of sandstone or limestone, a more consolidated material. A second construction phase is marked by the introduction of reinforced concrete elements in the floors, while masonry was kept for the walls. The third phase, starting in the thirties, saw the emergence of reinforced concrete buildings and the fifties were marked by the first social housing projects ("HLM"). After a pause in the first two decades following the independence (1962-1980), the construction boomed in the 80s and 90s with many new RC frame buildings and the reconstruction of existing buildings, with vertical or horizontal extensions.

The classification of buildings in the city of Oran has been limited here to in the "intramural" area. The itinerary method along a number of streets as displayed on Fig. 1, was adopted to provide a representative sample.

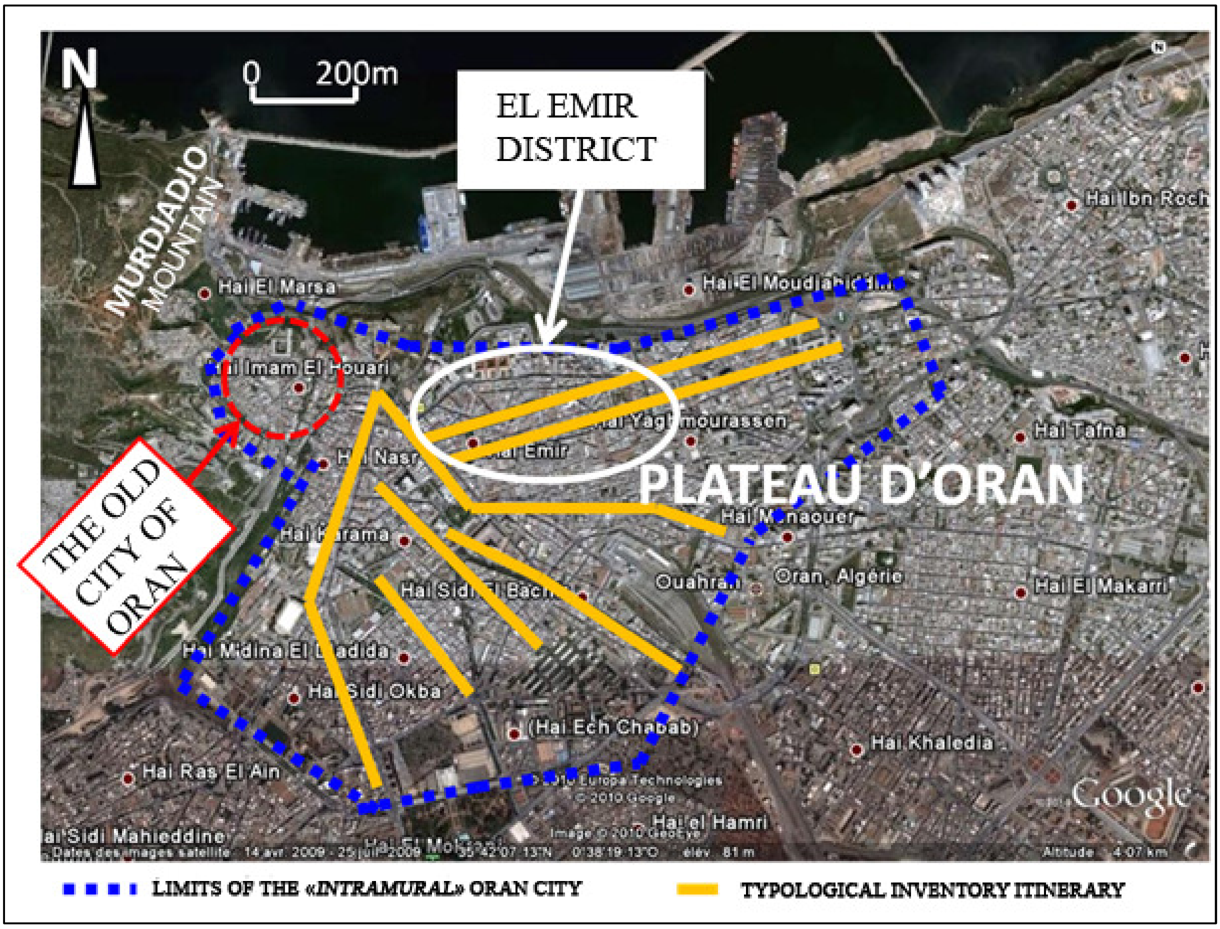

Figure 1. Area of the typological inventory of the "intramural" city of Oran and surveyed itinerary.

Table 1. Typological distribution of the building sample

Type	Description	Number	%	Subtotal (%)
Masonry				71,49%
M1.1	rubble stone	16	2,1%	
M3.3	Composite steel and masonry slabs	437	58,5%	
M3.4	Reinforced concrete slabs	81	10,8%	
Reinforced concrete				28,4%
RC1	Irregular frames	189	25,3%	
RC2	Regular infilled walls (regular structure)	23	3,1%	
Wood				0,1%
W	Wood structure	1	0,1%	
Total		747	100,0%	100,0%

This first approach for a preliminary assessment of the seismic vulnerability of Oran city consisted in the typological analysis of the existing building stock according the RISK-EU method (from a vulnerability point of view). The RISK-EU method assesses the vulnerability by the investigator judgment of some structural and architectural characteristics known to have an impact on the vulnerability. These factors, according to the situation, have an impact on the vulnerability increasing (positive value of Vm) or its decreasing (negative value of Vm). Some of the modifying factors are indeed easy to identify: number of floors, plan and elevation irregularity, position in the block, buildings of different height, staggered floors, roof type. Some others are indeed difficult to estimate from only an outside visual screening: structural system (distance between walls, connection between walls, diaphragms, connection between horizontal structures and walls), soft story, retrofitting interventions). For the latter category, we decided to use intervals accounting for the variability associated to the unknown characteristics.

The itinerary survey allowed to identify that the most common building types according to the RISK-EU classification, are M 3. 3, M3.4 and RC3.2 (Table 1). The M3.3 type, which corresponds to composite steel and masonry slabs, is the most frequent. M3.3 buildings in Oran are most often mid-rise, 3 to 5 floors (Table 2), regular in elevation, with a generally flat roof.

a b c

Figure 2. Typical M3.3 buildings (a&b) and details of slab(c)

Table 2. Number of floors class distribution of M3.3 type

Number of floors class distribution of M3.3 type		
Number of floors	Number	%
Low (1 or 2)	95	21,7%
Medium (3, 4 or 5)	315	72,1%
High (6 or more)	27	6,2%
Total M3.3	437	100,0%

Table 3. Roof type Distribution

Type	Number	%
Flat	366	83,8%
sloped	71	16,2%
Total	437	100,0%

4. APPLICATION TO VULNERABILITY ASSESSMENT IN THE EL-EMIR DISTRICT

After the typology definition and the assignment of the possible V* values, a preliminary vulnerability assessment of a district situated within the studied perimeter has been conducted (Figure 1). The objective is to collect, for all the 958 buildings of the district, the information allowing to estimate the modifying factors Vm. The Table 1 lists the results of this analysis with the average sum value of the modifying factors ΔVm, and also the average of the final vulnerability index V for each building type. With the exception of the RC2 and RC3 categories which have negative ΔVm, the others are positive. The highest average modulation increase is found for the RC1 type, which results also in average vulnerability indices V higher than those obtained for masonry types M3.3 and M3.4 (Table 1, Figure 3 and Figure 4), despite their relatively more recent period of construction.

Table 1. Average values of the modifying factors sum and vulnerability final index

Type	RISK-EU Description	Number	%	ΔVm Average	average Vulnerability Index V
Masonry		**827**	**86,51%**	**0,148**	**0,823**
M1.1	rubble stone	5	0,52%	0,083	0,956
M3.3	Composite steel and masonry slabs	546	57,11%	0,141	0,845
M3.4	Reinforced concrete slabs	276	28,87%	0,162	0,776
Reinforced concrete		**129**	**13,49%**	**0,226**	**0,861**
RC1	Reinforced concrete frame without earthquake resistant design.	120	12,55%	0,247	0,891
RC2	Reinforced concrete frame with moderate level of earthquake resistant design	6	0,63%	-0,127	0,411
RC3	Reinforced concrete frame with high level of earthquake resistant design	1	0,10%	-0,120	0,204
RC4	Reinforced concrete walls without earthquake resistant design	2	0,21%	0,200	0,744
	Whole sample	**956**	**100%**	**0,158**	**0,828**

From a vulnerability index point of view, the RC1 and M3.3 types are found to be the most vulnerable. The histogram of ΔVm distribution histograms displayed in **Figure 4** confirms their aggravating character. For the whole sample, the ΔVm sum of the modifying factors is centered around a value of 0.16, and vary mainly from 0.08 to 0.28. The rare RC2 and RC3 buildings exhibit a negative ΔVm. M3.3 distribution looks very similar to the one of the whole sample with a mode at 0.20 value. The RC1 histogram confirms the much higher values: ΔVm vary from 0.12 to 0.36 for RC1, with about one quarter of RC1 buildings having ΔVm=0.36.

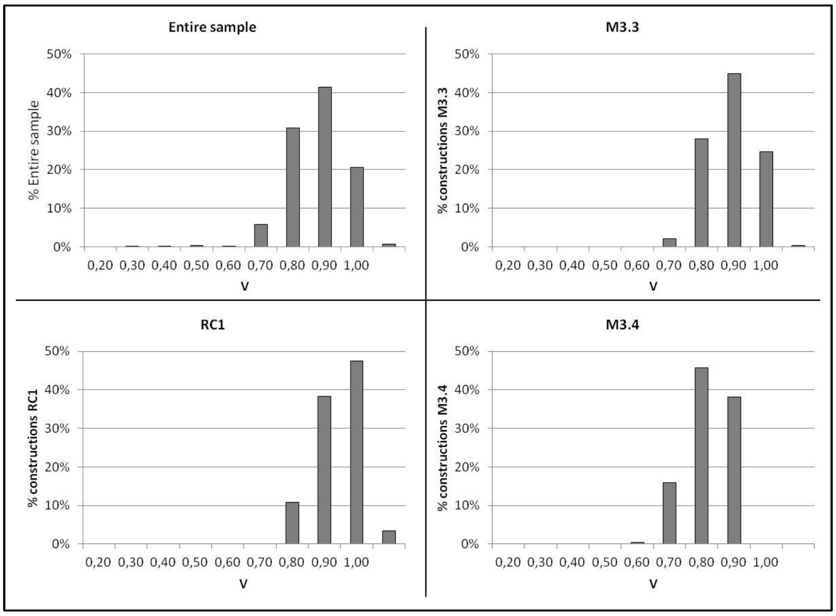

Figure 3: Distribution of RISK-EU vulnerability index values according the building type

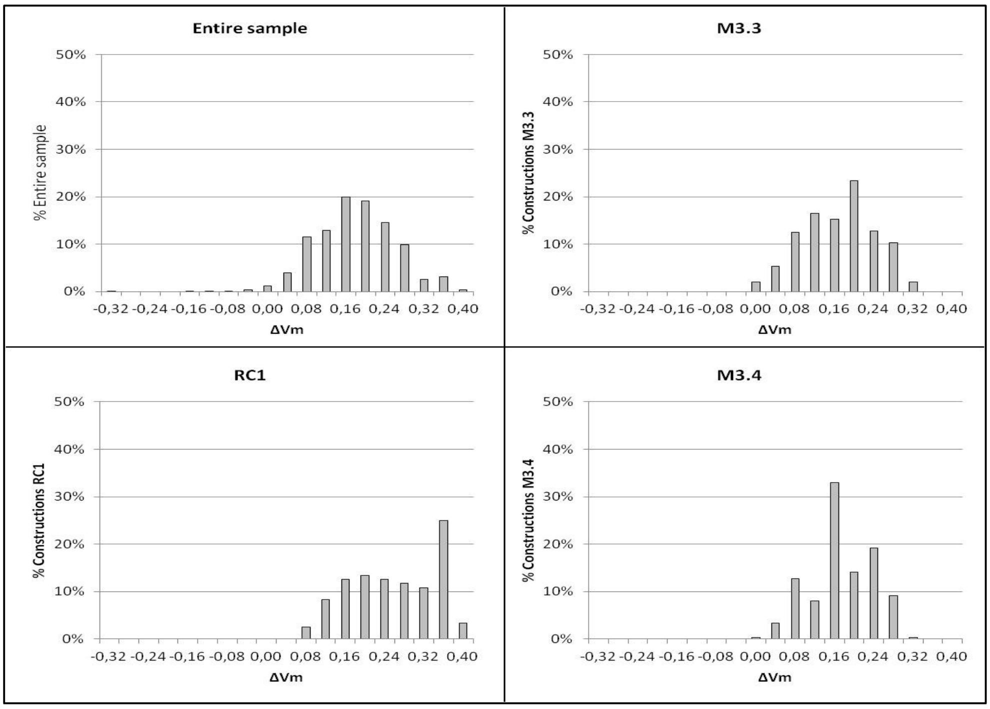

Figure 4: Distribution of the Sum of the modifying factors (ΔVm) according to building type.

The modifying factors of the studied buildings have thus a very significant aggravating impact. As displayed in Figure 5, the principal factors are: the number of floors, the plan irregularity, the position within the block, the existence of a soft story, and the presence of staggered floors. The "number of floors" factor affects more the masonry buildings, which is observed also for the "staggered floors" factor. The soft story factor concerns indeed the majority of buildings whatever their type because of the commercial nature of the district. Generally, the ground floor of a commercial use is characterized by a large open space and great story height. The building position plays a higher aggravating role for masonry buildings due to the small size of blocks, that result in a higher number of buildings located in block corners.

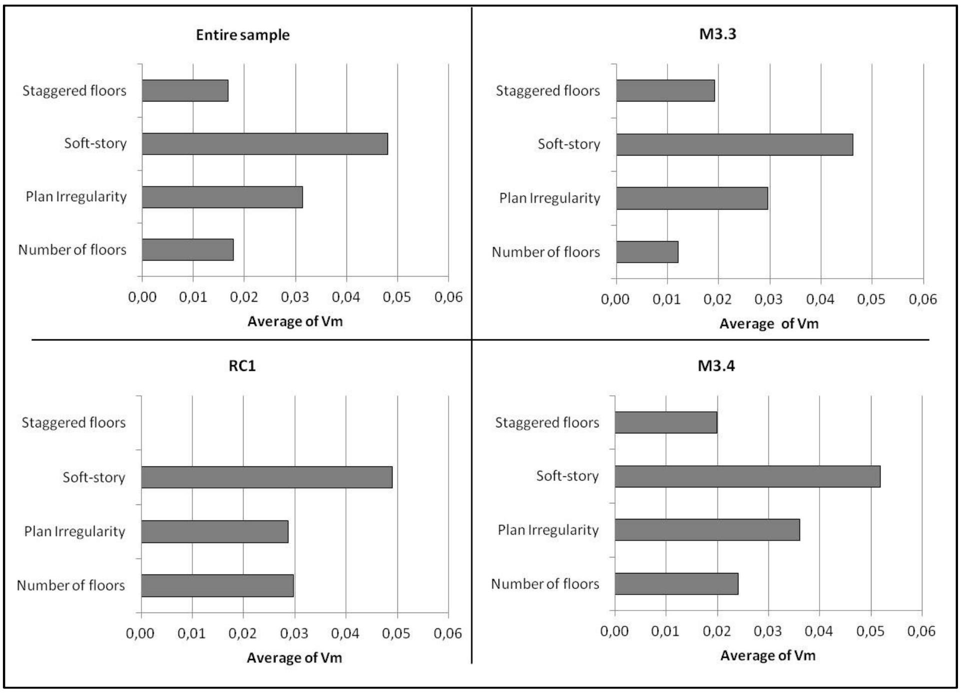

Figure 5: Distribution of the main modifying factors increasing the vulnerability

5. CONCLUSION

This study has confirmed both the helpfulness of the RISK-EU approach for a preliminary, global vulnerability assessment at an urban scale, and the primary importance of typology. This approach can cover large urban areas with relatively low costs and human resources. The typological study has allowed to identify easily the major building types for the city of Oran, according to the RISK-UE classification. However, the further details linked to the modifying factors did prove to have a very noticeable importance, since they result in average vulnerability index increase around 0.16. The origin of this vulnerability increase could be identified for each building type. The average values per type are proposed as reference values for further studies or to complement existing data.

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