VULNERABILITY INDEX OF ALGIERS MASONRY BUILDINGS

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ABSTRACT:

In Algeria, the seismic risk threat the large cities, and more particularly the Algiers Metropolitan City which contains a very old urban nuclei mainly made up of masonry buildings (stone and/or brick). The expertises carried out on this kind of structures showed the low resistance of this type of construction towards seismic action. The study of the seismic vulnerability of masonry buildings is thus of topicality and constitutes a fundamental stage for the reduction of the losses due to earthquakes in this city. This vulnerability can be reduced if preventive measures are taken. In this work, we will present an estimate of the vulnerability degree of Algiers masonry buildings by using the “Vulnerability Index Method”. This one will allow us to evaluate the seismic vulnerability of these buildings then to carry out their classification according to their seismic quality.

KEYWORDS : Seismic Risk, Earthquake, Masonry buildings, Algeria, Algiers, Vulnerability index.

1. INTRODUCTION

The seismic vulnerability studies of an urban area are of topicality in Algeria, particularly after the destroying earthquake of Boumerdes (21st May, 2003). To this end, several studies were undertaken. These studies related to the vulnerability of an urban area such as the study carried out by the National Centre for Applied Research on Earthquake Engineering (CGS) “Town Planning and Statistical Analyzes of Algiers City Buildings” [CGS, 2001] as well as the study carried out by the Japanese International Cooperation Agency (JICA) in collaboration with the CGS "The Seismic Risk Microzonation of Algiers Metropolitan City" [JICA, 2006]. Other studies related to the vulnerability index method. This method could be applied to the masonry, reinforced concrete and metal buildings.

This paper relates to the vulnerability index method applied to masonry buildings (stone and/or brick) of the Algiers metropolitan city. The expertises carried out on this frame as well as the post-seismic investigations which took place on this territory showed the low resistance of this type of construction with respect to the seismic action. Consequently, the seismic vulnerability study of these masonry buildings proves to be necessary and therefore constitutes a primordial stage for the reduction of the losses due to the earthquakes in this city. This vulnerability can be reduced if preventive measures are taken. Several studies throughout the world were carried out.

Various authors gave definitions to the seismic vulnerability of masonry buildings. According to [Benedetti et al., 1988], it is generally explained by the degree of loss of the elements concerned with the specific results caused by well defined factors. Ambraseys [Akkas, 1997] defines it as being the degree of damage which a seism of parameter X (magnitude, intensity, amplitude…) would inflict to a given construction as well as to the base. In other words, it is a measurement of the proportions lost following a given earthquake. To assess this seismic vulnerability, different methods exist. Among the most used methods, there is the Method of IZIIS [Bozinovski et al., 1993] developed at the engineering and seismology institute (institute IZIIS in Macedonia). There is also the ‘EPM Methodology’ [Italian seismic Regulation code, 1981] elaborate at the polytechnic school of Milan

(Italy). We have also two methodologies, the "I level GNDT" and the "II level GNDT" developed in Italy by (The National Group for Defence from Earthquakes) [Giovinazzi et al., 2001]. The methodology "I level GNDT" identifies various typologies of buildings and defines classes of vulnerability (A, B and C). The methodology "II level GNDT" is based on the approach of (Benedetti and Petrini 1984, GNDT 1994). In this approach, a certain number of typological and constructive information are collected for each building. These information are combined with coefficients to define a vulnerability index 'VI' which characterizes the damage rate which the building following a given earthquake could undergo. Another approach which used the vulnerability index is found in the Risk-UE project [Risk-UE, 2007]. This approach is used to assess the vulnerability buildings for use in earthquake loss modelling in Europe. In this method a number of parameters were listed with their weighting coefficients. These coefficients could be positive or negative.

Based on the method developed by Benedetti, we developed a tool allowing us to evaluate the seismic vulnerability of Algiers Metropolitan City masonry buildings.

2. DEVELOPED METHOD

The vulnerability index method consists to identify structural or non-structural parameters having an influence on the seismic response of the structure. Once these parameters identified, we affect them a coefficient to take account of their preponderance the ones compared to the others. This preponderance is affected also by the respect or not of the seismic regulations when they exist [Boukri, 2003], [Boukri et al., 2003].

2.1. Vulnerability Index Method According "Benedetti"

Table 1: Vulnerability index survey form according "Benedetti"
[Benedetti et al., 1988]

Element	Class				Weighted Parameter
	A	B	C	D	
1. Connection of walls	0	5	20	45	1.00
2. Type of walls	0	5	25	45	0.25
3. Soil condition	0	5	25	45	0.75
4. Total shear resistance of walls	0	5	25	45	1.50
5. Plan regularity	0	5	25	45	0.50
6. Regularity elevation	0	5	25	45	(*)
7. Horizontal diaphragms	0	5	25	45	(*)
8. Roof	0	15	25	45	(*)
9. Details	0	0	25	45	0.25
10. General maintenance conditions	0	5	25	45	1.00

Each considered element of structural or non-structural nature can have an influence on the seismic response of construction and can take only a single vulnerability, this one represents the class to which construction belongs. There are four classes: A, B, C and D.
Class A represents constructions realized according to the seismic regulation code into force and thus has a good resistance to the earthquake, as for the class D, it represents constructions having a bad resistance to the seismic action. The classes B and C are intermediate classes. With each class a weighting coefficient is affected.

The vulnerability index of an element is thus the affected coefficient with the class of construction multiplied by a weighted factor. The sum of the vulnerability indexes **"VI"** of all elements represents the vulnerability index of the building.

The method such as it is developed by Benedetti presents some disadvantages of use for the simple engineers, because we notice on table 1 that three elements considered for the vulnerability index calculation and mentioned by (*) have no pre-defined weighting factor, so their assignments remain to the operator (expert) according to his experiment. That introduced a part of subjectivity [Boukri, 2003], [Boukri et al., 2003].

2.2 Vulnerability Index Method for Masonry Buildings in Algeria

So we propose the following table of the parameters which we consider dominating in the estimate of the seismic quality of masonry constructions in Algeria [Boukri et al., 2006].

Table 2: Vulnerability index calculation elements for our survey [Boukri et al., 2006]

Element	Class				Weighted Parameter
	A	B	C	D	
1. Total shear resistance of walls	0	5	25	45	1.50
2. Plan regularity	0	5	25	45	0.50
3. Regularity elevation	0	5	25	45	0.50
4. Connection of walls	0	5	25	45	1.00
5. Type of walls	0	5	25	45	0.25
6. Floor	0	5	25	45	0.25
7. Roof	0	15	25	45	0.25
8. Soil condition	0	5	25	45	0.75
9. Details	0	0	25	45	0.25
10. General maintenance conditions	0	5	25	45	1.00
11. Modifications	0	5	25	45	0.50

The principal differences with the methodology developed by Benedetti are [Boukri et al., 2006]:

- Addition of a new element called "Modifications". It is a parameter which was deduced starting from observations on the site. Indeed, it holds account as far as possible anomalies at constructions level which we observe in our society. Among these anomalies, one can quote the additions, the suppressions which cause to generate a modification of the forces applied to the structure, which causes a change in the centre of mass which results in a deterioration in the response of the structure.
This element will have as a weighting coefficient **WM = 0.5**.

- Definition of the elements *"Details"*. Previously this parameter was not clarified. We propose to define it as being the state of:

a) the filling, b) the boarding, c) the partitions, d) the balconies, e) the railing, f) the cornice-acroterion, g) the chimneys, h) the underfloor space (bearing walls), i) the underfloor space (columns), j) the electrical supply system, k) the gas system, l) the water system, m) the sewerage system, N) the telephone system.
Thus it is necessary to look at the state of all these secondary elements. As regards the weighting coefficient of this element; it will be equal to 0.25.

- Assignment of fixed weighting factors to the elements which were assigned in the theory of Benedetti by the operator (the expert) and that we quoted previously. Indeed for these elements the expert had to introduce a weighting coefficient.

2.3 Classification

Based on the vulnerability index table 2, we define three ranges of vulnerability index values allowing classification of our constructions, for each range we associated a colour representing the state of the building. For values from the vulnerability index comprised between [0 - 35], the buildings are classified green and represent those which do not require any intervention, between [35 - 250], they are classified orange, therefore, require an intervention to reinforce them with respect to a future seism, finally for the values ranging between

[250 - 450], these buildings are classified red, therefore have a low seismic quality, which means that their destruction proves to be essential.

In order to determine classification, we must carry out an investigation post or pre-seismic into site. This investigation is based on an evaluation card which we developed.

2.4. Development of the Technique Card

The development of the technique card allowing the estimate of the vulnerability index **VI** after investigations into site, requires the knowledge of the parameters of structural and non-structural nature, having an influence on the behaviour of the structure and thus on the seismic response [Boukri, 2003].

The investigation card [Bensaibi et al., 2000] gathers the whole of the parameters which can have an influence on the seismic response of the buildings and which allows the calculation of the vulnerability index. This card includes the following principal elements:

a) Generals data (addresses, age, etc.);
b) Geometrical Characteristics;
c) Structural System;
d) Soil condition;
e) State of the non-structural elements;
f) State of the various systems;
g) General maintenance conditions.

These information permits to evaluate qualitatively and quantitatively the seismic quality of the buildings.

3. APPLICATION

In this present work, we will apply the concept developed previously. A first stage will be to validate our theory on a building taken individually and whose characteristics as well as the state were obtained by the Land Control of the town of Algiers city. Once this validation carried out we will pass at the second stage of our application. This stage consists in making the study of the masonry buildings located at the commune of Belouizdad. These buildings were digitized in a data base which comprises their technique enquiries cards by a Geographical Information system “GIS”. We developed a calculation program allowing us to calculate the vulnerability index value for each studied building. Injected into GIS, it enables us to visualize the classification of the concerned buildings.

3.1 Validation Example

It is about a building located at N° 26 Orleans street (Algiers), including a ground floor and three stages. Its plane surface is about 88 m^2. The ground floor is occupied by a store and deposits, the other parts of the building are intended for the dwelling. It takes day on the Marina and Orleans streets and on an interior court of 3.40 m^2 surface. An in plane sight of this building is given in figure 1.

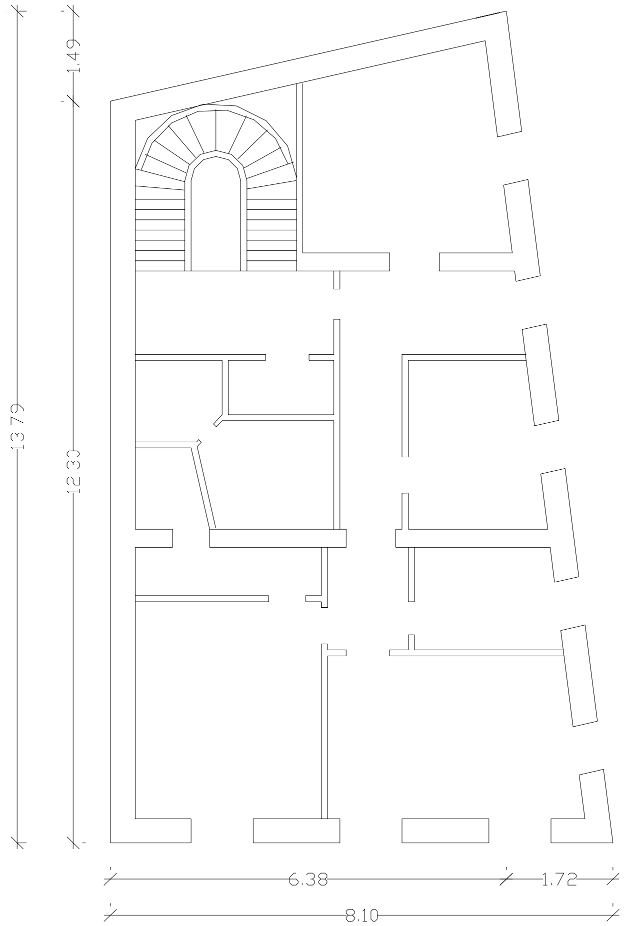


Figure 1 In plane sight of the building 26, Orleans street

Dimensions of this building and its characteristics are as follows:

3.1.1 Dimensions of the building

- Height of the building	**H**	=	15.80 m
- Height of stage	**h**	=	3.95 m.
- Length of the building	**L**	=	13.80 m.

3.1.2 Building characteristics

- Approximate date of the construction: 19th century.
- Regularity elevation: Slightly regular.
- Nature and external state of the walls: Brick and small rubble stones walls (light damage).
- Nature and state of the floors: Wooden Floors (mediocre state).
- Nature and state of the cover: No tight terrace.
- State of the secondary elements: Significant damage
- Nature of maintenance: enough good.
- Water supply: Four particular stations of water
- Water run-off worn: Irregular flow (of the evacuation grids in the angle of the galleries).
- Sewerage: All to the sewer.

3.1.3 Calculation result of the vulnerability index

After calculation, we find the vulnerability index of this building (VI = 136.25), therefore, it is included between [35 and 250]. It will be classified in the orange range, which is perfectly in conformity with the comments registered on its report doing by the "Land Control of the town of Algiers city", which recommends work of rehabilitations as well as modifications with the prohibition of some rooms to the dwelling and does not recommend its destruction.

3.2 Application Example

In order to compare the results given by the Vulnerability Index and the current state of the studied buildings, we carried out an investigation into some buildings of the site being the subject of our study [Boukri et al., 2003]. This investigation took place on April 23rd, 2003, a few days before the destroying earthquake of May 21st, 2003 whose epicentre was localised to 7 km in the north of the town of Zemmouri (wilaya of Boumerdes) of a strong magnitude of about 6.8 on the Richter scale causing severe losses in human lives as well as in infrastructures. The studied buildings of the commune of Belouizdad are located in a small area 135 (district 69) (see figure 2). During this enquiry we visualized the disorders and anomalies which appear in these buildings.

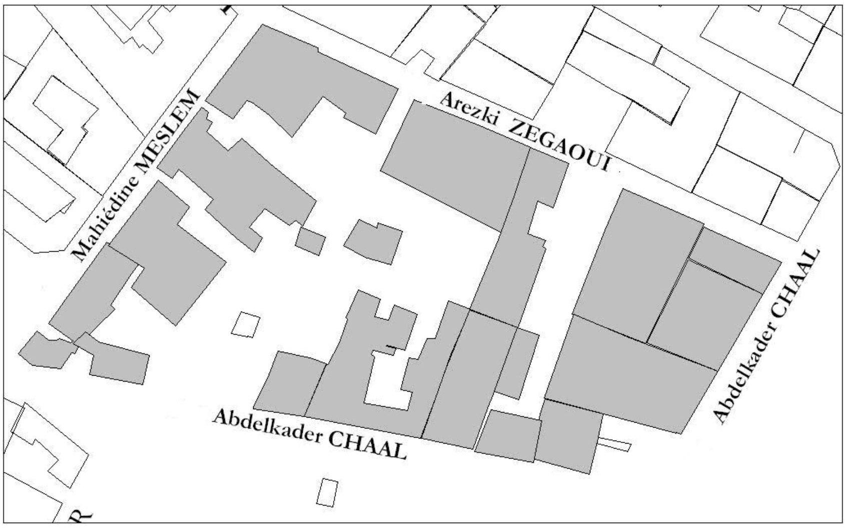
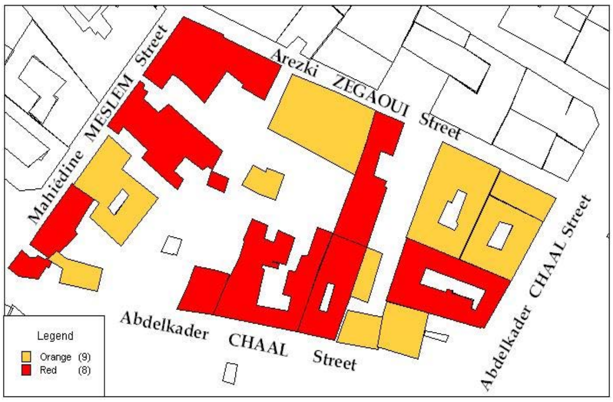


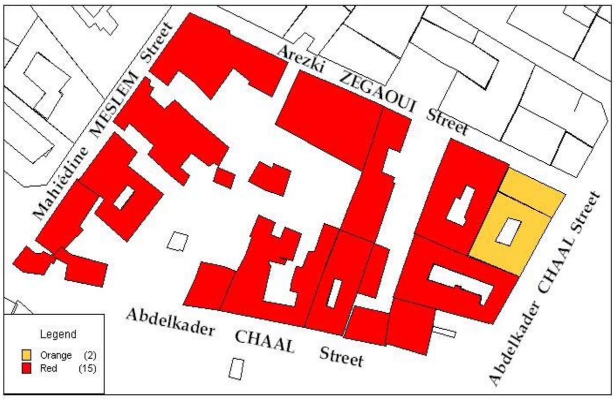
Figure 2 In plane sight of studied buildings (Area 135)

Thereafter we have to calculate the vulnerability index of these buildings, which permit to classify the half of these buildings orange and the others were classified red (see figure 3).

After this earthquake, we carried out a second enquiry into the same buildings studied formerly to check and validate our classification. We realize that the majority of the buildings classified out of orange before this earthquake, will be classified in red, considering their current degradation state (see figure 4). The buildings which were classified in red were dangerously degraded and risk the ruin constantly.

This validates well the vulnerability index method like an estimate tool of the buildings seismic quality.





Figures 3 and 4 Classification of the area 135 buildings before and after the Zemmouri earthquake

5. CONCLUSIONS

The analysis of the seismic vulnerability of the existing masonry buildings means the estimate of their consistency in quantitative and qualitative terms, in particular the estimate of their damage degree with respect to the seismic events. The estimate of this seismic vulnerability is carried out in this work by a method called "Vulnerability Index Method". This one consists to attribute a numerical value to each building; this value is called *Vulnerability Index,* VI, which is a representation of its seismic quality. This numerical value represents the weighted sum of the numerical values expressing the seismic quality of those structural and non-structural elements which plays a significant role in the seismic response of the structure. The study carried out allowed showing that the vulnerability index estimate of the studied buildings permits knowing their seismic quality. Indeed, the structure is more vulnerable as its vulnerability index is significant.

For each building, a vulnerability index was calculated allowing its classification. For values from the vulnerability index comprised between [0 - 35], the buildings are classified green, between [35 - 250], they are classified orange and those between [250 - 450], the buildings are classified red.

The estimate of the seismic vulnerability of these buildings will enable us to intervene before an earthquake occurs. This intervention which will be either reinforcement or destruction of the dwelling will allow reducing the losses in human casualties and infrastructures.

The developed method gives good results. Its application to structures having vicinities is in progress. Another required purpose is to develop the vulnerability functions of this type of building.

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