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Seismic Damage Scenarios for Existing Masonry Buildings for Educational Use in the Mostaganem City

Bendehiba Sabeur[a], **Sidi Mohammed El-Amine Bourdim**[b], **and Hugo Rodrigues**[c]

[a]*Materials and Construction Processes Laboratory, Civil Engineering Department, University Abdelhamid Ibn Badis - Mostaganem (27000), Algeria*
[b]*Dept. of Civil Engineering and Hydraulic, University Center of Maghnia, Tlemcen, Algeria*
[c]*RISCO, Civil Engineering Department, University of Aveiro, Campus Universitário de Santiago, 3810-193, Aveiro, Portugal*

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ABSTRACT

Mostaganem, in Algeria, has experienced several seismic activities in recent years. It was classified in a zone of high to medium seismic activity according to the actual Algerian earthquake regulation. This ensures the safety of new constructions, however, the code done not include a technical reference for the seismic analysis and protection of existing constructions, in Algeria. The aim of this research is to constitute seismic scenarios of the masonry buildings used for educational purpose; therefore, the realization of seismic scenarios consists in crossing the data resulting from the seismic hazard (intensities) with those resulting from the analysis of the vulnerability. The analyses of the urban system will make it possible to interpret the scenarios in terms of functional damage. Seismic vulnerability of existing buildings was assessed under the RISK-UE method, which was selected to be suitable and applied to Algerian buildings for its convenience and simplicity. As a sample, 29 educational establishments (among of 199 masonry buildings for different use: primary school, middle school, secondary school, universities.) located in the historic city center of Mostaganem were assessed to identify the seismic vulnerability index, to allow to simulate seismic scenarios. The seismic vulnerability index is varied between 0.6 and 1.10 according to the diagnoses of each building carried out in the study area, The data from the vulnerability analysis are combined according to the RISK-UE approach (beta law) with the latter estimate by seismic hazard (seismic intensity), This correlation led to the birth of eight seismic scenarios expressing the results in terms of functional damage. As a result, moderate to heavy damage is expected for vulnerable constructions, significant economic losses are also expected for IEMS-98 > 8 intensities. These seismic scenarios were considered and incorporated through a geographic information system (GIS) Guide decision makers estimated the severity and magnitude of the seismic risk for the remaining educational buildings in Mostaganem; or in other cities of the country to implement preventive measures and naturally reduce the risk of disaster by reducing vulnerability. Recommendations can be proposed to the Algerian authorities to simulate and facilitate efforts to take concrete preventive measures to strengthen existing educational buildings in order to reduce the negative effects of future earthquakes.

1. Introduction

North of Algeria has experienced several violent earthquakes in recent years, some of which are very devastating such as: The El Asnam earthquake 1980 (surface-wave magnitude Ms = 7.3 and Modified Mercalli intensity MMI = X) which caused more than 3,000 deaths, 8,369 injuries, 20,000 buildings destroyed and more than 480,000 homeless, Boumerdes 2003 (Ms = 6.8; MMI = IX) of a balance sheet of 2,287 deaths, 1,000 injured, 19,000 buildings destroyed and more than 100,000 homeless. Hamdache et

CORRESPONDENCE Hugo Rodrigues hrodrigues@ua.pt RISCO, University of Aveiro - Civil Engineering Department Campus Universitário de Santiago 3810-193 Aveiro, Portugal

al. (2011), Ayadi and Bezzeghoud (2015). In accordance with the probabilistic microzonation study carried out by the Algerian National Center for Earthquake Engineering CGS 2003 (Bezzeghoud et al., 1996), Mostaganem's city is part of the northern cities that carries a significant high seismic hazard due to the existence tectonics activity following permanent movement of the Eurasian and African plate (Casado et al., 2014). This city contains a historic urban stock whose masonry buildings present several conceptual and structural deficiencies and are therefore subject to a significant seismic vulnerability. Estimating potential damage and losses through seismic scenarios for future earthquakes is therefore essential to moderate the seismic risk (Vincente et al., 2008; Hwang et al., 2005).

The education building stock in Algeria has suffered considerable damage following recent major earthquakes and the undamaged school buildings have been used as shelters for affected families during earthquake events. During the last earthquake of Boumerdès 2003, more than 103 school buildings were classified as ruined structures and approximately 753 others suffered major damages (AFPS, 2003). Fortunately, this devastating event took place after hours of teaching, and as a result, there were no deaths or injuries in educational institutions (Meslem, 2006).

Different approaches have been adopted for evaluating the seismic vulnerability of buildings, these methods have been applied several times in different countries (Benedetti and Petrini, 1984; Benedetti et al., 1988; Giovinazzi and Lagomarsino, 2002; Milutinovic and Trendafiloski, 2003; RISK-UE, 2003; D'Ayala, 2005; Calvi et al., 2006; NZSEE, 2006; Vicente et al., 2008; Barbat et al., 2010; Alam et al., 2012; Kappos et al., 2016; Gaxiola-Camacho et al., 2017; Novelli, 2017; Yamin et al., 2017). they are based on vulnerability indicators and are better suited for large-scale assessments. Despite the large margin of guesswork and uncertainties, the main advantage of these methods is to assess the seismic vulnerability following a large number of buildings as well as to associate the uncertainty with the resulting vulnerability index. Such a margin of error allows the results obtained in terms of seismic scenarios to be qualified (Quiroz et al., 2010). Several vulnerability studies have been directed towards adapting these methods to the Algerian context (Bensaibi et al., 2011; Djaalali et al., 2012; Senouci et al., 2013; Athmani et al., 2014; Boukri et al., 2014; Boutaraa et al., 2018). The vulnerability of the educational constructions presented in our case study was assessed using the RISK-UE LM1 method (Giovinazzi and Lagomarsino, 2004). which has advantages over similar statistical methods, as it provides two types of results: a vulnerability index to prioritize buildings in the case of analysis of a group of buildings (city or neighborhood scale study and a distribution of the probable damage of buildings in the event of an earthquake (Hwang et al., 2006). This varies according to the seismic intensity considered (EMS 98 scale). It therefore has the advantage of giving both criteria to support the decision on the priorities of in-depth studies or reinforcement of the existing building (by the hierarchy obtained) (Tsai et al., 1990) an idea of the behavior of the constructions under the intensity of the deferential earthquakes. It also has the advantage of associating uncertainty with the vulnerability index. This margin of error allows the results obtained to be qualified. This methodology is part of a European (Mouroux et al., 2004) study project assessing the most likely vulnerability index VI*, the limit points of the plausible range [VI; VI+] as well as the lower and upper limits of the possible values [VI min; VI max] according to the type of constructions studied (Giovinazzi and Lagomarsino, 2004).

The main purpose of this paper is to assess the earthquake vulnerability of 29 schools from the 199 existing masonry structures in the historic center of Mostaganem in order understand the vulnerability and propose measures to reduce the damage due in future earthquakes. The analysis of the behavior of constructions is defined as the rate of seismic damage to buildings during a seismic event of specified intensity occurs (Lang and Bachmann, 2003), this evaluation is associated mainly with the conceptual characteristics and the mode of construction. masonry building (structural typology, position, geometry, quality of materials, type of foundations, etc.) (Barbat et al., 2010).

With the ultimate goal of conserving and enhancing the historic districts of Mostaganem, a safeguarded sector of the old city of Mostaganem was created in July 2015 by the Djanatu Al-arif foundation 2013 (Djanatu al-arif Foundation, 2013), with an area of 103 ha and 56 Ares, encompassing the districts of Derb Tobbana, Tidjditt and Metmore, as well as Oued Ain Sefra and various neighboring bhayer (Levis-Mirepoix et al., 1933). This protected sector includes the constructions that are the subject of this study. The general sources defining the vulnerability of the buildings are subject to a detailed field survey conducted in 2012, 2013, 2014 by the CTC (2012), CTC (2013), CTC (2014) (Construction Technical Control, Mostaganem unit) in order to assess and diagnose the existing buildings in Mostaganem. The objective of this investigation was to determine the vulnerability index of each building according to their typologies so as to maintain the conservation status (Guéguen et al., 2007).

Our research has a significant impact on seismic risk assessment to preserve educational facilities in the city of Mostaganem, the advantages and disadvantages gained from each vulnerability method in this context is very representative and effective, and also the significant damage to the expected educational buildings that should certainly concern decision-makers and justify the need for rehabilitation and renovations.

2. Seismic Context and Data

Mostaganem, formerly called Mustaghânim: would be composed of two distinct terms: Machta (winter station) and ghnem (a rich sheep breeder or one who has the usufruct of a land) (Petit(A), 1957), is one of Algeria's main towns, deferential sources have described historic and recent earthquakes known in the province of Mostaganem with a tolerable rate of damage (Harbi et al., 2020) As shown in Table 1. that the seismic hazard is important in this region, it has recently suffered an earthquake in 22.05.2014, longitude 0.259°E and latitude 35.725°N of magnitude Mw =

Table 1. Some Earthquakes Felt in the Province of Mostaganem Depending on Their Seismic Intensities

No	Earthquakes	Latitude °E	Longitude °N	Intensity	Refs
01	Mostaganem 5.10.1883	35.93	0.09	VI-VII	Harbi et al., 2020
02	Stidia 9.6.1894	35.83	-0.0005	V-VI	Harbi et al., 2020
03	Mostaganem 9.4.1896	35.93	0.09	V	Harbi et al., 2020
04	Mostaganem 22.5.2014	0.259	35.725	V	Abbouda et al., 2018

4.9, which has caused cracks to educational institutions and many private homes through some communes of Mostaganem (Abbouda et al., 2018). In addition, historically, the area adjacent to the province of Mostaganem (zone 1) has experienced several destructive earthquakes with remarkable intensities can cause adverse effects on this province according to the analysis of Fig. 1. Where occur the epicentral intensities of the historical earthquakes felt in zone 1 called: Oran 1 (Boughacha et al., 2004). These observed intensities have caused damaging effects on the city of Mostaganem on several occasions on the European macroseismic scale (Grünthal, 1998), This region borders two active seismic zones, Oran and El Asnam (Chlef now) (Ayadi et al., 2021), the latter have suffered destructive earthquakes: Oran on 09/10/1790 (I = IX-X on the EMS 98 scale) Seismic action was felt as far as Malta; 2000 deaths. Seriou's damage was recorded in the vicinity of the city of Oran (Manuel López Marinas and Salord, 2001; Chimouni et al., 2018) and El Asnam on 10/10/1980 (I = IX–X on the EMS 98 scale, Ms = 7.3) of an assessment: 2633 deaths, 8369 injuries, 348 homeless people, and the appearance of a long seismic fault is more than four meters high (Benhallou et al., 1985).

A recent update of the microzoning study conducted by the Seismic Engineering Research Center (CGS, 2010) As a result, seismic accelerations are felt in these moderate to high seismic risk areas as estimated by the Algerian Earthquake Regulation (RPA 99 V, 2003). The latter expresses moderate accelerations: 0.15 and 0.25 g for return periods of 200 and 475 years, respectively for zone 1 (Oran1), while with the same return period, the microzonation study defines new accelerations of order: 0.35 and 0.49 g respectively (Senouci et al., 2013).

2.1 Statistical Analysis of the Educational Park in Algeria

The country's economic and social development plans are successful if development in human terms is achieved; in this respect, the Algerian State has made the education and training sector an important priority since independence in 1962 (National Office of Statistics, 2020: NOS, 2020). Massive investments in infrastructure and the development of teaching staff have enabled a strong expansion of the school park in order to catch up with the quantitative delays in the education system (UNICEF Algeria, 2014).

In 2014, school infrastructure included 18,248 primary schools, 5,185 colleges and 2,065 secondary schools (National Office of Statistics, 2020: NOS, 2020). Construction efforts continued

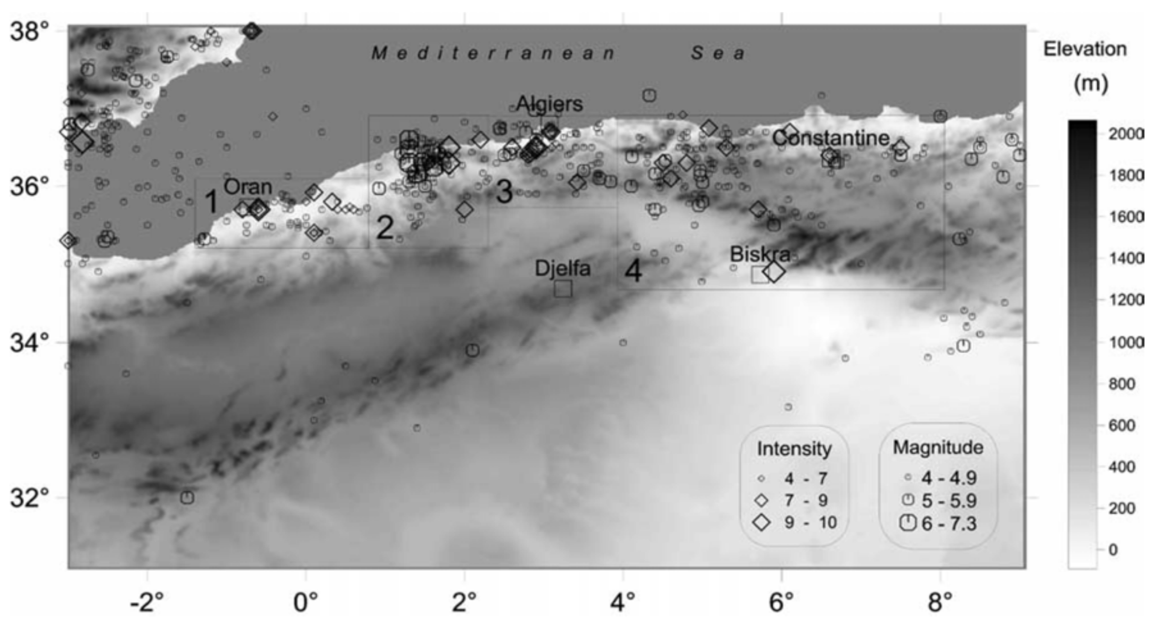

Fig. 1. Epicentral Presentations of Seismic Events Known during 1716 to 1910 from Northern Algeria and Measurement of Instrumental Intensity/Magnitude Values (1911-2000) for the Four Seismic Regions: Oran (1), El Asnam (2), Algiers (3), Constantine (4), (Boughacha et al., 2004)

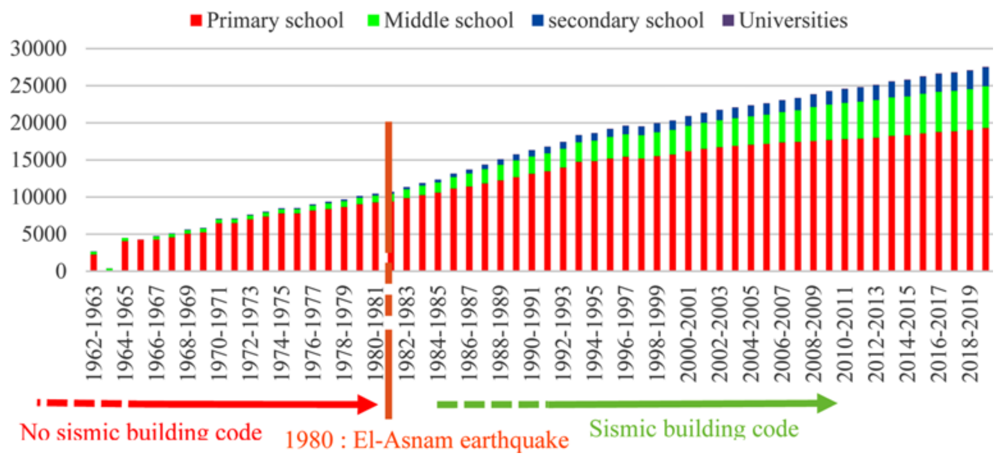

Fig. 2. Evolution of Algerian's School Buildings from 1962 to 2020 (NOS, 2020)

unabated and focused on meeting demand in the less favored regions of the Highlands and South. The graph (Fig. 2) below shows the growth of educational institutions after independence.

The Algerian university network comprises one hundred seven (107) higher education institutions spread over forty-eight (48) Algerian departments, covering the entire national territory. This network consists of 17 universities in the Central Region; 22 universities in the Eastern Region and 11 universities in the Western Region. There are also 13 university centers in each region and 31 graduate schools.

The Vocational Education and Training (VET) sector consists of 1,200 institutions with a capacity of approximately 500,000 students (745 Centers for Training and Apprenticeship (CTA) and their 346 annexes; 100 national specialized vocational training institutes (NVTI) and their 20 schedules). In 2010, this network welcomed 219,000 trainees in residential training and 247,000 in apprenticeship training in one- to three-year cycles. At the same time, it organized evening classes for 21,000 trainees, correspondence training for 35,000, as well as specific courses for 55,000 housewives and 19,000 rural women (National Office of Statistics, 2020: NOS, 2020).

2.2 Analysis of Damage to Algerian School Buildings Following Past Earthquakes

Factors defining the damage to school buildings may be better able to assess whether the period of construction was considered at the time of construction of these establishments. In fact, the Algerian education sector can be classified into three categories.

1. First category, Housing stock during the colonial period (1830-1962) (Louis Abadie, 1999) are characterized by a rather remarkable deterioration due to aging and poor maintenance, they present 30% of the educational park.
2. Second category, following the rapid growth of the population after independence, there was a significant shortage of educational institutions built without Algerian earthquake code. During the 1970, in particular, in what has been called the cultural revolution, the government quickly built various formats of housing that meet the requirements of

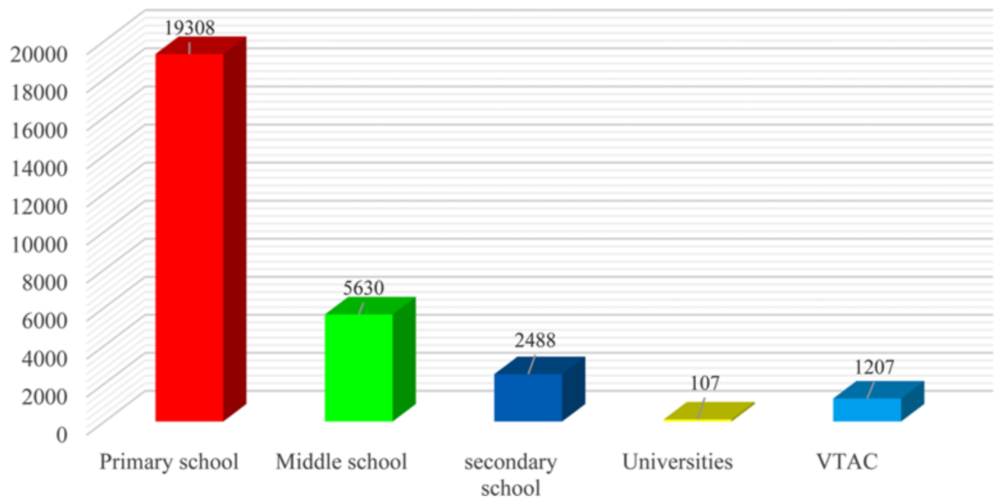

Fig. 3. Distribution-Type of School's Buildings in Algeria (National Office of Statistics, 2020: NOS, 2020)

Table 2. Statistics on the Damage Caused to Algerian Schools by the Recent Destructive Earthquake (Meslem, 2006)

Earthquake	Intensity (MMI)	No or light damage	Moderate damage	Extensive to complete damage	Total	Damage ratio
El-Asnam (1980)	X	5	25	70	100	95%
Chenoua (1989)	VIII-IX	167	36	7	210	21%
Beni Chougrane (1994)	VIII	30	16	4	50	40%
Ain Temouchent (1999)	VIII	36	17	6	59	39%
Algiers Boumerdes (2003)	VII	1304	753	103	2160	40%

control and quality, in order to cover the existing deficiency (Senouci et al., 2013).

3. The third category, Algeria experienced in 1980 a devastating earthquake of El Asnam, an Algerian earthquake regulation was developed at an organization called the National Earthquake Engineering Centre (CGS) (Athmani et al., 2015), for this purpose, all new constructions that were built after this earthquake are subject to the requirements of the Algerian earthquake regulation (RPA 99 V, 2003).

The educational building stock has suffered considerable damage due to local earthquakes in western Algeria (earthquakes shown in Table 2), on which the distribution of damage is established according to Table 2. Many reports indicate deficiencies found in: design, construction techniques and materials (poor concrete quality for example) (Meslem, 2012). These factors recorded during recent earthquakes have caused the following typical damage: Breaking of stairwells, breaking of knots, collapse of short posts, damaged masonry, appearance of plastic areas in posts, collapse of pancakes due to weak columns, massive beams and heavy roofs (reinforced concrete slabs).The structural system is an important factor in many schools, the structural change observed in schools that have been affected by destructive earthquakes becomes a factor aggravating the seismic vulnerability and their destruction from the occurrence of a violent earthquake (AFPS, 2003).

3. Historical and Urban Context of School Buildings in the City of Mostaganem

The center of Mostaganem is built in amphitheater on the banks of the wadi Ain Sefra, the latter divides the city into two distinct agglomerations. Upstream of the wadi, Arabo-Turks consider the first settlements occupy the city through the neighborhoods of Derb Tobbana, Tidjditt, Metmore and bhayer during the period 1080 to 1830 (Djanatu al-arif Foundation, 2013), the city has a great extension downstream of the wadi during the French colonial period between 1830 and 1964, as a result, the islets and neighborhoods have undergone modifications and some constructions have been replaced by colonial buildings.

the educational establishments associated with the initial period of this extension are realized with walls of masonry of a thickness of 50 cm thick masonry walls and voutain floors including the metal frame (Fig. 4). Generally speaking, it is a traditional construction in which unprocessed stones, rubble from local, rather brittle, tuffo-limestone, and sometimes sandstone or limestone are used as the base material (Senouci et al., 2013), often with a mortar of poor quality, which leads to heavy buildings and having a low resistance to lateral loads, the floors generally wooden and offers no function of horizontal stiffening.

At the beginning of the XX century, precisely in 1930, to enhance the resilience of school buildings, a new construction method was adopted introduction the application of RC buildings. After independence, a shortage of construction activity during the period 1962-1980, Algeria experienced the use of reinforced concrete constructions in the late 1980 and early 1990. Secondly, in view of population growth, the Algerian state has generalized the use of this mode for deferential types of construction (Athmani et al., 2015).

The study area include in this article, is part of the historical core of the city of Mostaganem, covering a large area, 2.00 km along the north-south and 1.50 km the wide east-west (See Fig. 5). Currently, it consists of two agglomerations, one concerns the old town of Derb, Tobbana and the colonial districts, and the other corresponds to the extension of the city after independence. It is full of historical monuments such as: old educational establishments, museums, a lighthouse, old mosques, ancient districts, caves and archaeological excavations.

From the sample, current research concerns the 26 existing masonry school facilities (corresponding to 199 buildings) located in the province of Mostaganem. This project is coordinated with the municipalities concerned as well as with the province of Mostaganem and also with some local associations such as DLEP, DUC, CTC, URBOR, CDE ORAN, directorate of education.

The study area includes schools of different categories, it contains: 18 primary schools, 8 middle schools, 1 university, 1 vocational training center, 1 paramedical center. These buildings correspond to the 199 masonry constructions of different typologies. Fig. 6 present the distribution of educational establishments by category in the study area, where primary schools have a fairly high percentage compared to other categories.

The historical core of the city of Mostaganem includes masonry constructions, among which most of the schools surveyed are located in this core. In addition, given the easy and quick access to these buildings to allow us to carry out investigative missions in the field of study justified this choice.

Fig. 4. Examples of Masonry Buildings Include Age: (a) Tedlawti School (1905), (b) Zerrouki Chikh High School (1848), (c) Abd Elhamid Ibn Badis University (1884-1904), (d) Middle School Saliha Ouled Kabliya 1881

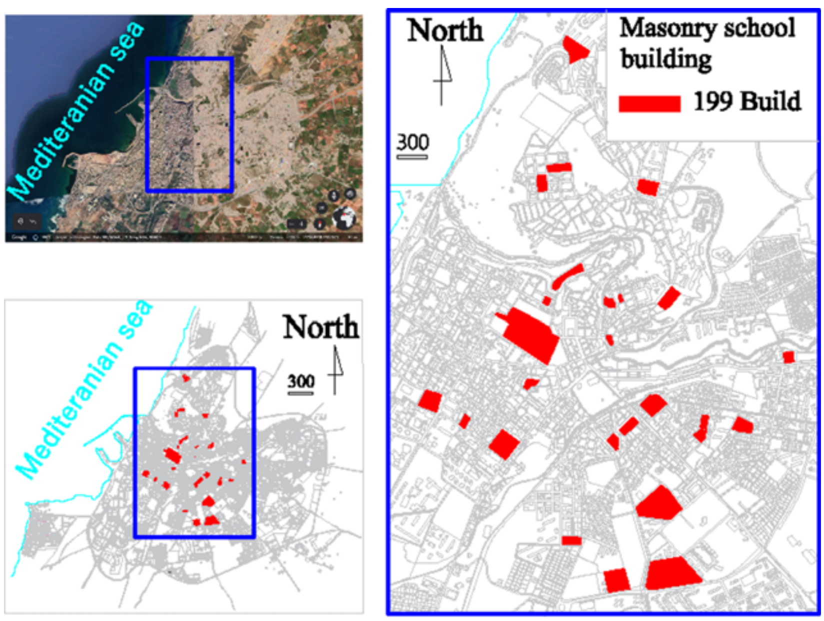

Fig. 5. Coverage of the Study Area

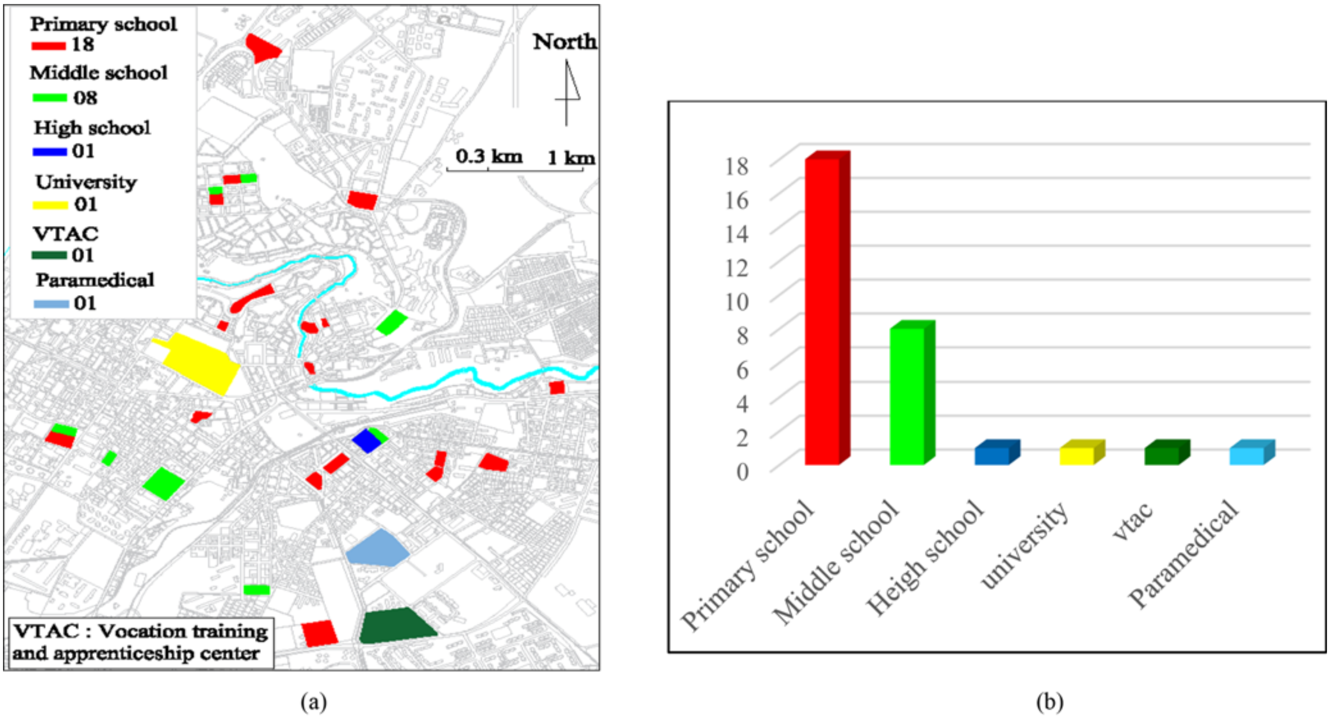

Fig. 6. Spatial Distributions/Uses oF Educational Buildings: (a) Localization of Existing Buildings in the Study Area, (b) Categories of Existing Masonry School Building

4. Study Methodology

As part of the improvement of this methodology, much of the work has been developed by the associated organizations of the RISK-UE project (AUTh, BRGM, CIMNE, CLSMEE, IZIIS, UTCB, UNIGE) (Giovinazzi and Lagomarsino, 2002). all buildings in our study area have been assessed using the RISK-EU macroseismic method (Level 1), which is to estimate the general sources of the seismic vulnerability index, the latter plays an important role in the seismic behavior of buildings following the constructive typology and general sources that can identify the fragility of these buildings. It is now possible to establish a correlation between this vulnerability index and the macroseismic intensity according to EMS-98, in order to estimate the distribution of damage probabilities, and to define the fragility curves of each building (Mouroux et al., 2004). In particular, for a grouping of a large number of buildings, this methodology classifies the structures in different states of deterioration according to the probabilistic calculations of damages by the beta law, from these calculations, the constructions were affected to degrees of damage according to EMS-98 (Giovinazzi and Lagomarsino, 2002).

The fragility models (FM) have been defined using the probabilities of damage which are associated mainly with the degrees of seismic motion, these models have been developed by correlating the seismic hazard-damage by the matrix of probability of damage (DPM) which established the deferent states of damage to buildings. Fragility (FM) models defining conditional probabilities to reach the matrix (DPM) or exceed (FM) and a defined seismic motion level are obtained directly from the cumulative beta distribution function. The relationship between macroseismic intensity and damage alters the FM/DPM (LM1) method, which is based on statistical damage to structures following past earthquakes, and the European macroseismic intensity (EMS-98). LM1 recognizes “no damage” and five degrees of damage called “light”, “moderate”, “substantial” to “heavy”, “very heavy” and “destruction” (Grünthal, 1998).

All the steps of the method have a relevant justification, which makes it possible to prejudge the quality of the method. The method has the advantage of being able to be applied to the buildings of the historic centers by simply adding the consideration of adjoining buildings. This change is part of the analysis of historical monuments and old centers carried out as part of the Work Package 5 of the RISK-UE project. It also has the advantage of associating uncertainty with the resulting vulnerability index. This margin of error allows to qualify the obtained results. Below, A representative flowchart in Fig. 7 describing the processes of the RISK-UE method:

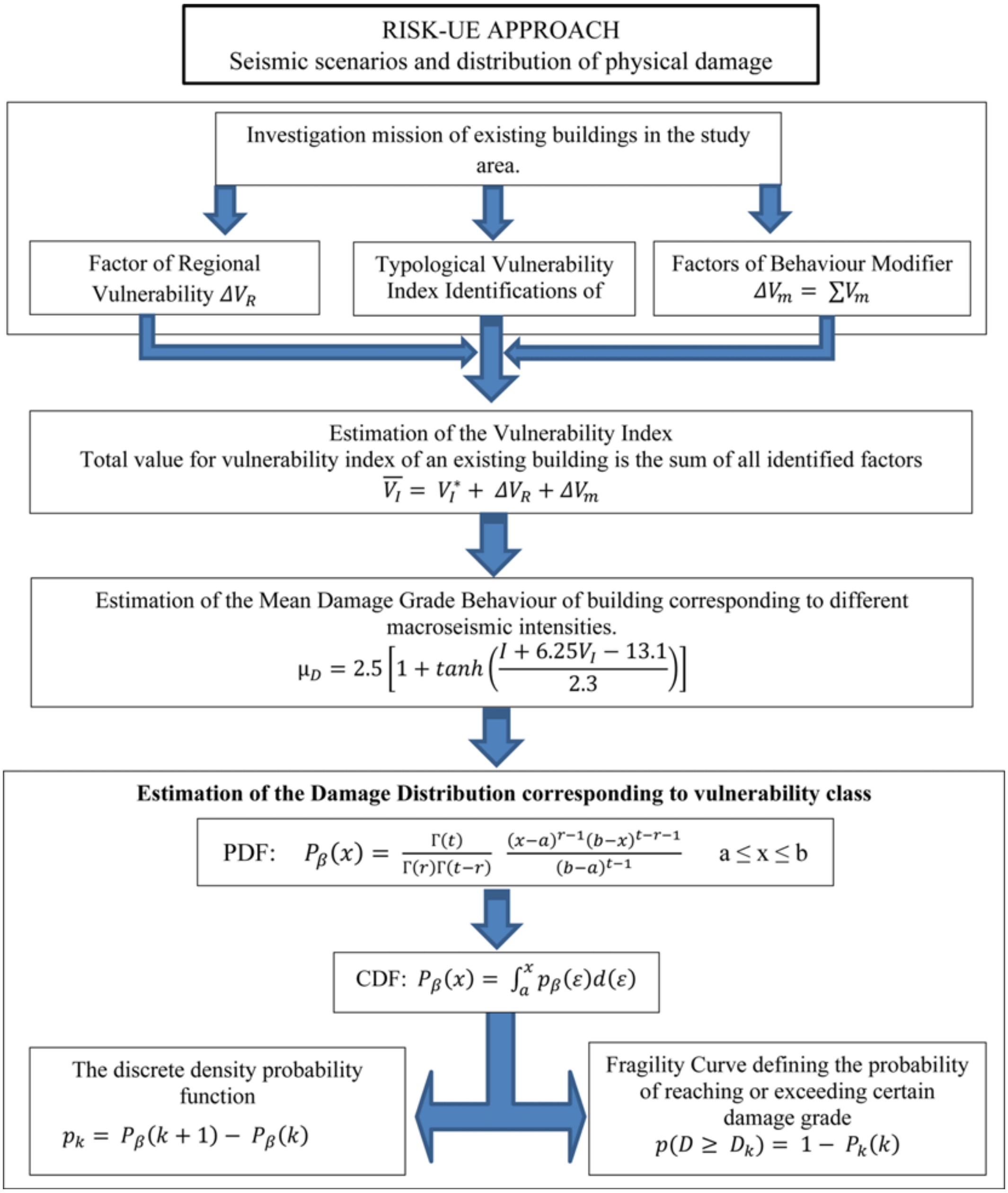

Fig. 7. Representative Flowchart Describing the Processes of the RISK-UE Method

According to the vulnerability index (Table 3) obtained by the proposed methodology, a typological classification model (Giovinazzi and Lagomarsino, 2002) is established to determine the seismic performance of each structure, The probable vulnerability index VI is calculated for each typology as a result of behavior al changes in each building, according to the equation below (Milutinovic and Trendafiloski, 2003):

$$\overline{V}_I = V_I^* + \Delta V_R + \Delta V_m, \tag{1}$$

where, the vulnerability index VI is related to the building class (Table 3), ΔV_R is a factor used to account for the characteristics of certain typologies at the regional level. It is considered null for this research, ΔV_m are modifiers that show the influence of different parameters of the typology on the seismic behavior of the building (Table 4).

It is now possible to assess and map the typology of buildings according to the RISK-UE approach, Table 3 presents the typology of school buildings. This educational park includes four types of masonry buildings (M3.1, M3.3, M3.4 and M4), two are clearly dominant, M3.1 (34.17%) and M3.4 (39.20%). These buildings were built during the colonial period 1830 to 1962, they are clearly associated with the most vulnerable category that dominates this educational park.

For a single building, the factor ΔVm is an overall score of the sum of the modification factors assigned to the various identified parameters:

Table 3. Building Typologies according to the RISK-UE Method (Giovinazzi, 2005)

RISK-UE type		Description	Number	(%)	∑(%)
Masonry	M3.1	Wooden slab	68	34.17	100
	M3.3	Composite steel and masonry slabs	33	16.58	
	M3.4	Reinforced concrete slabs	78	39.20	
	M4	Reinforced or confined masonry walls	21	10.05	
Total			199	100	

Table 4. Scores for Vulnerability Factors Vm: Masonry Buildings

Vulnerability	Factors	Scores for Vm
State of preservation	Good maintenance	-0,04
	Bad maintenance	+0.04
Number of floors	Low (1 or 2)	-0.02
	Medium (3, 4 or 5)	+0.02
	High (6 or more)	+0.06
Structural system	Wall thickness Distance between walls Connection between walls (Tie-rods, angle bracket) Connection horizontal structures- walls	-0,04 ÷ +0,04
Soft-story	Demolition/Transparency	+0.04
Plan Irregularity		+0.04
Vertical Irregularity		+0.02
Superimposed floors		+0.04
Roof	Roof weight + Roof Thrust Roof Connections	+0.04
Retrofitting interventions		-0,08 ÷ +0,08
Aseismic Devices	Barbican, Foil arches, Buttresses	no indication
Aggregate building: position	Middle	-0.04
	Corner	+0.04
	Header	+0.06
Aggregate building: elevation	Staggered floors	+0.02
	Buildings of different height	-0,04 ÷ +0,04
Foundation	Different level foundation	+0.04
Soil Morphology	Slope	+0.02
	Cliff	+0.04

$$\Delta V_m = \Sigma V_m \tag{2}$$

On the basis of the RISK-UE method, it should be noted that the vulnerability indices previously assessed are directly linked to the vulnerability classes according to the EMS-98 seismic scale (Grünthal, 1998). Therefore, this connection gives a bounded interval corresponding to the typology of buildings for several types of masonry: massive masonry, unarmed masonry, with units made of stone and reinforced or confined masonry. associated with vulnerability classes B, C and D.

In addition, according to the investigations carried out on the study area following the requirements of the RISK-UE approach, nearly 80.90% of buildings have a vulnerability index greater than 0.78 (equivalent to vulnerability class A) and 19.10% of buildings belonging to vulnerability class B (0.86 ≥ VI ≥ 0.62). The spatial distribution of the vulnerability index is illustrated in Fig. 8 for pre-diagnosed educational buildings. The above map is considered to be a valuable database useful for strategic civil protection purposes, which presents indicators of the vulnerability of educational buildings to their fragility.

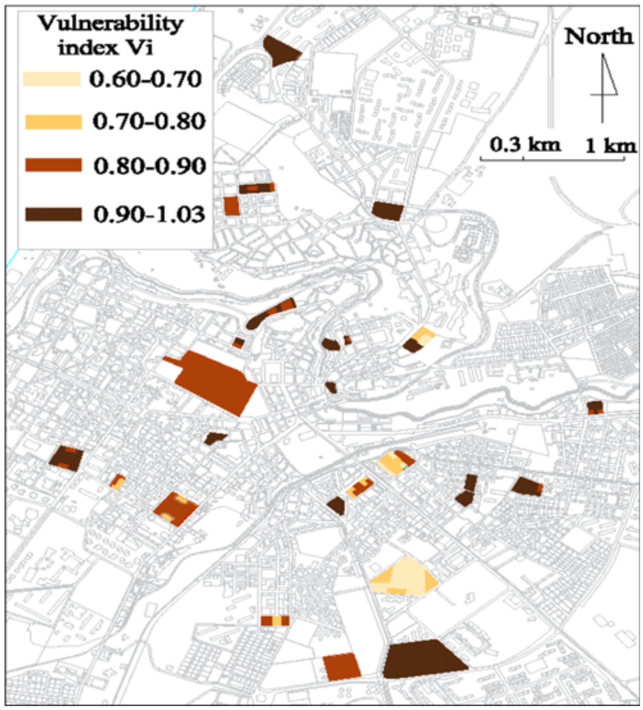

Fig. 8. Mapping of the Vulnerability Index (Spatial Distribution) according to the RISK-UE Method

5. Results and Discussion

5.1 Estimating the Average Damage Index

In accordance with the RISK-UE method, the average damage μd is assessed by semi-emperor relationships, correlating the seismic intensity I considered with the vulnerability index in order to introduce the fragility curves.

$$\mu_D = 2.5\left[1 + \tanh\left(\frac{I + 6.25\,V_I - 13.1}{2.3}\right)\right] \tag{3}$$

From this relationship, we assess the average degree of damage of the school building for each selected intensity value (Giovinazzi, 2005). This can give us the different behavioral information that a building can take, corresponding to the different macroseismic intensities.

The semi-empirical equation N°03 produced fragility diagrams illustrated in figure N°09 (curves of mean damage μD) more or less parallel, this one because of the similarity of a certain vulnerability class according to the degree of seismic intensity (I = V to XII) another vulnerability class next.

5.2 Seismic Scenarios and Distribution of Physical Damage

An adequate probability distribution at damage levels (a discrete distribution) can complement the DPM. the statistical application of the beta distribution proved to be a great success in analysing the data generated by the Irpinia earthquake in 1980 (Italy) (Braga et al., 1982) corresponds to the Chlef earthquake in Algeria in the same year, but the simplicity of this distribution, which is based on a single parameter, does not allow to define the dispersion of degrees of damage around the mean value.

The binomial distribution shows a rather large divergence according to Sandi (Sandi, 1995), according to the detailed assessment on constructions. Over-estimation was observed in the extensive damage of several buildings with relatively low average damage slope values. The most appropriate distribution for the requirements is the beta distribution (also used in ATC-13, 1985), the beta law belongs to continuous probabilistic series, it is well defined in the probability theory and statistics on the interval [0,1], configured by two form parameters, typically noted t and r. which present a particular case of Dirichlet with regard to these two parameters. Where Γ is the gamma function. the beta distribution has identified itself as a constant normalization, it shaves a lot at the binomial distribution, which allows the density to converge towards unity. The seismic scenarios should be calculated using the beta distribution. For each vulnerability class, this damage distribution function is defined as follows (basic equation of the beta distribution):

Distribution function of probable damage:

$$P_\beta(x) = \frac{\Gamma(t)}{\Gamma(r)\Gamma(t-r)} \frac{(x-a)^{r-1}(b-x)^{t-r-1}}{(b-a)^{t-1}} \quad a \le x \le b\,. \tag{4}$$

Cumulative distribution function of probable damage:

$$P_\beta(x) = \int_a^x p_\beta(\varepsilon)d(\varepsilon)\,, \tag{5}$$

where: the beta distribution and set by *a*, *b*, *t* and *q*, and *x* presents the continuous random variable that extends between a and *b*. *Γ* is the gamma function.

It is now possible to correlate the average damage index with the two parameters of the beta function as follows:

$$r = t(0.007\mu_D{}^3 - 0.052\mu_D{}^2 + 0.28\mu_D). \tag{6}$$

The parameter t defines the beta distribution, on which if t = 8 this distribution converges towards the binomial distribution. The use of this distribution is based on the 5 degrees of damage DK, which belong to the types of discrete variables range from zero degrees (no damage) to ruin, it is better to assign the value 0 to the factor a and 6 to the factor b (Lagomarsino et al., 2002).

The probabilistic calculation is based on the discrete density of the beta distribution as a function of damage levels, as indicated below:

$$p_k = P_\beta(k+1) - P_\beta(k), \tag{7}$$

the fragility curves describing the different deterioration states of

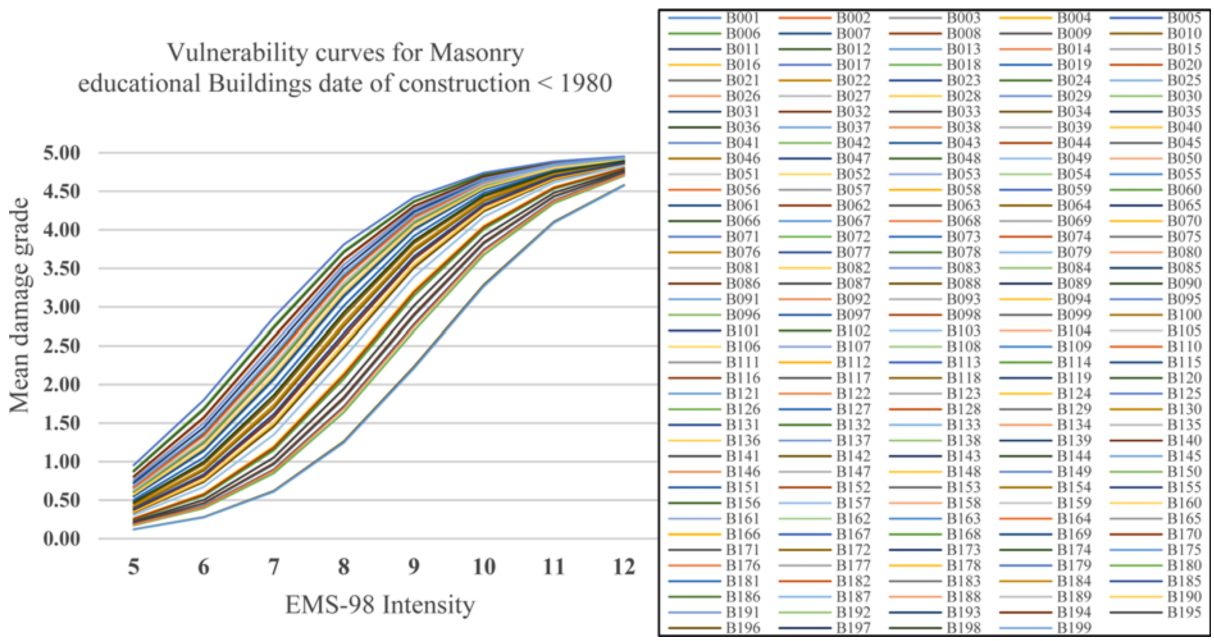

Fig. 9. Mean Damage Grade Estimation for Masonry School Building

the buildings, which are derived from a cumulative probabilistic calculation allowing to reach or exceed a certain degradation is performed by the beta distribution as follows:

$$p(D \geq D_k) = 1 - P_k(k)\,. \qquad (8)$$

The above damage assessment has been defined using the RISK-UE method, on which the results obtained from the use of this methodology have been presented in the form of damage scenarios for seismic intensities of order V to XII. A presentation of the deferential seismic scenarios in histogram of damage distribution (Fig. 10) of the sample is the subject of our study, expressed in EMS98 grades, shows that the RISK-UE classifies the constructions is part of the study area in the degrees of damage Dk well specified according to the intensity of the seismic scenario concerned.

The color code corresponds to the degrees of damage EMS 98: D0: light green, (no structural damage); D1: dark green, (no structural damage, slight non-structural damage); D2: yellow, (Moderate damage: slight structural damage, moderate non-structural damage); D3: dark yellow, Substantial to heavy damage (moderate structural damage, heavy non-structural damage); D4: purple, Very heavy damage (heavy structural damage, very heavy non-structural damage); D5: red, Destruction (very heavy structural damage).

These histogram graphs show the seismic scenarios presented above are used to assess damage in terms of functional damage and are therefore highly effective tools for the targeted implementation of individual and/or larger-scale urban rehabilitation processes and reinforcement strategies.

The Fig. 10(a), evaluates a seismic scenario for the IEMS-98 intensity = 5, all masonry school buildings found in the degree of damage D0, with a percentage damage distribution of 98.99%, other vulnerable constructions have been classified in degree of damage D1 of percentage 1.01%, this probable seismic scenario has no damage content, and no damage/degradation has been found in the constructions forming our study area, however, Mostaganem has recently suffered an earthquake in 22.05.2014, longitude 0.259 ºE and latitude 35.725 ºN of magnitude Mw =

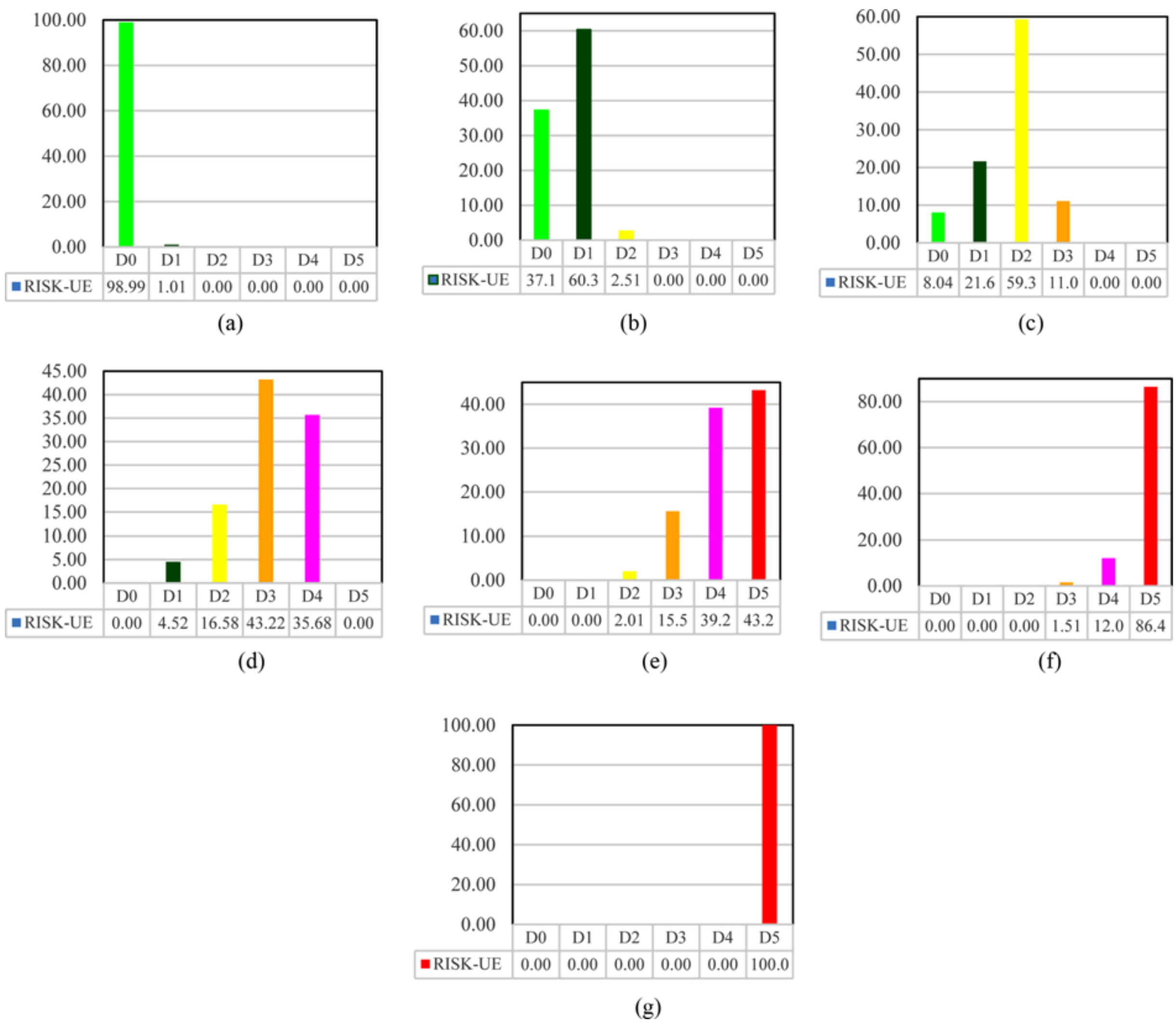

Fig. 10. Histogram Distribution of Damage according to EMS-98 Intensities (Seismic Scenarios): (a) Intensity = 5, (b) Intensity = 6, (c) Intensity = 6, (d) Intensity = 8, (e) Intensity = 9, (f) Intensity = 10, (g) Intensity = 11, 12

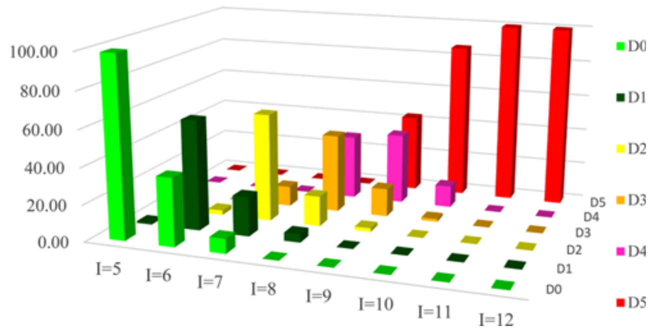

Fig. 11. Synthesis of Global Damage Scenarios for Different EMS-98 Intensity for Mostaganem School Buildings

4.9 or Intensity = 5, which has caused cracks to educational institutions and many private homes through some communes of Mostaganem (Abbouda et al., 2018).

The Fig. 10(b), presents the probable damage levels estimated according to the RISK-UE method for the IEMS-98 intensity = 6, where negligible to light damage is predicted for approximately 37.1 for D0 and 60.30% for D1 of buildings, Except, 2.51% of the buildings analyzed have a damage category D2.

For 59.30% of the buildings in the sample shown in Fig. 10(c), converge to the dominant degree of damage D2 for the seismic intensity IEMS-98 = 7, the probable damage of the other constructions reaches the degrees of damage D0, D1, D3. With a percentage distribution of 8.04%, 21.60%, 11.00%, respectively. The damage observed for this scenario is light to moderate damage to non-structural parts.

A seismic scenario (Fig. 10(d)) occurred as a result of the IEMS-98 = 8 macroseismic intensity, a large majority of masonry buildings show a fairly high percentage of damage corresponding to the degrees of damage D1, D2, D3 and D4, whose last two degrees dominate the damage of these constructions, Taking into account the above-mentioned intensity, the majority of educational establishments located in the historical core of the city of Mostaganem suffered moderate to very heavy damage for the non-structural and Heavy for structural parts with a percentage of about 4.52%, 16.58%, 43.22% and 35.68% for degradation D1, D2, D3 and D4, respectively.

Figure 10(e) shows the histograms of damage following a macroseismic intensity IEMS-98 = 9, almost half of the buildings (about 43.20%) are likely to collapse for degree D5. In addition, about 39.20% of buildings are resolved with a quasi-collapse state, exhibiting D4. The estimated values for category D2 and D3 were 2.01 and 15.05, respectively.

The main lesson extracted from a geographical information system presented in Fig. 11 is the absolute variation of damage estimated following the deferential intensities, over all schools, with a low damage content for I = 5; 6, moderate for intensity I = 7; 8, heavy damage for I = 9 and finally destruction or ruin of structures for intensity I = 10; 11; 12.

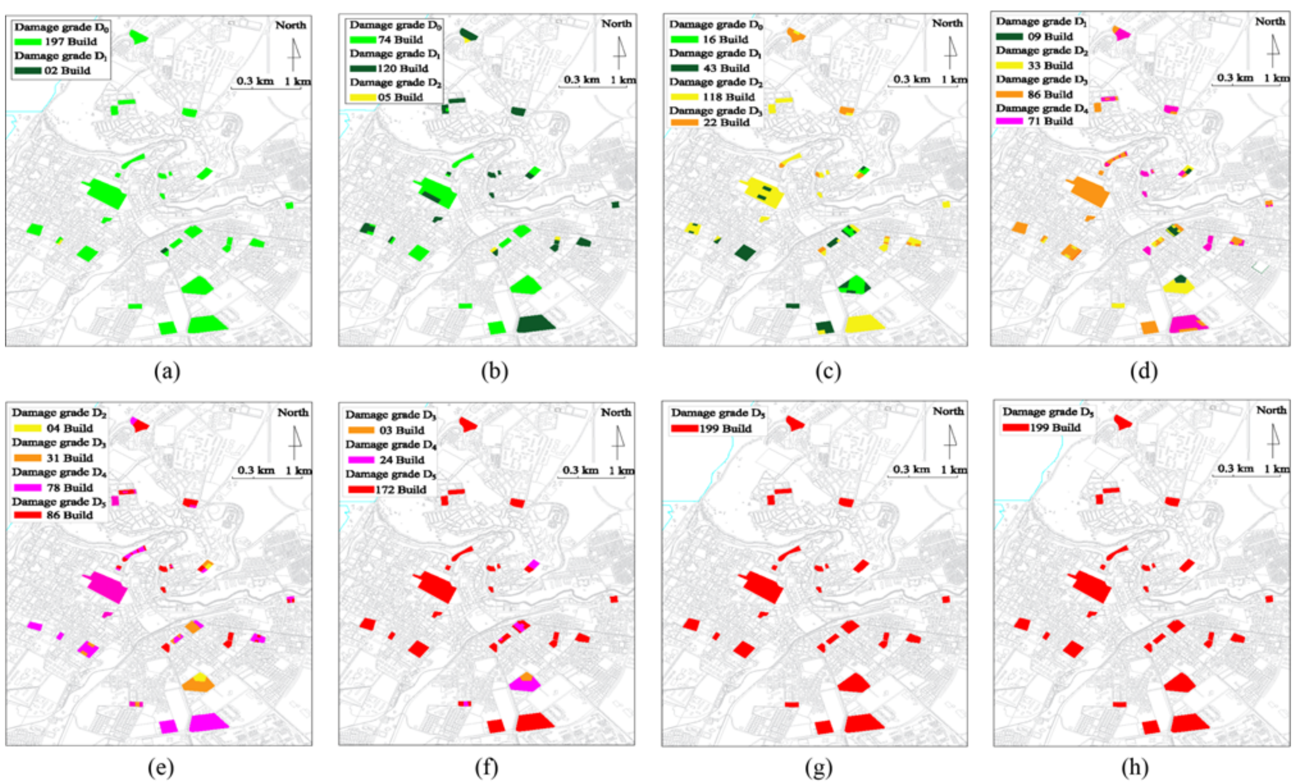

Fig. 12. Spatial Distribution of RISK-UE Damage for the Seven Different Intensity Levels (5, 6, 7, 8, 9, 10, 11 and 12). (a) Intensity I = 5, (b) Intensity I = 6, (c) Intensity I = 7, (d) Intensity I = 8, (e) Intensity I = 9, (f) Intensity I = 10, (g) Intensity I = 11, (h) Intensity I = 12

5.3 Spatial Distribution

Urban damage related to school's estimated by the RISK-UE method is appropriate for a large-scale analysis, the damage assessment according to this methodology offers a design based on a visual and statistical diagnosis of the damage.

In addition, the results generated by the different seismic scenarios present a spatial process. To achieve statistical significance, the number of buildings must exceed 100. The spatial distribution of damage shown in Fig. 12 shows that all school buildings are in the study area with varying degrees of damage depending on the seismic intensities for each scenario. In particular for cases of low intensity (5 and 6) the degrees of damage D0, D1 is mostly characterized by the damage content presented in both maps (Figs. 12(a) and 12(b), the resulting damage levels are low to negligible. Figs. 12(c) and 12(d). shows an increase in the damage content, on which degrees D2, D3 dominates the damage observed following the seismic intensity IEMS98 = 7; this is 8 due to the high severity of the seismic action and the high vulnerability of the buildings. A very heavy balance brings partial/total destruction of buildings illustrated in Figs. 12(e), 12(f), 12(j), 12(h), according to intensities IEMS98 = 10; 11; 12, all buildings are in degrees D4; D5.

The city of Mostaganem experienced maximum intensities of order VI to VII (earthquake of Mostaganem on 5/10/1883) (Harbi et al., 2020), and according to the damage scenarios obtained, they can be considered as a guide for decision-makers to estimate the severity and magnitude of the seismic risk for surveyed buildings in Mostaganem, or in other cities of the country to apply preventive measures and naturally reduce the seismic risk.

6. Conclusions

The main objective of this research project is to summarise briefly a sequence of seismic damage assessments obtained by the use of all data by the RISK-UE method to prevent damage likely to occur during future earthquakes. 199 school buildings are considered in this study, located in the heart of the province of Mostaganem were studied to identify the general sources of seismic vulnerability.

The results obtained can be summarised as follows:

1. A vulnerability index has been estimated based on field-based investigative missions to determine the general sources defining the seismic vulnerability of masonry school buildings.
2. The assessment of the average degree of damage for each building according to seismic intensity (EMS-98) shows a very satisfactory agreement for masonry buildings, and the assessment of vulnerability curves for Algerian school buildings.
3. Based on these results, a series of seismic damage scenario analyses were conducted and the assessment of potential damage was corrected for each building. In the light of these results, a series of scenario analyses of seismic damage have been carried out, on which the pre-diagnosed constructions have an assignment of the probable damage defines their state of damage (Fig. 12). Results show that those most vulnerable masonry buildings are those built before 1981, and especially those built during the French colonial era (before 1961).

This study defines the structural information resulting from the survey mission on the study site, the vulnerability assessment consists of identifying the general sources affecting seismic vulnerability and predicting damage scenarios for pre-diagnosed constructions. For the first scenario of intensity, I = 5, all buildings are classified in degree D0 (negligible damage). The second scenario, under seismic intensity I = 6, the constructions suffered minor damage. For the third scenario (I = 7) the expected damage is light to moderate. The fourth scenario concerns I = 8, the damage observed is moderate to heavy. The fifth scenario (I = 9) carries a heavy damage balance sheet, from I = 10 the seismic scenarios carry very heavy damage balance sheets (total destruction).

When analysing the constructions to identify the general sources of seismic vulnerability, the several criteria must be defined as age of construction, structural design, basic materials, foundations, etc. The limitations and obstacles encountered during the assessment of the vulnerability of the constructions examined are: the absence of an archive describing the way of realization and the history of the deferential constructions in the colonial period, lack of deferential plans of execution (architectural and civil engineering plans) bearing the type of infrastructure, the age of the building, the layout of the braces, etc. etc. this lack of information has forced us to look for other means and methods to properly estimate seismic vulnerability.

In order to mitigate the damage induced by seismic vulnerability, several adequate measures have been implemented to preserve the deferential educational establishment through the rehabilitation of old buildings. In addition, given the importance of educational heritage, mitigation processes are implemented to protect student/student lives. Site effects play an important role in the accuracy of the results generated by the methodology used in this research; this precision is improved by taking into account the impacts on the site. To better understand and locate the buildings most likely to be affected during the next earthquakes, a GIS environment has been created to present the results obtained in the form of very easy damage maps, these maps can be of great assistance in emergency management and risk reduction.

However, the average assessment of the seismic behaviour of the different intensity-resolved buildings resulted in vulnerability curves for each building type. They may have been considered for other applications in other regions with similar characteristics. In this sense, the next step is to estimate the economic loss and cost of repairs, as well as the likelihood of death and homelessness. In addition, this information can help to support planning strategies and classify seismic response and rehabilitation work. At this point, we have concluded that it is very important that if research focuses on how schools should play to psychically protect schoolchildren after the earthquake or any catastrophic event. This research project is a first step and must be followed by another analysis, to mitigate the seismic risk in school buildings in Algeria.

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ORCID

Bendehiba Sabeur https://orcid.org/0009-0004-3261-387X
Sidi Mohammed El-Amine Bourdim https://orcid.org/0000-0001-7187-8126
Hugo Rodrigues https://orcid.org/0000-0003-1373-4540

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