

Msila Algeria Earthquake Of May 14, 2010: Main Features And Building Damage Analysis

Belazougui Mohamed

*Director of the Centre National de Recherche Appliquée en Génie Parasismique,
CGS, Algiers, Algeria*



ABSTRACT:

The moderate earthquake of May 14, 2010, with 5.2 Magnitude, that struck mainly two communes of the province of Msila and one commune of the province of Bordj Bouarreridj, at about 150 Km south-east of Algiers, has resulted in 3 dead people, 86 injured, 1720 out of shelter families, 6431 dwellings or constructions damaged, among them more than 1000 have collapsed or are considered as non repairable.

The great majority of the built environment of this rural region is constituted by bearing masonry structures which are the most widely used building system in that region and partly by reinforced concrete beam-column structures.

In this paper, the main features of this seismic event triggered by a blind fault will be briefly presented. Then, the building damage will be analyzed in terms of nature and degrees of severity for different categories of structures and the main weaknesses and insufficiencies of such structures and the main causes of damage will be underlined.

Finally the main lessons learned from this event, in terms of bearing masonry and reinforced beam-column building systems behavior, will be presented and some recommendations will be given in order to improve Algerian building practice and Algerian seismic code requirements related to such systems. Among the lessons learned, we can mention the very good behavior of the confined bearing masonry structures that have been built since the last serious earthquake that has stricken the region in 1960.

Keywords: Post earthquake investigation, Structures earthquake behavior, Confined bearing masonry

1. INTRODUCTION

The 14th of May 2010 at 13 H 28 GMT an earthquake of magnitude 5.2 shook a region at about 150 Km south-east of Algiers (Fig 1.1.a), namely, the communes of Beni Ilmane and Ouanougha, in the northern part of the Wilaya (Province) of Msila and the neighbouring commune of Ben Daoud connected with the Wilaya of Bordj Bou Arreridj (Fig 1.1.b)

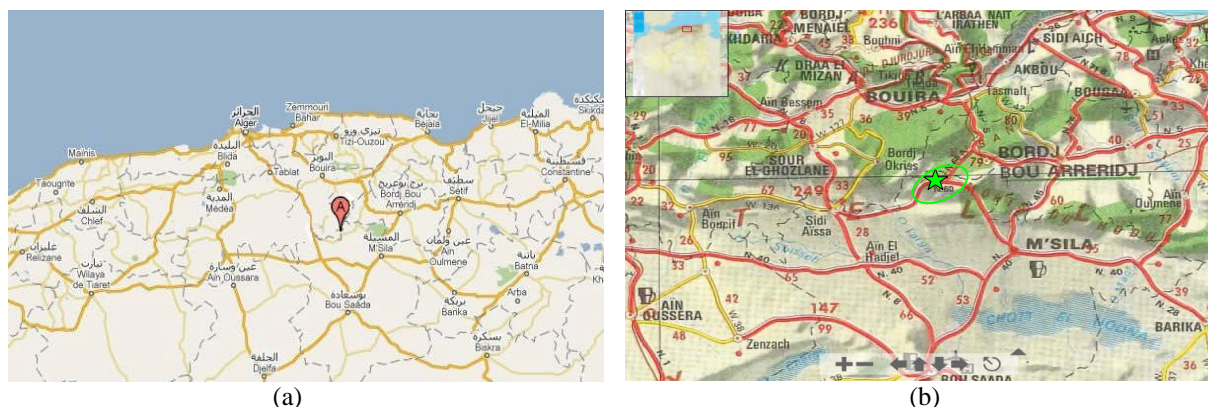


Figure 1.1. Region Hit by the May 14 th, 2010 Msila Earthquake

This earthquake has been felt extensively in the surrounding wilayas (Msila, Bordj Bou Arreridj and Bouira) till a distance as far as 60 Km from the epicentre that was located 10 Km about from Beni Ilmane City. The main shock has been followed, in the following days, by more than 30 aftershocks, the two strongest reaching a magnitude of 5.0 and the remaining ones varying from 3.0 and 3.8.. The stations of the Accelerographs network of CGS installed in the region recorded the main shock and the main aftershocks.

About 586 buildings or dwellings have been destroyed and 2011 others have been heavily damaged in the communes of Beni Ilmane, Ouanougha, and Ben Daoud.

We deplore otherwise (last official report) 3 deaths, more than 86 injured and about 1720 homeless families.

2. CHARACTERIZATION OF THE EARTHQUAKE

2.1. The seismic event

As reported previously, it is therefore on May 14, 2010 at 12H28 G.M.T that a Magnitude 5.2 (Richter scale) earthquake shook the communes of Beni Ilmane, Ouanougha, and Ben Daoud in the region of Msila, at about 150 Km south-east of Algiers (Fig 1.1 and 2.1.).

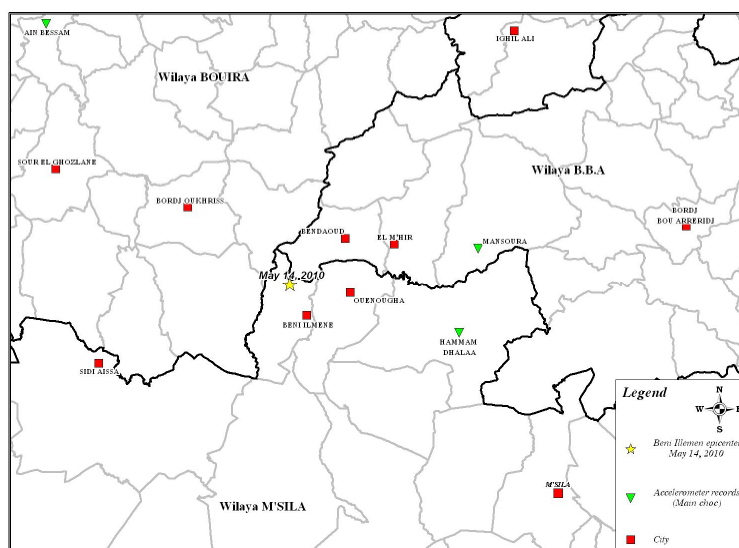


Figure 2.1. Region Hit by the May 14 th, 2010 Msila Earthquake

The characteristics of the seismic event are summarized in the table 2.1

Table 2.1. Characteristics of the seismic event

Magnitude	Mb 5.2
Region	Msila (Northern Algeria)
Date and time	2010-05-14 at 12:29:22.3 UTC and 13:29 local time
Location	35.90 N ; 4.12 E
Depth	2 km
Distances	43 km NW of M'Sila (pop 118,153 ;) 11 km NW of Ouanougha (pop 25,701)

In the hours that followed the main shock, several after-shocks have been recorded. These after-shocks continued the days after without overtaking a magnitude of 4.

2.2. Seismic records

Concerning strong motion, some records have been obtained by the national accelerographs network of C.G.S. The stations in nearest free field that recorded the main shock are located at 25 to 50 Km from the epicentre (Fig. 2.1). The maximal accelerations recorded by three (03) stations are given in Table 2.2.

Table 2.2: Recorded accelerations of the main shock

Station	Component (g)			Distance between the station and the epicenter (Km)
	E-W	Vert.	N-S	
Hammam Delaa	0.0183	0.006	0.0177	26.9
Mansoura	0.0239	0.0106	0.0189	34.2
Ain Bessam	0.0031	0.0026	0.0026	48.6

3. DAMAGE ASSESSMENT AND ANALYSIS

To rehouse the maximum number of the homeless as soon as possible in adequate conditions of security, and to let a quick and efficient recovery, a mission for damage assessment has been required expressly by the Ministry of Housing, mobilizing 58 experts (Researchers, Engineers and technical staff) from scientific and technical Organizations as CGS, C.T.C, local technical administrations, etc...

These experts were dispatched in the field forming teams of about 2 or 3 experts controlled by a Head Quarters located at Beni Ilmane.

3.1. Damage assessment form

To assess damage and to classify immediately buildings that require repair and/or strengthening, and those that are irretrievable, a damage assessment form containing about sixty informations has been used.

This form that has already been used for Chlef earthquake in 1980, Tipaza in 1989, Mascara in 1994 Ain Benian in 1996, Ain Témouchent in 1999, Beni-Ouailane in 2000, and Boumerdes in 2003, acts as a guide for the structural engineers who are in charge of damage assessment.

Each form has been filled to consign the damage report of each assessed building. The use of this form contributed to make the procedure of assessment of the damages systematic and to make homogeneous the appreciations of the inspectors.

This form includes general information (as building identification, building occupancy, number of levels, etc.), soil problems, an assessment of the structural and non structural elements damage, commentaries on the damage causes, global building damage level and the recommendations of emergency measures if necessary. For damage level assessment of the construction elements and global building damage level, a classification of 5 levels (and 3 colors) has been used.

GREEN (levels 1 and 2): for the constructions having undergone no damage, or slight damage, and that can be reoccupied immediately.

ORANGE (levels 3 and 4): for the constructions having undergone some damage and requiring a second extensive expertise that will permit to decide if (and how) these constructions can or can't be repaired and strengthened according to the damage importance and the cost of repair and strengthening.

RED (level 5): for the constructions partially or totally collapsed and definitively lost.

3.2. Damage distribution

This section presents the general damage results that constitute a balance as well as statistics of damage levels.

Table 3.1 shows the distribution of the assessed 6431 constructions in the area hit by the May 14th, 2010 Msila earthquake. The damage assessment was done till 01-06-2010 according to the five damage levels regrouped in three colors (green: levels 1 and 2; orange: levels 3 and 4; and red: level 5). We note that the major assessed constructions among the total (6431) are residential buildings (6263, 97.40 %).

Among the 6431 assessed buildings we note that:

- 3834 have been classified into the levels 1 and 2 (green colour), that is to say among the buildings not having undergone practically any damage or having undergone light damage requiring simple repair. The percentage of this class represents 59.60 %.

- 2011 are classified into the intermediate levels 3 and 4 (orange colour), that means these buildings are requiring a more deepened expertise for future repair and strengthening. The percentage of this class represents 31.30 %.

- 586 have been classified to the level 5 (red colour), that means these constructions were partially or totally collapsed and are requiring a demolition and an ulterior reconstruction according to the seismic code. This class represents 9.10 %.

Table 3.1: Building damages distribution in total area (Wilayas of Msila and BBA)

Construction use	Green		Orange		Red	Total
	Level 1	Level 2	Level 3	Level 4	Level 5	
Residential buildings	1702	2031	1071	878	581	6263
Administrative buildings	5	9	3	1	0	18
Schools	5	24	10	15	4	58
Hospitals	4	4	0	3	0	11
Sportive and cultural buildings	3	4	2	2	0	11
Commercial buildings	9	1	1	1	0	12
Industrial facilities and hangars	0	0	0	0	0	0
Other (water tanks, etc...)	24	9	13	11	1	58
Total	1752	2082	1100	911	586	6431
%	27.24	32.37	17.11	14.17	9.11	100
	59.61		31.28		9.11	100

4. DAMAGE CAUSES AND FEATURES

In the present paper the main damage features observed after the May 14th, 2010 Beni Ilmane earthquake will be described and analysed.

We can say that there is no fundamental differences compared with previous seismic events sustained by Algeria during the last 60 years.

However, two (2) notable particularities can be mentioned for these event and region.

Firstable, the built environment is mainly constituted by one story non confined bearing masonry units without mortar joints or with very poor mortar joints. This has resulted, in a radius of about 20 Km

around the epicentre, in important damage characterized by partial or total collapse of these very vulnerable constructions and this, even though the magnitude was very moderate. The second notable observation deal with the existence of a number of individual houses or schools built in confined stone (or sometimes brick) bearing masonry that had a very good behaviour (no damage and even no crack was observed, Figure 4.2). Following some local information, this building system was introduced by the existing authorities after the previous and similar event in 1960 for reconstruction purposes; we can say that this building system has positively succeeded the seismic test of May 14, 2010.

Otherwise, the damage deal with reinforced concrete building systems where the design or the execution are characterized by several insufficiencies; their damage features, both with the other building system (bearing masonry), will be addressed hereafter

4.1. Kinds of damage encountered in reinforced concrete beam-column buildings

Damage that different buildings have suffered in the two Wilayas of Msila and Bordj Bou Arreridj can be summarized as follow:

- Collapse of buildings for diverse reasons
- Separation or partial collapse of bearing masonry walls
- Shear of short columns
- Hinging of reinforced concrete columns due to diverse reasons (under dimensioning, global torsional effect and lateral displacement due to soft stories)
- Horizontal or diagonal cracks in masonry infill
- Shear failure of reinforced concrete beam-columns joints with two cases :
 - Shearing of the joint core (« strong masonry... »)
 - Shearing of the upper part of the column after crushing of the masonry infill corner («weak masonry.»)
- Shearing and dislocation of numerous masonry infill due to important inter-story drifts
- Cracking of many external covers (that are often thick)
- Many vertical and horizontal cracks at the junction of structure and infill due to lateral and vertical displacements
- Collapse or cracks in the top of minarets

4.2. Causes of damage

The causes of damage to the constructions is mainly due to insufficiencies in design, dimensioning and execution.

4.2.1 Poor conceptual design (Building Configuration and Structural Layout) for seismic resistant buildings.

The most notable defects are the following:

- Traditional non confined (or non tied) bearing masonry structures (in rural and urban areas) (Figure 4.2)
- Short columns in « vides sanitaires » (crawl spaces under the first story) and between upper windows of classrooms or, sometimes, in other configurations (Figure 4.3)
- Use of irregular building configurations with severe discontinuities in mass, stiffness, strength, and ductility resulting in torsional effects and stress concentration (Figure 4.4)
- Presence of soft stories, generally at the ground zero (first story) used as car parking or stores, with lack of infill and/or height greater than for upper stories (Figure 4.5)
- Use of very heavy roofs
- Use of "strong girders / weak columns" and masonry-structure interaction (Figure 4.6)
- Use of important and heavy cantilevers
- Insufficient dimension of the seismic joint (between two blocks of the same building, or between two buildings)
- Use of many heavy ornamental elements at building facades, as well as unnecessary parapets on the roofs



Figure 4.1. Collapse of non confined bearing masonry structures



Figure 4.2. Confined bearing masonry structures (one school and three houses) that behave very well.



Figure 4.3. Short columns



Figure 4.4. Vertical dissymmetry and poor quality of execution



Figure 4.5. Soft story (Classroom at the 1st story under rigid apartment 2nd story)



Figure 4.6. Masonry-structure interaction and bad quality of design and execution

4.2.2 Lack of structural design or under-dimensioning (non seismic resistant design)

This is the case of all the buildings aged before 1981 or the great majority of individual or private houses built after 1980 (more than 60% of the new built environment) (Figure 4.7).



Figure 4.7. Under-dimensioning

4.2.3 Poor quality of execution and poor quality of structural material

In this framework we can note the very low strength of concrete checked in the field (generally less than 20 MPA instead of 25 MPA required by the standards for current buildings) and the very inadequate recastings of concrete in columns at the beam-column joints (Figure 4.8).



Figure 4.8. Poor quality of execution and inadequate concrete recasting

4.2.4 Inadequate proportioning and detailing of structural elements (Figure 4.9).

In this framework, we can mention the lack of transverse reinforcement in the core of reinforced concrete beam-column joints (no confinement) or great distance between these transverse reinforcement (insufficient confinement in the remaining of joint area).



Figure 4.9. Inadequate proportioning and detailing of structural elements

4.2.5 Poor inspection and control of construction process

4.2.6 Inadequate building maintenance

5. CONCLUSION

The May 14th, 2010 earthquake that hit the region of Msila is then characterized by notable damage in spite of the very moderate magnitude of the event. This is firstly due to the traditional deficiency of non confined bearing masonry which is very extensively used in the region, coupled with very poor mortar joints (or lack of them). It is also due to the deficiency of many other constructions in design and quality of materials and execution.

Three (3) main recommendations seemed to be evident after this event:

- Apply more strictly the Algerian earthquake resistant regulations (“RPA 99/2003”) and the other building codes in force
- Promote at maximum possible use of confined stone bearing masonry that showed a very good behavior during this event.
- Perform and promote more training and better organization of the building staff and professions to improve quality in design and execution.

REFERENCES

CGS (2010), Preliminary report on Msila Earthquake