

Diagnosis, seismic analysis and reinforcement of an old building in El-Maleh, Algeria

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Abstract: The Northern part of Algeria is considered to be the most active seismogenic area in the Western Mediterranean region. This area has a rich history of seismicity and had experienced many destructive earthquakes such as the Chlef (1954), El-Asnam (1980), Beni-Chograne (1994), Aïn-Temouchent (1999) and recently Bouverdes (2003) earthquakes. The earthquake of Aïn-Temouchent on December 22, 1999, was of magnitude 5.7, killed at least 28 people and made thousands of families homeless. Consequent damage was seen in all the structures located in a radius of 30 km. In the city of El-Maleh, located 12 km northeast of Aïn-Temouchent, the “The National Bank Branch” of El-Maleh suffered moderate damage, but enough to justify questions about its safety. The project of rehabilitating this building required a broad analysis of its static and dynamic, past and present behaviors. The study reported in this paper was a necessary preliminary step toward the development of an optimal retrofit solution.

Keywords: old masonry structure; structural analyses; modeling; retrofit

1 Introduction

Algeria is known to be part of an active tectonic structure, where the African plate collides with the Eurasian plate. These collisions create a zone of compression, which manifests itself by a series of thrust and normal faults that have been mapped in the area. This region is considered to be the most active seismogenic area in the Western Mediterranean area. It has a rich history of seismicity and experienced many destructive earthquakes such as the worst one of 1365, which completely destroyed the city of Algiers. Reports on other earthquakes that struck Northern Algeria in 1716 (20,000 dead), 1887, 1910, 1922, and 1934 are also available (CRAAG, 1994). Several more moderate earthquakes occurred in this region in recent years (Benouar and Laradi, 1996). On October 10, 1980, the city of El Asnam (today Chlef) was severely damaged by an earthquake of magnitude 7.1, killing roughly 3,000 people. The same city had been heavily damaged on September 9, 1954, by an earthquake of magnitude 6.7 which killed more than 1,000 people. Five other damaging earthquakes, of magnitude 5.4 or higher, were reported in the country in the short period from 1989 to 2000 (such as the events of Ain Temouchent 1999

($M_w = 5.7$) and of Beni Ourtilane 2000 ($M_w = 5.6$)). Recently, an earthquake of magnitude 6.8 surprised the city of Bouverdes and killed at least 2,278 people on May 21, 2003 (Boughacha *et al.*, 2004).

The town of Aïn-Temouchent is located in northwest Algeria, at mid-distance between the economic town of Oran and the historical citadel of Tlemcen. The area presented a weak seismic activity in the past, but during the 20th century, seven earthquakes of magnitude larger than 5 happened in the region. On December 22, 1999 (at 19:37:30), the province of Aïn-Temouchent was affected by an earthquake. This shock was felt throughout the Algerian West (Oran, Tlemcen, Mascara...) as far as Morocco (Oujda). The earthquake caused widespread damage, high losses (28 dead and 3,000 homeless families) in addition to causing great panic in the population. More than 2,000 buildings were damaged, including 39% with severe damage and 15% to be subsequently demolished. The village of Ain Lâalem was completely destroyed; half of the villages of Ain Tolba and Sidi Ben Adda were destroyed.

The earthquake's epicenter was located by the Algerian seismic network at the coordinates 35.25°N - 01.30°W, in Aïn-Allem, located 20 km southwest of Aïn-Temouchent. The results of the study by Yelles-Chaouche *et al.* (2004) showed that the maximum intensity of this earthquake was $I_0 = VII$ (MSK), its depth was 4.0 km, with a dislocation duration of 5 sec and a magnitude $M_w = 5.7$ (Fig. 1). By using the Interferometric Satellite Aperture Radar (InSAR) images technique, Belabbes *et al.* (2009) found evidence of geological slips cumuli due to cycles of earthquakes on the geological fold named

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