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TRAFFIC IMPACT ON THE STABILITY OF THE PALACE OF DEY IN THE CASBAH OF ALGIERS

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Abstract

Cultural heritage is a fundamental part of the history and identity of societies; it contributes to the preservation of their memory and their welfare. This heritage, which cannot be estimated economically, must be protected against all risks whether natural or caused by human activity. The Citadel of Algiers (Casbah) is composed of several buildings, the main one being the Palace of Dey, which is classified as historical monument. It is a set constituted by imposing civilian and military buildings. The Citadel has a total area of 9000 m2 where 7500 m2 are occupied by buildings. Its construction dates back to the early XVIth Century. The purpose of this work is to study the impact of car traffic in Mohamed Taleb Street, which crosses the citadel, on the Palace of Dey in order to take the necessary protective measures if the vibrations generated by this traffic prove harmful to structure of the building. The analysis, carried out using ambient vibrations recordings performed continuously for 21 hours, showed that there is a significant impact on the Palace of Dey structure due to car traffic in Mohamed Taleb Street.

Keywords: Casbah of Algiers, Palace of Dey, ambient vibrations, cultural heritage

1. introduction

The National Center of earthquake engineering (CGS) requested by the National Management Agency of Exploitation of cultural protected heritage (OGEBC), in order to make a diagnosis of the Palace of Dey (Citadel) and try to explain the appearance of cracks, and even erosion of brick in some places, in the absence of known causes such as earthquakes, landslides or subsidence of land etc.

The Citadel of Algiers (located in the Casbah) is classified as historical monument. It is an imposing set of civil and military buildings. The total area of the Citadel is 9000 m^2 of which 7500 m^2 occupied by buildings. Its construction dates back to the beginning of the 16th century. Indicatively, the main elements (fig. 1) forming the Citadel are: Bastions and ramparts, Casemates, powder magazine, Palace of Dey, former Harem, old mosque, summerhouse, baths of Agha, Palace of Beys, dependency of Palace of Beys, summer garden, winter garden and Park ostrich.

According to historians, the powder keg would have exploded in the 18th century and was rebuilt using the same construction techniques and materials. It is also noted that, following the 1716 Algiers earthquake, many damaged buildings have been rebuilt. Since the Algiers region is known for its high seismicity [1], [2], [3], recent studies have been conducted to assess the seismic hazard and scenarios were performed to estimate the damages that could occur in the city in case of earthquake.

There are no known causes such as soil problems, water infiltration, etc. which may explain the continued degradation of the walls of Palace of Dey. This guided the expertise to study the automobile traffic and its impact on the structure of the Palace of Dey and if it is the cause of the observed disorders. The Palace of Dey is located along the Mohamed Taleb Street that crosses the citadel. This street which did not exist originally was realized to allow a junction between the old city (Casbah) and the new city. Building vibrations induced by road traffic can reach levels that cause human annoyance and possible damage to old and historical buildings [4].

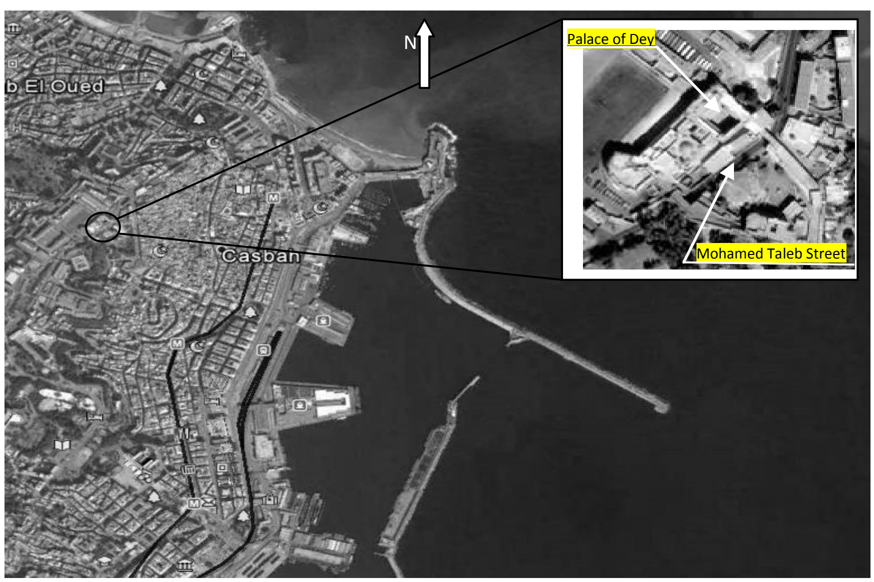


Fig. 1: Aerial photo of the Citadel

2. Vibration measurements

To diagnosis and analyze the movements of the Palace of Dey, technique and equipment of ambient vibrations have been used. The main advantage of using ambient vibrations technique is the possibility of conducting registration campaigns on buildings, not only after the occurrence of the earthquake, but also before the earthquake, at any time, for evaluating of structure characteristics. The measures on the site were therefore conducted using an 18 channel acquisition station CityShark II and a 3 components Lennartz 5sec velocimeter sensor (Fig. 2), ensuring a coherent response between 0.2Hz and 50Hz [5].

Vibration recordings of the structure of the Palace were performed continuously during 21 hours between 3:31 p.m. and 11:31 a.m. the next day (point 4 on fig. 3).

Punctual recordings on the ground were also made with the same station using 3x3 components Lennartz sensors 5 sec (points 1, 2 and 3 on fig. 3).

Fig. 2: Station CityShark II (right) and 3 components Lennartz 5 sec. Velocimeter (left)

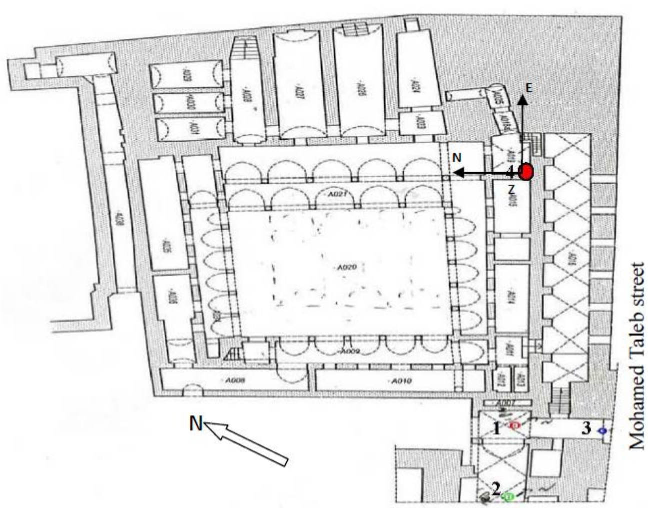


Fig. 3: Palace of Dey, Architectural drawing Level 1
Sensors positions on ground (1, 2 and 3) and on the structure at level 3 (4)

Ambient vibrations are a random loading, and analysis of the dynamic response of the structure to this solicitation is to calculate the Fourier spectra on several windows of the response signal and averaging them by calculating their standard deviation. However, all windows signal cannot be used because the ambient vibrations are a solicitation that comes from the ambient activity around the studied structure. In order to be used in dynamic analysis, it is necessary that they represent a white noise, at least in the frequency range from civil engineering structures [6].

The signals were treated by calculating spectral amplitudes using the *geopsy* software [7] on stationary windows of 25 sec length. The spectra have been smoothed using the function of smoothing of Konno and Ohmachi with a smoothing constant b = 40.

Road traffic produces generally vibrations with predominant frequencies in the range from 5 to 25 Hz [8]. Many factors influence the generation of these vibrations which affect the adjacent buildings. Some among these factors are the road roughness, vehicle weight and speed, soil type and profile, site topography, etc. [8].

3. Analysis of data

3.1 Analysis of ground recording data

Spectral ratios H/V of the recordings at points (1, 2, 3) (fig. 4) shows that the spectral amplitudes do not exceed the value of 2 [9], [10], [11], [12]. They are represented by a flat spectrum with presence of small peaks representing no real peaks in frequency. This can be interpreted by the soil type which is rocky soil [13], [14]. According to the Algiers geological map, the Algiers Castle site is composed by metamorphic rocks (schist).

In consequence, there is no amplification effect of the excitations transmitted through the soil to the structure of the Palace of Dey.

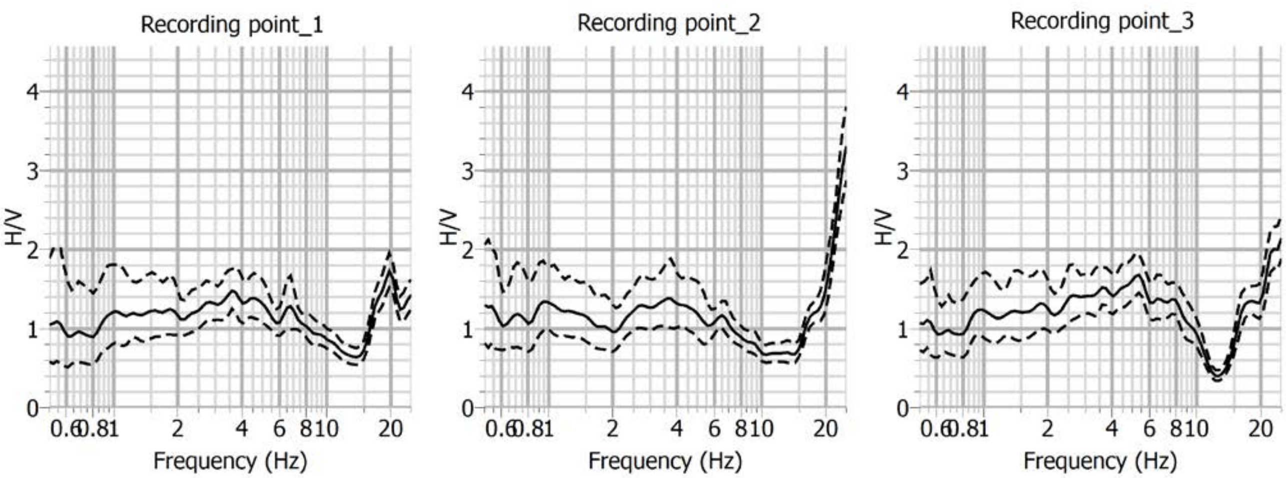
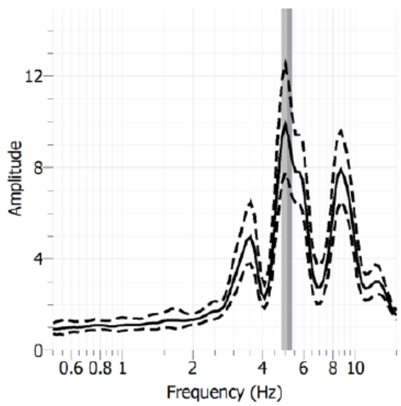


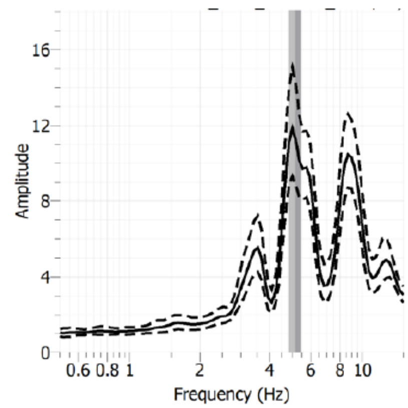
Fig. 4: Ground H/V spectra of the 3 channels

3.2 Analysis of recordings on the structure

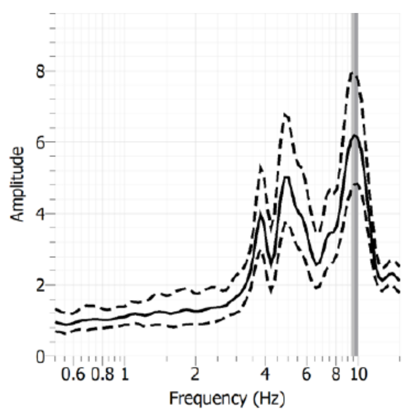
The structure vibrations have been recorded during a period of 21 hours with 01 hour signal length. The visualization of these recorded signals shows that there is a big difference in the contained energy between the Northern component and the two other components (east and vertical directions) on the three following time intervals: [15H31, 19H31], [20H31, 05H31] and [06H31,11H31]. The curves of the fig. 5 show the spectral amplitudes of the Palace of Dey in North and East directions. We can remark that vibration frequency in the North direction is in 5.16-5.18 Hz interval, and in the East direction in 9.70-9.80 Hz interval. These frequencies avoid the resonance of the Palace of Dey structure with the ground motions whose vibration frequency is in the range 0.5-1.5 Hz (fig. 4). We can also remark that all the vibration frequencies of the structure appear in the same time. This indicates that there is a fairly significant torsional motion of the building. The movements are quickly attenuated as showed on the fig. 6 of damping curves, but this does not prevent the damage suffered by the structure having regard to the age of the materials.



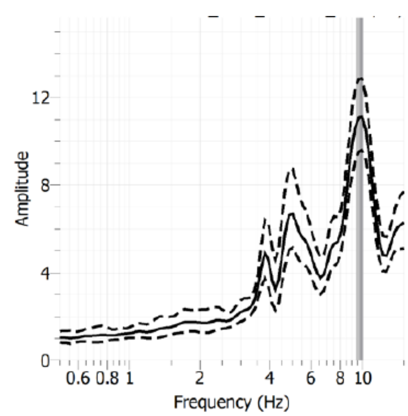
North Components (Ch4/Ch2) f0=5.16Hz



North Components (Ch4/Ch1) f0=5.18Hz



East Components (Ch4/Ch2) f0=9.7Hz



East Components (Ch4/Ch1) f0=9.8Hz

Fig. 5: Spectral amplitudes of the structure movements

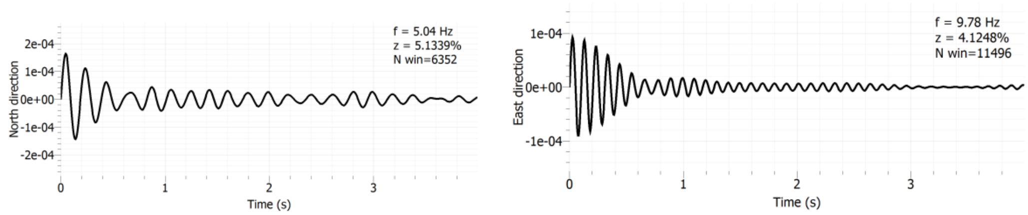


Fig. 6: Structural damping in North and East directions

The maximum amplitude of each spectrum of 01 hours duration signal is taken into consideration for characterizing the movements of the Palace structure during the observation period [15], [16].

For plotting the amplitude variations of the 3 channel components in a same graph, the maximum amplitudes observed for every 01 hour signal for the three components are normalized to the highest one of the 3 signal spectra (fig. 6) [17], [18].

There is a wide variation of the three components spectral amplitude of the structure movement over time. The three curves show a very low movement of the Palace structure on the interval of time between 21:00 and 06:00 O'clock. This clearly indicates that the movement of the Palace of Dey structure is attenuated with the decrease in street traffic.

Despite these movements are very low, the structure of Palace of Dey suffers damages. In case of earthquake, the damages can be important considering that Algiers region is classified in high seismic zone (zone 3 of Algerian Seismic Regulations) [19].

Traffic at the level of the Mohamed Taleb street has a great influence on the variation of the structure vibration, it decreases the night and increases during the day (fig. 7). This influence is more important in north direction as we can show it on fig. 7.

To confirm this influence of traffic in north direction, 'Particle Motion' graph was plotted (fig. 8). We can note on this figure that the excitation (waves produced by traffic) is more important in north direction where is situated the Palace of Dey (fig. 9).

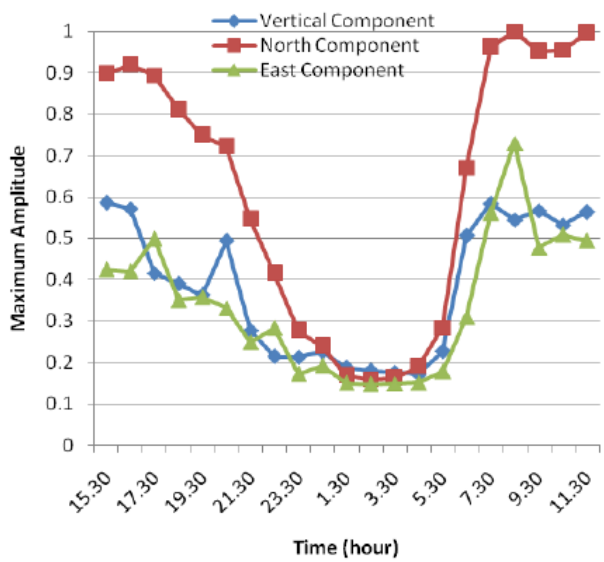


Fig. 7: The Spectral Amplitude Variation of 21 records on the Palace of Dey structure during 21 hours

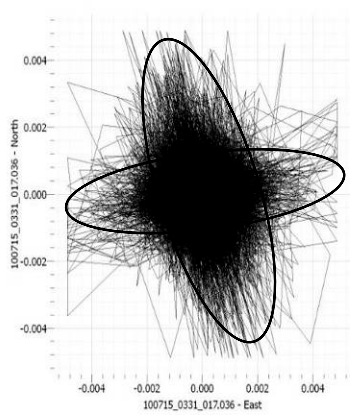


Fig. 8: Direction of the noise source

4. Conclusion

Ambient vibration measurements on sites of the Palace of Dey offer quite good knowledge of the properties of the local dynamic response of soil. The results show that the nature of the soil in this part of the city is a metamorphic rock (schist and Mica-schist) but highly heterogeneous, altered, or well deteriorated by water infiltration. This is probably due to historical seismic activity in this Castle area. This shows that there is absence of site effects, and therefore, there is no amplification of the structure movements on this site.

The achieved diagnosis reveals that excitations from the street Mohammed Taleb which crosses the Castle have a large influence on the structure movements of the Palace of Dey. The structure of the Palace and the materials that compose it, essentially cooked bricks bonded with earth mortar, are weakened by the time and lack of maintenance increases the degradation. These conditions make the Palace very sensitive even to very low loads like the ones generated by traffic. Some urgent measures can be taken, as changing the traffic in the street and make it one way, building speed bumps or in-ground barriers, before proceeding to a depth expertise taking into account the characteristics of the materials is more than necessary to consider a rehabilitation operation to preserve this cultural heritage which reflects a glorious period of Algiers city.

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