Site Effect and Expected Seismic Performance of Buildings in Palestine- Case Study: Nablus City

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Abstract. The effects of local geology on ground-motion amplification and building damage were studied in Palestine-West Bank. Nakamura's method of microtremor analysis was applied in this study. The measurements showed significantly higher amplification in the frequency range of building vulnerability in different parts of Nablus city. This finding is consistent with the distribution of the earthquake damage grades in the urban areas struck by the 11 February 2004 earthquake (ML= 5.2) with a focal depth of 17 km beneath the northeastern part of the Dead Sea Basin. Quite large differences in amplification between around 1 and 9 were computed between the eastern and western rims of the city. The downtown built in the central part of the city on soft clay, marl and valley deposits, whereas the northern and southern parts of urban areas in Nablus city lying on mountains consist of consolidated carbonates bedrock. In the central part of the city and at the rims, where the thickness of fluvial deposits and soft formations is about 15 m, amplifications between 6.74 and 8.67 for dominant natural period range of 0.8 - 1.1 sec were obtained. On the southern and northern mountains, which are located on limestone rocks covered with a thin layer of soil, the amplification in the same frequency range was low. Calculating the natural period of the existing common buildings (T_b) in the studied area (buildings with 10-12 stories), by using the dynamic analysis method. The values of T_b obtained were much closed to the site dominant natural period (Ts).The findings of this study indicate that the expected differences in damage grades for urban areas in Nablus city could be attributed to variations in the thickness and physical properties of Tertiary-Quaternary sediments, which appear to be rather heterogeneous.

Keywords: site effect, amplification, buildings, vulnerability, Palestine.

INTRODUCTION

Local site effect (landslides, liquefaction, amplification and faulting systems) plays an important role on the intensity of earthquakes. Thus, Earthquake- resistant design of new structures and evaluating the seismic vulnerability of existing buildings are taking into account their response to site ground motions. Geophysical studies of seismic activity in Palestine, deep seismic sounding, paleoseismic excavation, and instrumental earthquake studies of half a century [1-14] demonstrate that the damaging earthquakes were located along the Dead Sea Rift/Transform fault (Fig. 1). These damaging earthquakes caused in several cases severe devastation and many hundreds and sometimes thousands of fatal casualties.

Recent studies of large destructive earthquakes have shown that damages during the earthquakes are often caused by the amplification of seismic waves in near-surface geology [15-20], where the post disaster damage assessment showed that the local site effect may have a dominant contribution to the intensity of damage and destruction.

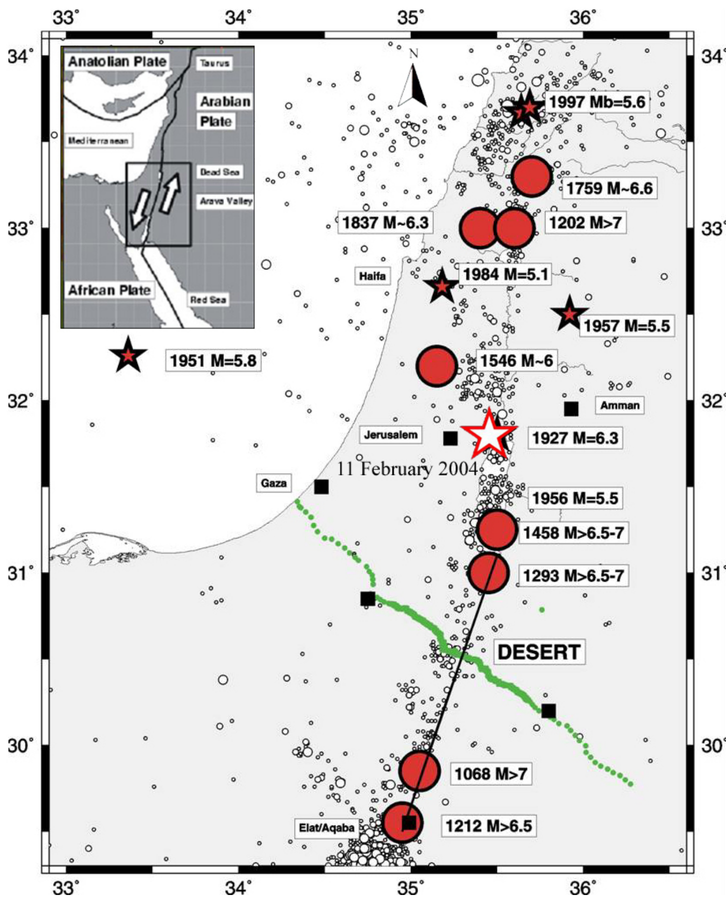

FIGURE 1. Seismic activity in the Dead Sea Transform region; the map shows locations of historical earthquakes [11-14]. Also shown is the most recent earthquake of 11 February 2004, ML 5.2.

The estimation of site response is therefore critical, in order to evaluate the seismic hazard potential of a given area. Since sedimentary deposits are often the prime locations for development of urban areas, local amplification is a major concern in earthquake-prone regions, but also in moderate seismicity areas where the mid-size cities developed could be struggle with future damaging events due to the combination of site effects and urban development. In the present study, the local site effect on ground-motion amplification and buildings vulnerability were studied in Nablus city/ West Bank (Fig. 2). The regions in Palestine suffer, in general, from planning absence, random urban expansion, and multiple land use with lack of seismic information and shortage of studies on the soil and ground response due to earthquakes [21-23].

The primary research goal is to construct the theory of urban planning for disaster reduction in Palestine. It is necessary that the planning contain both hardware and software in order to raise the force of the urban areas for the disaster such a way of reducing the impact of potential earthquakes (Fig. 2).

Local Geology

The exposed sequence of rocks in Nablus region mainly consists of carbonates; limestone, dolomite, marl and chalk and it includes other sediments as chert, clay, gravel and some sandstone, with ages ranging from upper Cretaceous to Recent (Fig. 2). The limestone formation is massively bedded at base and becomes increasingly thin towards the top [24].the formation outcrops and reported lithology from groundwater boreholes indicate that the limestone thickness ranges from about 170-280 m containing occasionally dolomite. Besides, some chalk, chalky marl and marl appear in thin laminations throughout the formation. Tertiary and Quaternary sediments as gravel deposits and clay sediments cover the central part of Nablus city and form the main soil layer at the eastern and western sides of the city.

METHODOLOGY AND DATA ANALYSIS

Nakamura's Technique

One of the most appealing techniques for estimating site response is Nakamura's method [25] since it only requires records from a single three-component station deployed at the site of interest an does not need a reference seismogram measured at the substratum bedrock. As introduced by Nakamura [25], the technique was intended to assess S-wave amplification from microtremor measurements. There are four components of spectral amplitudes involved in this one- layer problem, namely, the horizontal components of motion at the surface and bottom of the sedimentary layer, referred as $H_s(f)$ and $H_b(f)$, respectively; and the vertical components of motion at surface and bottom, correspondingly denoted as $V_s(f)$ and $V_b(f)$.

The prime objective of Nakamura's technique is to isolate the amplification effect suffered by horizontal components of substratum motion. In order to do this, he first constructs the theoretical borehole ratios that are widely regarded as the most reliable transfer function estimates for horizontal and vertical components, as given below, respectively:

$$S_h = \frac{H_s}{H_b} and \tag{1}$$

$$S_v = \frac{V_s}{V_b} \tag{2}$$

With these two ratios Nakamura constructs an additional transfer function S_t which gives formally the factor by which the horizontal ratio exceeds the vertical one:

$$S_t = \frac{S_h}{S_v} = \frac{H_s / H_b}{V_s / V_b} or \tag{3}$$

$$S_t = \frac{H_x / V_s}{H_b / V_b} \tag{4}$$

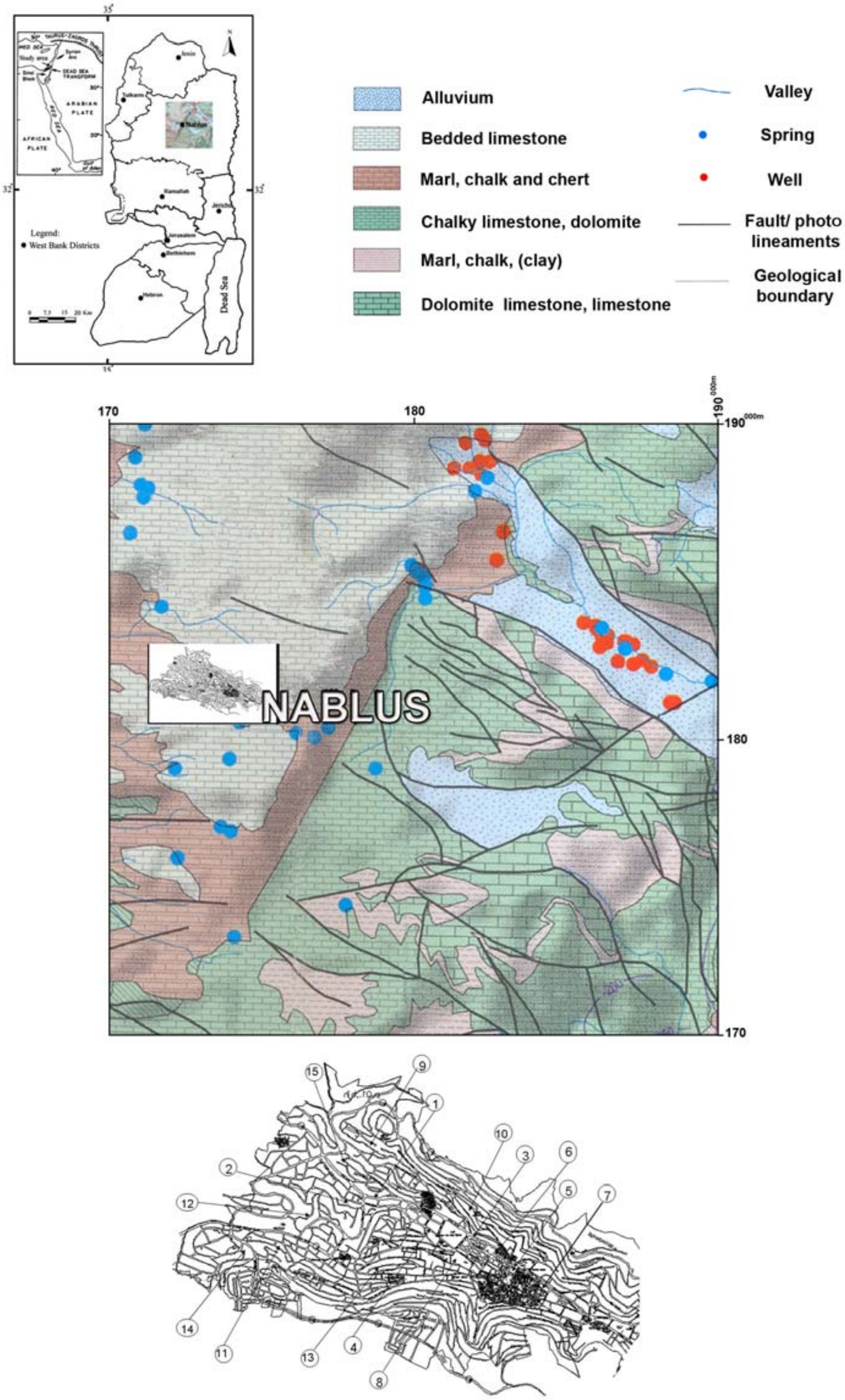

FIGURE 2. Geological map shows the main outcropping formations in Nablus region, and a sketch site map shows the distribution of the microtremor measurements in Nablus city.

Microtremor Measurements

An attempt was made to understand the site effect conditions on damage distribution during a probable strong ground motion in Nablus City [22]. Several points have been selected in different sites of the city. The criterion for each point is the variations in the geology as well in the topography, where points have been measured on rock cover of mainly limestone, chalk and marl (mountain areas), while other points selected to be on soil and soft sediments (valley areas of caly and gravels). Microtremor measurements were carried out at 15 selected sites to represent different geological formations and to cover a comprehensive area in order to give a macrozonation general idea about the dominant frequency in the study area, see Fig 2.

The site effects have been investigated by taking measurements of ambient noise collected by short period seismic station and making the spectral analysis using the packages programs [26]: SDA software for data acquisition and SEISPECT for data analysis. The measurements were made during the daytime, when the contaminating effects of traffic and industrial noise were significant.

Spectral Analaysis Results

The analysis of ambient vibration measurements developed a spectral ratio site response for each site, an example of average Fourier spectra for selected windows is presented in Fig. 3, and also the relation between dominant frequency at the site and the amplification factor (spectral ratio) is presented in Fig. 4 for the sites 3 and 4. The dominant frequency (or period) and its amplification factor of all measured locations are presented in Table 1. The results showed obvious difference among the dominant frequencies even the studied area is small.

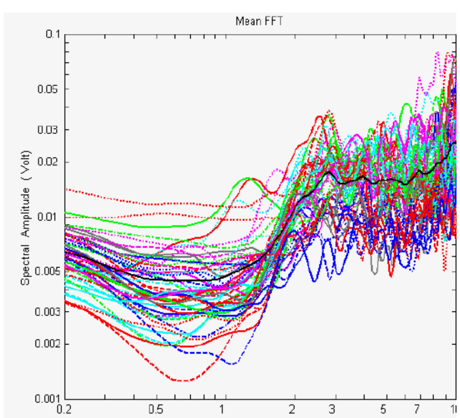

FIGURE 3. Spectral amplitude for site 4.

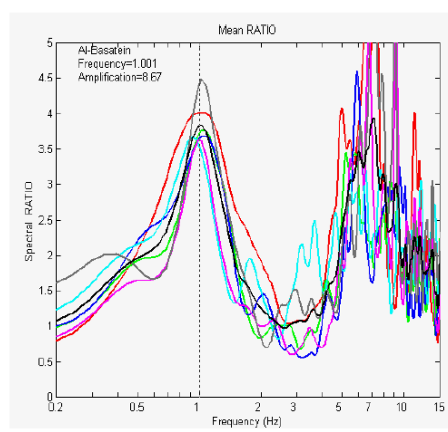

FIGURE 4. Spectral ratio for site 3.

The distribution of the dominant frequencies values of the measured sites varied from eastern part to the western part. Quite large differences in amplification between around 1 and 9 were computed between the eastern and western rims of the city. The downtown built in the central part of the city on soft clay, marl and valley deposits, whereas the northern and southern parts of urban areas in Nablus city lying on mountains consist of consolidated carbonates bedrock. In the central part of the city and at the rims (see table 1, sites 1-8), where the thickness of fluvial deposits and soft formations varies between 15-25 m, amplifications between 2.6 and 8.66 for dominant natural period range of 0.8 - 1.4 sec were obtained. On the southern and northern mountains, which are located on limestone rocks covered with a thin layer of soil (see Table 1, sites 9-15), the amplification was relatively low.

merical Methods Using Seismic-Geotechnical Data

The period of vibration corresponding to the fundamental frequency is called the characteristic site period:

$$T_s = \frac{4H}{V_s} \qquad (5)$$

The characteristic site period which depends only on the thickness (H) and shear wave velocity (V_s) of the soil provides a very useful indication of the period of vibration at which the most significant amplification can be expected [27]. The selected sites (sites 3, 5, 6 and 8) underlain by 18 to 25m of soft soil with an average s-wave velocity of about 100 m/sec, where the characteristic site periods were estimated by using equation 5 at 0.72 to 1 sec. The value of the characteristic site period obtained by using the numerical method was closed to the values obtains by using microtremor measurements indicated in Table 1.

TABLE 1. Results list of dominant frequencies, amplifications and natural periods.

Microtremor Measurements				Numerical method
Site	**Dominant Frequency Hz**	**Amplification Factor**	**Natural period sec**	**Natural period sec**
1	0.700	3.55	1.429	-
2	0.688	3.35	1.453	-
3	1.001	7.44	0.999	0.9
4	0.846	2.634	1.182	-
5	0.952	3.405	1.050	0.88
6	0.906	8.66	1.103	1
7	0.797	6.736	1.255	-
8	1.2	2.6	0.833	0.72
9	1.306	1.393	0.766	-
10	1.074	1.416	0.931	-
11	1.251	1.894	0.799	-
12	1.453	2.337	0.688	-
13	1.492	2.952	0.670	-
14	1.13	1.937	0.885	-
15	1.7701	1.104	0.565	-

The Fundamental Natural Period of Common Buildings in Nablus City

The fundamental period of few buildings (buildings between 8 and 12 levels) in selected sites were calculated by using building code empirical formula (UBC 97 and IBC Codes) and dynamic analysis (see Table 2 for the common buildings with 10 levels), most of these buildings had fundamental periods equal to or some what less than the characteristic site period. Accounting for the period-lengthening effect of soil-structure interaction and the tendency for the fundamental period of a structure shows that they increase during a strong earthquake, due to the reduction in stiffness caused by cumulative architectural and structural damage [27].

This double-resonance conditions (amplification of bedrock motion by the soil deposit and amplification of the soil motion by the structure) combined with structural design and construction deficiencies are expected to increase the seismic vulnerability of the common buildings in the studied area.

TABLE 2. Structural analysis results, cracked and non-cracked sections, show building natural periods using UBC97.

Building type	**Period, T For Exterior frame**		**Period, T For Interior frame**		**Period, T For Space frame**		**Period, T Using UBC97**
	Uncr.	**Cracked**	**Uncr.**	**Cracked**	**Uncr.**	**Cracked**	
10-story frames (h=3.25 m)	0.85	1.25	1.2	1.78	1.04	1.5	1.0
10-story perimeter walls (h=3.25 m)	0.31	0.47	1.29	2.92	0.0.47	0.50	0.664

CONCLUSIONS

Based on the effects of local geology, there is good correlation between the different values of the amplification factor and the changes in the lithology. Where in the southern and northern mountains, consist of consolidated carbonates bedrock, slight amplification is expected in comparison with quite larger amplification factor was computed at the eastern and western rims of the city and the downtown built on soft clay, marl and fluvial deposits. This is also in good agreement with the reported obvious difference of intensity grades felt in the different parts of Nablus city during the past and recent seismic activity in Palestine.

Regarding the spectral ratio analyses of the selected sites in the study area, the high spectral ratio range of 6.7-8.7 is shown in the sites 3, 6 and 7 in the frequency range of about 0.8 - 1. 0 Hz. This ratio range shows good agreement with the reported obvious differences in damaging levels reported at the different urban areas in Nablus city after 11 July 1927 and 11 February 2004 earthquakes (ML 6.3 and 5.2, respectively) that have been attributed to site effect variations related to the physical properties of

Tertiary-Cretaceous sediments, which appear to be rather heterogeneous in the lithology [22].

The natural frequency of many common buildings in the studied area are very close to the site dominant frequency, therefore this will increase their seismic vulnerability.

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