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Assessment of Seismic Site Effect

(GEOPHYSICAL SEISMIC STUDY)

Al-Bathan Road

Final Report

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(Part One)

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1. INTRODUCTION

1.1 Background

The Bathan road is located in Nablus District in the northern part of West Bank (see Figure 1.1). The Urban Planning and Disaster Risk Reduction Center UPDRRC (Earth Sciences and Seismic Engineering Units ESSEU) at An Najah National University was approached by the Ministry of Public Works and Housing seeking to conduct a Geophysical Seismic Study to understand the mechanics of the Bathan road (Movement and Sliding) depending on the subsurface geology.

Figure 1.1: Geographic setting of the studied area in the West Bank

1.2 Seismic Risk and Site Effect

Seismic information including historic and prehistoric data indicates that major destructive earthquakes have occurred along the Dead Sea Transform (DST). The DST is a left-lateral fault between the Arabia and the Sinai tectonic plates that stretches from the opening at the Red Sea to the Taurus-Zagrous collision zone. The estimated Moment Magnitude Scale (MMS) intensities of historical earthquakes in the Dead Sea region reach up to X, where the determinable magnitudes of the recorded earthquakes range between 1.0 and 7 on the local magnitude scale. These damaging earthquakes caused, in several cases, severe destruction and many hundreds and sometimes thousands of fatal casualties.

Generally, local site effects, mainly (landslides, liquefaction, amplification and faulting systems) play an important role in the intensity of earthquakes. Thus, Earthquake-resistant design of new structures and evaluating the seismic vulnerability of existing buildings take 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 demonstrate that damaging earthquakes occurred along the Dead Sea Transform fault. The topography, geomorphology and geology of the West Bank have been the main reasons behind several sizeable landslides that occurred around ten years ago in different parts of the West Bank. Also, it has been shown that Palestine suffered from several landslides during historical earthquakes.

Based on the seismic peak ground acceleration map (PGA Map) for the region (Figure 1.2), the studied area is located in zone 2B. The seismic zone factor (Z) on the rock for the zone 2B is equal to 0.2. According to the Uniform Building Code (UBC97), International Building Code (IBC), Jordanian Building Code 2005 and Arab Uniform Code 2006, it can be considered as moderate seismic area.

1.3 General Information about Landslides

The first sign of an imminent landslide is the appearance of surface cracks in the upper part of the slope, perpendicular to the direction of the movement. These cracks may gradually fill with water, which weakens the soil and increases the horizontal force which initiates the slide. Frequently, inclined shear cracks can also be observed on both sides of the slide, as well as a slight bulge at the toe of the slope.

Landslides are primarily caused by gravitational forces but occasionally seismic forces can be a contributing factor. A landslide is primarily the result of a shear failure along the boundary of the moving mass of soil or rock. Failure is generally assumed to occur when the average shear stress along the sliding or slip surface is equal to the shear strength of the soil or rock as evaluated by field or laboratory tests.

The geologist regard landslides as one of the many natural processes which act on the surface of the earth as part of the general geological cycle. However, the engineer, on the other hand, tries to determine the maximum angle at which a slope is stable and studies the stability of a slope in terms of a factor of safety.

Landslides may be classified according to the shape of sliding which are falls, rotational slides, translational slides or flow.

Causes of Landslides

The main factors that cause landslides are:

- Construction Operation
- Erosion
- Tectonic Movements
- Earthquakes (Vibrations)
- Rains or Melting Snow
- Frost Action
- Dry Spells
- Rapid Draw Down
- Seepage from Artificial Sources of Water
- Seepage from Artificial Sources of Water

Investigation and Analysis of Landslides

To investigate landslides one should do field studies, laboratory studies and slope stability analysis. It is important that the field and laboratory investigations be supplemented by field measurements so that the behavior of a slope can be checked and corrective measures be taken in times.

The first step in landslides analysis is the collection of available information geological, hydrological, topographical, and soil maps.

Methods of Correcting Landslides

Several methods are available for correcting landslides as follows:

1- Geometrical Methods to increase slope stability (factor of safety form analysis) including:

• Flattening of slope

• Excavation at top of slope

• Fill at toe of slope

2- Hydrological Methods are aimed to drainage of surface water and lowering of ground water level. Methods may include:

• Surface drains

• Drain holes

• Sand drains

• Inverted filters.

3- Mechanical Methods to increase the shear strength of the soil to resist the forces causing sliding or inserting reinforcing technique to increase slope instability. These methods include:

• Compaction

• Freezing

• Grouting

• Rock Bolts

• Piles

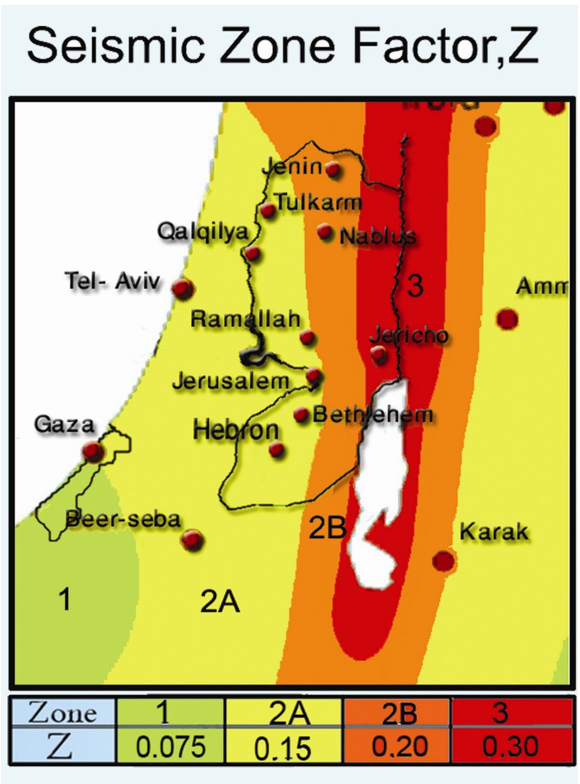
• Retaining Walls, Sheet Pile Walls, and Toe Walls.

1.4 **The scope of Assessment of Site Effect (ASSE)**

The UPDRR at An Najah national University was approached by the Ministry of Public Works and Housing seeking to conduct a geophysical seismic study at Al Bathan road - Nablus. This kind of studies provide engineering data and recommendation to find out suitable solutions for the investigated site.

Based on the scope of services, field visit, data collection, data acquisition and data analysis, the geophysical seismic investigation under the contract should deliver a seismic report including the following tasks for the studied area:

1) Soil profiles.
2) Primary and shear wave velocities (V_p and V_s).



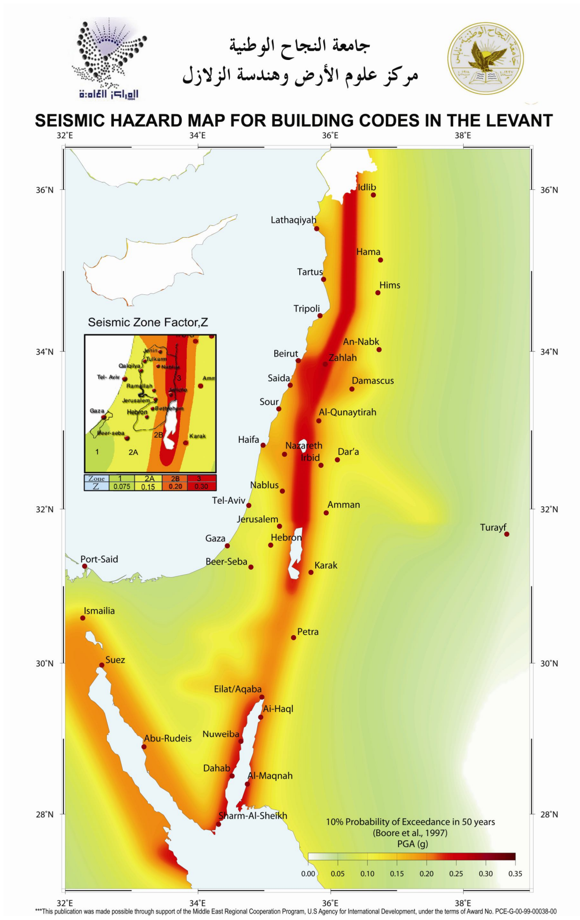


Figure 1.2: Seismic Hazard Map and Seismic Zone Factor (Source UPDRR).

2. GEOPHYSICAL SEISMIC STUDY: Site Investigations

2.1 Local Geology

Investigating the subsurface geology of a site is critical in order to select the kind of structure foundation design to use in a given area since sedimentary deposits are often the prime locations for the development of urban areas.

The exposed sequence of rocks in the studied area (Northern part of West Bank) mainly consists of carbonates; limestone, dolomite, marl and chalk and it includes other sediments such as chert, clay, with ages ranging from lower Cretaceous to upper Cretaceous.

2.2 Cavities in Rock

A topic of concern in many projects involving rock excavation is whether or not there are undetected cavities below an apparently solid bedrock surface or whether cavities could develop after construction. These cavities may occur naturally in karst or pseudokarst terrains, may be induced by human interference in natural processes, or they may be totally due to man's activities. The term "cavities" is used since it covers all sizes and origins of underground openings of interest in rock excavations.

Geophysics may be of some use in initial site investigations in locating larger cavities but may also miss smaller ones. Remote sensing using air photos, infrared imagery, and side-looking radar are useful in determining trends of cavities and jointing in an area, as well as determining the structural geology features associated with rock salt exposures.

Since cavity occurrence is difficult to determine on a local scale, the only practical solution, after initial site studies, is to place a test boring at the location of each significant load-bearing member. Such an undertaking is costly, but represents the only reasonable approach in areas of high concern.

2.3 Methodology and Data Analysis

2.3.1 Geophysical experiment

The subsurface geology determined by seismic studies is extremely important for the development of highly populated, tectonically arid regions such as the Middle East. The shallow upper part (ten to hundred meters) of the rock formation section is the most significant part for civil infrastructures. The seismic refraction technique is considered an accurate geophysical method to investigate the shallow geological structures of an area. During the past decades, the seismic parameters obtained by a refraction survey have been widely used in cases of site investigation as indicators of rock mass quality. The main objective of the seismic refraction method is to estimate the first arrival velocities of P-waves, which are used to determine the depths of different layers and obtain the dynamic characteristics of rocks. These parameters are of great importance in land use management of various civil engineering purposes.

2.3.2 Detection of Seismic Waves

Seismic waves are generated usually by weight dropping, i.e. a sledge hammer. The seismic signals generated from the shot propagate in different direction; it is reflected, refracted, or diffracted. The different seismic signals can be recorded using a system of receivers (geophones) distributed in a profile in the direction of the shot point. In detecting direct and refracted waves a number of detectors are placed on the ground along a straight line passing through the shot point, this system is known as (In-line spread) and is widely used in most seismic refraction techniques.

For this study the system used was the Smart Seis Exploration seismograph model S/N 70253, manufactured by Geometric Europe (U.K). The detectors used in the present study have a natural frequency of 28 Hz each, the signal is amplified and the undesirable frequencies can be filtered out. These signals, after suitable amplification and filtering, are fed into a recording unit. The recording system contains 24 channels.

2.3.3 Data Acquisition and Analysis

The seismic refraction survey was conducted on 6 seismic profiles (see Figure. 2.1 for the location of the profiles and the photos in Appendix no.1). The distance between the two receivers (geophone interval) was 5 meters. Many interpretation techniques are published in seismic refraction data analysis and each of them depends on the character of the refractor. In the present study, the seismic refraction data was interpreted using the modeling and interactive ray tracing techniques.

Figure (2-1): location of the seismic lines.

The travel time-distance curves and the corresponding ground models for P-waves were obtained. Depths of the interfaces were obtained from the travel time-distance curves for the P-waves. Table 2.1 summarizes the results obtained from the seismic profiles for this study:

The P-waves were picked up as first arrivals. The underground model beneath the profiles indicates two different layers beneath the seismic lines. The bed rocks beneath these profiles from the two main layers, the first layer with thickness ranges between 8 to about 22 meters (see appendix no. 2). The travel time curves analysis showed longitudinal wave velocities (P waves) ranging from 350 to 1000 m/s for the first layer and 1400 to 2900 m/s for the second layer beneath all seismic lines. The first layer is a deep one and interpreted as weathered materials like clay for Vp equal with 346 m/sec, 449 m/sec and 437 m/sec as well as marl for Vp equal with 731 m/sec, 831 m/sec and 1026 m/sec, where the second layer is interpreted as unconsolidated carbonate materials of marly and chalky limestone are the typical lithology of layer two for most of the seismic profiles (Line 5-5, Line 6-6, Line 7-7, Line 9-9 and Line 10-10. The second layer in the seismic profile “Line 8-8” is interpreted as consolidated carbonate materials of chalky limestone.

Table 2.1: Summary of results obtained from the seismic profiles

Line Nr.	Layer 1		Layer 2	
	Vp m/sec	**Thickness (m)**	**Vp m/s**	**Thickness (m)**
Line 5-5	346	~ 8	1404	∞
Line 6-6	731	~ 15	2264	∞
Line 7-7	831	~ 20	1824	∞
Line 8-8	449	~ 11	2991	∞
Line 9-9	437	~ 12	1298	∞
Line 10-10	1026	~ 22	1923	∞

Appendix no. 2: shows the travel time curves and the corresponding velocity ground models (geological cross sections for the two layers) beneath the 6 seismic lines.

4 Conclusions and Recommendations

Based on the outcropping geological cross-section in the study area and the ground velocity models deduced from the P-wave velocities of this study, the subsurface geological formations beneath the seismic profiles are interpreted as soil cover of soft weathered material (clay) which forms the first layer beneath all seismic lines, with a maximum depth of around 22 meters. The second layer is explained as unconsolidated carbonate materials of marl and clay for the all seismic lines and chalky limestone for line 8-8 that shows relatively high P-velocity. The outcrops can be easily seen in some places on the surface.

The corresponding velocity ground models (geological cross sections for the two layers) beneath all the seismic profiles show clearly an overlapping between layer one and layer two at different locations of the study area which means that there are lateral and vertical variations in the mineralogy and the geomorphology of the layer boundaries.

The investigated subsurface geology beneath the profiles does not show clear cavities at shallow depths.

Based on the values of P-wave velocities and using the approximate values of the Poisson's Ratio (ν) for each layer (ν = 0.40 – 0.45 for clay and weathered materials and ν = 0.30 – 0.35 for marly and chalky limestone), the value of shear wave velocity (V_s) will be as follows:

- **V_s** = 198 m/sec, 257 m/sec, 417 m/sec and 474 m/sec for the first layer.
- **V_s** = 1500 m/sec, 800 m/sec, 1150 m/sec and 1040 m/sec for the second layer.

(Note: The line 8-8 shows relatively high S -velocity (V_s = 1400 – 1600 m/sec)

Based on the international and regional seismic design codes, such as: Uniform Building Code 97, International Building Code IBC, Jordanian Building Code 2005 (or 2008) and Arab Uniform Building Code 2006, the type of soil profile for the shear wave velocities mentioned above, will be S_D and S_C for the first layer and S_B for the second layer.

PART 2: Landslides – Slope Stability Analysis

In many parts of the world, especially in mountainous countries, landslides are very common and have serious consequences for almost all construction activities in these countries. Even relatively small changes of the stability may trigger landslides, especially in areas where slides previously have taken place. Landsliding is mainly caused by gravitational forces and is a result of shear failure along the sliding surface. Slope stability analysis is usually carried out to determine the degree of safety of a given slope. For more details about slope stability analysis which have been done for the landslides occurred in Al Bathan road, see chapter 2.

REFERENCES

1. A. Ginzburg, J. Makris, K. Fuchs and C. Prodehl, Tectonophysics, **80**, 109-119 (1981).
2. E. A. Al-Tarazi, Natural Hazards, **10**, 79-96 (1994).
3. J. Mechie, K. Abu-Ayyash, Z. Ben-Avraham, R. El-Kelani, A. Mohsen, G. Rümpker, J. Saul, M. Weber, Geophys. J. Int., **156**, 655-681 (2005).
4. S. Kramer, Geotechnical Earthquake Engineering, New Jersey: Prentice Hall, 1996, pp. 308-315.
5. Das, Braja, **Principles of Geotechnical Engineering**, Fifth Edition, Thomson, Brooks/Cole, USA, 2002.
6. Tomlinson, M. J., **Foundation Design and Construction**, Sixth Edition, Longman Scientific and Technical, London, U.K, 2001.
7. Krahn, John, **Stability Modeling with Slope/w (An Engineering Methodology)**, first edition, 2004.
8. Dad, Braja, **Foundation Analysis and Design, Fifth Edition**, Thomson, Brooks/Cole, USA, 2004.