Seismic Evaluation of the Near-Surface Foundation Layer Characteristics: A Case Study for a New Industrial City, Aswan, Egypt

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Abstract: ***It is well known that the first step in the strategic projects is the planning stage, so site characterization acts as the essential factor which should take into consideration during this step for secure project toward natural hazard and disaster. Site characterization plays an important role for sustainable development of societies in earthquake prone areas. Recently, Egypt started a new development era, so many expansion projects initiated in Egypt including many industrial cities to face the future industrial revolution. New Aswan industrial zone classified as one of these cities and lactated near to the principal prone earthquake area in Aswan region, so it became very important to perform the current such study prior any construction for the future earthquake hazard mitigation on the industrial facilities. The scope of this study is the studying the foundation rock's properties using active and passive seismic techniques (seismic refraction and ambient vibration measurements). Based on the seismic measurements at the selected locations, the zoning map indicated that the area has shallow bedrock without a significant amplification which is a good foundation rocks for engineering targets.***

Keywords: New industrial city, P-wave velocity, characterization, Frequency

1. Introduction

In many recent earthquakes, it has been proved that local site effects play major role on the damages observed. The earthquake motions can be amplified or de-amplified by the local soils based on their characteristics. According to Daniell et al. (2011), more than 2 million persons died in as a consequence of earthquakes occurrence during the 20th century; building collapse caused approximately 75% of those deaths with about $ 2 trillion as a cost of earthquakes. So, earthquake hazard mitigation using advanced methodologies is of major importance for the reduction of seismic hazard in urban areas.

Generally, it is known that buildings on soft soil suffered damage larger than that located on stiffness rock. Also it is observed that the amplification is strong on areas with low shear wave velocity. For evaluation the dynamic properties of near-surface soil and for characterizing the given site, the top 30 m shear-wave velocity value is using.

The geotechnical and geophysical techniques are the primary sources of information that are applied to minimize and mitigate the seismic hazard posed by ground conditions, so the geophysical/geotechnical investigations is the required step to perform tests to collect geophysical data and geotechnical soil properties to give information for detailed site characterization at any new project in planning stage. The obtained information from the investigations will assist to ensure the project is designed and constructed to be safe, reliable, and cost effective.

Several new projects initiated in North and South Egypt including many industrial cities to face the future industrial revolution, one of these cities is Aswan new industrial city. The planned new industrial city is situated on the western side of the River Nile as extension of new Aswan city (figure 1). The proposed location is very close from earthquake prone region in Aswan, the epicenter of large event such that occurred on November, 1981 (M 5.6). On November 7, 2010, along spillway fault zone 12 km South the city site an earthquake (M 4.6) was occurred and strongly felt in Aswan area. This event motivated us to conduct the site investigation across the proposed Aswan industrial city site. The main purpose of the research is a trial to investigate the subsurface structure conditions, for determining the dynamic properties of the foundation rocks using the seismic refraction and the Horizontal to Vertical Spectral Ratio (HVSR) techniques.

2. Earthquake Activity in South Egypt

Before the initiation of seismic network, a few numbers of strong events occurred in Red Sea and one in Gulf El-Kebir had been reported in Upper Egypt, because the nearest station to record epicenters was Helwan station (690 km from Aswan), it was difficult to determine the low sequence magnitude from Upper Egypt. The Soviet short-period (SMK) stations installed at Aswan and Abu-Simbel in 1975 were the first seismographs for small earthquakes monitoring, while a temporary network with 3 stations was distributed by NRIAG around Abu Dabbab area.

Based on the earthquake distribution, many areas shows different activity level such as Shedwan Island, Red Sea, Abu Dabbab, Eastern Desert, Kalabsha, and Western Desert. Across this region several significant earthquakes occurred (Figure 1); among these events are the following:

1955 November 12, Abu-Dabbab Earthquake

This is the extreme serious quake in Abu Dabbab area with MS 5.3 occurred on November 12, 1955 earthquake. The depth of this event is not well constrained but it is clearly within the crust.

1969 March 31, Shedwan Island Earthquake
The magnitude of this earthquake was 6.3 (mb) with a maximum intensity of IX in a small zone of the Shedwan Island, not withstanding the scarcity of the population in Shedwan, which consisted of a few army units. On the island, landslides, earth slumps and rock falls were common. Fissures and cracks in soil were recognized with a main direction nearly parallel to Red Sea-Gulf of Suez direction.

1978 December 9, Gilf El-Kebir Earthquake
It is the largest instrumentally located earthquake in the south western region of Egypt. This event had a magnitude of 5.3 and focal depth of about 7 to 10 km. The intensity classification of this earthquake is not estimated because the southern region of Egypt is an unpopulated desert. The closest station to the epicenter was Helwan, 850 km away.

1981 November 14, Kalabsha Earthquake
This earthquake had a magnitude of 5.6 (mb) Kebeasy et al. (1982) and it is of significance because of its possible association with High Dam (Nasser's) Lake. Although its epicenter is located along Kalabsha area 60 Km southwest of Aswan, it was strongly felt in Aswan and up to Assiut in the north; and to the South up to Khartoum. Its intensity near the epicenter was ranged from VII to VIII. The focal depth of the event is estimated to be 25 Km.

1984 July 2, Abu-Dabbab Earthquake
This 1earthquake had a magnitude of 5.1. Five portable field stations were operated in the Abu-Dabbab area during the period from June 1984 to August of 1984. Large number of foreshocks and an extensive sequence of aftershocks were observed. The focal depths of the whole sequence were less than 12 km.

The seismicity of Shedwan Island, Red Sea, Abu Dabbab, Eastern Desert, Abu Simbel and Western Desert are less significant to the Aswan region area relative to Kalabsha area, so the later are significant and discussed in the following.

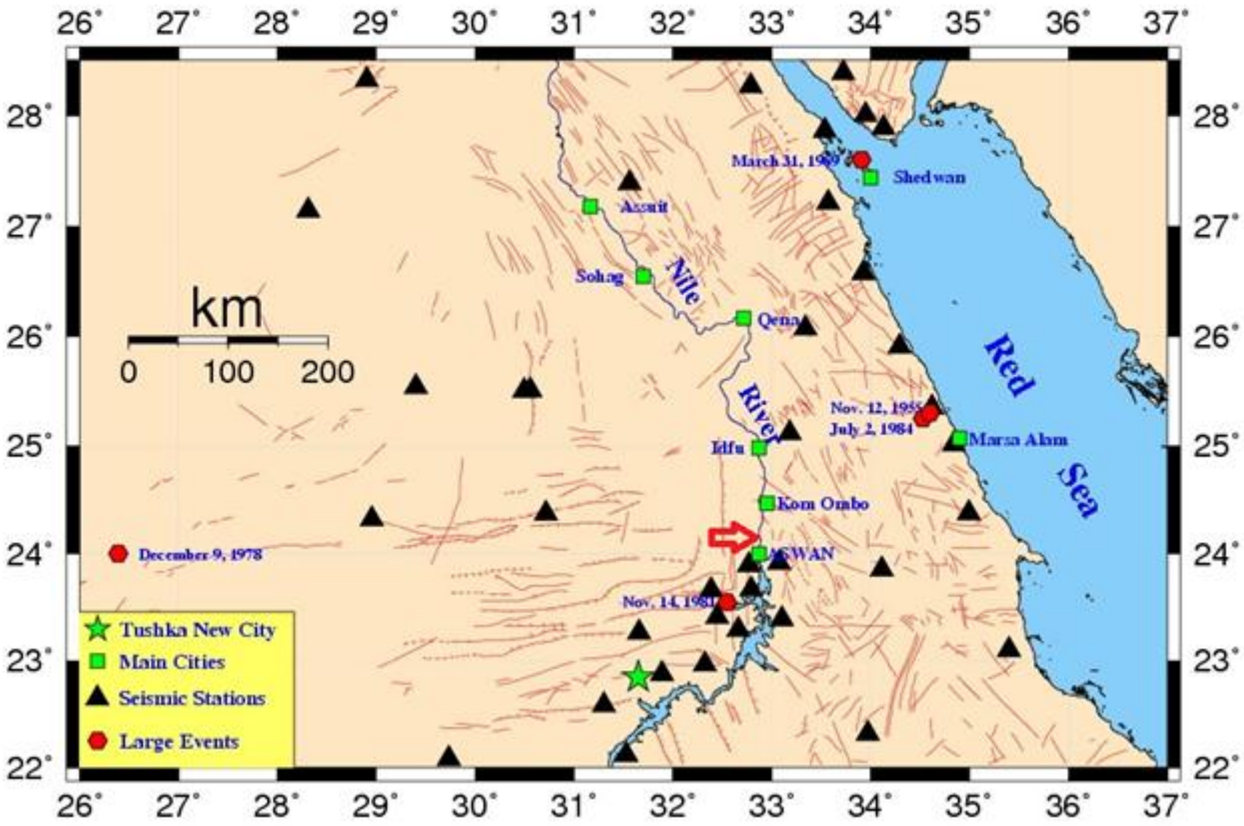

Figure 1: Location map of the study area (Red Arrow) with the significant earthquakes in southern part of Egypt

3. Structure, Geology and Seismicity of Aswan area

Woodward-Clyde Consultants (WCC, 1985) evaluated the fault system in the Kalabsha area and reported that the Western Desert Fault System consists of two sets of faults, (E-W) faults that exhibit dextral-slip displacement, and (N-S) that exhibit sinistral-slip displacement (Figure 2). The E-W trending faults as the Kalabsha and Seiyal faults, which lay to the west of High Dam Lake. The Kalabsha Fault is about 185 km. The N-S trending faults can be subdivided into two main sets: The first set lies to the NW of High Dam Lake and consists of three faults: the Gebel El-Barqa fault, the Khor El-Ramla fault and the Kurkur fault. The Gebel El-Barqa is a left-lateral strike-slip fault, with a total length of 110 km. The Khor El-Ramla fault is about 36 km in length, and it has no direct indication of its sense of movement. The Kurkur fault is characterized by its low seismic activity if compared with the neighbor faults and is a left-lateral strike-slip fault. The second set of faults is lying to the SW of High Dam Lake, and consists mainly of two faults: the Ghazala and the Abu Dirwa faults. Abu Dirwa fault is a 20 km long left-lateral strike-slip fault and it has a very low degree of seismic activity. In addition, for the Gazelle fault, the analysis of its geomorphic expression shows no active features, and that there is no ground cracks observed along the fault trace. Likely this fault is inactive (Issawi, 1968). To the east of High Dam Lake, the third fault system trending NNE-SSW is laying. The Dabud fault, which represents the main fault of this group, is about 36 km length. Geological evidences indicate reverse-slip, opposed to the tectonic setting of the area.

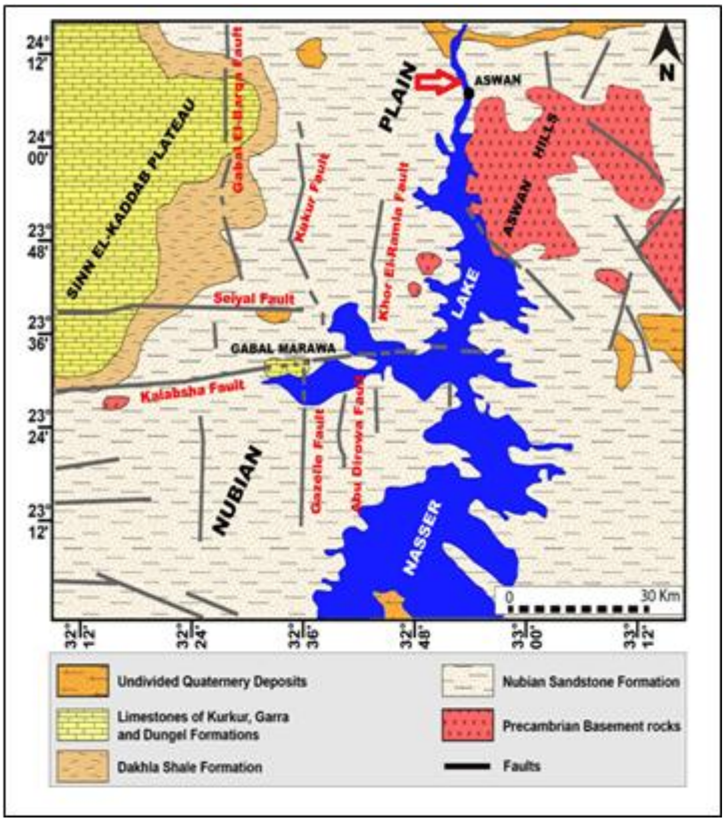

Figure 2: Tectonic and geologic setting in and around the study area (after WCC, 1985 and EGSMA, 1981)

Woodward-Clyde Consultants (WCC, 1985) valuded the fault system through Kalabsha area and conducted that the Western Desert Fault System has two fault's groups, (E-W) faults with dextral-slip displacement, and (N-S) with sinistral-slip displacement (Figure 2). The E-W trending faults (the Kalabsha and Seiyal faults) are located west of the Lake. The Kalabsha fault has 185 km long. Two main sets are recognized the N-S trending faults: The first one NW of Aswan Lake and has three faults: the Gebel El-Barqa fault, the Khor El-Ramla fault and the Kurkur fault. The Gebel El-Barqa is a left-lateral strike-slip fault, with a total length of 110 km. The Khor El-Ramla fault is has 36 km length where there is no indication for movement. Comparing to the other faults, low seismic activity observed on the Kurkur fault, this one is a left-lateral strike-slip fault. The second trend is SW of the Lake with two faults: the Ghazell and the Abu Dirwa faults. Abu Dirwa fault with 20 km length and very low earthquake activity. No active features and no ground cracks are observed through Gazell fault. Eastern side of the Lake has the third fault system (NNE-SSW) such as the Dabud fault with 36 km length.

The principal earthquake inside the Aswan region was the (Mb 5.6) November 14, 1981 (Kebeasy et al., 1982). Although its epicenter is inside Kalabsha area, 60 Km southwest of Aswan. It has a strong effect in Aswan, and in areas up to 440 km North Kalabsha fault. Many cracks on the western bank of the Lake, while several rock-falls with minor cracks on the eastern bank are found. This quake caused alarm due to its closeness to the Aswan High Dam, so in 1982, Aswan seismic network erected by the National Research Institute of Astronomy and Geophysics (NRIAG) and High and Aswan Dam Authority (HADA).

Based on the investigations of many pioneers (e. g., WCC, 1985; Isawi, 1978), the geological setting of Aswan region is dominated by four geomorphologic features; the Nile river valley, the Sin-El kaddap plateau, the Sin-El kaddap Escarpment, and the Nubian plain (Figure 2). The sedimentary rocks composed of sand and sandstone interbedded with clay and shale are a part of a vast clastic sequence covering almost of the North Africa which known as Nubian Formation. The sedimentary cover of southern Egypt is approximately 1 km thick with large variation in the thickness of the individual units. The cretaceous Nubian Formation around Aswan area uncomfortably overlies the Precambrian basement. The dominant geological section in and around the investigated area is the Nubian Formation with 30 to 50 km wide on the west side of the Nile River (Figure 2).

The stations of this network have a good distribution around the NS and EW fault's directions at the northern sector of the Lake. Aswan seismic network has thirteen seismic stations, eleven stations west and two stations east the High Dam Lake. After construction the Egyptian National Seismic

Network (ENSN) which covers all Egypt, the Aswan seismic network became an important branch from the ENSN covering the southern region of Egypt. Before the installation of Aswan network there was a shortage of the seismic monitoring in southern part of Egypt, therefore after the continues recording through this network since first seismometer installed up to date, a good contribution with a complete catalogue for earthquake hazard researches became available not only for Aswan area but for all Egypt. A catalogue from 1982 to 2021 is used to map the activity across Kalabsha region (Figure 3) and the map shows that the seismicity is concentrated around the faults and has a shallow depth (~ 30 km).

4. Applied Geophysical methods

There are very large numbers of geophysical techniques available for characterization of subsurface soils. Each of the approaches has its own characteristics and also limitations over other methods. There is always an ambiguity over the selection of a particular method for site investigation. Selection of a certain method depends on the many factors starting from the purpose and the scope of the study, availability of resources (equipment and expertise personal), type of analysis to be carried, type of soil, etc. In this research, the site investigation was performed at the new industrial city site in Aswan area by using two geophysical methods, the seismic refraction and the H/V.

4.1 Shallow seismic refraction survey

During the last four decades, this method proved to be one of the most powerful techniques for shallow subsurface structures investigation, so the method was applied in the current study to assess the near-surface sediments, outline bedrock topography and its relative strength. Moreover, in complex geological structures areas, this technique has an advantage for construct a clear geological model, because it provides inclusive coverage over the exploration area. Many workers have utilized seismic refraction method to characterize bedrock in delineating subsurface structures for engineering and hydrogeologic studies. Among those are Mohamed (2004&2010); Fat-Helbary et al. (2006); Basheer et al. (2014); Mohamed et al. (2015) and Arafa (2015).

In the current study, shallow seismic refraction approach was applied for determining the subsurface layering, the changes in lithology (the lateral and the vertical), and investigate structural features such as, micro faults and cracks at the new Aswan city site. The evaluated seismic velocities are used in interpretation of lithology, structural features, rock material quality and dynamic characteristics, which are very useful for building and other engineering purposes. Seismic refraction lines were measured using Strata Visor-NZ 48 channels. Ten seismic refraction P-wave profiles were performed across the area (Figure 4) and indicated that the area is made of two layers (Figure 5), surface and bedrock, the P-wave velocity is computed for the both. The results indicated that the surface layer is mainly sand and fragments of sandstone with P-wave velocity from 598 to 1054 m/sec (Figure 6) and the bedrock layer mainly composed of Nubian sandstone with P-wave velocity from 1387 to 2567 m/sec in the area (Figure 7).

4.2 H/V Spectral ratio method (Nakamura technique)

Over the past years, the Nakamura's (1989) horizontal-vertical-spectral ratio (HVSR) approach for microtremor has gained much popularity due to its inherent advantages of the ease of microtremor recording with a single station. It is a passive inexpensive technique can be used in low seismicity region. Over the years, the method has found wider field of applicability for evaluating the sediment thickness (Delgado et al., 2000 and Parolai et al., 2000) and for seismic microzonation purposes (Lachet et al., 1998; Mirzaoglu and Dykmen, 2003 and Tuladhar et al., 2004).

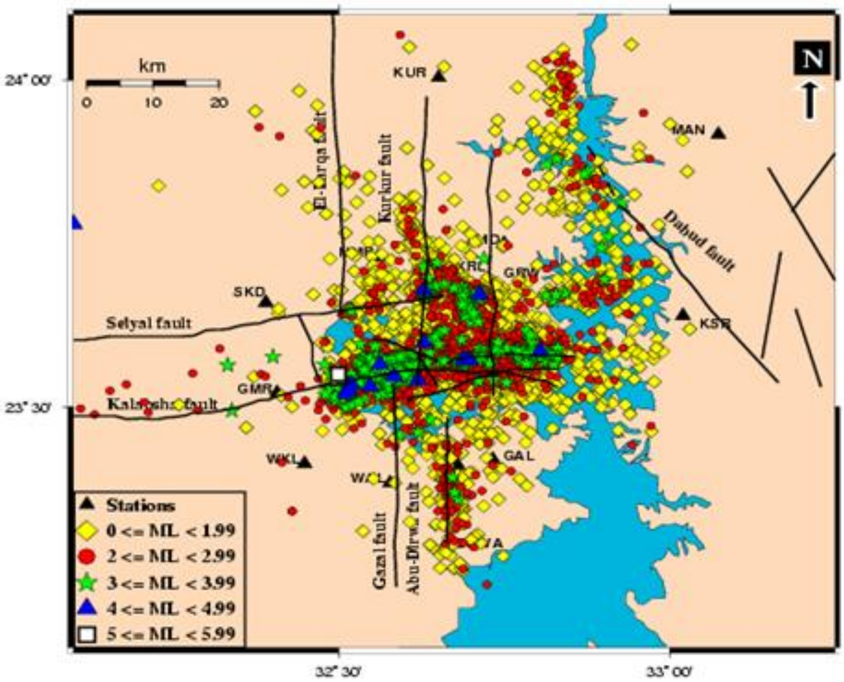

Figure 3: Seismic activity in Aswan area from 1982-2021

In the current study, the H/V spectral ration technique was applied to calculate the fundamental frequency and the amplification factor inside the site of the industrial city. Due to the low cost and quick implementation of this technique, it 1is one of the most applied methods for site response estimation using the microtremor measurements; therefore this approach was selected to apply in this investigation. In 20 sites (Figure 4), the microtremors were recorded for two hours duration during the daytime and using the Taurus portable seismograph and a three-component, force-balance broadband seismometer (Trillium 120s).

The results showed that, some sites have clear peaks in the H/V spectral ratio, which indicates that site effects might be expected at these sites. The majority sites have no peak. At these points, occurrence of shallow firm sediments or bedrock condition could be assumed and it has a good correlation with the gained results by Mohamed (2004) in and around the area, so the shallow bedrocks in the proposed site may have a direct effect on the measured peak frequency. The range of the fundamental frequency (Fo) across the area from 0.90 to 2.0 Hz (Figure 8). The amplification factor (maximum H/V amplitude Ao) ranged from 2.0 to 3.0 (Figure 9).

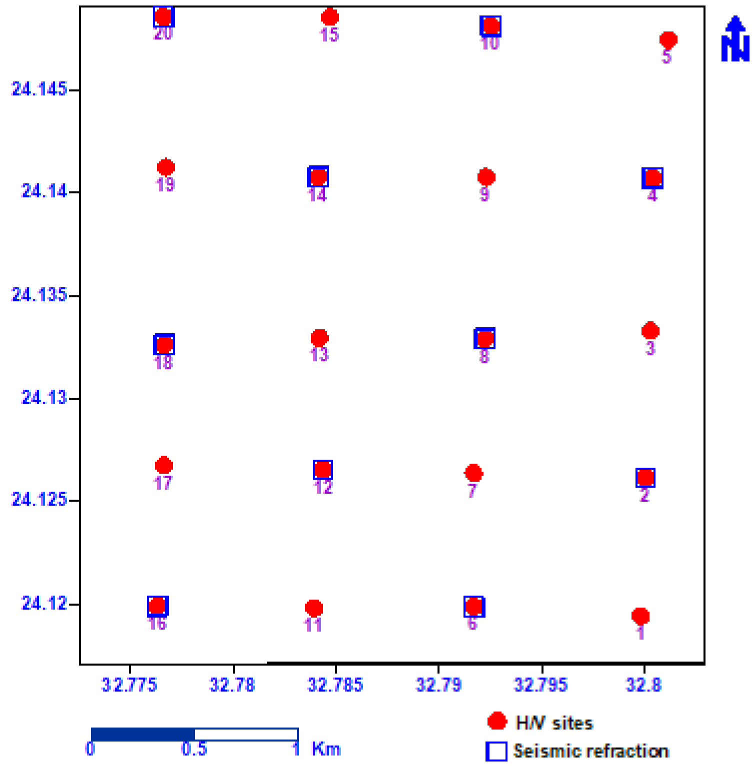

Figure 4: The Location map of the conducted H/V and seismic profiles at the study area

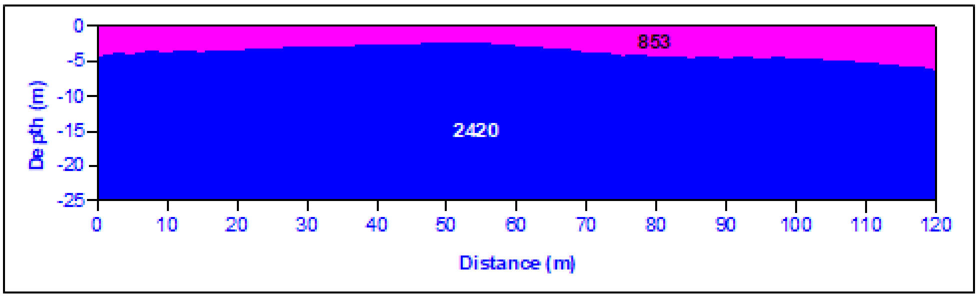

Figure 5: A representative example of the 2-D P-waves velocity model

5. Conclusion and Recommendations

Site characterization using Geophysical techniques is the primary valuable step in earthquake hazard mitigation. In this study, the validity of site characteristics deduced from the shallow refraction measurements and 'single site' ambient noise H/V has been investigated in order to provide reliable information on the dynamic behavior of the surficial layers.

The outputs are very useful to solve problems, which connected with the construction of different civil engineering targets and earthquake's resistant structure design, so this kind of studies strongly recommend applying in planning stage of all the new strategic buildings and projects and should be taken into consideration for earthquake disaster mitigation.

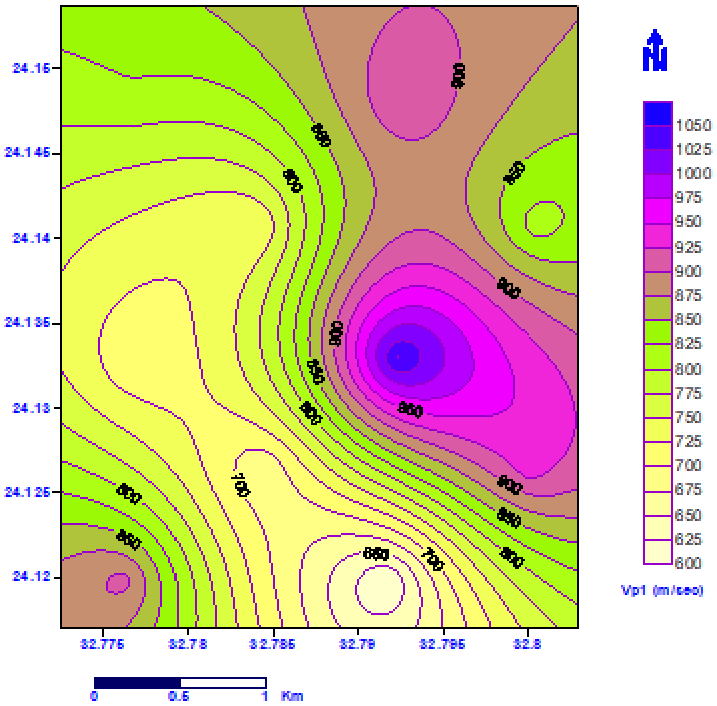

Figure 6: The P-waves velocity distribution of the surface layer

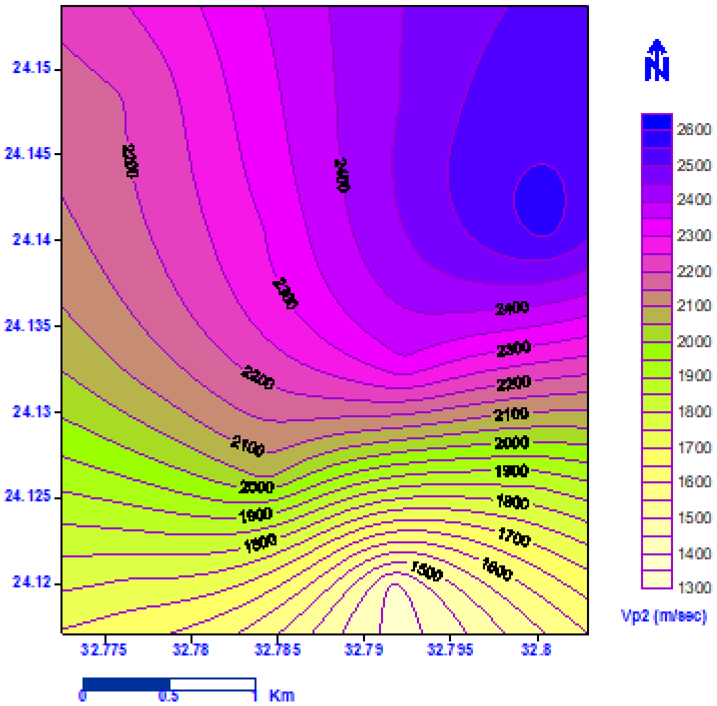

Figure 7: The P-waves velocity distribution of the bedrock layer at the study area

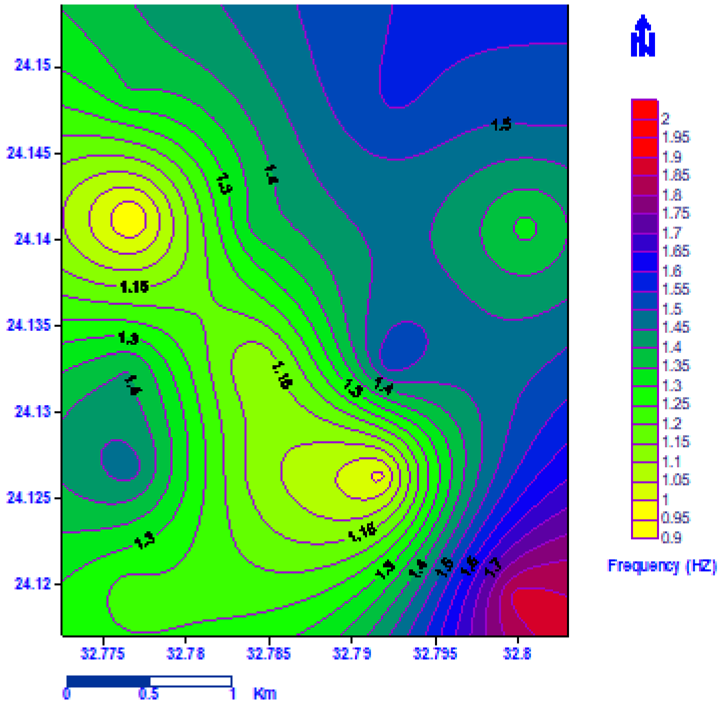

Figure 8: The fundamental frequency distribution at the study area

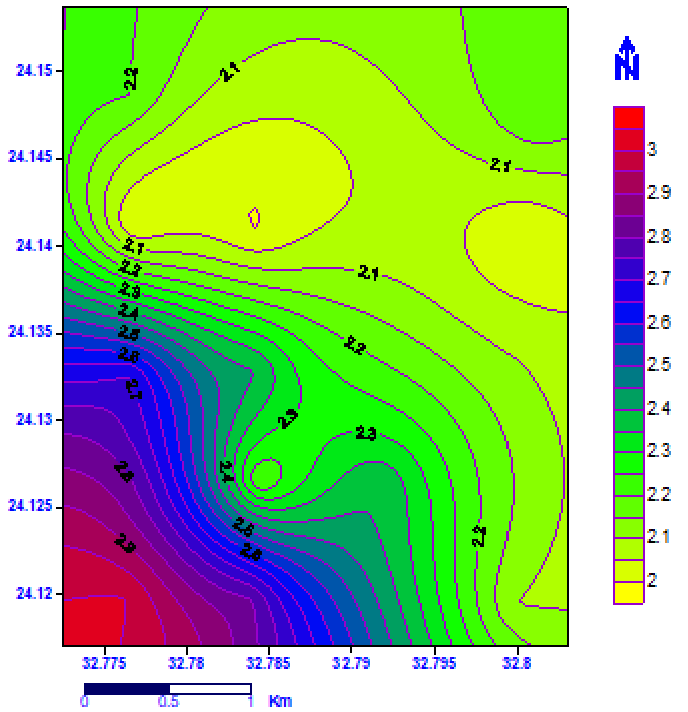

Figure 9: The maximum amplitude of H/V (amplification factor) at the study area

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