IOSR Journal of Applied Geology and Geophysics (IOSR-JAGG)
e-ISSN: 2321–0990, p-ISSN: 2321–0982.Volume 9, Issue 6 Ser. I (Nov. – Dec. 2021), PP 32-40
www.iosrjournals.org

Microtremors for site effect evaluation at the new Kima factory, Aswan, Egypt

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Abstract:
The evaluation of site effect is one of the key parameters in seismic hazard mitigation. Over the most recent quite a few years, destructive earthquakes happening near populated and metropolitan zones showed that site effect can assume a significant part to the resulting damages. Numerous techniques have been applied to quantify the site response and characterize the site effect functions. Microtremor method is probably the most used technique to calculate the resonance frequency within urban areas. The Egyptian government constructed a new factory (new Kima factory) for fertilize, southeast Aswan city. New Kima factory site is very close to the principal active earthquake area inside Aswan region, where Nov. 14, 1981 earthquake (M = 5.6) and Nov. 7, 2010 earthquake (M = 4.6) were occurred. Nov. 7, 2010 earthquake was felt strongly and accompanied by a strong audible voice in Aswan urban area, which caused a panic among the residents. Because of that the principle focuses of this investigation is to estimate the site effect at the study area. Microtremor records have been achieved at 12 selected sites covering the targeted area in an attempt to understand the influence of site condition on damage distribution during the probable strong ground motion at the new Kima factory site. The outputs of microtremor measurements and analysis are outlined in this research as fundamental frequency and maximum amplitude (amplification) at each selected site. The site response spectra exhibited significant peaks from 0.64 to 0.768 Hz and the amplification ranged from 3.1 up to 5.9.
Key Word*: Site effect; Microtremors; Kima factory.*

Date of Submission: 10-11-2021 Date of Acceptance: 26-11-2021

I. Introduction

It is widely accepted among the earthquake engineering community that the site conditions (e.g., geology, topography, boundary conditions between sediments and the underlying bedrock) have a significant effect on seismic ground motion which called site effect. Site effect may cause amplification of the waves during earthquakes and plays an essential role for site-specific ground motion predictions and earthquake hazard estimation (Zandieh and Pezeshk, 2011). Hence, a definite investigation of this impact involves extraordinary significance civil engineering. The response of men made structures during earthquakes are not only related with structural features but also are controlled by two main factors: earthquake source characteristics and local site conditions. The local site characteristics could be very different due to variations in thickness and characteristics of soil layers, water table and depth of bedrock and could have considerable effects on the properties of earthquake ground motions at the ground's surface. For earthquake hazard assessment, the site effect is ordinarily addressed by the dominant frequency (f_0) and the associated amplification (A_0). At the point when the resonance frequency (f_0) of the site coincides with the natural period of the buildings and/or structures, the resonance phenomenon may happen and structures have the greatest probability of getting harmed (Mukhopadhyay and Bormann, 2004).

In the past several earthquakes like Mexico earthquake (1985), San Francisco earthquake (1989), Los Angeles earthquake (1995) have established the fact local site conditions has significant role in the amplification of ground motion especially on those area, that located on unconsolidated young sedimentary material (Hunter et al., 2002). The Egyptian ministry of industry started to construct a new factory (new Kima factory) for fertilize, southeast Aswan city (Figure, 1). New Kima factory site is very close to the principal prone earthquake zones in Aswan region, where Nov. 14, 1981 earthquake (M = 5.6) and Nov. 7, 2010 earthquake (M = 4.6) were occurred. Nov. 7, 2010 earthquake was felt strongly and accompanied by a strong audible voice in Aswan urban area, which caused a panic among the residents. Around the factory site, many buildings were suffered from damages represented by cracks. Such damage of this area, even if it is located on the zone of moderate seismic activity, is probably a result of ground motion amplification caused by the existence of thick basin sediments. Because of that, the principle focus of this work is to estimate the site effect of the studied zone in terms of fundamental frequency (f_0). This estimation is of prime importance for seismic risk mitigation. The site response can be estimated empirically by using the weak (and strong) event ground motion. A portion of the broadly utilized approaches formulated for the assessment of site effect using earthquake recordings are soil/bedrock spectral ratio (Borcherdt, 1970), generalized inversion scheme (Andrews, 1986), coda-wave analysis (Phillips and Aki, 1986; Margheriti et al., 1994), parameterized source and path inversion (Boatwright et al., 1991) and horizontal/vertical spectral ratio (receiver function) (Lermo and Chávez-García, 1993). Without weakness and strong motion records, the local resonant periods have been effectively assessed with the microtremors. The most normally applied methods are H/V noise ratio (Nogoshi and Igarashi, 1971; Nakamura, 1989) and exhibit examination (Malagnini et al., 1993). The best appraisal of site effect will be established thick strong motion observations utilizing spectral ratio of earthquake's signals from sedimentary locales concerning bedrock reference sites, because the nonlinear effect is included (Jarpe et al., 1988, 1989; Darragh and Shakal, 1991; Satoh et al., 1995; Hartzell, 1998; Reinoso and Ordaz, 1999; Zaslavsky et al., 2006 and others). In regions where seismicity is comparatively low and recording strong ground motion may take a long time, as in Egypt, this kind of analysis is usually impractical. A proposed elective is to utilize microtremor recordings for site effect assessment as an efficient and low cost method. In this examination, the estimation of the site effect for new Kima factory site was conducted according to the most popular and world-wide approach through the calculation of the horizontal to vertical spectral ratio (Nakamura technique) for the recorded ambient vibrations.

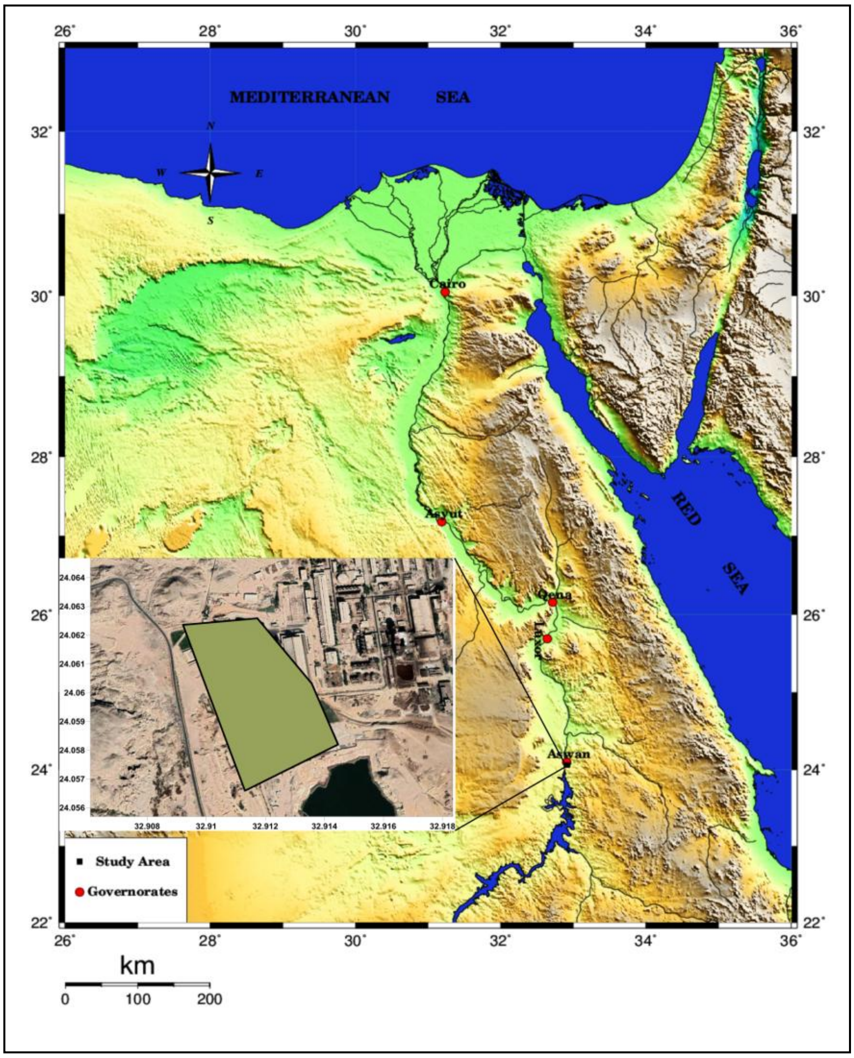

Figure 1. The site of the investigated area, Aswan, Egypt.

Geological setting

The regional geology of Aswan and surrounding areas in South Egypt is depicated in Figure 2. The rocks of this area belong to the Nubian Formation. Several pioneers have previously studied the geology of the region. The Nubian Formation named as Kalabsha plain according to Butzer and Hansen (1968) and as Nubian plain according to Issawi (1968). They are concurred that, the Precambrian basement complex uncomfortably covered by the Nubian Formation sedimentary unit. The geological succession of the study area which represents a zone of the Egyptian eastern Desert is composed of Upper Cretaceous thick sedimentary Nubian sandstone Formation that covers the Precambrian basement rocks. This sector is composed of sandstone and clays. Within the sandstone layers, the clays are found as beds and lenses with different dimensions. According to the geological cross sections of the drilled wells at the factory site; the location of new Kima factory is occupied by Quaternary sediments mainly gravel and alluvial sand (Figure 2). The sediment's thickness as noticed from these wells is approximately around 100 m.

II. Materials and Method

The H/V method, suggested by Nakamura (1989, 2000), utilizes one single station. It is very quick to implement and at a low cost. Its standard comprises for measuring the ambient vibrations of the ground during an interval of time and in calculating the spectral ratio of the horizontal component over the vertical one. As demonstrated by various authors the resulting curve generally shows a peak at the frequency of the site. The dependability of this technique to calculate the frequency of a soil column has been examined both numerically (Field and Jacob, 1993; Lermo and Chavez-Garcia, 1993; Lachet and Bard, 1994), also, tentatively (Duval, 1994; Bard et al., 1997; Seo, 1998). The outcomes revealed that the last is stronger and is a less expensive technique for estimating the frequency (Bard, 1998). Nonetheless, estimations and the investigation ought to be performed with alert (Lermo et al., 1988; Field and Jacob, 1995; Bard, 2000; Parolai et al., 2001& 2002; and SESAME project, 2004). The calculation of the amplification factor at resonance frequency based on H/V mechanism is controversial, with some researchers finding good outputs (Seekins et al., 1996; Chàvez-Garcia and Cuenca, 1998; Mucciarelli, 1998; and Mucciarelli and Gallipoli, 2004) while others (Horike et al., 2001; Mukhopadhyay and Bormann, 2004; SESAME, 2004; Turnbull, 2008; and others) find significant differences using other procedures of site effect valuation.

To compute the fundamental frequency at new Kima factory site, ambient vibration signals were collected twelve (12) selected points distributed covering the area (Figure 3). Data acquisition were conducted through the daytime utilizing a seismic station furnished with a three channel information logger model Taurus and Trillium 40s, three component velocity sensor. Taurus with a three channel 24-bit digitizer, GPS receiver and system clock, removable data storage, and remote communication options.

Trillium 40s is a force-balance three-component broadband seismometer suitable for fixed and portable applications, works without manual recentring over a wide temperature range and with very low power consumption. The extended response at higher frequencies makes it ideal for local and regional networks as well as volcano hazard observing and aftershock studies. In the current investigation the guidelines used in the European (Site Effects Assessment using Ambient Excitation, SESAME, D23.12, 2004) project were followed, in order to ensure reliable experimental conditions. This specifically considering the following points: at every point, the signal was recorded with a sample rate of 100 Hz for at least 90 minutes, the sensor was set down directly on compact ground as it is possible, and avoid tuning the sensor on soft grounds, records were done as far as possible from near structures such as buildings, trees, etc., avoid recording on windy or rainy days (the weather was generally calm with no strong winds or rain). Following H/V technique, the horizontal motion may be considered to be amplified through multi-reflections by surface layer, while the vertical motion isn't amplified. For this situation, the artificial noise induces the surface layer to cause a major change in the microtremors. The impact might be considered as noise to calculate the upper most layer dynamic characteristics utilizing ambient vibrations (Al-Qaryouti and Al-Tarazi, 2007).

The collected data were processed utilized the H/V Nakamura's technique (1989). The time series was tapered using a cosine taper and an amplitude spectrum is calculated for every component. GEOPSY program (http://www.geopsy.org) was used for data analysis of the acquired signals. Data was converted to SESAME ASCII Format (SAF); the common file format accepted by Geopsy software. The data processing was conducted in the frequency range from 0.5 to 20 Hz. microtremor signals were processed as follows: for ambientvibration recording relative to each ground motion component was subdivided into time windows. Each time window was selected using the automatic window selection in Geopsy of 30-50s length.

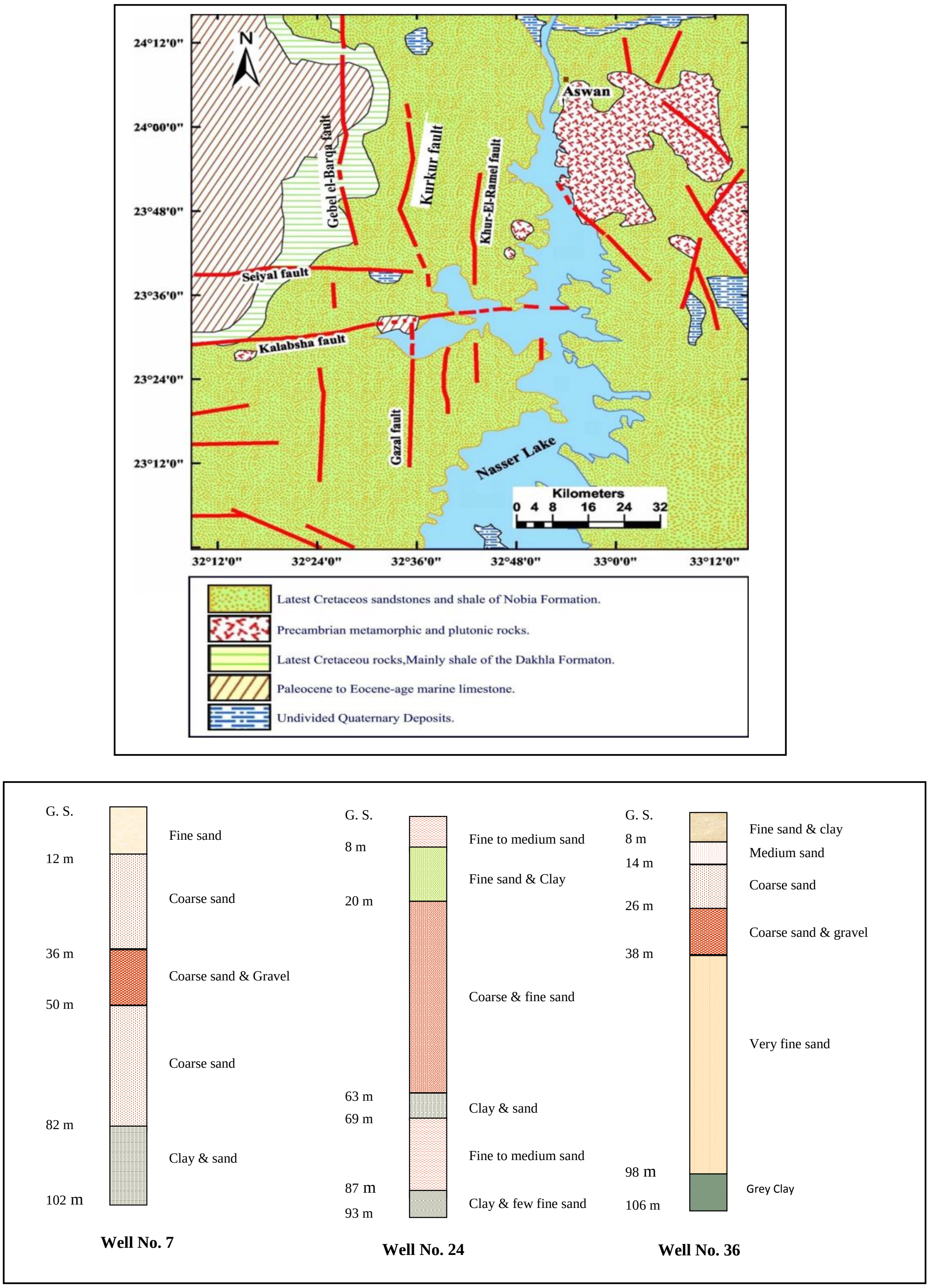

Figure 2. Geological map of Aswan and surrounding areas (Upper) and geological cross sections of the drilled wells at new Kima factory site (Lower), G. S. represents Ground Surface.

The signals with noticeable harmonic sources induced from vehicle passing and the other sources are not permitted in the used time windows. Following the H/V processing module of Geopsy software, the following steps were applied for each windowed signal: (1) baseline correction; (2) 5% cosine tapered; (3) computation of Fourier spectra in all components (E-W, N-S, and vertical) using the Fast Fourier Transform (FFT); (4) smoothing of the Fourier amplitude spectra using algorithm of Konno-Ohmachi (1998). For every time window, the horizontal recording spectrum was split by the vertical one, separately for both horizontal components, in order to discover any significant difference between EW/V and NS/V spectral ratio. In a lastphase, the geometrical mean is processed to consolidate the two horizontal components (E-W, N-S) to obtain the outcome (H) components as recommended in the SESAME project (D23.12, 2004). This task is realizedbase on the following equation (1):

$$H = \left(\left| x(f).y(f) \right| \right)^{½} \qquad (1)$$

Where: H is the horizontal component computed by geometric mean.
X(f) is the modulus of spectra of the N-S component.
Y(f) is the modulus of spectra of the E-W component.

Then, the Horizontal to Vertical Spectral Ratio (HVSR) for every single time window was computed by dividing the spectra of the joint horizontal components. Finally, the spectral ratios relative to all the time windows were considered then averaged, and the main HVSR curve was computed. The selection of both (f_0) and (A_0) were made both visually and automatically in Geopsy software. In this investigation, the comprehension of the HVSR curves was done similarly to global agreement measures of SESAME project (D23.12, 2004). According to these, the clearness and dependability of HVSR peak were checked. Definite assessments ought to be made on H/V peaks before the extraction of data to guarantee the accuracy of the peaks. Reliability implies stability, this implies that genuine H/V curve got with the chosen recordings, be illustrative of H/V curves that could be gotten with other microtremor measurements and/or with other physically feasible window selection. In this examination, the peaks or troughs which have an artificial origin, identified with some sort of apparatus (turbine, generators, etc.) were distinguished by the tests are suggested at SESAME report, D23.12 (2004) and not take into account in any understanding.

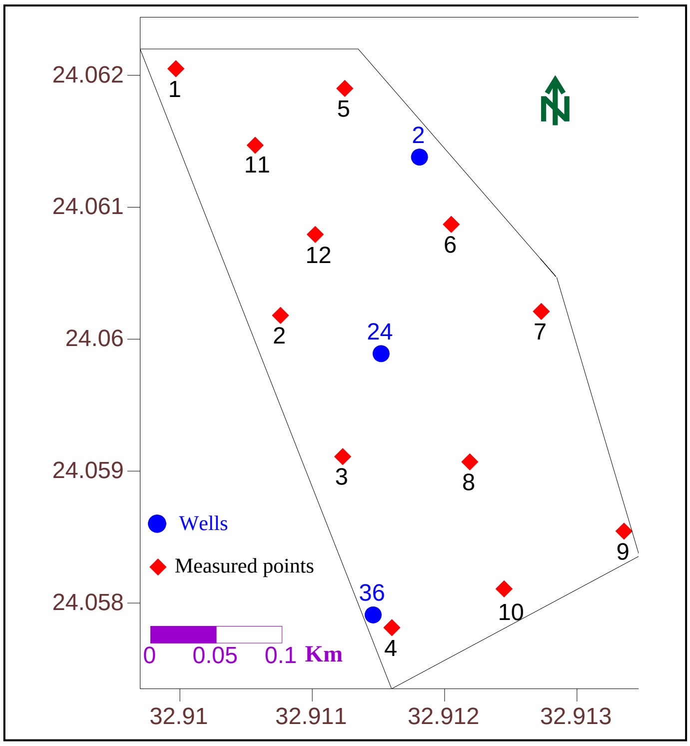

Figure 3.Sites of the measured points along the study region.

III. Results and Discussion

The technique for ambient vibrations H/V spectral ratio counts on the existence of a soil layer of low inflexibility overlying another more rigid. In such case, the proportion of H/V generally exhibits a peak, that relates to the frequency (F_0) and the comparing peak amplitude is viewed as (A_0) of the site. On account of destinations laying on rock, this condition isn't met since no differentiation exists between materials at the surface and those at depth. Therefore, on outcropping rocks, the HVSR curve is level without significant peaks. The outcomes of this research at the measured points were investigated (Table 1) and exhibited that all sites have clear peaks (the obtained H/V spectral ratio curve is reliable), which refers that site response might be expected at these locations. In case of plots showing a single peak, the corresponding frequency was considered as the resonance frequency (F_0) at the measured site. Few sites show two/multi peaks at various frequencies. In this case, the accuracy of the H/V peaks was checked to guarantee that no artificial source of these peaks. We found some peaks with industrial source, so they discarded and the frequency corresponding to the peak which has maximum capacity is considered to be (F_0). These peaks of artificial sources concerning with the factory's site inside an urban area and also the microtremores were acquired through the daytime. The frequency (F_0) inside the area ranged from 0.64 to 0.768 Hz, while the amplification (A_0) ranged from 3.1 to 5.9. This H/V peak is deciphered due to the effect of the impedance disparity amidst the bedrock layer and the covering sediments. A representative model of the outputs at the area is showing in Figure (4).

The obtained results ((F_0) and (A_0)) represented as surface maps at the study area (Figures 5 and 6). From these figures, the minimum frequency value is about 0.64 Hz through the southeastern zone of the area, where the maximum value (0.768 Hz) founded at the northwestern part (Figure 5). Also it tends to be reasoned that, the lower amplification value is about 3.1 at the eastern locality of the area, while at the southwestern zone the extreme value 5.9 was reported.

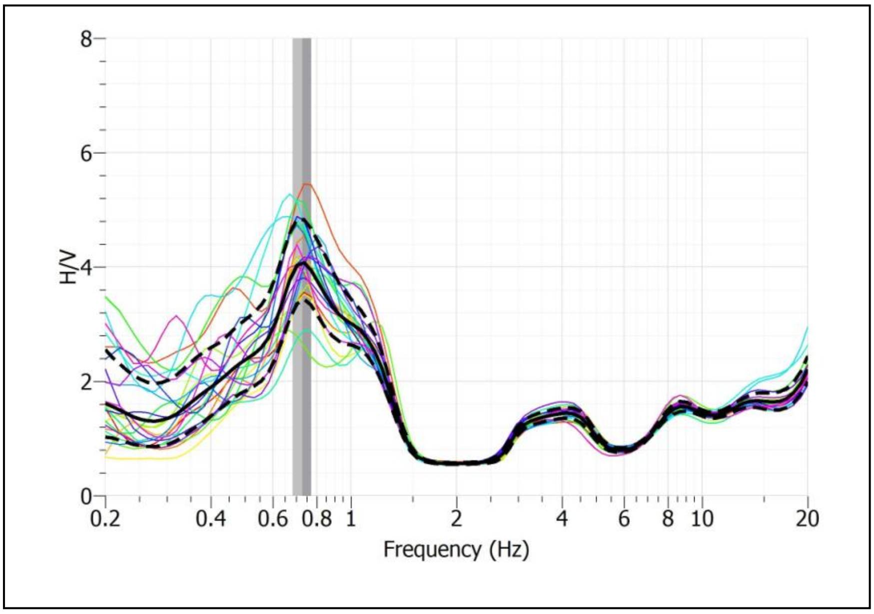

Figure 4. A representative example of the outcome results in the current study (F_0 and A_0) observed at site No. 2.

Table 1. The coordinates of the measured sites with their results.

Site No.	Longitude	Latitude	F_0	A_0
1	32.91160	24.0578	0.74	4.9
2	32.91335	24.05854	0.743	4.16
3	32.91219	24.05907	0.743	5.9
4	32.91123	24.05911	0.73	5.5
5	32.91076	24.06018	0.74	4.0
6	32.91273	24.06021	0.768	3.2
7	32.91205	24.06087	0.701	4.0
8	32.91124	24.061905	0.706	3.5
9	32.90997	24.06205	0.65	5.3
10	32.91245	24.058088	0.74	5.0
11	32.91057	24.061488	0.64	4.8
12	32.911041	24.060747	0.72	4.3

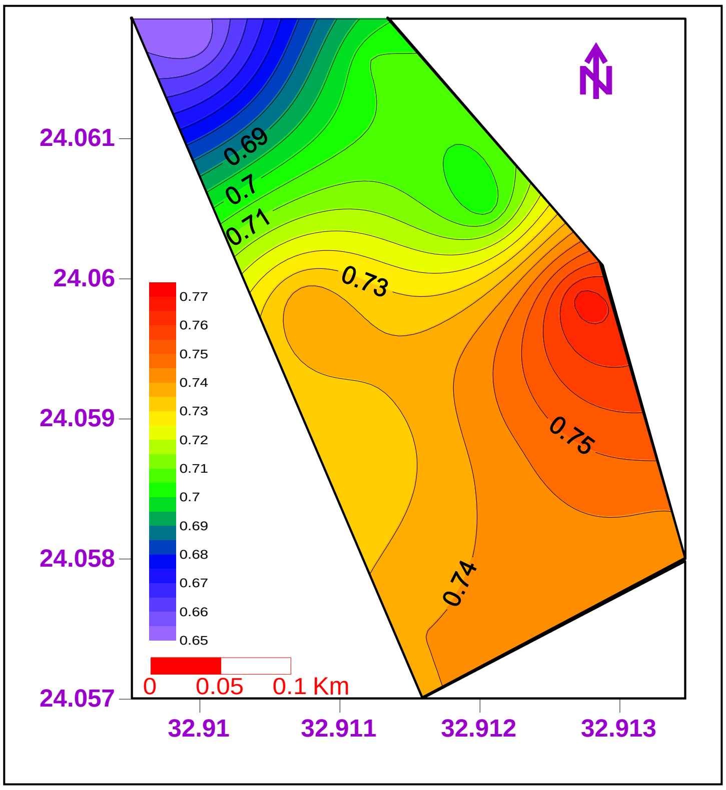

Figure 5. The distribution of the conducted frequency in the investigated area.

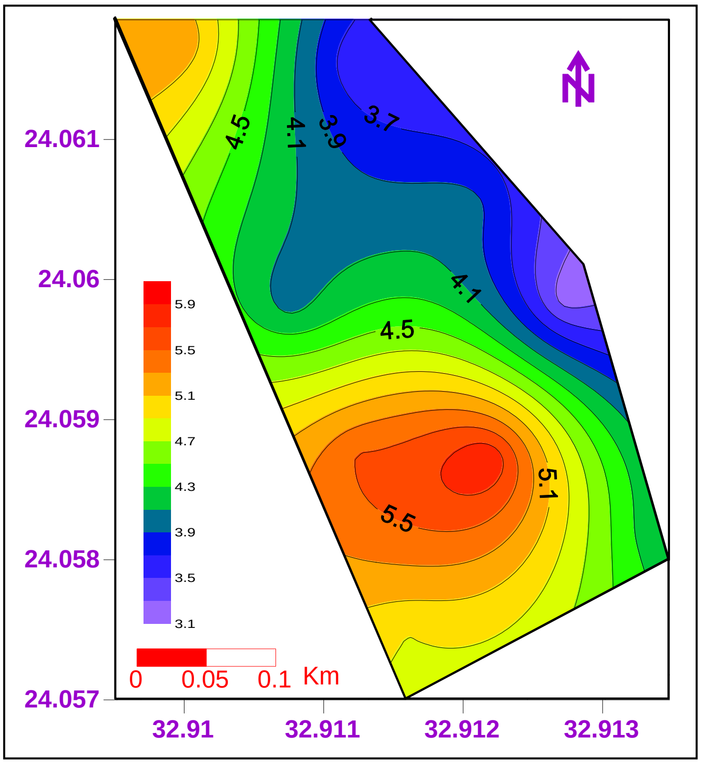

Figure 6. The amplification value over the factory's site.

IV. Conclusion

In the current investigation, the principle target of this study was to appraise the site effect along the new Kima factory site, so the validity of seismic site effect characteristics deduced Nakamura method has been investigated and in outline, the following results were gained: - The frequency limit of the peak H/V ratio falls in extremely narrow band ranging from 0.64 to 0.77 Hz for the new Kima factory site, this is may be as anoutcome of the sediment's homogenous at the area which mainly composed of graded sand from fine to coarse with some gravel. - There is a perfect engagement both of the fundamental frequency (F_0) and its amplification level (A_0) with the sediment's thickness. - The outcomes exhibit the helpfulness of the H/V technique utilizing ambient vibrations, to give reliable data on the dynamic behavior of surficial layers. This study strongly recommends that the gained outcomes should be taking into consideration to design and construct seismically resistant structure of new Kima factory.

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