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in

Proceedings of Indian Geotechnical Conference

Report No: IIIT/TR/2012/-1

Centre for Earthquake Engineering
International Institute of Information Technology
Hyderabad - 500 032, INDIA
December 2012

Proceedings of Indian Geotechnical Conference
December 13-15, 2012, Delhi (Paper No I906)

SEISMIC SITE EFFECT ESTIMATION USING MICROTREMOR STUDIES IN VIJAYAWADA

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ABSTRACT: Mechanisms related to the local soil and rock properties have the capacity to influence ground motions and inturn regulate damage. Amplification mechanisms control the frequency content of ground motions. The city of Vijayawada which falls in zone III according to IS 1893:2002 is one of the important and a major business centre in the state of Andhra Pradesh, India. It is located on the banks of the river Krishna which occupies an area of about 73 km^2 and is located at 16 31' N latitude and 80 39' E longitude. To identify the dominant earth period and study the dynamical behavior of alluvium in the city of Vijayawada the microtremor survey in 67 sites have been recorded. Microtremor is one of the recent advances in the geophysical survey techniques but is quite different from the other methods. The results from the Microtremor survey provide the fundamental basis for the analysis of the response of the ground to earthquake movement. With spectral analysis of microtremor records, predominant frequencies, amplification factors, vulnerability index of the ground can be determined.

INTRODUCTION

Earthquake effects are usually quantified on the basis of degree of damage in addition to the recorded ground motions at a site. Local soil conditions dominate the damage and loss of life in earthquakes such as the 1985 Mexico City, 1989 Loma Prieta, 1994 Northridge, and 1995 Kobe earthquakes, Tohoku 2011, Christchurch 2011. Urban agglomerations in the world may be mostly disrupted due to near fault earthquake rather than due to tectonic activity. Consequently, demanding for a better understanding of the mechanisms that control fault motions and the interaction of near-fault ground motions with soil deposits. Assessment of ground motion characteristics and evaluation of response of the soil and structures, for the ground motion is necessary.

The predominance of the site response mechanism in the near-surface allows seismic investigations conducted to depths of only 30 m to provide good estimates of site response [1-3]. Low near-surface V_S values contributed to the destruction caused by the 1989 Loma Prieta earthquake [4] near San Francisco, and the 1985 Michoacan earthquakes [5] near Mexico City.

Amplification factor and peak ground frequency are representative of site effects. Amplification undoubtedly has the utmost importance when dealing with the response and hence, natural resonant frequency of the soil and structures need to be estimated. By employing laboratory and field testing, one can obtain an approximate value of natural frequencies. Geophysical tests like downhole, cross-hole, suspension logging tests etc and surface geophysical methods, such as the surface wave methods or refraction methods, can be used. Time, cost and portability are key points to look for before selecting a specific method. Microtremor is rapid, cost-effective and efficient method for damage study. It provides a fundamental basis for ground response analysis, particularly in densely populated urban areas where there is growing difficulty in utilizing conventional seismic techniques.

In this paper, study has been done on Vijayawada city (zone III) [6], to estimate the site effects using microtremor survey. The Nakamura technique has been adopted for the analysis (HVSR). The H/V technique [7] involves calculation of ratio between the Fourier amplitude spectra of the horizontal and the vertical components of ambient noise vibrations. The ratio is the resonant frequency of the site. The H/V ratios are calculated at all the test locations in Vijayawada city.

GEOLOGY AND SEISMOTECTONICS

Vijayawada (16.52°N Latitude 80.62°E Longitude) is the 3rd most populated metropolitan area in Andhra Pradesh. It is one of the important urban agglomerations in the country with considerable historical, agricultural importance and cultural heritage. Vijayawada has a population of 2 million as per 2011 census. By 2030, the percentage of total population living in urban agglomerations is expected to increase up to 41% (NHUD 2007) which inturn increases the seismic risk interms of loss of lives and damage potential to structures. It is also one among the 38 cities listed by Government of India for carrying out geotechnical site characterization and ground response studies.

The geology of city can be generalized into four categories that characterize the soils of the region namely black cotton soils (58%), sandy clay loams (23%), red loamy soils (17%), and sandy soils (2%) [8]. For reference, a typical geologic column and a cross section of soil from Rao hospital to SBI office is shown in Fig. 1.

The groundwater in Vijayawada occurs under water table to semi-confined conditions in the weathered/fractured zones of Khondalites and sand zone of Alluvium. The ground water table depth observed to be varying from 0-7 m below ground level. From the 2004 Indonesian quake it has been observed that GWT can cause quantifiable changes in locations which are about thousand miles from the epicenter (USGS, 2005). Groundwater level influences the ground response significantly and hence cannot be neglected for site effect analysis.

The main geologic features of the region consist of rivers Krishna and Budameru, low range hills in the Northern, North-Western, and South-Western parts. The topography of Vijayawada is flat, with three canals originating from the north side of the Prakasam barriage reservoir (Eluru, Bandar and Ryves).

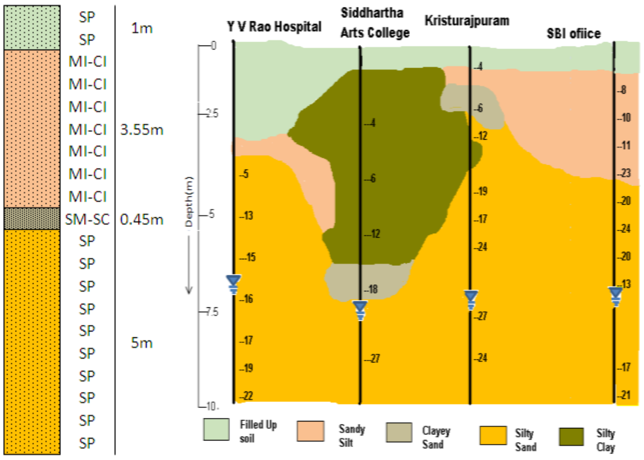


Fig. 1 Predominant soil profile and cross section of soil

Vijayawada which falls in zone III of the Indian seismic code has no major recorded earthquake .There are around 22 seismic sources (mainly faults) in and around Vijayawada in a radius of 300km and among them the prominent active fault is the Gundlakamma Fault which trends in a NW-SE (fault length of 76 km, lat (start) 79.51, long (start) 80.066, lat (end) 15.788, long (end) 16.473; SEISAT). The city does not have a record of any major earthquake but has been experiencing mild tremors during different events this year (June, April,Januray) and in the past (June 2010, M_w 7.5;August 2009, M_w 7.6;May 2008, M3.7;March 1967 M_b 5.2) due to insitu faults and far field effects.

SITE EFFECTS

The effects of alluvial basin geometry on the magnitude and duration of ground motions can be significant. The velocity contrast between the soft alluvial soils within the basin and the hard bedrock forming the edge of the basin serves to trap body waves and causes some incident waves to travel through the basin soil as surface waves [9].

The trapping of body waves and the creation of slowly attenuating surface waves results in stronger shaking and longer durations than would be experienced under typical one-dimensional conditions [10]. The curvature of a sediment-filled basin structure in particular can capture body waves and cause some incident body waves to propagate through the alluvium as surface waves resulting in stronger shaking effects and longer duration of strong ground motion [10]. Vijayawada is underlain by loose silty clay which makes it vulnerable to destruction caused due to the ground motion amplification of the young, loose soil deposits in the area.

METHODOLOGY

Microtremors measurements yield a series of parameters that can be used to estimate the expected ground motion during an earthquake. Reference [11] has explained a theoretical interpretation and practical engineering application of microtremor method as a convenient tool for evaluating frequency properties of surface ground. The microtremor measurements can be evaluated using different methods out of which Horizontal to Vertical spectral ratio (HVSR) method in one among them. Some of the studies indicate that the HVSR results can be correlated with the spatial distribution of damage, especially when damage variation is mostly controlled by near-surface geology. HVSR method was initially proposed by [12] and later has been updated by [7,13]. The procedure involved in calculating HVSR consist the application of Eq.1 to the average amplitude spectra of the three components of the motion.

$$\frac{H}{V} = \sqrt{\frac{F_{NS}^2+F_{EW}^2}{F_V^2}} \qquad (1)$$

Where, H/V is the HVSR, F_{NS}, F_{EW} and F_v are the Fourier amplitude spectra of the NS, EW, and vertical components respectively.

RESULTS

Extensive ambient noise measurements were performed in Vijayawada spreading from Enikepadu in the East, Jakkampudi in the North to National Highway on the south of the city. The ambient noise vibrations were recorded using MR 2002-CE data logger coupled to sensor MS 2003+, SYSCOM (three components velocity meter). A total of 67 locations were selected for measurement of ambient noise in the city. The vibrations were recorded for duration 60 minutes each with 1 sec of pre-event and post event time. GIS was used for recording the latitude and longitude data. The selection of locations for the recordings was carefully done to avoid the influence of trees, buildings, underground structures and traffic as far as possible. Figure 2 gives the predominant frequency curves at different locations.

The HVSR was computed as the average of both horizontal component spectra divided by the vertical spectrum for each window using View 2002 software. Then the noise signals selected are smoothened for 10 to 20 times using moving average technique.

The required range of fundamental frequencies of the soil for in this study is from 0–10 Hz only. Based on the shape of the H/V spectra, resonance frequency and soil characteristics, the response curves of all test locations are classified into three categories T1 (>4Hz), T2 (2-4Hz), T3 (<2Hz). Table 1 shows the few analysis results at different locations along with proposed classifications. Most of these peaks are clear and often sharp, but at a number of sites exhibit peaks of high amplitude (>4Hz).In Table 1 the spectral amplification factors (SAF) are also mentioned which were obtained by [14].

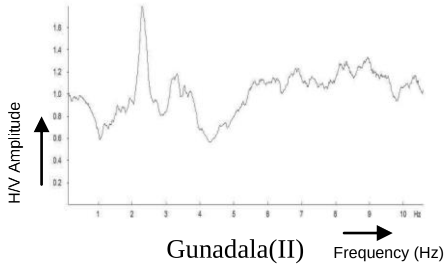
From HVSR spectrums it is observed that most of the amplification peaks are in frequency range of 1.0 to 9.85 Hz. The high-frequency range (7.5-9Hz) is characteristic of the north-western and south-eastern parts of the city. The northern part of the city is characterized by very medium sediment frequencies (4.5-6Hz). A transition between lower frequencies in the western part and medium frequencies in the eastern part is from 1.5 to 6Hz.The H/V amplitude has been compared with the spectral amplification factors obtained by [14]. It has been observed that these values were higher than the H/V amplitude

Table 1 Classification of different sites and the corresponding predominant frequencies

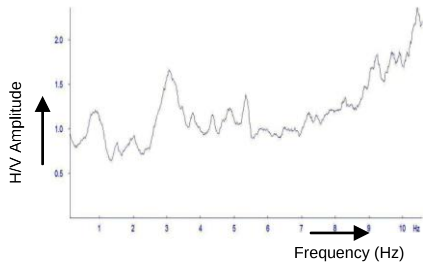
S. No	Site Details /(SAF)	H/V	Freq.(Hz)	Type
1.1	Gunadala (2.5)	1.8	2.3	II
1.2	Ryves Canal Gunadala (2.4)	2.4	9.9	I
1.3	Bankcolony, Gunadala (3.1)	1.7	5.4	I
2.1 2.2	Kanuru Panchayat (3.0)	1.3	7.2	I
3	Bhavani Puram (4.05)	2.4	0.5	III
4	Ida ,Kondapalli (1.85)	1.3	9.2	I
5.1 5.2 5.3	Across Eluru Canal, Near Seethannapeta (2.2)	3.4	9.6	I
6.1 6.2	Ramalingeswara Nagar (1.5)	1.4	1.9	III
7.1	Madhugardens, Moghalrajpuram (2.25)	1.7	7.5	I
7.2	Sivalayam Street, Moghalirajapuram (2.5)	1.4	4.7	I

CONCLUSIONS

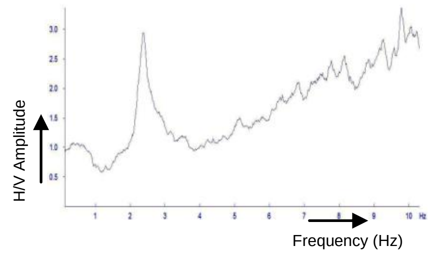
Estimation of local site effects is a preliminary step in the microzonation studies. Microtremor investigations can be used to survey large area in a reasonable time and with relatively low costs in order to detect the potential danger of soil structure resonance using microtremor. In this paper, microtremor measurements were carried out at 67 different locations in the Vijayawada region. The ambient noise data is processed using the computer program VIEW 2002 to generate an HVSR plot for each site. Depending on the shape of the response curve and the estimated resonance frequency all the sites are classified into three categories I, II, III. The H/V spectral ratio approach provided a simple means of determining the predominant frequency of a soil site.



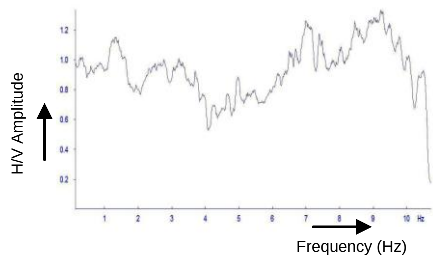
Gunadala(II)



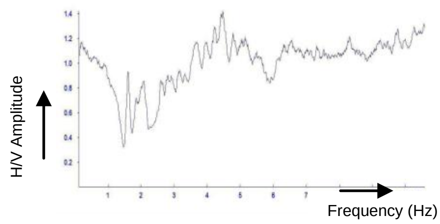
Ryves Canal, Gunadala (I)



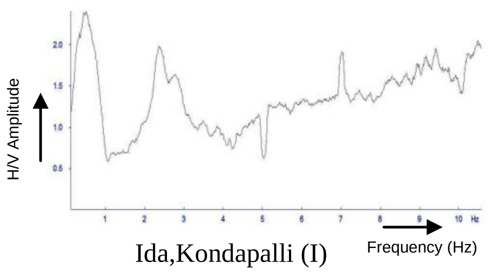
Bank colony, Gunadala (I)



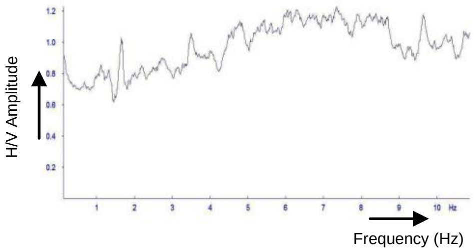
Kanuru panchayat (I)



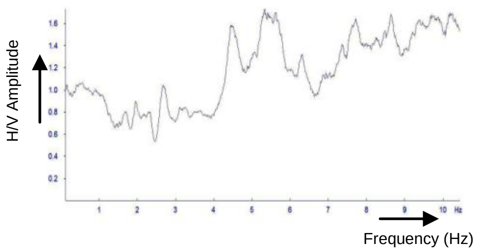
Bhavanipuram (III)



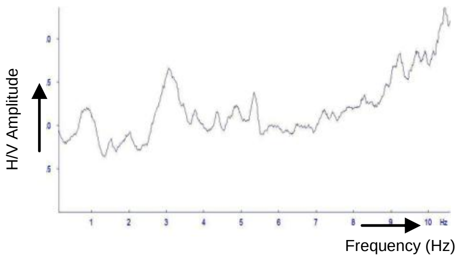
Ida,Kondapalli (I)



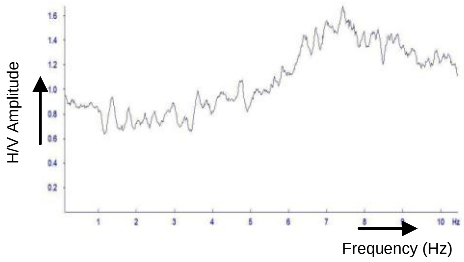
Eluru canal, Seethannapeta (I)



Across Bunder Canal (III)



Madhu gardens,Moghalirajapuram (I)



Sivalyam street,Moghalirajapuram (I)

Fig. 2 H/V Amplitude vs. Predominant frequency curves at different test sites

The study is helpful to assess the engineering geological and geotechnical characteristics and to perform seismic hazard studies. The results can be used for establishing seismic microzonation of the city and eventually in developing codes that ensure the safety of engineered structures.

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