International Journal of Engineering and Advanced Technology (IJEAT)
ISSN: 2249-8958 (Online), Volume-8 Issue-5, June 2019

Ambient Vibration Testing of Existing Buildings in Surat city

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Abstract*: *Day by day the popularities of apartment structure systems are increasing in India instead of load bearing structures and typical frame structures. The design of such structures gains more exposure, particularly for the equal static analysis, precise time calculations are essential [1]. Very few numbers of codes are available in India to calculate dynamic properties of structures for seismic design. According to Indian Standards, the approximate fundamental natural period of building can be calculated based on Height and width of Structure. But no specification or equations are available about effect of Structure age on Natural Period of structure and Number of storey's in Indian Standards. During the assessment of a structure and its construction method, calculations and/or assessments of its fundamental frequency are crucial. [2]. Buildings of Surat City selected for survey based upon number of storeys, type and age of structures. Microtremor record was taken for 30 minutes for each storey in each selected building. After obtaining Microtremor records, random discrete technique was performed to estimate relevant characteristics. An approximately 20-25% reduction found in Amplifications at terrace level of each structure due to reduction in storey stiffness and mass at terrace level. Also from the data analysis, the frequency of structure increases with increase in age of structure due to increment in brittleness of building material with passing days.

***Index Terms*: Amplification, Ambient vibration, frequency, Micro-tremor.**

I. INTRODUCTION

The seismic risk in India in the latest years has increased quickly and has succeeded wretchedly in seismic buildings in high seismic areas. The seismic hazard in India has been expanding quickly in the late years and nation has fizzled pitiably in guaranteeing tremor safe developments in high seismic districts. In last two decades we have seen 6 direct seismic tremors: Muzzafarabad, Kashmir (M7.2) in 2005, Bhuj, Gujarat (M7.7) in 2001, Chamoli, Uttaranchal (M6.8) in 1999, Madhya Pradesh (M6.0) in 1997, Latur, Maharastra (M6.3) in 1993, Uttarkashi, Uttaranchal (M6.6) in 1991 and Bihar-Nepal fringe (M6.4) in 1988 [3]. More than 2 lac causalities were measured in India but if similar type earthquake take place in developed countries like USA, Japan, etc., such causalities will not take place.An alternative way to enhance the understanding of current structures and provide their vibrant features and condition after the earthquakes is to propose Ambient vibrant analyses [4]. To analyze the large amount of building in very short time, this is very useful and low-cost method comparing to other methods. Because construction frequencies immediately control the layout of the earthquake and the recording of ambient vibrations is inexpensive and easy to do, frequencies obtained from the recording of ambient vibrations could be used as an effective instrument to help improve the performance of the structure and then the evaluation of seismic hazard. In this paper, examples of the examined construction systems using micro-tremor records were given. The information collected were analyzed using methods used for color proportion to evaluate the vibration frequencies of the constructions examined.

Fig 1: Location map of Surat city. Inset - (a) Location of Gujarat state in India (b) Location of Surat City in Gujarat State and (c) Surat City (study Area).

Trifunac, 1972, indicated that although forced and ambient vibration screening is dependent on tiny concentrations of excitation relative to powerful earthquake surface movements, it still provides a solid foundation for rational changes in vibration theory [5]. In 1997, 19 MRFs were examined using ambient vibration study to evaluate the empirical phrase for the basic era of Indian structures in 19 reinforced concrete (MRF), with strengthened unreinforced masonry (URM) infill panels [6]. A series of ambient vibration tests (microtremor records) were performed to evaluate structural dynamic properties like frequencies in longitudinal and transverse direction, Amplification value storey wise [7], [8], [9], [10], [11]. Prepared detailed map of city by evaluating Seismic Vulnerability database will provide a valuable pre-damage standard for these type structures. In case of earthquake which leads to structural damage to many structures, comparing the results of ambient vibration studies before and after the event may provide insight into whether significant damage has occurred.

Manuscript published on 30 June 2019.
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Finally, comparing this data with the consequences from ambient vibration measurements for similar buildings in other parts of the world may provide insight into the importance of local factors such as seismicity, geology, and design and construction practices [12].

II. SEISMICITY OF SURAT CITY

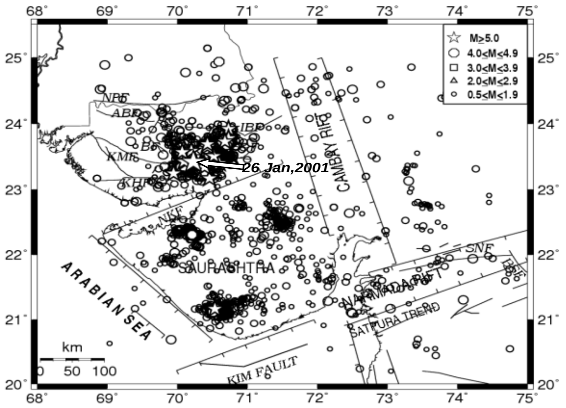

Fig 2: Showing Bhuj 2001 earthquake (biggest star) and aftershocks occurred in the Gujarat State during 2001 to Dec-2015. The solid lines indicate the major faults[21]

Surat is the district's administrative center. The town is situated at 284 kilometers south of Gandhinagar, the state capital, and the core at the mouth of the river at about 22 kilometers (14 mi) (fig. 1). Surat is the second largest town in Gujarat, after Ahmedabad, and its population reached 4.6 million at the 2011 census. The city of Surat is located at the intersection of the Cambay Rift Basin (CRB) and NRB [13]. Rann of Kutch, Cambay and Narmada- Tapti regions are considered as one of the most active zones of the Peninsular India [14]. More than 2 lac causalities were measured in India but if similar type earthquake take place in developed countries like USA, Japan, etc., such causalities will not take place. In Bhuj 2001 earthquake most of public affected directly or indirectly. More than 20,000 people died due to 2001 Bhuj earthquake out of that 782 people in Ahmedabad and 18 people dies in Surat city. [15], [16]. Even the Ahmedabad and Surat city is about 250 and 350 km, respectively away from the epicentral region of Bhuj earthquake. One Building Harekrishna collapsed in Varachha area and many building got moderate to severe damaged [15]. Narmada fault which can generate Magnitude 7.0 earthquake is 80 kilometer away from Surat City which affect city very severely [16], [17]. Extensive research of the Surat region of Gujarat is essential in this regard. Most historic earthquakes have been recorded in Peninsular India close to the weak areas of the rifting [14] (Fig. – 2). Also many medium to moderate earthquakes have took place in and nearby Surat (eg., M3.7 1684, M5.7 1856, M4.3 1871, M5.0 1935, M5.7 2008, M3.2 2013, M4.7 2016 and M3.5 2018).

III. MICROTREMORS AND DATASET

H /V is a widely tested method and a comprehensive list of recommendations is available for its application. [18]. Micro-tremors recordings were collected at ground level and at each n-floor of the studied building constructed. The Cityshark II Acquisition System AND Lennartz 3D/5sec seismometer were used for microtremor recordings. For all local ambient noise recordings, the N-S microtremor corresponds to the lengthy and E-W microtremor elements, which correspond to a transverse direction of the building. The SESAME (2004) guidelines were followed [19]. Jeary (1997) recommended at least 500 windows, i.e. one hour of recording, as sufficient for almost buildings having fundamental frequencies between 0.5 and 2Hz [20]. The processing of HVSR data was carried out using the Sesarray software (www.geopsy.org). Only 30-40-s wide stable windows selected data with an anti-trigger using the subsequent parameters: short term averaging (STA) = 2s, long term averaging (LTA) =30 s [21]. Sample data was collected as per the guidelines of SEASEME at 125 Hz.

IV. RESULT

Majorly the phenomenon frequency of the Surat city soil only similar to the frequency of 1-5 story buildings and a few bridges [21]. During the 2001 Bhuj earthquake numerous single and two-story buildings in the city were damaged, which support our observation on the relation of resonant soil frequencies and building stories. Structures which damaged during earthquake were at random in city area. Microtremor survey was carried out for more than 15 structures of Surat city for analyzing the fundamental frequency and amplification.

Table – 1 Measured Frequencies of Buildings

Storey	Building	Construction Year	Measured Frequency	Frequency as per IS	Frequency as per Canadian Code	Frequency as per ATC3-6(1978)
G+1	Hariom Bunglow	2007	5.54	5.8	10.0	3.50
G+2	Sahaj Bunglow	2000	4.71	3.45	5.0	2.40
	Jaldarshan Varachha	1973	5.58			
	SVNIT	1960	5.54			
G+3	Circuit house	1985	3.93	2.56	3.33	2.0
	Navnirman Soc.	1970	4.83			
G+4	Kruti Appartment	1996	3.43	2.08	2.5	1.67
	Kapodra, Varachha	2003	3.19			
	Shagun Square	2016	1.72			
G+5	Sahajanand Hills	2008	1.98	1.75	2.0	1.46
	Shagun Residency	1988	3.31			
G+10	Mahima Heights	2006	1.41	1.05	1.0	0.95
	Sargam Complex	1998	1.70			
	Siddheswar Complex	1998	1.77			

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The fundamental frequencies of screened structures were measured by seismometers using ambient vibrations listed in **Table 1**, and the jointly related fundamental periods were then calculated. For every structure the sensors were fixed at each storey for duration of one hour. Micro-tremors were recorded in each floor level of 10-storey R.C.C. frame structure with infill walls building of Surat city which was constructed in 1998. The **fig. 3(a)** shows the building where measurements recorded at each storey. A set of 60 minutes recording each, sampled at 125 Hz, were acquired. The soil fundamental frequency of this site is estimated ~4.8 Hz. We observed that the fundamental frequency of the structure is 1.61 Hz in N-S direction; while it is 1.8 Hz in E-W direction due to asymmetric plan configuration (**fig. 3b & 3c**). The amplification factor is estimated about 5 (**fig. 3d**).

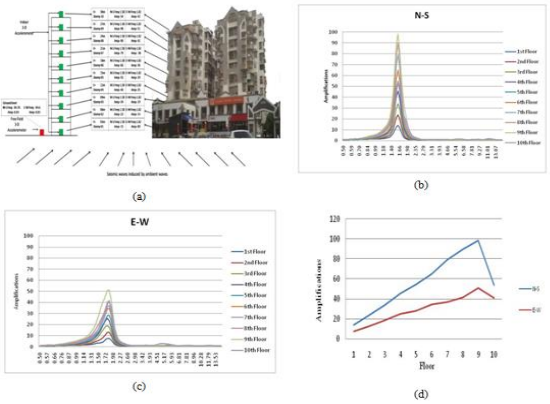

Fig. 3. a) Micro tremors in Structure, b) HVSR spectral characteristics from Ground Floor to Terrace in N-S direction, c) HVSR spectral characteristics from Ground Floor to Terrace in E-W direction d) amplification increase from Ground Floor level to terrace level

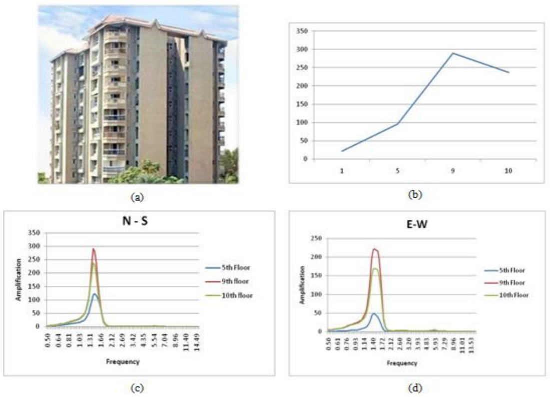

Fig. 4. a) Photo of analyzed building, b) amplification increase from Ground Floor level to terrace level c) HVSR spectral characteristics from Ground Floor to Terrace in N-S direction, d) HVSR spectral characteristics from Ground Floor to Terrace in E-W direction

Furthermore, R.C.C. frame structure with infill masonry wall structure of Surat city which constructed in 2006 was analyzed using microtremor data. The **Fig. 4(a)** shows the photo of analyzed building and the amplification factor measured is about 5 (**fig. 4b)**. It is clearly noticed that the fundamental frequency of structure is 1.40 Hz in both directions due to almost symmetric plan configuration (**Fig. 4 - c & d**).

Approximate frequency of R.C.C. building can be finding by 1 divide by the number of storey [21] and 1 divide by number of floor – 1 [20]. Many standards equations are available in various countries to calculate approximate fundamental frequencies [23], [24]. But none has not mentioned clearly about the age effect on the fundamental frequency of the structure. But as per the surveyed building, it shows that the frequency of building is higher comparing to codal equations. And according to the result from analyzed data, the frequency of structure increases with the age of structure but rate of increasing is low (Table – 1). All the structures having higher frequency compare to approximate formula given by Indian and Canadian Standard. Recently constructed structures having nearby values but old structures are having higher values compare to Codal provision.

V. CONCLUSION

The fundamental frequencies of building in both directions are similar in case of symmetric plan configuration but it may be differ based upon asymmetric plan configuration or stiffness. From the analysis of collected data, it was found that amplification value is reducing up to 20 % at terrace level due to decrement in stiffness value. Structures are become more brittle by the passing days so due to this fundamental frequency of structure will increase.

ACKNOWLEDGMENT

Authors are thankful to Dr. M. Ravikumar, Director General, I.S.R. for the permission and encouragement to conduct such studies for the benefit of science and society. The landowners and Building owners are acknowledged for permission to carry our field and building survey on their property. We would like to thanks Janmejay Raval, Harsh Patel, Harsh Sohagiya, students of Civil Engineering Department, SVBIT for their help in survey.

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