USING THE H/V SPECTRAL RATIO FORESTIMATING THE VULNERABILITYINDEX OF A URBAN AREA

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ABSTRACT

The subsurface topography and the dynamic specification of soils have important effect on the ground motion response. During the age of cities, the building have constructed by the different techniques, materials, styles and standard codes. The researches have shown that the buildings have different response to earthquake related of their materials and design rules. The soil layer specifications are recognizing by different geotechnical and geophysical methods, including geotechnical and geophysical as well as spectral ratio. Horizontal-to-vertical spectral ratio (H/V) of microtremore was introduced by Nakamura (1989). This method is very usable in site characterization studies due to its low budget and easy use. In this paper, it has presented a method for estimating the degree of vulnerability of structures using spectral ratio H/V. In a vulnerability study in the city of Shiraz, the predominant frequencies are derived for the different parts of the city. These data have used to define a coefficient of vulnerability for the earth. For this purpose, 11 different building such masonry, steel or concrete structures were selected. The main frequency and amplification of microtremor H/V spectral ratio for building has been obtained. Furthermore, the resonant frequency and amplification factor of the ground have been calculated. The vulnerability index of soil K_g and vulnerability of building K_b were defined. Comparison of these coefficients it was recognized a damage factor η of building during the earthquake. This parameter leads to a fast and inexpensive method for preparing a disaster program for an urban area. In this paper, the damage rate of different building at Shiraz City was obtained. In addition, the damage potential of all the city area was calculated.

INTRODUCTION

Several methods were used to identifythesoil layer properties. The conventional techniques, such as geophysics or boreholes are being used, however, these methods are too expensive and too much time is spending on the exploration and analysis of data.During last three decade, the H/V spectral ratios of microtremorwereperformedinmicrozonationstudies.Following,the researchers were relayed by several studies emphasizing the stability of the H/V ratios (Lermo and Chavez-Garcia 1994; Duval et al. 1995; Ohmachi and Umezono 1998, Bard 1999, Haghshenas et al., 2008,). Since then the estimation of the natural frequencies of the soil profiles from horizontal to vertical (H/V) spectral ratio by use of the single stations method has become common (Kudo 1995; Bard 1999). The use the H/V spectral ratio spreads very fast and the researchers attempted to use this method as a tool for site characterization programs. Moreover, some researchers used the H/V spectral ratio for engineering applications. For instant some researchersshowed the correlation between frequency and depth (ex. Ibs-Von Seht M. 1999; Parolai 2002; Hinzen, 2004, Mokhberi et al. 2013).

In order to identify the relationship between building damage and local site effect, Nakamura (1997)proposed the vulnerability factor K todisaster identification. Thevulnerability method is to start from the observed damage, by assessing the building collapse after different intensity earthquakes. Making reference to the Nakamura’s approach which implicitly contains a vulnerability identify model.Based on observation of structure materials and damage leveland combining with the vulnerability index Kb, this paper proposed a new model for damage estimating and disaster management for urban area.

METHODOLOGY

The H/V spectral ratio method in the microtremor analysis was used in the disaster anagement. The H/V spectral ratios of ground microtremors as well as the buildings were obtained with Geopsy software proposed with SESAM group.On specifications of Nakamura techniques for evaluating the vulnerability of building the vulnerability index Kg, for ground and various structures Kb were defined. Based on Ishihara (1978) suggestion, the sedimentary layers has plastic properties onγ $=1000\times10^{-6}$, whereas at $\gamma>1000\times10^{-6}$the sediment can undergo deformation and collapse. This approach could explain for structure members.The formulations described in detail by Nakamura (1997, 2000), brief description of shear strains are introduced in equations (1) and (2) respectively.

$$K_g= (A_g)^2/F_g \quad (1)$$

$$K_b=(Ab)^2/F_b \quad (2)$$

Here F_g and A_g are predominant frequency and amplification factor on groundsurface and the K_b and A_b are predominant frequency and building amplification factor respectively. If maximum acceleration is 100 cm/s^2 at the basement and Kg value is 20, the average strain at the surface ground layer is estimated 2000×10^{-6}, and the strain may cause some damage to this ground. Many researchers confirmed the relationship between K values and the actual earthquake damages.

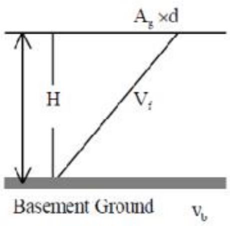


Figure 1. Shear deformation of surface ground (Nakamura 1997)

VULNERABILITY INDEX FOR SELECTED BUILDING

In order to evaluate the damage potential, the Disaster factor η has determined. For this purpose the vulnerability index of buildings K_b and ground K_g in the city of Shiraz were compared. The 7 Richter magnitude earthquakes as deterministic earthquake and 9 Richter earthquakes as a probabilistic earthquake have been considered. Figure (2) shows the selected area at central part of ShirazCity.

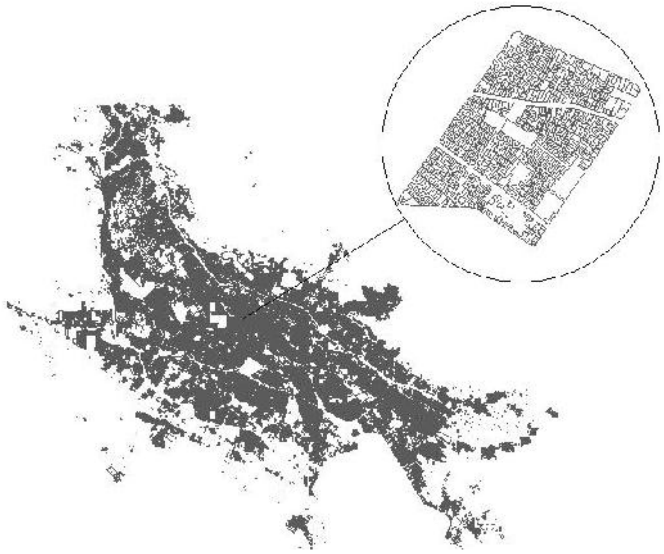


Figure 2 .the studied region in the municipal 1 at Shiraz City

The structures studies were obtained.In order to calculate the vulnerability index K, the resonance frequency F_b and amplitude magnification $A_b$of11 different buildings in terms of construction ages, number of floors, and construction style and building materials were selected. Figures (3a) to (3f) show some building pictures. As mentioned in Table (1) the building types I, II, V, VII and IX had built by old technology or designed on former Iranian earthquake code. Conversely, the building types III, IV, VI, VIII, X and XI were constructed onnewedition of Iranian earthquake code.

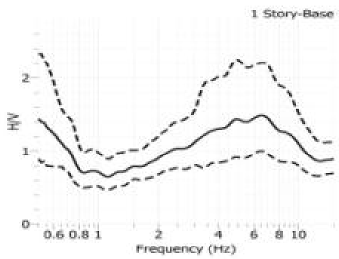
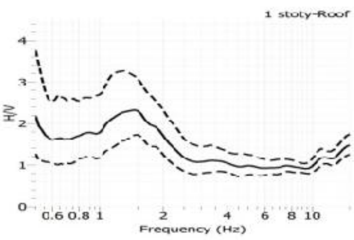
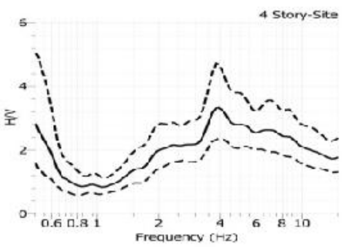
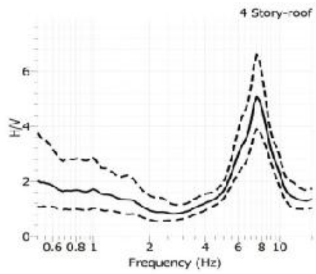
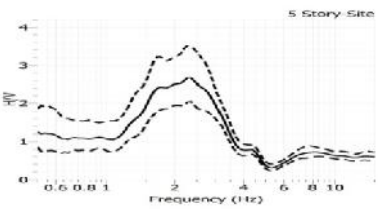
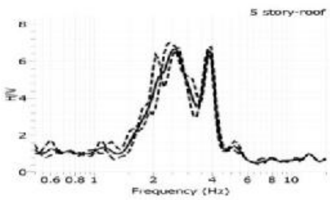
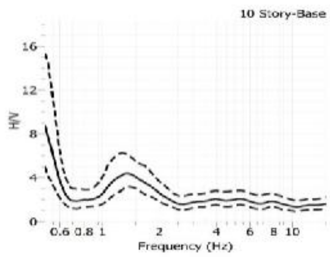
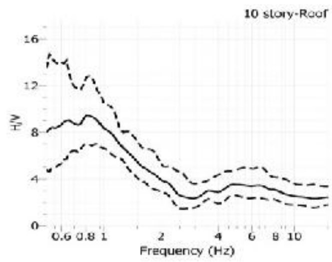
	No of stories	Building pictures	The H/V spectral ratio on the ground	The H/V spectral ratio on the building roof
a	1		unknown	unknown
b	2			
c	4			
d	5			
e	7			

Figure 3. Demonstration of the H/V spectral ratio on the ground and on the building roof of number of studied buildings

Mentioned Parameters Were Assessed In Two Stages: First, On The Ground. The Microtremor Components Were Recorded In The Vertical Direction, East-West And North-South. Following The Same Procedure The

Microtremors Recording Were Carried Out On The Building Roof. Figure (3) Illustrated The Pictures And Related H/V Spectral Ratio For Studied Buildings.

DISASTERFACTOR FOR VULNERABILITY MANAGEMENT

Using the mentioned method, the building damage caused by the earthquake can be estimated. In an urban area, the vulnerability indexes Kg can calculates from the resonant frequency and magnification factor obtains from seismic microzonation studies. This ratio indicates how earthquakes cause the resonance in the sedimentary cover, and how the vibrate the structures located on it. The ground vulnerability index Kg, determines the soil instability caused by the earthquake. In addition, the building vulnerability K_b obtains from the amount the amplitude and the frequency of the structure in resonant status.Table (1) compares the results of the ground and building K_g and K_b related to their material types and soil classification.

Table 1.the specification of selected building

	Buildings Style	No of floor	Frequencies on the roof	Amplification factor in building	$avK_b=A^2/F$	Free-field frequencies	Amplification factor on the ground	$Kg=A^2/F$	η=Kb/Kg	Damage Rates
I	Old masonry	1	10	-	-	6	1.5	0.325	-	-
II	Old masonry	2	8	4	2.00	6	1.5	0.325	6.15	D
III	Reinforced masonry	2	9	7	4.90	6	1.5	0.325	15.08	D
IV	New designed and constructed	3	7	4	2.00	2.5	2	1.8	1.11	B
V	Old designed and constructed	4	7	7	7.00	4	3	2.25	3.11	D
VI	Retrofitted buildings	4	6	4	2.29	4	3	2.3	1.00	B
VII	Old designed and constructed	5	5	7	9.80	2	2.5	1.65	5.94	D
VIII	New designed and constructed	5	5	4	3.20	4	2	1	2.20	C
IX	Old designed and constructed	7	3	7	16.33	2	7	25	0.65	A
X	New designed and constructed	7	2.7	3	3.33	2	7	25	0.13	A
XI	New designed and constructed	10	0.8	4	20.00	1.5	4	12	1.67	B

Comparing the soil vulnerability index Kg and building vulnerability K_b can assess the damage in the structures. The vulnerability ratio is defined as disaster factor η, recognized in equation (3).

$$\eta=k_b/k_g \quad (3)$$

In this study, the performance the value of η used to evaluate the vulnerability of existing structure in an urban area. The rate of structures damage is classified for A to D related the amount of η as discussed in table (3).

The results indicated that the vulnerability index K isimitating the height of building and number of stories. Equations (4) and (5) show the relation between Kb and number of building stories.

$$(K_b)\ new = 0.05e^{0.7N} \quad (4)$$

$$(K_b)\ old= 0.05e^{1.5N} \quad (5)$$

Table 3 the Disaster factor related to buildings style studied in this research

Disaster factor	A	B	C	D
	[illegible]	1<η<2	2<η<3	3<η
Damage Rate	poor	moderate	high	strong

DISCUSSION

In order to evaluate the disaster rate, the ground vulnerability indexes K_g of the different point of the municipal 1 of Shiraz City area were utilized. Furthermore, the K_b of existing buildings in the selected area has considered. The Disaster factor η determined for all the buildings located in this area. Given that there are different buildings in each municipal area, the type of buildings in each area was estimated.

According to Shiraz Municipality's report, the values have listed in Table (4). The vulnerability index of building compared with the coefficient of soil vulnerability in all regions separately. In this study, the estimated Disaster factor of municipal 1 has extended for all other areas.

Table 4 the amount on different buildings in Shiraz City area

	1	2	3	4	5	6	7	8
No of pollution	212491	263134	191405	196320	158828	79083	176544	150237
No of Family	58058	73092	52328	50819	37371	21968	43292	42857
Estimated Number of Building	15500	36000	17000	16000	15000	3550	25000	28000

Obviously, the actual determination the Disaster factors for whole building area are impossible. The buildings disaster evaluation needed to spend a lot of budget and time. Despite this, the vulnerability estimation can determine from generalization of Disaster factor approach mentioned in this paper. The results obtained from a limited area can improve for extended area.

As discussed in the table (4), there are about 15500 building in region 1. Based on earthquake magnitude 7 and 9 Richter, Table (5) illustrated the approximation of damage in this area. Generalizing the η estimating approach to all zones of metropolitan area, total damage obtains. This approach achieves a disaster management program with low cost and time.

In this region around 30% of buildings consist of masonry buildings classified at grade D, 35% are old masonry buildings with grade C and D, 20% are consist of old framed structures graded at B classes and 15% consist of new designed structures which classifies in grade A.

Using the above mentioned procedure and comparing the ground vulnerability index and building vulnerability index for the region 1, in a 7.0 Richter earthquake magnitude the following results can be estimate.

THE CENTRAL PART OF CITY

The soil classification of central part on this region consists of deep silt-clay layer or poorly-graded sand which located on the deep alluvial silty layers. The vulnerability index of ground is strong. Following describes the vulnerability status related the soils types and building specifications:

- Nearby the 25% of building which consist of masonry reinforced building are achieves to damage grade C.
- The 30% old masonry buildings are achieved to failure grade D.
- The 10% old concrete framed structures and 15% old framed steel structures that designed with past earthquake standards are achieves to damage grade C.
- The 25% new structures which design and constructed with new edited standard have no failure or damage with grade A.

THE BORDER PART OF CITY

These areas are located on the northern hills with the shallow alluvium cover. The soil in this area consists of dense silty-sand or silty-clay. The water table depth is above 50 meters. Therefore, soil vulnerability index is low. The buildings disaster in this area describes as follows:

The masonry reinforced building which consist 25% of building are achieves to damage grade A.

- The 5% old masonry buildings are achieved to failure grade C or D.
- The 10% old concrete framed structures and 15% old framed steel structures which designed with past earthquake standards are achieves to damage grade B.
- The 10% new concrete structures which designed and constructed with new edited standard have no failure or damage with grade A.
- The 50% new steel structures which design and constructed with new edited standard have no failure or damage with grade A.

The results can repeat for a 9 Richter magnitude earthquake which obtains in a probable risk analysis in Shiraz City.

CONCLUSIONS

Using the H/V spectral ratio, the ground vulnerability index Kg, building vulnerability index for buildings Kb, disaster index for ground and building μ were investigated. This research has been conducted in 11 different building at Shiraz City. Following the obtained results were discussed.The central part of city consists of weak soil layers, especially low plasticity clay (CL) with large void ratio, therefore the damage factor are increase directly with the building age. Whereas the boarder part consists of granular soils and the damage factors are smaller than central part. The buildings vulnerability index K_b, ground vulnerability index K_g and Disaster factor η influenced by building design, building foundations, Structure strength and age of the building.The H/V spectral ratio of microtremors is obtained in short time with low coast. They can give valuable information about the natural frequency, amplification factor and weak points on all types of soil and structure. This study is able to determine the weak stations of ground, building structure and weak points of ground and buildings to estimate the real earthquake damage before an earthquake. The result is ground vulnerability index K_g, buildings vulnerability index K_b, Damage factor for ground and buildings and such, this method can be used for earthquake disaster mitigation. The damage distribution map of an urban area can prepare by comparing the K_g obtained from microzonation studies and K_b suggested in this paper. Estimation of damage can be done accurately and quickly. This procedure helps the manager improve to reduce disaster damages.

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