Earthquake Microzonation and Strength Building Evaluation at Gelora Bung Tomo Stadium Surabaya Using Micro-Tremor Method

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Abstract

Surabaya has alluvial domination that causes high rise of implication. This research is to know the natural frequency of building and ground, the damping ratio and earth quake micro-zoning. We use FSR (*Floor Spectral Ratio*) and RDM (*Random Decrement Method*) method for building analysis, and HVSR *(Horizontal to Vertical Fourier Spectral Ratio)* method for ground motion analysis. From the analysis, the building has good ability to muffle ground motion, and it has strong structure but 5th floor has more rise.

Keywords: Microtremor, FSR, RDM, HVSR

1. Introduction

Surabaya is the area with geological condition of sandstone, tuff and alluvial from river and shallow marine deposits (Sukardi, 1992). A region with sandstone, tuff and alluvial deposits condition has a greater potential hazard of ground motion due to amplification and ground motion interaction of the building due to earth quake (Nakamura et al, 2000)

Surabaya has a great building that is Gelora Bung Tomo stadium which is the 3rd largest stadium with sophisticated technology in Indonesia. Gelora Bung Tomo stadium has a capacity of over 55.000 people. However, there is rumour that Gelora Bung Tomo stadium suffers damage that make worries for the user. Among the rumours are the cracks in the wall of stadium and the tribune.

This study is conducted to get an overview of the building resistance. One of the parameters causes significant damage to a building is the building structure characteristic and the tremor effect such as natural frequency, damping ratios and index of building resistance. Therefore it is conducted an analysis of micro tremor for evaluating the strength and structures building on account of ground motion of earth quake.

The analysis determines the natural frequency using FSR (Floor Spectral Ratio), RDM (Random Decrement Method), HVSR (Horizontal to Vertical Spectral Ratio) and spectrum. The result could show the relationship between the damping ratio and natural frequency, and the relationship between damping ratio and index of building resistance.

2. Regional Geology

Surabaya is a plain area with the slope of terrain between 0% -5% and smooth undulating hills with the slope of terrain between 5%-15% composed by Alluvial deposits (Qa), Kabuh formation (Qpk), Pucangan formation (Qtp) and Lidah formation (Qtl) (fig. 1). Therefore, the sedimentation at Surabaya area is dominated by sandstone. The bedrock is limestone which has high contrast impedance. Surabaya is also a region that is close to an Lasem fault in the North at a distance of about 70 Km, Watukosek fault in the south-east stretching from Mojokerto to Madura with a distance of about 30 Km, Girindulu fault that stretching

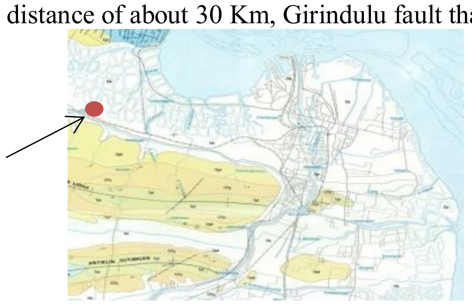

Fig. 1. Regional geology of research are

from southern Pacitan to Mojokerto with a distance of about 40 Km. And, southern pasuruan fault that stretchs from Pasuruan to Mojokerto with a distance of about 50 Km.

3. Microtremor

Microtremor, or commonly is called by the ambient noise, is a ground tremor with amplitude that can be caused by artificial or natural event, such as the wind, the ocean wave or the tremor by vehicles. Generally, human activities that could cause vibration has a small effect on microtremor with frequencies below 0.1 Hz. Lately, microtremor application has been used to identify the resonance of the building and the soil natural frequencies (Warnana, 2011).

Microtremor is a low amplitude (in the order of micrometres) ambient vibration of the ground caused by man-made or atmospheric disturbances. Observation of microtremor can give useful information on dynamic properties of the site such as predominant period and amplitude. Microtremor observations are easy to perform, inexpensive and can be applied to places with low seismicity as well. So, microtremor measurements can be used conveniently for seismic microzonation. More detailed information on the shear wave velocity profile of the site can be obtained from microtremor array observation (Nakamura, 1989).

Earth quake microzonation is the process of dividing into smaller zones based on the geological response of earth quake. Characteristic of this response is determined by the condition of soil and rock in the sub surface structures. The analysis for microzonation is HVSR (Horizontal to vertical spectral ratio) method introduced by Nogoshi and Igarashi which further developed by Nakamura (1987). HVSR method can be used to estimate the natural frequencies were not dependent source and time. The natural frequency is known from the peak value of Microtremor data.

Calculation process is done to determine the value of soil and building resonance using the following formula:

$$f(FSR) = \frac{fb\ NS}{ft\ NS} \quad (1)$$

$$f(FSR) = \frac{fb\ EW}{ft\ EW} \quad (2)$$

$$R = \left|\frac{fb - ft}{ft}\right| x\ 100\% \quad (3)$$

Equation (3) is used to calculate the value of ground and building resonances. Equation (1) and (2) are the equation in FSR analysis where Fb is building frequency, Ft is the soil frequency, Ns and Nw are a the components of each data.

4. Methodology

Acquisition data of this study using a set of MAE Digitalizer (fig. 2) that consist of portable digital seismograph 3 components (two horizontal component and one vertical component), data cable and GPS. Sampling interval is 1/100 second with the duration of each location for 20 minutes.

Fig. 2. A set of MAE Digitalizer

Stages of this study consist of data acquisition, data processing and data interpretation. Data acquisition is done in the area of Gelora Bung Tomo stadium which is at coordinate 7° 13' 30.51" S, 112° 37' 18.15" E. Prior to data acquisition previosly conducted a survey and study of geological condition around the stadium area. Data collection was done on 9 point (fig. 3). 8 points measurement performed in the building, while 1 point on the ground around the stadium. In the data processing is only done to 7 points data, because we assume that data of first floor is similar with data on the ground. Data processing used the SEG2CONV, GEOPSY, Win-Quake, and Microsoft Excel program.

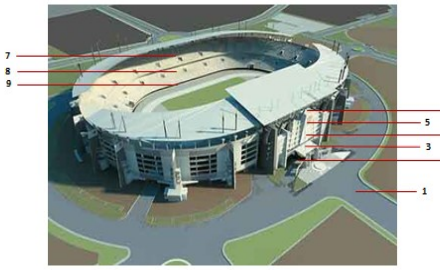

Fig. 3. Data Point acquisition

5. Result

From 9 data, only 7 data will be process and interpretation. Every data has 3 data types, EW (East-West), NS (North-South) and vertical component data (fig. 4).

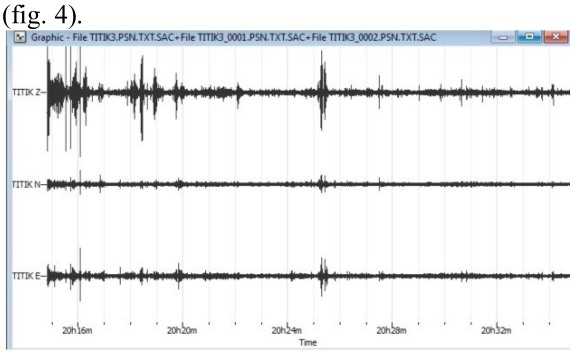

Fig. 4. Data acquisition result at point. 3, the data has 3 data types (EW, NS, and Vertical compnents)

Data processing is continued with windows selection process with the selection of stationary or constant signal (fig. 5).

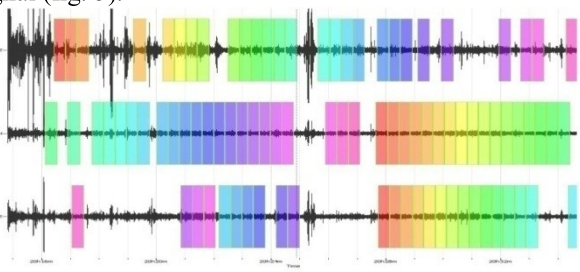

Fig. 5. Windows selection process at point.3 data.

In the building data analysis, we use spectrum and damping ratio analysis method in the horizontal component of NS and EW signal. In ground data analysis is used the entire vertical and horizontal signal components. Stationary windows that selected at point 3 are 25 and 29 windows for each EW and NS data component. Further done analysis of spectrum and obtained a graph (fig. 6). Data processing is used taper cosine function 5% with *Konno-Ohmachi* smoothing correction 40 bandwith. In the natural frequency estimation, frequency which has the largest amplitude value with the frequency value above 1Hz is the real natural frequency value.

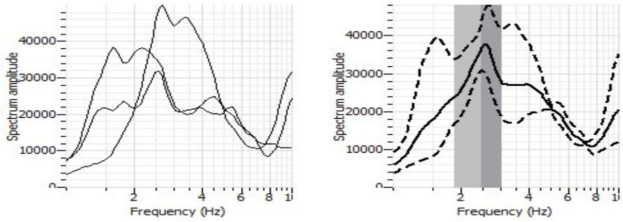

Fig. 6. Frequency and amplitude graph using spectrum analysis

In additional to the building data, also obtained the data of ground. Ground data acquisition is performed in the area was assumed to have the same geological conditions with geological condition under the surface of the building. Human activity will affect the signal of microtremor data, so it need to minimize the activity when acquisition data.

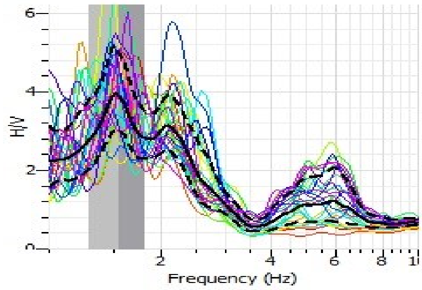

Fig. 7. Frequency and amplitudo graph of ground using HVSR method

Ground natural frequency obtained from HVSR analysis is the average frequency of each vertical and horizontal spectrum. In the ground data analysis, the selected windows as much as 29 windows with natural frequency value obtained 1.51991 Hz. Data processing is used high-pass filter with *Konno-Ohmachi* smoothing correction 40 bandwith.

5.1. *Spectrum Analysis of Building*

Table 1 show the value of horizontal components at all points of building acquisition. If seen carefully, the average value of each component frequency spectrum is ±2 Hz. The frequency value tends to be low and some of its components have the same value. This is due to the data is from the same building so that the value of building frequencies has similar trend.

5.2. *Floor Spectral Ratio Analysis*

FSR (Floor Spectral Ratio) analysis was conducted todetermine the natural frequency of building. If a building is analyzed by HVSR method, the natural frequency of ground will possible to influence the building natural frequency (Herak, 2010).

The building frequency may not be below 1 Hz, so that the amplitude appeared at that frequency can be ignored. Fig. 8 showed a graph of the amplification at point 3 that have more than one amplification pick value, so that further analysis is required to determine the actual value of the natural frequency (Warnana, 2011). So, we got the values of natural frequency at point 3 on the EW and NS component are 3.85353 Hz and 3.59381.

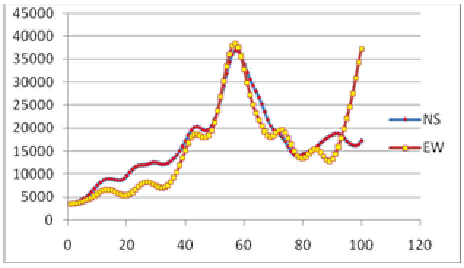

Fig. 8. FSR Analysis at NS and EW components

Table 2 showed the comparison between FSR and spectrum analysis. From this case study, the result from FSR analysis is better than spectrum analysis, because the value of FSR analysis shows more stable value. Based on the natural frequency measurement on each floor of building, it was concluded that the amplification value is proportional to the height of the floor.

5.3. *Ground and Building resonance*

Natural frequency of building derived from the ratio of building spectrum to ground spectrum (Herak, 2011). The danger level of ground and buildings resonance can be determined by knowing the ratio value between natural frequency of building and ground using equation (3). Then, clasified into three levels, high level is when the ratio value < 15%, middle level is when the ratio value 15%-25%, and low level when the ratio value >25%.

5.4. *Random Decrement MethodAnalysis*

RDM method in this study is for the comparator of FSR data analysis. The frequency value that calculated using RDM analysis almost similar with frequency value from spectrum analysis, but it more stable than spectrum analysis (table 3). The principle of RDM analysis is to knowing the building damping ratios by done the bandpass filtering and natural frequency evaluation from fourier spectrum before RDM process.

Table (1), table (2), table (3), and table (4) shows the result of ground resonance, building resonance, and building resistance (Kg) analysis using FSR RDM and spectrum method. Point (1) is ground microtremor data around Gelora Bung Tomo stadium. Based on HVSR analysis we get the value of ground natural frequency is 1.51991Hz. The comparison of natural frequency data from ground and each floor level building show that the stadium is the strong building. This is evidenced by the low level of resonance on the overall floor value except 2nd floor level that has middle resonance level value on RDM analysis.

Table 4 shows the resistance index and damping ratio of Gelora Bung Tomo. Table 4 shows that the largest index is 5th floor executive tribune. From data analysis, we know that the 5th floor is more prone to the damage, earth quake or ground motion because it has big resistance index value.

6. Conclusion

Based on calculation and analysis result, we can conclude that the natural frequency of ground at Gelora Bung Tomo Stadium is 1.51991 Hz, meanwhile the natural frequency of building is about 2.56 – 3.94 at EW component and 2.64 – 3.59 at NS component. Damping ratio of the building is about 23.05%-61.79% at EW component and 24.89%-64.84% at NS component. Gelora Bung Tomo stadium is strong building, however in the event of earth quake, 5th floor has most potential damage because it has big resistance index.

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Table. 1. Table of spectrum analysis

No	Point	Ground Frequency (Hz)	Building spectrum (Hz)		% Resonance		Level of resonance
			EW	NS	EW	NS	
1	2	1.51991	2.53536	1.59228	67%	69%	Low
2	3A	1.51991	5.46228	2.31013	259%	52%	Low
3	4	1.51991	2.36449	2.53536	56%	67%	Low
4	5A	1.51991	2.36449	2.59502	56%	71%	Low
5	5B	1.51991	2.36449	2.65609	56%	75%	Low
6	3B	1.51991	4.2858	2.56226	182%	69%	Low

Table 2. Table of Floor Spectral Ratio analysis

No	Point	Ground Frequency (Hz)	FSR (Hz)		% Resonance		Level of Resonance
			EW	NS	EW	NS	
1	2	1.51991	3.67838	3.67838	67%	69%	Low
2	3A	1.51991	3.85353	3.59381	259%	52%	Low
3	4	1.51991	3.76494	3.51119	56%	67%	Low
4	5A	1.51991	3.85353	3.51119	56%	71%	Low
5	5B	1.51991	3.94421	3.51119	56%	75%	Low
6	3B	1.51991	2.56226	2.64098	182%	69%	Low

Table. 3.Table of Random Decrement Method analysis

No	Point	Ground Frequency (Hz)	RDM (Hz)		% Resonance		Level of Resonance
			EW	NS	EW	NS	
1	2	1.51991	7.92	3.22	421%	21%	Middle
2	3A	1.51991	8.01	4.46	427%	37%	Low
3	4	1.51991	4.68	4.89	208%	72%	Low
4	5A	1.51991	6.88	3.63	353%	31%	Low
5	5B	1.51991	3.47	9.9	128%	242%	Low
6	3B	1.51991	7.21	3.55	374%	28%	Low

Table.4. Table of index resistance and damping ratiosof building

No	Floor	EW		NS	
		Kb	Z	Kb	Z
1	2	89314.4	36.25	17629.4	52.49
2	3A	31388.91	29.06	202556.2	48.45
3	4	66413.46	40.24	324643.4	64.84
4	5A	373264.1	59.41	866378.8	24.89
5	5B	294478.9	61.79	483457.8	33.7
6	3B	303280.2	23.05	644991.2	32.08