Spatial Analysis of Seismic Hazard based on Dynamical Characteristics of Soil in Kota Baru, South Lampung

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Abstract. Kota Baru, a new capital Lampung province location, planned and developed since 2012, will be a densely populated in near time. The province located in near Semangko fault, southern of Sumatra Island, is a vulnerable area to earthquake. Seismometer was deployed for 15 points in Kota Baru for recording mictrotremor. The signal was analyzed by HVSR method produced fundamental frequency f_0, amplitude A_0, and seismic vulnerability index Kg. The range of frequency value is about 0.56 Hz to 1.46 Hz. The range of amplitude value is about 2.3 to 6.17. There is linear relation between Kg and the damage caused by earthquake. The Kota Baru classification of seismic hazard map was generated by plotting the value of Kg. The area at the northeast of Kota Baru is more risky to be inhabited because it has higher value of K_g. The more safety area located in near T7 and T15 because it has lower value of K_g than the others.

1. Introduction

Kota Baru located in South Lampung regency is an area planed to be the new capital of Lampung province. This situation will make Kota Baru to be populous city in near time. Lampung province located in the southern of Sumatra island is vulnerable to earthquake because of it location near Semangko fault. Interaction of Indian-Australian, Eurasian, and Pacific plate is very potential to make other faults that can be a new source of earthquake.

Earthquake prediction is still too difficult because the earth interior is very complex. Another mitigation method for reducing the earthquake loss is seismic hazard mapping from the parameter of soil characteristics, like dominant frequency f_o, amplification factor A_o, and seismic vulnerability index Kg. All of these parameters can be obtained by *Horizontal Vertical Spectral Ratio* method introduced by Nakamura that widely used for site effect studies by means of analyzing of microtremor recordings.

The research site is located in Kota Baru, South Lampung Regency (5,28064^o to 5,29936 ^{o} S, and 105,3740 ^{o} to 105, 4289 ^{o} E). The site is at distance, approximately, 23 km from Bandar Lampung Town. Based on Tanjung Karang geological map, All of Kota Baru area is a part of Barisan zone volcanic sedimentary. The rocks unit are dominated by pumiceous tuff, rhyolitic tuff, welded tuff tuffit, tuffaceous claystone, and tuffaceous standstones.

2. Microtremor

Every time, the surface of Earth is always in motion at seismic frequencies. These constant ambient vibrations of the Earth's surface are called microseisms or microtremors. The classification of these ambient vibrations [1] can be seen in Table 1. The amplitude of these microtremors is, with some extreme exceptions, generally very small. Displacements are in the order of 10-4 to 10-2 mm. Accordingly, microtremor activity varies over time. This variation is very complex and irregular, and not repeatable [2].

Table 1. Ambient vibration classification based on it source

	Nature	Living thing
Name	Microseismic	microtremor
Frequency	0.1 – 0.5 to 1 Hz	0.5 to 1 – 10 Hz
Source	ocean wave	traffic, industry, human activity
Arrival wave	Surface wave	surface wave and body wave
Amplitude variability	related to storm or ocean wave	day/night, weekend

3. Horizontal to Vertical Spectral Ratio (HVSR)

HVSR method [2] based on spectral analysis of microtremor data for estimating frequency at the specific area. The fundamental routine of HVSR method is the horizontal spectrum divided by the vertical spectrum. HVSR method can figure out local sites effect and produce dominant frequency and amplification factor. Flow chart about HVSR method can be seen in Figure 1.

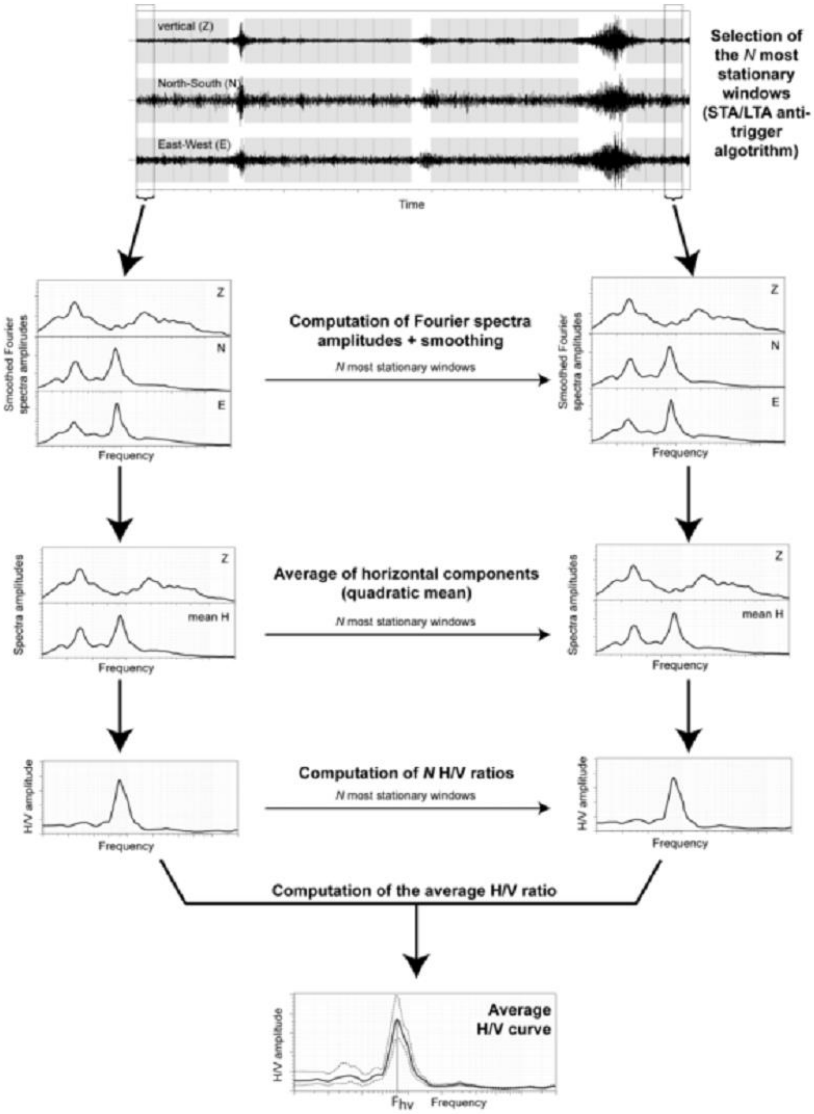

Figure 1. HVSR flow chart [1]

3.1. Dominant frequency (f0)

Dominant frequency can be obtained simultaneously when H/V graphic is produced by HVSR method. Dominant frequency is the peak of H/V curve. It means that the frequency is a fundamental natural frequency of deposits. The reliability of its value will increase with the sharpness of the H/V peak. The first requirement, before extraction of information and any interpretation, concerns the reliability of the H/V curve. Reliability implies stability. Three criteria for a reliable H/V curve are based on the relation of peak frequency to the window length, number of significant cycles, and standard deviation of peak amplitude. Six criteria for a clear peak are based on the realtion of the peak amplitude to the level of the HVSR curve elsewhere, and standard deviations of the peak frequency and of its amplitude (the amplitude should decrease rapidly on each side) if alla three criteria for reliable curve and at least five criteria for clear peak are fulfilled, the frequency of the peak is considered to be the fundamental frequency of sediments. All of criteria can be seen in Figure 2.

Criteria for a reliable H/V curve

i) $f_0 > 10 / l_w$

and

ii) $n_c(f_0) > 200$

and

iii) $\sigma_A(f)<2$ for $0.5f_0<f<2f_0$ if $f_0>0.5Hz$
or $\sigma_A(f)<3$ for $0.5f_0<f<2f_0$ if $f_0<0.5Hz$

Criteria for a clear H/V peak
(at least 5 out of 6 criteria fulfilled)

i) $\exists f^- \in [f_0/4, f_0] \mid A_{H/V}(f^-) < A_0/2$

ii) $\exists f^+ \in [f_0, 4f_0] \mid A_{H/V}(f^+) < A_0/2$

iii) $A_0 > 2$

iv) $f_{peak}[A_{H/V}(f) \pm \sigma_A(f)] = f_0 \pm 5\%$

v) $\sigma_f < \varepsilon(f_0)$

vi) $\sigma_A(f_0) < \theta(f_0)$

- l_w = window length
- n_w = number of windows selected for the average H/V curve
- $n_c = l_w \cdot n_w \cdot f_0$ = number of significant cycles
- f = current frequency
- f_{sensor} = sensor cut-off frequency
- f_0 = H/V peak frequency
- σ_f = standard deviation of H/V peak frequency ($f_0 \pm \sigma_f$)
- $\varepsilon(f_0)$ = threshold value for the stability condition $\sigma_f < \varepsilon(f_0)$
- A_0 = H/V peak amplitude at frequency f_0
- $A_{H/V}(f)$ = H/V curve amplitude at frequency f
- f^- = frequency between $f_0/4$ and f_0 for which $A_{H/V}(f^-) < A_0/2$
- f^+ = frequency between f_0 and $4f_0$ for which $A_{H/V}(f^+) < A_0/2$
- $\sigma_A(f)$ = "standard deviation" of $A_{H/V}(f)$, $\sigma_A(f)$ is the factor by which the mean $A_{H/V}(f)$ curve should be multiplied or divided
- $\sigma_{logH/V}(f)$ = standard deviation of the $\log A_{H/V}(f)$ curve, $\sigma_{logH/V}(f)$ is an absolute value which should be added to or subtracted from the mean $\log A_{H/V}(f)$ curve
- $\theta(f_0)$ = threshold value for the stability condition $\sigma_A(f) < \theta(f_0)$
- $V_{s,av}$ = average S-wave velocity of the total deposits
- $V_{s,surf}$ = S-wave velocity of the surface layer
- h = depth to bedrock
- h_{min} = lower-bound estimate of h

Threshold Values for σ_f and $\sigma_A(f_0)$					
Frequency range [Hz]	< 0.2	0.2 – 0.5	0.5 – 1.0	1.0 – 2.0	> 2.0
$\varepsilon(f_0)$ [Hz]	0.25 f_0	0.20 f_0	0.15 f_0	0.10 f_0	0.05 f_0
$\theta(f_0)$ for $\sigma_A(f_0)$	3.0	2.5	2.0	1.78	1.58
$\log\theta(f_0)$ for $\sigma_{logH/V}(f_0)$	0.48	0.40	0.30	0.25	0.20

Figure 2. Criteria for Reliability of HVSR curve [1]

3.2. Amplification (A0)

Amplification can be obtained from H/V curve peak produced by HVSR method. Amplification is influenced by S-wave velocity v_s, density ρ, P-wave velocity v_p, and shear-wave attenuation Q_s [4]. The reliability of f_0 will increase with the sharpness of the H/V peak A_0. This value may however be considered as indicative of the impedance contrasts at the site under study [1].

3.3. Seismic vulnerability index (Kg)

Seismic vulnerability index is a parameter related with the vulnerability level of area from earthquake risk. There is linear relation between K_g and the damage caused by earthquake. The damage caused by earthquake is bigger when the value of K_g at the area is higher. The index can be obtained by:

$$K_g = \frac{A_0^2}{f_0} \tag{1}$$

A_0 is amplification and f_0 is dominant frequency.

4. Kota Baru classification of seismic hazard map

The seismometer was deployed at 15 locations in Kota Baru for obtaining microtremor recordings. Distribution of location can be seen in Figure 3. Microtremor data were analyzed by HVSR method. The most stationary recording was chosen manually for the further analysis. Some parameters were inputted in smoothing parameter based on the condition of the curve. The majority value was 10 for Konno & Ohmachi smoothing parameter. For improving the clarity and stability, the smaller value was inputted. All of H/V peak from 15 locations were reliable peak. From these reliable peak, f_0 and A_0 can be obtained, vice versa the K_g. All of these values can be seen in Table 2.

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Tabel 2. Some soil parameters value obtained by HVSR method

Locations	Longitude (E)	Latitude (S)	f_0	A_0	K_g
T10	105,4188	-5,28139	0,59	4,4	32,8
T15	105,4189	-5,29394	1,44	3,25	7,3
T4	105,3931	-5,28494	0,63	5,34	45,3
T5	105,391	-5,29336	0,66	3,81	22,0
T6	105,3909	-5,28442	0,78	3,55	16,2
T1	105,3784	-5,28064	0,56	3,47	21,5
T2	105,3788	-5,28689	0,59	3,22	17,6
T3	105,374	-5,29908	0,63	5,34	45,3
T9	105,4062	-5,29828	1,19	5,84	28,7
T8	105,4053	-5,288	0,8	4,14	21,4
T7	105,4047	-5,28208	0,75	2,3	7,1
T11	105,4154	-5,28889	1,46	6,17	26,1
T12	105,4179	-5,29936	1,17	5,58	26,6
T14	105,428	-5,28783	0,67	4,25	27,0
T13	105,4289	-5,28122	0,7	4,64	30,8

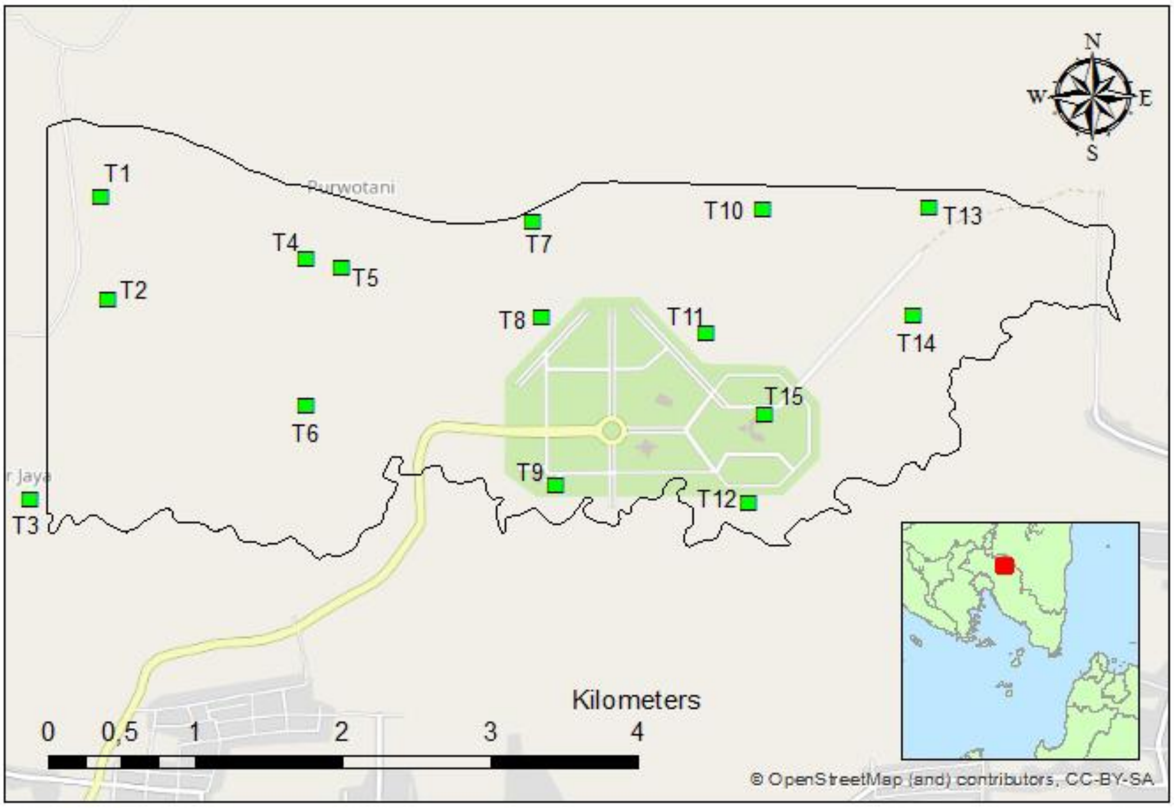

Figure 3. Distribution of recording locations denoted by green solid squares

The range of frequency value obtained by HVSR method was 0.56 Hz to 1.46 Hz. These value is suitable with the range of microtremor in Table 1. All of spectrums at 15 recording locations can be seen in Figure 4. Spectrums of locations T1, T2, T4, T5, T6, T7, T8, T14, and T15 exhibit two peaks spectrum with $f_0 > f_1$. We suggest that these locations have two large contrasts at shallow and large depth at two different scales.

The range of amplitude value obtained by HVSR method was 2.3 to 6.17. From both value, f_0 and A_0, K_g can be obtained. The Kota Baru classification of seismic hazard map can be generated by plotting the value of K_g at the longitude and latitude of locations. The map can be seen in Figure 5. Area at the northeast of Kota Baru is more risky to be inhabited because it has higher value of K_g. The more safety area located in near T7 and T15 because it has lower value of K_g than the others.

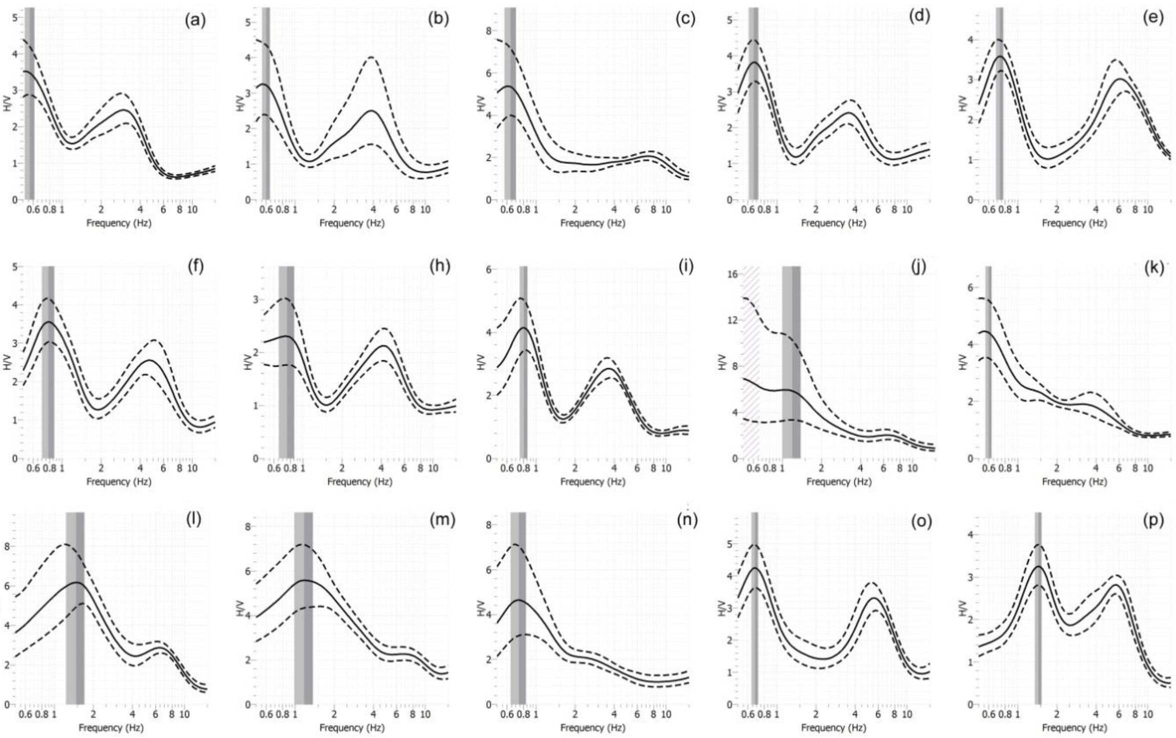

Figure 4. Spectrums of 15 locations, a) spectrums of T1, b) spectrums of T2, c) spectrums of T3, d) spectrums of T4, e) spectrums of T5, f) spectrums of T6, g) spectrums of T7, h) spectrums of T8, i) spectrums of T9, j) spectrums of T10, k) spectrums of T11, l) spectrums of T12, m) spectrums of T13, n) spectrums of T14, o) spectrums of T15

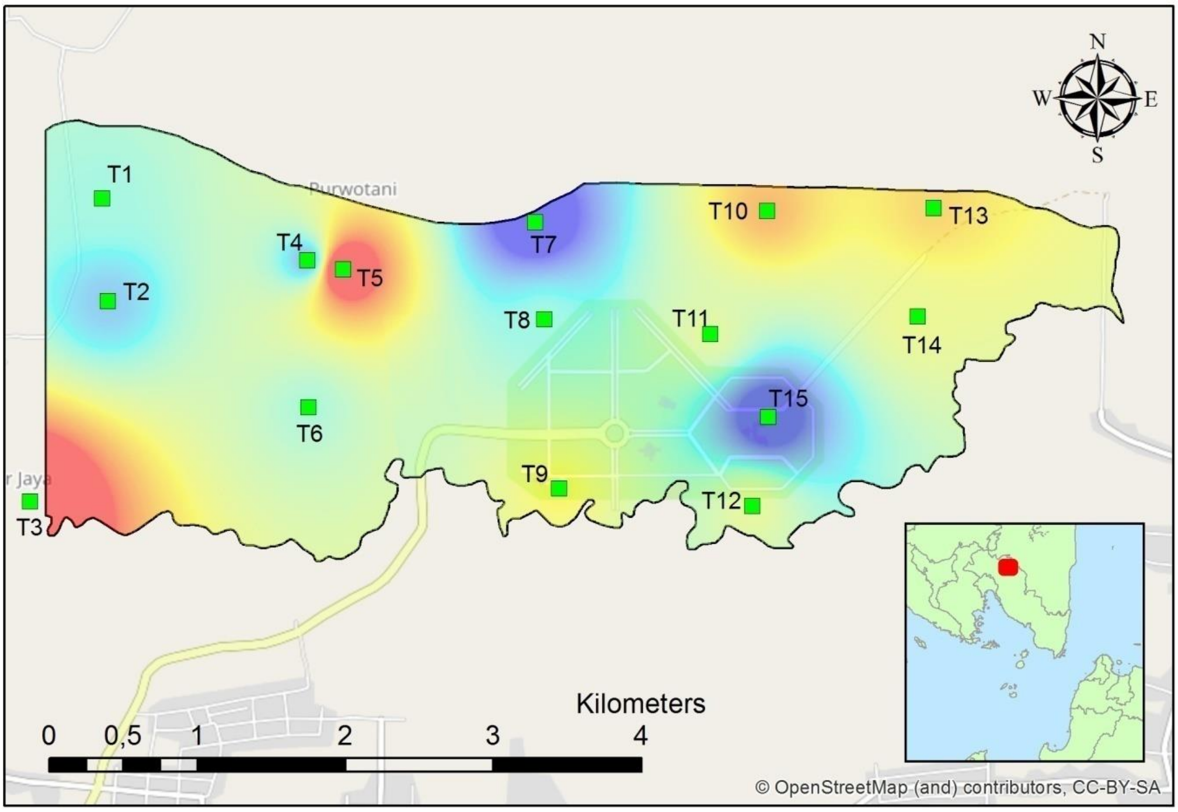

Figure 5. Kota Baru classification of seismic hazard map. The more red area means more hazardous because has higher value of K_g. The blue one can be interpreted as less hazardous area

Acknowledgments
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5. References

[1] SESAME European Research Project., 2004. *Guidelines for the implementation of the H/V spectral ratio technique on ambient vibrations measurements, processing and interpretation*.
[2] Okada, H., & Suto, K. 2003. *The Microtremor Survey Method*. doi:10.1190/1.9781560801740
[3] Y Nakamura 1989 *QR Railway Technical Research Institute* **30** 25
[4] Y Nakamura 1996 *Quarterly report of Railway Technical Research Inst. (RTRI)* **37** 112