APPLICATION OF FLOOR SPECTRAL RATIO (FSR) METHOD IN MICROTREMOR MEASUREMENT IN ONE OF THE BUILDINGS AT JAMBI UNIVERSITY

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ABSTRACT

Research has been conducted related to microtremor measurements in one of the buildings at Jambi University by applying the FLOOR SPECTRAL RATIO (FSR) method.The purpose of this study is to describe the structure of buildings against vibration. The FSR method is a method used to determine the natural frequency, resonance and susceptibility index of buildings from the transfer function on each floor between the building and the ground. Geologically, this building is located in the Muara Enim formation (Tmpm) which is composed of claystone, sandstone, siltstone, and coal. Microtremor measurements were carried out on a 4-story building. Data collection was carried out as many as 40 points with each floor of 10 points spread throughout the building. The results of the study obtained the average natural frequency value of the building was 4,58 Hz. The average amplitude value in the building was 11,21. The resonance value of the building is 151,83% so it is in the low category. The vulnerability index of the building is 10 m/s2 with the highest vulnerability value being on the 4th floor. Based on the value of the building's vulnerability index, one of these buildings is safe against vibration.

Key word : index, one of these buildings is safe against vibration.

1. Introduction

Jambi University is one of the universities that has increased in the field of education, marked by the addition of new faculties and study programs. The addition was accompanied by the addition of building construction that can be used for the learning process. The construction of the building must pay attention to the condition of the building and the land on which it is built. The condition of the soil is based on the geological conditions of the local area. Geologically, Jambi University is located in the

Muaraenim Formation (Tmpm) which is included in the Jambi sub-basin where it is composed of sedimentary rocks [8]. Geological conditions can affect the resilience of buildings.

The resilience of a building can be known by testing, namely measuring microtremor. Microtremor measurement can be applied to the field of engineering, one of which is in buildings. The microtremor method is a passive seismic method that uses very small and continuous ground vibrations. This method can determine the characteristics of soil layers and buildings based on the parameters of the waves recorded on the tool.

Soil vulnerability analysis is closely related to the stability of the building. Therefore, a study is needed in conducting a vulnerability analysis to buildings. To conduct a building vulnerability analysis, the Floor Spectral Ratio (FSR) method is applied. This FSR method was proposed by Gosar in determining the natural frequency and resonance of buildings to describe the characteristics of buildings against earthquakes [5]. Therefore, research was conducted on one of the buildings at Jambi University by applying the FSR method in measuring microtremor in analyzing building stability.

2. Literature review

2.1. Regional Geology

The research area is geologically included in the regional geological map of Jambi sheet. Based on the regional geological map (Figure 1), the research area is included in the Muara Enim formation (Tmpm). The formation is composed of interspersed rocks between tufaan sandstones and tufaan claystones, interspersed quartz sandstones with quartz claystones, interspersed with coal and iron oxides. [8]. The thickness of the Tmpm formation ranges from 50-1000 meters in Late Miocene to early Pliocene age [2].

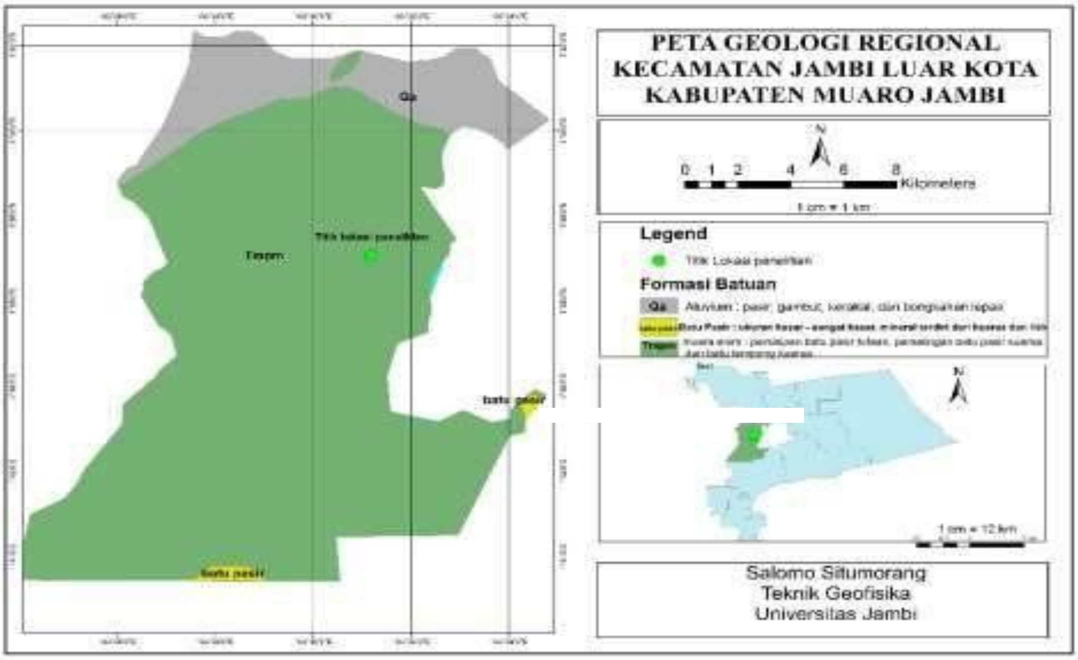

Figure 1. Geologic Map of Regionsl research Areas.

2.2. FSR (*Floor Spectral Ratio*) Method

The FSR method is a method used to determine the natural frequency and resonance of buildings that describe the characteristics of buildings against earthquakes [5]. The FSR method is a method of transfer function of any floor between the spectral building and the ground. The transfer function of the structure has been estimated by the spectral ratio of the structure and the spectral of the soil or spectral free field called the floor spectral ratio (FSR). By recording microtremor data, it can evaluate the strength of buildings caused by seismic waves and building characteristics [1].

The FSR method has advantages in addition to knowing the characteristics of buildings, it is also a more accurate method in determining soil resonance [9]. Building characteristics that can be obtained from the FSR method in addition to natural frequency are building resonance index and building vulnerability index.

The resonance index of buildings can be obtained from the natural frequency values of buildings and soil. If the natural frequency value of the building (($f0_b$) with the natural frequency value of the ground ($f0_t$) is the same, then the resonance process of the earthquake wave occurs. The resonance process will increase stress in the building [3]. In building construction, must consider the possibility of resonance. The resonance value of the building can be calculated by the equation:

$$R = \left|\frac{f0_b - f0_t}{f0_t}\right| x100\% \qquad (1)$$

According to Gosar's recommendation [4], the degree of resonance of buildings to earthquakes is classified into 3 levels (Table 1).

Table 1. Resonance Level Classification

No	Resonance value	Classification
1	>25%	Low
2	15-25%	Moderate
3	<15%	high

The vulnerability index of buildings can be given from the deformation of structures related to seismic movements of the ground surface and structure. The building vulnerability index can determine the value of damage from the building from earthquake vibrations. The building will collapse if the building vulnerability index is above 100 m/s2 – 200 m/s2. Buildings safe against damage caused by earthquake vibrations have a building vulnerability index below 100 m/s^2 [6].

The building vulnerability index (Kb) is determined based on the equation proposed by Nakamura [10] as follows:

$$\overline{K_b} = \frac{A}{(2\pi f)^2}\frac{10000}{H} \qquad (2)$$

The index of building vulnerability is influenced by the value of building amplitude (A), natural building frequency (f0b) and building height (H).

3. Methodology

3.1. Research Location

The research was conducted in one of the buildings at Jambi University which has 4 floors.

3.2. Data Acquisition

Data collection was carried out in one of the buildings at Jambi University consisting of 4 floors. The tools used in microtremor measurements are MAE A6000S Seismograph, Seismometer, connecting cable, 12 Volt Battery, GPS, Compass, Logbook, Laptop and Camera. The amount of data taken in microtremor measurements as many as 40 points consists of 10 points on each floor. Microtremor data collection was carried out for 1 hour on two components, namely the North - South (NS) component and the East - West (EW) component. The position of the scattered measurement points represents one building according to the acquisition design (Figure 2).

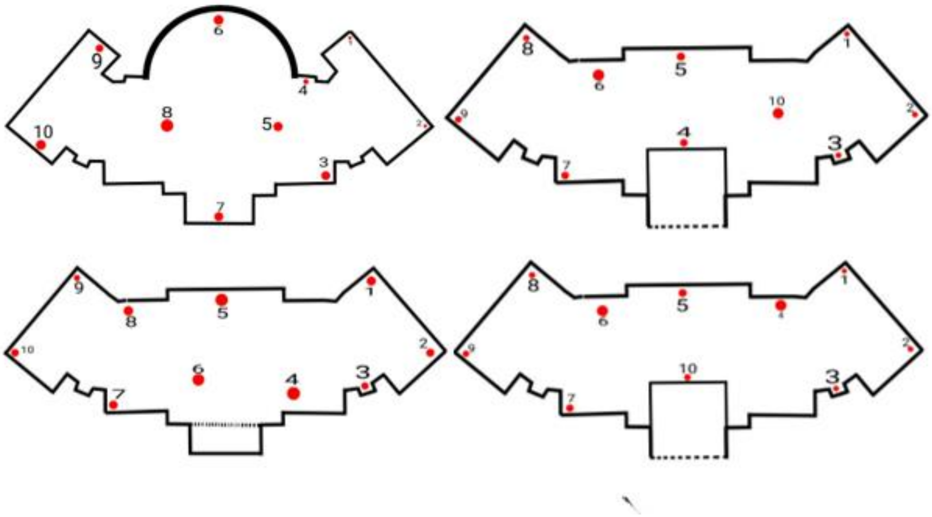

Figure 2. Data Acquisition Design

3.3. Data Processing and Analysis

The results of microtremor measurement recordings are in the form of signal recordings in sg2 format. Furthermore, data processing using Geopsy software using Fourier spectrum analysis serves to change microtremor data from the time domain to the frequency domain. Fast Fourier Transform (FFT) algorithm on the spketrum analysis. In spectrum analysis, each recording wavelength is separated into 20-40 sekond non overlapping window [1].

The results of the FFT process were smoothed using Konno and Ohmachi smoothing filters with a bandwidth coefficient of 40 [7]. The selection of windows is done by selecting a constant signal, where each window contains 25 seconds of data with a minimum amount of data of 20 windows. The results of the analysis are in the form of a spectrum that shows the value of the natural frequency (f0) and amplitude (A0) of the building [11]. The natural frequency of buildings from the FSR method, then the calculation of the resonance value with equation (1) and the building vulnerability index with equation (2) is carried out.

4. Results and Discussion

4.1. Natural Frequency and Amplitude of Buildings

Based on the results of the spectral curve in the FSR (Floor Spectral Ratio) method, it produces natural frequency (f0b) and building amplitude (A0b) from East-West (EW) and North-South (NS) components (Figure 3).

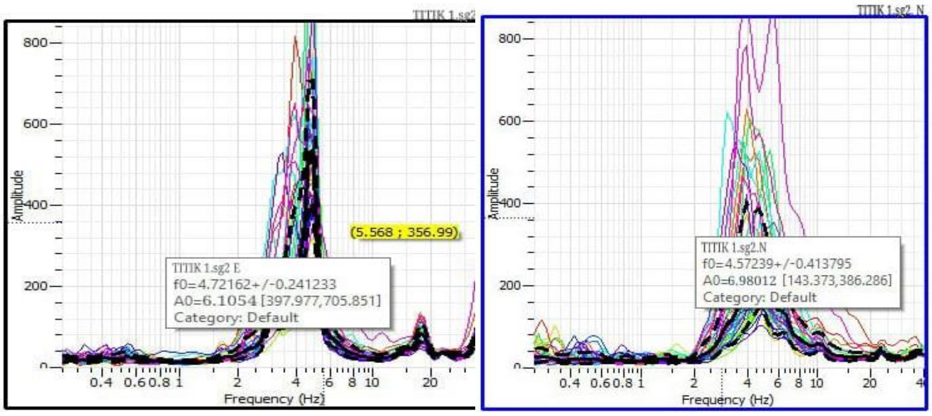

Figure 3. Results Curve Spectrum data Building Record EW and NS components FSR analysis

Based on Table 2, the natural frequency value in the basement in the East-West (EW) component ranges from 3,87 Hz to 4,86 Hz. While the North-South (NS) component ranges from 3,61 Hz – 5,24 Hz. The amplitude value obtained for the East-West (EW) component has a value range of 6,10 – 7,48 while the North-South (NS) component has a value of 5,88 to 8,31.

Based on Table 3, the natural frequency value on the 1st floor in the East-West (EW) component ranges from 3,52 Hz – 5,71 Hz, while the North-South (NS) component ranges from 3,56 Hz to 5,32 Hz. The amplitude value obtained for the East-West (EW) component has a value range of 6,67 – 8,74 while the North-South (NS) component has a value of 6,86 – 10,29.

Based on Table 4, the natural frequency value on the 2nd floor in the East-West (EW) component ranges from 3,82 Hz – 4,75 Hz, while in the North-South (NS) component it ranges from 3,4 Hz to 5,43 Hz. The amplitude value obtained for the East-West (EW) component has a value range of 7,59 to 14,02 while the North-South (NS) component has a value of 6,34 – 10,88.

Based on Table 5, the natural frequency value on the 3rd floor in the East-West (EW) component ranges from 4,63 Hz – 5,44 Hz, while in the North-South (NS) component ranges from 4,3 Hz to 5,54 Hz. The amplitude value obtained for the East-West (EW) component has a value range of 7,46 – 50,24, while the North-South (NS) component has a value of 7,4 – 27,84.

Based on the average value of natural frequency and amplituo using the FSR method on each floor can be explained in Table 6. Based on Table 6, the average natural frequency of buildings is 4,58 Hz higher than the average natural frequency of soil (f0t) which is 1,52 Hz. The average value of the amplitude of buildings is 11,21. The comparison shows that the basement does not experience damage in the event of shock, the amplitude value is greater with the increase in floor level both in components (EW and NS) because the higher the floor level, the amplitude of the building is not in direct contact with bedrock.

4.2. Resonance

The natural frequency of buildings obtained from the FSR method, compared to the natural frequency of the soil. The result of the comparison between the natural frequency of the building with the natural frequency of the soil will obtain the resonance value of the building. The natural frequency value of the soil obtained from the measurement of the HVSR method ranges from 1,3 to 1,82 Hz. In the calculation of the resonance value of the building, the maximum value of the soil frequency used is 1,82 Hz.

Table 2. Natural Frequency Value, Amplitude, Building Susceptibility and Resosnancy in the Basement

Datum	natural frequency (Hz)		Amplitude		Building Vulnerability		Resonance	
	EW	NS	EW	NS	EW	NS	EW	NS
1	4,72	4,57	6.11	6,98	5,35	6,52	159,34	151,10
2	4,86	4,67	6.98	7,21	5,76	6,45	167,03	156,59
3	3,93	4,34	6.89	5,88	8,70	6,09	115,93	138,46
4	3,88	4,28	6.59	7,01	8,54	7,46	113,19	135,16
5	4,86	4,81	7.00	6,10	5,78	5,14	167,03	164,29
6	4,73	5,24	6.99	6,42	6,09	4,56	159,89	187,91
7	4,69	5,08	7.46	5,99	6,62	4,53	157,69	179,12
8	4,31	4,54	6.78	8,20	7,12	7,76	136,81	149,45
9	3,87	3,61	7.00	8,31	9,12	12,44	112,64	98,35
10	4,33	4,39	7.48	6,71	7,78	6,79	137,91	141,21

Table 3. Natural Frequency Value, Amplitude, Building Susceptibility and Resosnancy on 1st Floor

Datum	natural frequency (Hz)		Amplitude		Building Vulnerability		Resonance	
	EW	NS	EW	NS	EW	NS	EW	NS
1	4,58	4,12	7,32	7,90	6,81	9,08	151,65	126,37
2	4,73	4,68	8,48	10,29	7,39	9,16	159,89	157,14
3	5,71	5,22	8,74	8,42	5,23	6,03	213,74	186,81
4	5,05	5,32	6,80	6,91	5,20	4,76	177,47	192,31
5	4,74	4,75	7,10	7,49	6,16	6,47	160,44	160,99
6	3,89	3,56	7,65	6,89	9,86	10,60	113,74	95,60
7	3,52	3,85	6,67	6,92	10,50	9,11	93,41	111,54
8	4,74	4,78	7,24	7,19	6,29	6,14	160,44	162,64
9	4,31	4,16	6,98	7,20	7,33	8,11	136,81	128,57
10	4,77	4,71	7,18	6,86	6,15	6,03	162,09	158,79

Based on Table 2, the resonance value of buildings on the basement floor ranges from 112,63%-167,03% in the East-West (EW) component, while in the North-South (NS) componet ranges from 98,35% - 187,91%. Based on Table 3, the resonance value of buildings on the 1st floor ranges from 93,41% - 213,74% in the East-West (EW) component, while in the North-South (NS) component ranges from 95,6% - 192,31%.

Tabel 4. Natural Frequency Value, Amplitude, Building Susceptibility and Resosnancy on the 2rd Floor

Datum	natural frequency (Hz)		Amplitude		Building Vulnerability		Resonance	
	EW	NS	EW	NS	EW	NS	EW	NS
1	4,04	4,34	9,36	6,34	11,19	6,57	121,98	138,46
2	4,75	4,64	7,59	7,23	6,56	6,55	160,99	154,95
3	4,39	5,43	12,24	8,42	12,39	5,57	141,21	198,35
4	4,38	5,37	9,80	6,69	9,96	4,52	140,66	195,05
5	4,44	4,29	9,22	10,88	9,12	11,53	143,96	135,71
6	3,82	3,4	14,02	9,47	18,74	15,98	109,89	86,81
7	4,02	4,33	9,54	6,42	11,51	6,68	120,88	137,91
8	4,64	4,79	8,63	9,70	7,82	8,25	154,95	163,19
9	4,5	4,32	10,09	10,32	9,72	10,79	147,25	137,36
10	4,17	4,23	7,70	6,52	8,64	7,11	129,12	132,42

Table 5. Natural Frequency Value, Amplitude, Building Susceptibility and Resosnancy on the 3rd Floor

Datum	natural frequency (Hz)		Amplitude		Building Vulnerability		Resonance	
	EW	NS	EW	NS	EW	NS	EW	NS
1	6,45	6,32	160,99	162,64	6,45	6,32	160,99	162,64
2	10,82	19,40	198,90	190,66	10,82	19,40	198,90	190,66
3	21,25	14,55	165,38	170,88	21,25	14,55	165,38	170,88
4	16,52	8,08	157,69	151,10	16,52	8,08	157,69	151,10
5	20,95	10,10	154,40	157,69	20,95	10,10	154,40	157,69
6	28,56	10,39	160,44	165,38	28,56	10,39	160,44	165,38
7	32,22	7,55	161,54	159,89	32,22	7,55	161,54	159,89
8	22,60	14,44	155,49	136,26	22,60	14,44	155,49	136,26
9	43,07	6,71	162,09	181,87	43,07	6,71	162,09	181,87
10	18,88	10,64	198,35	204,40	18,88	10,64	198,35	204,40

Based on Table 4, the resonance value of buildings on the 2nd floor ranges from 109,89% - 160,99% in the East-West (EW) component, while in the North-South (NS) component ranges from 86,81% - 198,35%. Based on Table 5, the resonance value of buildings on the 3rd floor ranges from 154,4% - 198,9% in the East-West (EW) component, while in the North-South (NS) component ranges from 136,26% - 204,4%.

Table 6. Average Value of Natural Frequency, Amplitude, Resonance and Susceptibility of Buildings Based on FSR Method on each floor.

Floor	natural frequency (Hz)		Amplitude		Resonance		Building Vulnerability	
	EW	NS	EW	NS	EW	NS	EW	NS
Basement	4,42	4,55	6,92	6,88	142,75	150,16	6,92	6,92
1	4,6	4,52	7,42	7,6	152,97	148,08	7,09	7,28
2	4,31	4,51	9,82	10,56	137,09	148,02	10,57	8,36
3	4,87	4,88	26,51	13,99	167,53	168,07	22,13	10,82

Based on Table 6, the resonance value of buildings in the EW component ranges from 137,09% - 167,53%, while in the NS component ranges from 148,02% - 168,07%. So the average value of building resonance is 151,84%. Based on Table 1, the resonance value of buildings belongs to the low classification, where the resonance value of buildings is more than 25%. The low building resonance value is caused because the natural frequency value of the soil (1,52 Hz) is smaller than the natural frequency value of the building (4,58 Hz). The natural frequency value of the soil and building will affect the resonance value.

4.3. Building Vulnerability (Kb)

The vulnerability of buildings can be estimated from the movement of structural deformation. The vulnerability of buildings can be estimated based on the results of the natural frequency and amplitude of East-West (ES) and North-South (NS) components based on the FSR method, building height and noise effects on recording.

Based on Table 2, the vulnerability value of buildings on the basement floor ranges from 5,35 m/s^2 – 9,12 m/s^2 in the East-West (EW) component, while in the North-South (NS) component ranges from 4,53 m/s^2 – 12,44 m/s^2. Based on Table 3, the vulnerability value of buildings on the 1st floor ranges from 5,20 m/s^2 – 10,50 m/s^2 in the East-West (EW) component, while in the North-South (NS) component ranges from 4,76 m/s^2 to 10,60 m/s^2.

Based on Table 4, the vulnerability value of buildings on the 2nd floor ranges from 6,56 m/s^2 – 18,74 m/s^2 in the East-West (EW) component, while in the North-South (NS) component ranges from 4,52 m/s^2 – 15,98 m/s^2. Based on Table 5, the vulnerability value of buildings on the 3rd floor ranges from 6,45 m/s^2 – 43,07 m/s^2 in the East-West (EW) component, while in the North-South (NS) component ranges from 6,32 m/s^2 – 19,40 m/s^2.

Based on the vulnerability value of buildings on each floor ranges from 6,92 m/s2 to 22,13 m/s^2 with an average value of 11,67 m/s^2 in EW components. While in the NS component, the vulnerability value on each floor ranges from 6,92 m/s^2 to 10,82 m/s^2 with an average value of 8.35 m/s^2. The average value of building vulnerability is 10.01 m/s^2 including the low vulnerability value. If the floor increases, the value of the building's vulnerability is even greater. This is according to the measurement results (Table 6) on each floor, the more the floor level, the higher the vulnerability value of the building. The highest building vulnerability value is on the 3rd floor, so shocks will be easily damaged because the vulnerability value is high. From the average value of the susceptibility of the building obtained, the building is considered safe against shocks and will not suffer damage.

5. Closing

5.1. Conclusion

Natural frequency of one of the buildings at Jambi University from the results of the FSR method with an average value of 4.58 Hz and an average building amplitude value of 11.21. The average value of building resonance is 151.84%. The average value of building vulnerability is 10.01 m/s2. Based on the results of the analysis of the FSR method, it was obtained that the natural frequency of the building (f0b) is higher than the natural frequency of the soil so that the resonance value of the building is low and the building vulnerability index is also low.

5.2. Suggestion

In taking microtremor data should be done when the research location has no more activity there, so that the recorded data is free of noise.

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