THE STUDY ON VIBRATIONS WHICH IS CAUSED BY THE ROAD TRAFFIC ACTIVITIES ALONG SEVERAL MAIN STREETS IN JAKARTA

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Abstract

The vibrations which is caused by road traffic activities have been monitored along several main streets in Jakarta, i.e Jalan MH. Thamrin, Jalan Merdeka Barat (around Taman Monas) and Hayam Wuruk Street (Gajah Mada Plaza and Glodok). Where in the near future, the Indonesian Government has planed to construct a new large scale project so called Mass Rapid Transport (MRT) along these roads. The purpose of this works was to study the existing vibrations radiated by the road traffic activities impacting to the buildings adjacent to the road. Furthermore, these vibrations data can also be used as supporting data in the realization of MRT project. From observation results showed that the amount of traffic volume along MH. Thamrin Street, Merdeka Barat Street and Hayam Wuruk Street, happened in the afternoon time, i.e. from 14.00 p.m. to 17.00 p.m. Where in this range time the large vehicles such as busses or trucks were frequently passing on these roads, and they generated the maximum vibration levels on the surface of ground with the levels of 0.315 mm/sec up to 0.332 mm/sec, and these maximum vibrations occurred at the frequency of 4 Hz. Refer to BAPEDAL Standard, the limit of buildings vibration at frequency 4 Hz must be less than 2 mm/s. Thus, the measured vibration levels were very low compared to the standard, therefore it would not damage to the structures of buildings adjacent to the road.

***Keywords**: vibration monitoring, road traffic activities, Mass Rapid Transport (MRT), BAPEDAL standard*

Abstrak

Studi Tentang Getaran yang Disebabkan oleh Kegiatan Lalu Lintas Jalan Sepanjang Beberapa Jalan Utama di Jakarta

Telah dilakukan pemantauan getaran akibat aktivitas jalan raya pada beberapa ruas jalan utama di wilayah Jakarta, yaitu: Jalan MH. Thamrin, Jalan Merdeka Barat (sekitar Taman Monas) dan Jalan Hayam Wuruk (Gajah Mada Plaza dan Glodok). Dimana pada waktu yang akan datang, di sepanjang jalan tersebut akan dibangun proyek berskala besar untuk sarana transportasi massal yang bebas hambatan yang disebut "MRT" (Mass Rapid Transport). Tujuan dari penelitian ini adalah untuk mengetahui sampai seberapa besar pengaruh getaran yang diakibatkan oleh aktivitas kendaraan di jalan raya terhadap bangunan-bangunan yang berada didekat jalan. Selain itu, data getaran tersebut dapat dijadikan sebagai data pendukung dalam pembuatan konstruksi projek MRT nanti. Dari hasil observasi, menunjukkan bahwa di sepanjang Jalan MH. Thamrin, Jalan Merdeka Barat dan Jalan Hayam Wuruk, peningkatan volume lalu lintas kendaraan terjadi antara jam 14.00 sore sampai dengan jam17.00 sore. Dimana pada rentang waktu tersebut kendaraan-kendaraan berat seperti bus dan truk banyak sekali yang melintas pada jalan-jalan tersebut, dan kendaraan-kendaraan tersebut ternyata menghasilkan level getaran maksimum pada permukaan jalan, dengan level getaran berkisar antara 0.315 mm/s hingga 0.332 mm/s, dimana level getaran maksimum tersebut terjadi pada frekuensi 4 Hz. Mengacu kepada standar BAPEDAL, disebutkan bahwa batas tingkat getaran untuk gedung pada daerah frekuensi 4 Hz harus berada di bawah 2 mm/s. Dengan demikian dapat simpulkan bahwa tingkat getaran yang ditimbulkan oleh aktivitas lalulintas kendaraan di jalan raya tersebut masih berada dalam batas toleransi yang diizinkan, sehingga tidak akan menyebabkan terjadinya kerusakan terhadap stuktur gedung yang berada di sekitarnya.

***Kata kunci:** Pemantauan getaran, aktivitas jalan raya, mass rapid transport (MRT), standar BAPEDAL*

1. INTRODUCTION

Vibration is a frequent problem in buildings. Common internal sources are machinery, HVAC systems, elevators and the activities of occupants. The external vibration sources are earthquakes, wind, blasting, construction operations, and rail traffic or road traffic activity[1]. However, the excessive vibration of the road traffic activities will cause physical movement on buildings adjacent to the road-traffic, e.g. when a heavy vehicles passing on the road, the windows will vibrate, ornaments rattle and vibrations may be felt by the occupants. The condition of the road surface near the buildings will give a significant effect on the vibration level, where the vehicles passing on a smooth road surface will create much lower levels of vibration than do similar vehicles passing at similar speeds on an uneven road surface. Moreover, poor road surfaces with badly filled potholes will generate much more vibrations.

In the near future, the Indonesian Government has planed to construct a new large-scale project so called Mass Rapid Transport (MRT) along several main streets in Jakarta[2]. Nevertheless, since this project will be constructed in dense urban areas, it is likely requiring environmental impact statements including an vibration assessment. Due to that, in August 2009 the author carried out the vibration measurements along the corridor of jalan MH. Thamrin, Jalan Merdeka Barat and Jalan Hayam Wuruk, Jakarta. The purpose of this works was to study the effects of vibration on buildings adjacent to the road-traffic. The vibration monitoring was performed on the hard surface of the ground or on the sidewalk between the buildings and the road construction.

2. THEORY

2.1 Vibration

Vibration is a mechanical oscillations which is referred to an equilibrium point. The oscillations may be periodic such as the motion of a pendulum or random such as the movement of a tire on a gravel road [3]. The motion is repeated in equal intervals of time and it is called period (T). Thus, the frequency (f) can be calculated using the formula:

$$f = \frac{1}{T} Hz \text{ ....1)}$$

Where:

f = frequency (Hz);

T = period (second)

Harmonic motion is often represented as the projection on a straight line of a point that is moving on a circle at constant speed, as shown in Figure 1 below.

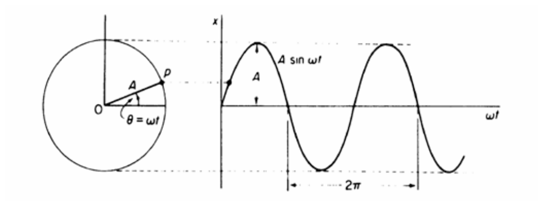

Figure 1 The Ilustration of Harmonic Motion

The quantity ω so called angular frequency is generally measured in radians per second. Because the motion repeats itself in 2π radians, we have the relationship:

$$\omega = \frac{2\pi}{T} = f\,2\pi \text{ ....2)}$$

The displacement (x) can be written as:

$$X = A \sin \omega t \text{ ....3)}$$

and then the velocity and acceleration of harmonic motion can be simply determined by differentiation of Eq.3. Using the dot notation for the derivative, as follow:

velocity: $\overset{o}{X} = \omega A \cos \omega t$ ....4)

acceleration: $\overset{o.o.}{X} = -\omega^2 A \sin \omega t$ ....5)

2.2 Standardization of Vibration

As mentioned above, vibrations can be described in three parameters, namely acceleration level, velocity level and displacement level. As the basic for the judgment of measured values was used the BAPEDAL standard (Environmental Impact Management Agency), it is according to KEP-49/MENLH/11/1996 [4]. This standard defines numerical values of the vibration limit, that is radiated from any vibration sources to the structural construction of buildings. The BAPEDAL standard also suggests that for the evaluation of the damages on the buildings, the vibration shall be measured in the parameter of “velocity” with the unit of mm/sec. In this standard has also laid down vibration limits and categories for determination of the effects of existing vibration on building structures.

Tabel 1 Vibration limit and categories for determining the effects of existing vibration on building structure in according with BAPEDAL standard (KEP-49/MENLH/11/1996) [4]

VIBRATION			Vibration Limit, in mm/s (peak)			
			According to Standardization of Vibration Level (KEP-49/MENLH/11/1996)			
Parameter	Unit	Frequency (Hz)	Category A	Category B	Category C	Category D
		4.0	< 2.0	< 2.0 - 27	> 27 - 140	> 140
		5.0	< 7.5	< 7.5 - 25	> 25 - 130	> 130
Velocity	mm/ s	6.3	< 7.0	< 7.0 - 21	> 21 - 110	> 110
		8.0	< 6.0	< 6.0 - 19	> 19 - 100	> 100
Frequency	Hz	10.0	< 5.2	< 5.2 - 16	> 16 - 90	> 90
		12.5	< 4.8	< 4.8 - 15	> 15 - 80	> 80
		16.0	< 4.0	< 4.0 - 14	> 14 - 70	> 70
		20.0	< 3.8	< 3.8 - 12	> 12 - 67	> 67
		25.0	< 3.2	< 3.2 - 10	> 10 - 60	> 60
		31.5	< 3.0	< 3.0 - 9.0	> 9.0 - 53	> 53
		40.0	< 2.0	< 2.0 - 8.0	> 8.0 - 50	> 50
		50.0	< 1.0	< 1.0 - 7.0	> 7.0 - 42	> 42

Remark:

Category A : No damage
Category B : Possibility of plaster cracks
Category C : Probable damage to load bearing structural units
Category D : Damage to load-bearing units destruction.

2.3 Measurement Procedure

The author measured vibration at the side of the roads along several main streets in Jakarta. The high sensitivity accelerometer, type ENDEVCO 7703A-1000 was used as the vibration transducer [5]. The accelerometer was stick on the hard shoulder surface of the sidewalk or ground between the buildings and the road construction. This means that the measurement points were very closed to road traffic activities as the vibration sources. The output of accelerometer was connected to the input of FFT Analyzer, type B&K 2144. So that, the FFT-Analyzer can directly measure the vibration signal which is transmitted from accelerometer, thus the vibration spectrum as the function of frequency will be immediately displayed on the screen of FFT-Analyzer. The vibration was measured in acceleration vibration levels, however the acceleration value can be converted into velocity and displacement values by using formula [6].

$$v = \frac{a}{2\pi f} \ldots\ldots\ldots \frac{m}{sec} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 6)$$

$$d = \frac{a}{4\pi^2 f^2} \ldots\ldots\ldots m \ldots\ldots\ldots\ldots\ldots\ldots 7)$$

where:

a= Acceleration level, in meter/sec^2

v= Velocity level, in meter/sec

d = Displacement level, in meter

f = Frequency, in Hz.

In each location, the vibration monitoring was carried out in the range time of 2 x 24 hours, namely 24 hours during working day and 24 hours during off day (Saturday and Sunday), in which the data acquisition was taken within 10 minutes non stop in every one hour. Figure 1 shows the illustration of Instruments set-up for the vibration monitoring.

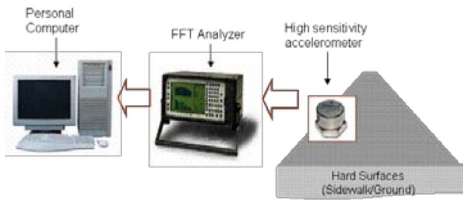

Figure 1 The Configuration of Instruments Set-up for Vibration Monitoring

3. MEASUREMENT RESULTS

The four locations correspond with the vibration levels during monitoring activities are presented in appendix I, and the pictures of vibration monitoring activity are presented in appendix II. The maximum vibration levels which were recorded at each location are summarized and presented in Table 2.

Table 2 The Maximum Vibration Levels Recorded at Four Locations Compared with Vibration Limit which is Defined by BAPEDAL Standard (KEP-49/MENLH/11/1996)

Frekuency	Maximum Vibration Levels, in mm/ s (peak)				Vibrations Limit, in mm/s (peak)			
(Hz)	HOTEL NIKO (JL.MH.THAMRIN)		MONAS		According To The Satandard (KEP-49/MENLH/11/1996)			
	date: 15-08-09	date: 19-08-09	date: 15-08-09	date: 19-08-09	Kategori A	Kategori B	Kategori C	Kategori D
4.0	0.332	0.331	0.332	0.326	< 2.0	< 2.0 - 27	> 27 - 140	> 140
5.0	0.239	0.247	0.225	0.225	< 7.5	< 7.5 - 25	> 25 - 130	> 130
6.3	0.031	0.036	0.033	0.036	< 7.0	< 7.0 - 21	> 21 - 110	> 110
8.0	0.163	0.151	0.158	0.159	< 6.0	< 6.0 - 19	> 19 - 100	> 100
10.0	0.124	0.150	0.142	0.105	< 5.2	< 5.2 - 16	> 16 - 90	> 90
12.5	0.008	0.036	0.040	0.018	< 4.8	< 4.8 - 15	> 15 - 80	> 80
16.0	0.091	0.095	0.091	0.070	< 4.0	< 4.0 - 14	> 14 - 70	> 70
20.0	0.059	0.067	0.065	0.081	< 3.8	< 3.8 - 12	> 12 - 67	> 67
25.0	0.009	0.011	0.006	0.005	< 3.2	< 3.2 - 10	> 10 - 60	> 60
31.5	0.048	0.039	0.054	0.039	< 3.0	< 3.0 - 9.0	> 9.0 - 53	> 53
40.0	0.028	0.003	0.023	0.024	< 2.0	< 2.0 - 8.0	> 8.0 - 50	> 50
50.0	0.004	0.003	0.004	0.003	< 1.0	< 1.0 - 7.0	> 7.0 - 42	> 42

Frekuency	Maximum Vibration Levels, in mm/ s (peak)				Vibrations Limit, in mm/s (peak)			
(Hz)	GAJAH MADA PLAZA		GLODOK		According To The Satandard (KEP-49/MENLH/11/1996)			
	date: 20-08-09	date: 22-08-09	date: 20-08-09	date: 22-08-09	Kategori A	Kategori B	Kategori C	Kategori D
4.0	0.321	0.315	0.321	0.321	< 2.0	< 2.0 - 27	> 27 - 140	> 140
5.0	0.212	0.225	0.203	0.243	< 7.5	< 7.5 - 25	> 25 - 130	> 130
6.3	0.035	0.035	0.031	0.031	< 7.0	< 7.0 - 21	> 21 - 110	> 110
8.0	0.158	0.152	0.101	0.093	< 6.0	< 6.0 - 19	> 19 - 100	> 100
10.0	0.092	0.106	0.119	0.108	< 5.2	< 5.2 - 16	> 16 - 90	> 90
12.5	0.020	0.036	0.008	0.010	< 4.8	< 4.8 - 15	> 15 - 80	> 80
16.0	0.076	0.096	0.049	0.063	< 4.0	< 4.0 - 14	> 14 - 70	> 70
20.0	0.075	0.056	0.036	0.017	< 3.8	< 3.8 - 12	> 12 - 67	> 67
25.0	0.006	0.007	0.006	0.007	< 3.2	< 3.2 - 10	> 10 - 60	> 60
31.5	0.041	0.036	0.025	0.032	< 3.0	< 3.0 - 9.0	> 9.0 - 53	> 53
40.0	0.023	0.021	0.037	0.038	< 2.0	< 2.0 - 8.0	> 8.0 - 50	> 50
50.0	0.004	0.003	0.004	0.004	< 1.0	< 1.0 - 7.0	> 7.0 - 42	> 42

4. DISCUSSION

The vibration monitoring in each location was carried out in the range time of 2 x 24 hours, namely 24 hours during working day and 24 hours during off day. All vibration data are presented in appendix I, however the maximum vibration levels which were recorded at each location are summarized in Table 2. According to the BAPEDAL Standard for the evaluation of the damage risks on the building construction, the vibration shall be measured in the velocity parameter (peak level) within the unit of mm/sec[4]. Therefore, all vibration data were converted into velocity parameter.

4.1 Location of MH. Thamrin Street

In the measurement point of Jalan MH.Thamrin, the vibration monitoring was performed on the sidewalk in front of Hotel Niko Building. The measurements were conducted on Saturday August 15, 2009 for off day and on Wednesday August 19, 2009 for working day. From measurement results, it was obtained that for off day the maximum vibration level occurred at 15.00 pm with the level of 0.332 mm/ sec (peak), meanwhile for working day the maximum vibration level occurred at 17.00 pm with the level of 0.331 mm/sec (peak). Both vibration levels occurred at the same frequency, i.e. at 4 Hz. It is evidently seen that the vibration levels obtained in the condition of off day was slightly higher than those in the condition of working day.

4.2 Location of Merdeka Barat Street (Monas Garden).

In the measurement point of Jalan Merdeka Barat, the vibration monitoring was performed on the sidewalk in front of Police Station building (Pos Polisi Monas). Similar with the location of Jalan MH.Thamrin, the measurements were conducted on Saturday August 15, 2009 for off day and on Wednesday August 19, 2009 for working day. In the condition of off-day the maximum vibration level was 0.332 mm/sec (peak) with the frequency of 4 Hz occurred at 17.00 pm, and in the condition of working day the maximum vibration level was 0.326 mm/sec (peak) with the frequency of 4 Hz occurred at 16.00 pm.

4.3 Location of Gajah Mada Plaza (around Hayam Wuruk Street)

The vibration monitoring around the location of Hayam Wuruk St was performed on the hard surface of the ground in the area of Gajah Mada Plaza building. For the condition of working day the measurements were conducted on Thursday August 20, 2009 and then for off-day the measurements were conducted on Saturday August 22, 2009. In the condition of working day the maximum vibration level was 0.321 mm/sec (peak) with the frequency of 4 Hz, meanwhile during off-day day the maximum vibration level was recorded at the level of 0.315 mm/sec (peak) with the frequency of 4 Hz. Either on working day or off-day the maximum vibration levels in Gajah Mada Plaza area occurred at 16.00 pm.

4.4 The Location of Glodok (around Jalan Hayam Wuruk)

In the location of Glodok (Hayam Wuruk St) the vibration monitoring was performed on the hard surface of the ground in the area nearby Electronic Trade Center Glodok. For the condition of working day the measurements were conducted on Thursday August 20, 2009 and for off-day the measurements were conducted on Saturday August 22, 2009. Either in the condition of working day or off day the maximum vibration levels exhibited the same value namely 0.321 mm/sec at the frequency of 4 Hz. However, the maximum vibration has occurred at different time i.e. at 14.00 pm for the condition of working day and at 15.00 pm for the condition of off day.

Graphic characteristics of maximum vibration levels as the function of frequency, which was recorded during off day and working day are shown in Figure 2 and Figure 3. From both Figures, it is shown that either in the condition of working day or off day indicate the similar vibration characteristics. In which three dominant frequencies, so called: f1, f2 and f3 always appeared in the low frequency range, namely at 4 Hz, 8 Hz and 10 Hz. The vibrations at low frequency region might be transmitted through the ground, therefore it is called as ground borne vibration [7]. These vibrations might be produced by the interaction between rolling wheels and the road surfaces. The condition of traffic volume on the road has also given a significant contribution to the amount of vibration levels, particularly if the vehicles were fast moving and heavy traffic.

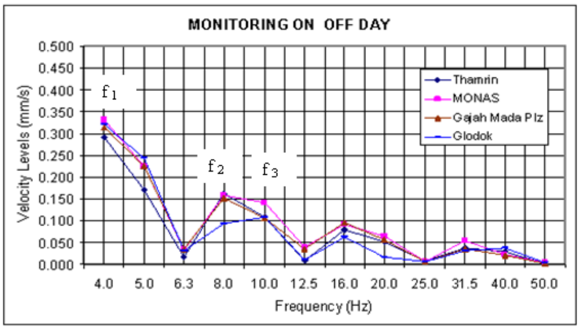

Figure 2 Graphic characteristics of maximum vibration levels as the function of frequency which was recorded during off day, obtained from 4 locations, i.e. Location: Thamrin, Monas, Gajah Mada Plaza and Glodok.

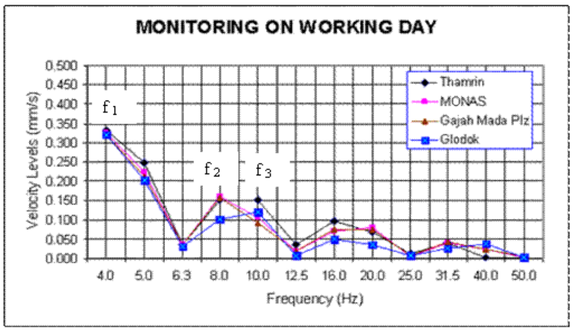

Figure 3 Graphic characteristics of maximum vibration levels as the function of frequency which was recorded during working day, obtained from 4 locations, i.e. Location: Thamrin, Monas, Gajah Mada Plaza and Glodok.

Based on our investigation, it can be identified that the amount of traffic volume along the corridor of MH. Thamrin St – Merdeka Barat St and Hayam Wuruk St, happened in the afternoon time, i.e. from 14.00 p.m. up to 17.00 p.m., where in this range time the large vehicles such as busses or trucks were frequently passing on these roads. This situation has generated the maximum vibration levels on the surface of ground/ sidewalk adjacent to the road-traffic with the levels of 0.315 mm/sec to 0.332 mm/sec, and these maximum vibration levels occurred at the frequency of 4 Hz. It is obviously proved, that there was a positive correlation between traffic volume and vibration levels, where the denser of traffic volume created more vibrations on the structure of roads. However, in the higher frequency range i.e. above 10 Hz, all locations produced lower vibration levels namely less than 0.1mm/s. These vibrations were more often transmitted through the air so called air-borne vibration, seemingly these vibrations were generated by the engines or exhausts of vehicles.

As already discussed above, that the maximum vibration levels caused by road traffic activity along the corridor of Jalan MH. Thamrin – Jalan Merdeka Barat and Jalan Hayam Wuruk were in the levels of 0.315 mm/ sec to 0.332 mm/ sec at frequency 4 Hz. According to the BAPEDAL standard, the limit of vibration levels at frequency 4 Hz must be less than 2 mm/s. Thus, the measured vibration levels along this corridor were very low compared to the standard, therefore it would not damage to the structures of buildings adjacent to the road.

5. CONCLUSION

Based on vibration monitoring study conducted on the road traffic activities along several main streets in Jakarta, following conclusions could be drawn:

1. The vibrations which were radiated by the road traffic activities along several main streets in Jakarta occurred in the low frequency region, where three dominant frequencies always appeared at the frequencies: 4 Hz, 8 Hz and 10 Hz.
2. The maximum vibration levels caused by road traffic activity along the corridor of MH. Thamrin St – Merdeka Barat St and Hayam Wuruk St were in the levels of 0.315 mm/sec to 0.332 mm/sec at frequency 4 Hz. According to the BAPEDAL standard, the limit of vibration levels at frequency 4 Hz must be less than 2 mm/s. Thus, the measured vibration levels along this corridor were very low compared to the standard, therefore it would not damage to the structures of buildings adjacent to the road.
3. There is a positive correlation between traffic volume and vibration levels, where the denser of traffic volume created more vibrations on the structure of roads.

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