Traffic noise control in SMAN 5 Surabaya

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Abstract. The development of transportation technology is now very rapidly with increasing of number vehicles that causes a traffic jam. The location nears a crowded highway that causes a noise pollution in SMAN 5 Surabaya. Based on noise standards of Minister of Environment of Indonesia (KEP-48/MENLH/11/1996), the permitted sound pressure level in educational environments is 55 dBA. The SPL in the environment of SMAN 5 Surabaya is 87 dBA. It is necessary to design noise barrier to reduce noise. To decrease the noise level 32 dBA, it can use noise barrier with 12 m height. The most effective method is using Maekawa based on direct calculations. This method is more accurate. The other methods used in this research are graph method, double screen and Nomograph. The best material of noise barrier planning is steel with thickness 1.25 mm that decrease noise about 32.32 dBA.

1. Introduction

Recently, the main problem on the street is noise which caused by traffic jam. Traffic noise is the second biggest environmental problem according to WHO after air pollution and it is affecting health the most [1]. Traffic noise arises from vehicle engine (engine operation, exhaust or exhaust system). This noise can be heard up to several meters from the source of noise [2]. Frequency of this traffic noise has the same range of frequencies audible to humans, but it can impair human comfort. Traffic noise is very disturbing to the human comfort who lives near the highway. It is very disturbing not only the human comfort who lives the highway but also human activities such as such as in the office environment, hospital environment, trade and service environment, and educational environment [1]. In this case, the authors will examine the control of noise levels due to traffic to the educational environment in SMAN 5 Surabaya. Based on the traffic noise data, it can be known the noise level in the environment and evaluate the standard of noise level for the educational environment according to the regional allocation based on the Decree of Minister of Environment No. 48 / MENLH / 1996. November 25, 1996. It designs to reduce traffic noise as well as providing recommendations of some appropriate Noise Barriers.

2. Research Methodology

2.1. Noise

Noise Level of traffic can be described with graph of L_{eq} value. L_{eq} (Equivalent Continuous Noise Level) is a specific noise value from fickle noise (fluctuating in certain time equal with steady noise level) in the same time. L_{eq} is measured directly by integrated sound pressure level. L_{eq} is the level of energy average from some sound level Varian. It is not direct interference measurement. L_{eq} can be

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calculated using equation 1 [3].

$$Leq = 10 \log \left( \frac{1}{T} \sum t_{i} 10^{rac{L_{i}}{10}} \right)$$  \hspace{1cm} (1)

With $t_{i}$ as Length of time with noise $L_{i}$ and $T$ as $\sum t_{i} = t_{1} + t_{2} + t_{3} + \ldots$. To determine $Leq$ from ($L_{day}$ = Noise level in the noon) can be calculated from the equation 2 and equation 3 using ($L_{night}$ = Noise level in the night). To know the noise, exceed of noise level or not, we must determine the value of $L_{dn}$ from measurement of field data. $L_{dn}$ is calculated with equation 4.

$$L_{day} = 10 \log \frac{1}{16} \{T1 \cdot 10^{0.1L1} + \ldots + T4 \cdot 10^{0.1L4}\}$$  \hspace{1cm} (2)

$$L_{night} = 10 \log \frac{1}{8} \{T5 \cdot 10^{0.1L5} + \ldots + T7 \cdot 10^{0.1L7}\}$$  \hspace{1cm} (3)

$$L_{dn} = 10 \log \frac{1}{24} \{16 \cdot 10^{0.1L_{day}} + 8 \cdot 10^{0.1(L_{night}+5)}\}$$  \hspace{1cm} (4)

2.2. Noise standard

The Indonesian Government through of the Environment Minister Decree No: 48/ MELNH/ XI/ 1996 contains noise level limit criteria in residence and educational area which have maximum noise less than 55 dBA [4].

2.3. Noise barrier.

Noise Barrier is a barrier wall or partition used to control airborne noise transmissions, where the wall is located between the source and the receiver. The function of Noise Barrier is to provide a shadow zone or area where it has a quieter noise at the receiver [3].

2.3.1. Maekawa method.

Maekawa method is used to reduce sound pressure level using noise barrier. Maekawa method usually uses graph method. In this method, we can determine the reduction of sound pressure level which depend on sound frequency and distance between source to barrier. In single screen barrier, path length difference can be determined from equation 5. Equation 6 shows double screen barrier [5].

$$\delta = A + B - d$$  \hspace{1cm} (5)

$$\delta = \left[ \left( d_{ss} + d_{sr} + e \right)^{2} + a^{2} \right]^{\frac{1}{2}} - d$$  \hspace{1cm} (6)

Where, $\delta$ as path length difference (m), $d_{ss}$ distance from source to the first tip barrier(m), $d_{sr}$ as distance from the second tip to receiver(m), $a$ as distance between two barriers (m), $e$ is distance between barrier(m) and $d$ distance between source of noise and receiver(m).

Noise Reduction (NR) is the different value of sound pressure level from source to receiver. The equation of noise reduction is shown in equation 7. NR is noise reduction(dB), SPL$_{1}$ as sound pressure level of source(dB), and SPL$_{2}$ as sound pressure level of receiver(dB). It can be calculated using equation 8 which assumed after value of path length difference is obtained. With $B$ is barrier attenuation (dBA), $\delta$ is path length difference (m), and $\lambda$ is wave length.

$$NR = SPL_{1} - SPL_{2}$$  \hspace{1cm} (7)
\[ B = 10 \log \left( 3 + \frac{400 \delta}{\lambda} \right) \]  

(8)

2.3.2. Nomograph method. Nomograph method is used to determine the attenuation value on noise barrier using graph of Nomograph. We must know about barrier break, barrier position value, source noise with receiver and angle subtended.

2.3.3. Graph method. Graph method is one of method used to determine of attenuation on noise barrier. This method used of Fresnel Number for finding noise barrier. Fresnel number is obtained by calculating of Path Length Difference as similar with Maekawa method. Equation 9 show of Fresnel Number. We can describe of \( N \) as Fresnel Number.

\[ N = \frac{2\delta}{\lambda} \]  

(9)

2.4. Object measurement

The object measurement in this research is SMAN 5 Surabaya. This area is in the center traffic of Surabaya city near Kusumabangsa Street and Ambengan Street. The measurement was conducted on two measurement points. The first point (measurement point 1, ●) is placed on 10.5 meters from Kusumabangsa Street and the second point (measurement point 2, ○) on 6.5 meters from Ambengan Street. The position of measurement point in SMAN 5 Surabaya is shown in figure 2, 3, and 4.

Figure 1. The location of SMAN 5 Surabaya on Google Map.

Figure 2. The layout and position of all of measurement points.

Figure 3. The position of first measurement point.

Figure 4. The position of second measurement point.
3. Data Analysis

3.1. Data measurement of environmental noise
Noise data measurement of the first measurement point which located near Kusumabangsa street is taken every hour on 12.00 am – 09.00 pm (Indonesia Time Zone). From the data calculation of $L_{eq}$, it can be determined the value of noise level in the noon ($L_{day}$), noise level in the night ($L_{night}$), and average noise day night ($L_{dn}$) using equation 2, 3, and 4. The value of $L_{day}$ is 84.31 dBA, $L_{night}$ is 86.26 dBA and $L_{dn}$ is 87.96 dBA. Meanwhile, noise data measurement of the second measurement point which located near Ambengan Street is 71.22 dBA for $L_{day}$, 65.76 dBA for $L_{night}$ and $L_{dn}$ is 71.07 dBA.

Figure 5 shows the comparison of the value of $L_{eq}$ between Kusumabangsa Street and Ambengan Street on time domain. From the figure 5 we know that both of $L_{eq}$ between first and second measurement points are exceeding the standard from Minister of Environment.

![Figure 5. Measurement of $L_{eq}$ and Standard $L_{eq}$](image)

3.2. Noise Barrier Plan in SMAN 5 Surabaya
We will use the noise barrier planning several methods that will be applied in SMAN 5 Surabaya.

3.2.1. Maekawa method. From the Figure 6, we can design the noise barrier. The assumption of sound between source and receiver is same. The data of $c$ is 10.5 m, $c_1$ is 7.5 m, $c_2$ is 3 m, $f$ is 1000 Hz, $v$ is 340 m/s, and $\lambda$ is 0.34. So, using the equation 8, its design can reduce the noise about 32.76 dBA with the height of noise barrier about 12 meters. Meanwhile, different noise barrier design shown in Figure 7 can reduce noise about 21.19 dBA.

![Figure 6. Noise barrier design with the height with similar assumption.](image)

![Figure 7. Noise barrier design with the height of source and different receiver.](image)
3.2.2. Double Screen Method. It can reduce noise about 28,121 dBA shown in Figure 8 and table 1.

| Table 1. Design variation of height of different source and receiver |
|---------------------------------------------------------------|
| Var | \( h_S \) | \( h_R \) | \( x_1 \) | \( x_2 \) | \( h \) | \( a \) | \( b \) | \( c \) | \( NR \) |
|-----|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| 1   | 0.5   | 1.2   | 3     | 7.5   | 3     | 7.71  | 3.91  | 10.52 | 21.19 |
| 2   | 0.5   | 1.2   | 3     | 7.5   | 6     | 8.91  | 6.27  | 10.52 | 27.40 |
| 3   | 0.5   | 1.2   | 3     | 7.5   | 12    | 13.15 | 11.89 | 10.52 | 32.33 |
| 4   | 0.5   | 1.2   | 2     | 8.5   | 3     | 8.69  | 3.20  | 10.52 | 22.14 |
| 5   | 0.5   | 1.2   | 4.5   | 6.5   | 3     | 6.26  | 5.15  | 10.52 | 20.32 |

3.2.3. Graph Method. This method can determine the barrier attenuation used Fresnel Number from equation 9. The design of noise barrier with graph method is shown in Figure 9.

![Figure 8. Design of Noise Double Screen Barrier.](image)

![Figure 9. Design of Noise Barrier with graph method.](image)

3.2.4. Nomograph Method. It can be determined by \( x \) is barrier position about 3.1594 m and \( t \) is barrier break about 2.295 m. Length of gate SMAN 5 Surabaya in Kusumabangsa street is 154 m. Measurement point is 7.5 m and measurement angle is 166.2° look at picture 12. After the data is plotted in Nomograph form, we can get attenuation barrier value about 12.8 m (see the table 2).

| Table 2. Barrier attenuation based on frequency |
|-----------------------------------------------|
| \( f \) (Hz) | \( \lambda \) (m) | \( N \) | \( A \) (dBA) |
|---------|--------|------|--------|
| 125     | 2.72   | 0.805| 11.5   |
| 250     | 1.36   | 1.61 | 14     |
| 500     | 0.68   | 3.221| 16     |
| 1000    | 0.34   | 6.441| 20.3   |
| 2000    | 0.17   | 12.882| 24.8  |
| 4000    | 0.085  | 25.77| 26.4   |

![Figure 10. Noise graph in Nomograph method.](image)

![Figure 11. Angle Subtended.](image)

4. Discussion

Based on measurement data of the noise near Kusumabangsa street, the highest \( L_{eq} \) value in 00.00-01.00 is 90.42 dBA. It is caused by vehicle which through the street like truck, motorcycle, etc. In the night driver got the height speed than day because decrease volume of vehicle. So, it caused noise. Meanwhile in the noon at 14.00-15.00, it happened the lowest noise. In the other hand, on Ambengan street got the highest noise at 12.00-13.00 about 73.32 dBA. At this time, learning
activities were occurring and many classrooms were located near Ambengan street. Absolutely, it can disturb the student concentration. This area doesn’t obey the noise standard from MENLH No.48 /MENLH/11 /1996 which gave the maximum value of noise about 55 dB.

Design plan is using Maekawa method with some treatments such as change the height of noise barrier, position or distance of noise barrier with source of noise (Source) and with receiver. Based on the calculation of data, this method can reduce noise up to 32 dB at the height of 12-meter barrier noise. In the other variations, if the distance of the noise barrier shifted 1 meter near the noise source will increase the noise attenuation by 0.945 dB. When the noise barrier shifted 1 meter away from the noise barrier, it will reduce the noise damping by 0.881 dB. This is matching with the Maekawa method, which the higher the noise barrier will dampen the sound greater.

Design plan used the double screen method which the height of the main barrier is fixed as high as 3 meters and added the height variation and the distance position on the screen barrier. The design results made at the height of the screen barrier 5 meters and positioned 1 meter from the classroom wall which noise will reduce of 28.121 dBA. If the high screen barrier made 3 meters with the same position, it will reduce noise by 26.219 dBA. If the high screen barrier made 5 meters with a position of 2 meters from the class wall, it will dampen the noise of 27.325 dBA. Thus, the screen barrier is influenced by the height and position placement.

Design used the Nomograph method have results that the biggest noise reduction is at the height of the noise barrier 6 meters is 13.8 dBA. The lowest is 12 dB at the height of noise barrier 3. Noise reduction (NR) obtained with this method is not too large because the scale of attenuation barrier on graph maximum up to 20 dB. This method is not effective to apply for this case study for the graph method obtained attenuation barrier at each frequency. However, high accuracy is needed in the determination of attenuation on the graph because the scale on the Fresnel Number is not the same for each range of values. So, it is very difficult to get the right attenuation of the barrier.

All the methods have tried in designing the noise barrier. The most effective method of noise control in SMAN 5 Surabaya is the Maekawa method because this method obtained the NR value based on the direct calculation so that the value is more accurate. Basically, the design of the most emphasized noise barrier is the high barrier, position or distance barrier with the source noise and receiver, and the noise barrier material itself. The higher and closer the noise barrier distance with the noise source will produce a large NR. The noise barrier material should be selected that has a high density so that it can reduce the noise is greater but also pay attention to the artistic aspect of the noise barrier. While the best material in the design of noise barrier is Steel material with noise attenuation of 32.32 dBA at layer thickness 1.25 mm.

5. Conclusion

Based on theoretical and experimental results, it can be concluded several things: Lsm value near kusuma bangsa street is 87.96 dBA whereas near ambengan street is 71.07 dBA. It is too higher noise and not fullfil of standart value MENLH. The area of SMAN 5 Surabaya need noise barrier plan to reduce the noisethat caused by traffic. The effective plan is used the Maekawa method with the height of noise barrier 12 m that can decrease the noise (NR) about 32.76 dBA. The best material of noise barrier plan is steel with thickness 1.25 mm that decrease noise about 32.32 dBA.

6. References

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