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Evaluation the Best Distance between Noise Generation and Receptor for A Noise Barrier Construction around an Expressway in Malaysia

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ABSTRACT

Nowadays, the development of human society and increase the number of industrial equipment cause to raise negative impact of air and water such as air pollution, noise impurity, water contamination and so on. Noise is generally defined as an unwanted sound or set of sounds. Noise pollution has always been a problem, but nowadays it has become a major problem. Different modes of public transit and also industrial factories lead to noise impurity. This article was carried out to select the optimum distance for a noise barrier between a residential area and an expressway in Malaysia. The data was collected during peak and off-peak time for a day. Studied parameters included the area, distance, and volume of traffic. The results show that based on Wesler Traces method can determine best position of noise barrier between these two areas.

Keywords: barrier, impurity, noise, residential area, Wesler Traces.

INTRODUCTION

Due to planning and operation of transportation facilities, mitigation of environmental impacts is a significant purpose. In this case, there are two kinds of classification impact includes primarily occur at the system and primarily apply to individual facilities. Mitigation of environmental can be measured in different ways such as facilities design adjustment, modification to the operation of system, and construction of artificial habitats. Some important factors which have affected at the environment consist of storm water, noise, soil contamination, infringement on natural habit, air pollution and so on. In this article, noise effect was considered at the environment.

Noise

Sound is produced by any mechanical movement and is propagated as a motion wave through the air or any other material. Therefore, sound is defined by its mechanical energy and is measured in energy-related units. Sound pressure level is expressed in decibel units (*dB*) on a logarithmic scale [1]. Noise annoyance is a feeling of displeasure nuisance, disturbance, or irritation, which has a negative effect on an individual or a group of individuals [2]. Sound evokes physiological signals in the auditory system constituted by the ear and the auditory pathways. However, some sounds do not evoke those signals as they are out of the auditory perception range in humans, which theoretically ranges from 20 to 20,000 *Hz*. [1]. Noise effects include various impacts on mental and physical health and disturbance of daily activities (may affect sleep, conversation, lead to perception of annoyance, cause hearing loss, cardiovascular problems as well as affect task performance) [3].

The most important noise sources are road traffic, aircraft, railways and industries, noise in the community from industrial and construction site and noise at home [4]. But, they generally depend on our activity, location, and the time of day. In this article, noise generation comprises vehicles such as lorry, van, car, motorcycle and receptor are includes residential area which was near to the expressway.

Transportation divided into public and private vehicle. The most resource of noise in this factor is engine and exhaust of vehicle. Similarly, tire of vehicle is other factor for production of noise.

The effect of noise on whole communities rather than individuals or relatively small groups can have repercussion as change in form of community live. A high fraction of citizens are exposed to high levels of road traffic noise in and around their homes. Population starts to migrate out of cities, people prefer to live in a quiet and safety environment. However, traffic noise starts to affect property values and community atmosphere [4].

For decreasing level of noise, there are different methods such as relocation of some facilities, design facilities at the best area, decrease level of noise at the resource (use of mufflers to decrease engine and exhaust noise), isolation at the receptor to reduce tire noise with covering of some pavement such as open-graded asphalt

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concrete (OGAC), construction of barrier around the highway or freeway which are near to the residential area or other places.

When discussing about reducing noise, we must begin to conduct a risk assessment. This may involve carrying out noise measurements. The first impulse can be eliminated by the source of noise where possible, in sensitive areas such as hospital areas, kindergarten/school. In these areas, the exposure to noise is more dangerous. Reducing people exposure by restriction of access of vehicles in these specific areas is an inexpensive measure [4].

Noise measurement

For calculation of noise level, there are two methods. First, measuring single noise at transportation area and second noise in certain places which have generated two or more noise resources such as private vehicle, truck and so on. For the first time, these two methods were explained, then, one of these methods can be used in this article.

Individual noise

According to this method, there is only one level of noise. Generally, unit of noise for calculation is decibel (*dB*) which has related with sound pressure as follows:

$$dB\,(A) = 20 \log \left(\frac{P}{P0}\right) \qquad (1)$$

In this equation, P is the frequency of the sound and P_0 is standard reference pressure which is 20 N/m^2. Generally, many single sounds can be measured in average with this equation. After this step, level of individual noise is determined with equivalent level of noise L_{eq} as follows:

$$L_{eq} = 10 \log \sum_i Pi \;\; antilog \; \frac{Li}{10} \qquad (2)$$

In this equation L_i is level of noise pressure *dB (A)* and P_i is percentage of the noise pressure time in the interval L_i.

To combine more than one sound

This method will use at the some places which have two kind of sound resources or more. For example, noise production with private car and truck vehicle are combining the sound. In this method, there are various steps for calculation level of sound at the different area. Based on this method, the procedure of sound calculation can be used as figure (1). According to this method, level of noise will be calculated for different distance of highway center line.

In this article, the significant purpose was calculating noise barrier around one of the expressways near residential area in Malaysia. Therefore, for the first time, level of sound without barrier was calculated. After that, wall barrier was designed according to Fresnel equation.

The proper noise for human being

Appropriate noises for human being have a variety range. For instance, personal car with 60 km per hour (km/hr) has a special noise which is about 65 *dB(A)* until 20 meters, similarly, this range is about 85 *dB(A)* for diesel truck with 50 km per hour until 20 meters, whereas, normal conversation is about 70 *dB(A)*, a pneumatic drill or some train are approximately 80 *dB(A)*, and some aircraft have a noise equivalent to 120 *dB(A)*. If sound exceed to 70 *dB(A)*, it will be annoyed for human who are near the sound. Therefore, sound should be decreased or controlled in few places that are near to the residential area or other places such as hospital, kindergarten and so on.

Noise calculation without barrier

The significant purpose was finding the optimum distance between expressway and noise barrier for mitigation of annoyance sound for residential area or other places. Therefore, first step for this procedure is calculating of noise for expressway based on number of vehicle and distance from center of carriageway until residential area. In this case, there is an empirical equation based on mathematical formulation which is Wesler Traces as follow:

$$L50 = 57.68 + 8.5 \log V - 20 \log D \qquad (3)$$

Where V is volume of traffic in veh/hr and D is distance from center of carriageway (m). For determination number of vehicle at the expressway, time was divided into two parts includes peak time which is between 7:00 am until 10:00 am and off-peak time which was determined from 7:00 pm to 10:00 pm. During peak time, the number of vehicle which was passed from expressway was about 3500veh/hr and for off-peak time it was around 3000 veh/hr. For equation (3), it must be taken from the average between these two volumes. Therefore, number of vehicles in this expressway was 3250 veh/hr. other item is distance from center of carriageway until residential area which divided into each 5 meter interval. According to these data, level of noise between residential area and expressway was determined.

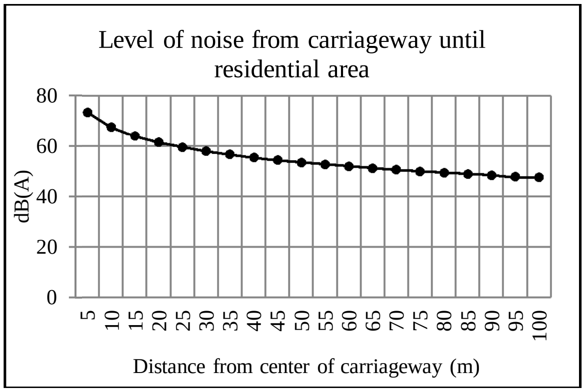

Fig. 1. The relation between distance and level of sound

This graph indicates level of noise from centre line of the highway from 5m until 120m. In 5m from centre of carriageway, level of noise was approximately 73.55 *dB*. After that, level of noise was reduced between 70*dB* until about 60dB from 10m of centre line at the expressway until 25m. It was decreasing slowly about 10 dB from 30m until 85m for level of noise whereas nearly 48.94 dB in 85m and it was about 47*dB* in 100m. In this graph, it can be seen that there is an indirect relevant between noise (*dB*) and distance (m) from the source of the noise.

Level of noise which is suitable for human being is about 60 *dB* until 90 *dB*. As a result of calculating noise for residential building, noise must be decreased less than 60*dB*. For this reason, barrier should be used between resources of noise and receptor at residential area. There are different kinds of barrier such as earth barrier and wall constructed which construct of concrete, wood, metal and some polymer. In this article, author wants to design a barrier for reducing level of noise which was produced from expressway. The best mechanism for design a barrier is Fresnel method that was used for this action.

$$\Delta=5*(1+0.6\varepsilon) + 20 \log \frac{\sqrt{2*\pi*|N|}}{\tan\sqrt{2*\pi*|N|}} \qquad \text{for} \qquad (-0.1916-0.065\,\varepsilon) \le N \le 0 \qquad (4)$$

$$\Delta=5*(1+0.6\varepsilon) + 20 \log \frac{\sqrt{2*\pi*N}}{\tanh\sqrt{2*\pi*N}} \qquad \text{for} \qquad 0 \le N \le 5.03 \qquad (5)$$

Where ε =0 for design a wall barrier and ε =1 other items. Also, Δ is level of noise that after computing will become decrease and N will calculate by the following.

In this article, it was assumed that residential area is about 30 m from carriageway center line. On the other hand, in this area, the height of sound originates for carriageway and receptor for residential building are approximately 2.4 m. At the following, the position of these two areas was shown in figure (2).

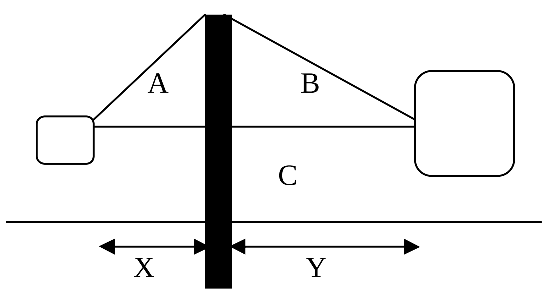

Fig. 2. Section of noise generation and receptor

According to figure (2), it was calculated the best position of barrier between noise generation and residential building. At the beginning of noise calculating, it was assumed that the height of noise barrier was about 5 meters. On the other hand, the position of barrier was 5 meters from carriageway center line and it should also be continued each 2.5 meter until receptor due to finding the best distance between these two cases.

$$A = \sqrt{5^2 + (5-2.4)^2} = 5.64$$

$$B = \sqrt{25^2 + (5-2.4)^2} = 25.13$$

$$C = 30$$

$\delta = A+B-C$ ➔ $5.64+25.13-30=0.77$

Assume $\lambda=0.6$ $N=\frac{2*\delta}{\lambda}$ ➔ $N=2.57$

$$\Delta=5*(1+0.6\varepsilon) + 20 \log \frac{\sqrt{2*\pi*N}}{\tanh\sqrt{2*\pi*N}} \quad \text{for} \quad 0 \le N \le 5.03$$

$\Delta= 17.08\ dB$

After noise computation, some properties of a noise barrier were found. Based on this calculation, a noise barrier with 5 meters heights and 5 meters from expressway center line could decrease 17.08 *dB* of noise for residential area. Therefore, this calculation continued each 2.5m until receptor. On the other hand, the height of barrier was 5m in all distance. After calculation in seven point, from 5 m until 20m each 2.5m to receptor, level of declining noise is based on following table(1):

Table1. Calculation of noise barrier

Distance	Height	A	B	C	δ	λ	N	Δ
5	5	5.64	25.13	30	0.77	0.6	2.57	17.08
7.5	5	7.94	22.65	30	0.59	0.6	1.96	15.90
10	5	10.33	20.17	30	0.50	0.6	1.67	15.20
12.5	5	12.77	17.69	30	0.46	0.6	1.53	14.83
15	5	15.22	15.22	30	0.45	0.6	1.49	14.71
17.5	5	17.69	12.77	30	0.46	0.6	1.53	14.83
20	5	20.17	10.33	30	0.50	0.6	1.67	15.20
22.5	5	22.65	7.94	30	0.59	0.6	1.96	15.90
25	5	25.13	5.64	30	0.77	0.6	2.57	17.08
27.5	5	27.62	3.61	30	1.23	0.6	4.10	19.11
30	5	30.11	2.60	30	2.71	0.6	9.04	22.54

In this table, N is the Fresnel number and Δ is level of noise which can be decreased after construction of noise barrier. Based on this table, there were not much different for decreasing of noise annoyance at the different position of noise barrier from carriageway until receptor. For the best understanding of this calculation, following graph shows the ranking of noise for different places of barrier.

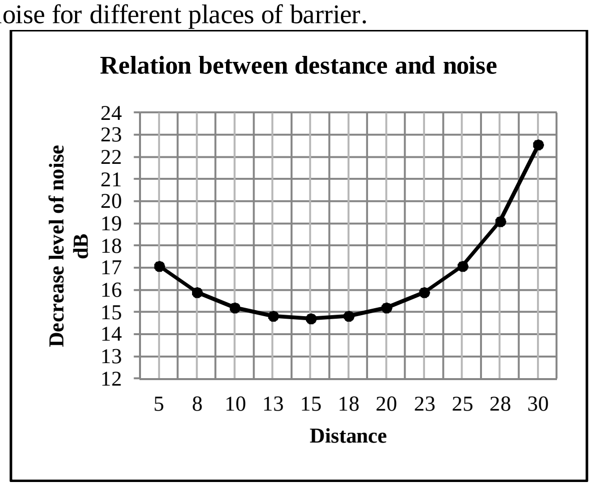

Fig. 3. The relation between distance and level of noise

In this graph, it can be seen that the relation between level of noise from center carriageway until residential area after construction a barrier. There was an exponential decline for noise which is between 17.08 *dB* until approximately 14.71 *dB* from 5m of center expressway until 15m. Then, noise barrier leads to the decrease of noise level about 14.83 *dB* at the 17.50 meters from expressway. Similarly, this range of noise was declined about 22.54 dB for a barrier which was constructed at the 30 meters from expressway. The highest level of noise which was declined about 22.54 *dB* at the final position of barrier. It means, with construction a barrier at the 30 meter of expressway, level of noise was fall down about 22.54 *dB* until lodging area. Other important point in this graph is 15m after carriageway. From 5 meters until 15 meters, there was a downward trend from about 17.08 *dB* to approximately 14.71 *dB*, but after that, it was started to an upward trend until around 22.54 *dB*. According to this graph, the best place for construction a noise barrier is from 7.50 *m* to 10 *m* from center of carriageway. But, this position of noise barrier was at the site plan of expressway; therefore, it cannot be constructed. Another place for noise barrier, base on this graph was from 12.50 *m* until 20m from carriageway center line. But, it has a kind of visual intrusion. Because, those places were near the residential area and cause to produce some problem for people such as air circulation, sun light ray, decline of landscape and so on. Therefore, those areas should be eliminated for construction of noise barrier. Base on figure (1), level of noise at the 20 m from expressway was more than 60*dB* and cause to problem for people who live at the residential building, thus, the best position for noise barrier was about 15 m from expressway, and it can be declined about 14 *dB* of noise. Base on Figure (1), level of noise annoying was exceeded of 10 *dB* for residential area, but noise barrier caused to decrease more than this range. Thus, the height of barrier should be declined.

Conclusion

In this article, it could be considered to a noise barrier construction around an expressway in Malaysia. For the first time, it is considered as noise along this carriageway without any barrier. Then, we found out that noise is unsuitable for residential area and it should be controlled about 10 *dB*. The best way for decreasing of noise was constructing a noise barrier around this expressway. Therefore, a barrier with 5*m* height with different distance of highway center line was chosen. After calculation of noise, the best position for barrier was found which was approximately 15 *m* from carriageway center line. But, noise was declined more than 10 *dB*, therefore, the height of barrier should be decreased.

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