



Japanese experience to reduce road traffic noise by barriers with noise reducing devices

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Summary

The history of development for novel designed noise barriers in Japan is described. These are called edge modified noise barriers which have noise reducing devices at the top position of the barriers. This kind of barriers has been developed since 1980's. The application to road traffic noise and the noise reducing abilities are shown. Finally recent new types of barriers are present. PACS no. 43.50.Gf

1. Introduction

Japan has a long experience on fighting against noise at around highways since 1970's. The first stage was 1965 when Japan's first Expressway was constructed and opened to traffic. It is called Meishin Expressway which is an intercity road with a speed limit of 100 km/h at maximum and connects major cities of Kobe and Nagoya. The second stage was 1969 when the second intercity road called Tomei Expressway which connects Tokyo and Nagoya was in operation. Since there was no consideration to traffic noise control at the stage of road designing, extremely high noise must be observed at the vicinity of expressways. Residents living around expressways could not endure the noise from running vehicles with high speed and they made claims to expressway company. Then, road traffic noise became a social interest known as one of the serious pollution problems.

For the treatment of noise problems, concrete panel fence was applied to the roads as noise control measure. It is denoted as noise barrier nowadays and it blocks direct sounds from road vehicles. Since, concrete panels are very heavy, the application was limited to earthwork structure, such as flat road, bank road and cut road. Due to the requirement of road structures such as viaduct or bridge road, light weight noise barrier was required.

In 1975, JH (Japan Highway Public Corporation, which was renamed as NEXCO [Nippon Expressway Company Limited] in 2005) developed a panel with light weight and having absorptive treatment on the panel surface. It is called "Toh-itsu-gata" or standard metallic absorptive panel, which has acoustical specification to absorption coefficient and sound transmission loss. This panel has been widely applied to national highways as noise control measure up to now.

During the 1980's, Japan's gross number of motor vehicles rapidly increased with a rate of 2 million vehicles/year and the road traffic noise levels often exceed the national standard for noise. As a noise abatement measure, very tall barriers with a height up to 8m were designed to new expressways. Since tall barrier has secondary problem such as land scape obstruction and sunshine blocking, novel designed barriers were required.

One idea was proposed by Prof. Fujiwara [1]. His idea was to mount an absorptive material on the top of a barrier. Knowing this idea, JH began to promote the technical development of this type of noise barriers.

In 1990's, Japanese government held a competition for novel designed barriers in order to encourage industrial companies to develop new barrier with high performance. More than 10 products were registered. However one or two were selected as excellent products. In this period, research and development investment increased and many research projects started both in academic society and industrial company.

After the year of 2000, various type of noise reducing devices were developed and some of the products were installed at the actual road. After that, research and development projects gradually decreased in the late 2000's.

In this paper the author would like to describe the Japanese experience to control road traffic noise by barriers with noise reducing device at the top edge.

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2. Noise barriers

2.1 Standard absorptive panel in 1975

Absorptive panel for noise barrier was developed by JH in 1975. The panel is a melic box with slits and has absorptive material (glass fiber) of 50 mm thickness inside the box as shown in Fig.1. For the acoustical specification, the absorption coefficient should be greater than 0.7 for 400 Hz and 0.8 for 1000 Hz, respectively. The transmission loss should be greater than 25dB for 400 Hz and 30 dB for 1000 Hz.



Fig. 1 Standard panel (JH)



Fig. 2 Photo of standard panel (JH)

This standard metalic absorptive panel has been the most populer one up to now and installed as noise barrier at almost all of the roads in Japan (see Fig.2). The most common barrier height is 3 m.

2.2 Background of research for edge modified barrier in 1980's

From 1970's to 2000's, the number of road vehicles increased greately and road traffic noise problem became more serious than before. Since

barrier with a height of 3m is not sufficient to satisfy the environmental standard for noise, tall barriers with a height of 5-8m height are required by adding panels on the top. However, this solution is not necessarily acceptable because the added height may cause a secondary problem such as reduced sunshine for the residents around expressways. Furthermore it may cost a great deal because the footings may need to be renewed to support the height addition to the walls. Considering cost efficiency benefits in reducing noise, efforts have been made to develop new noise reducing devices which are applied to the top of existing noise barriers.

2.3 Research and development for edge modified barriers in 1980's

In 1976, K. Fujiwara [1] found that additional sound reduction is obtained when an absorptive material is put on the top edge of a barrier. The sketch of his idea is shown in Fig. 3. He proposed a barrier with absorptive cylinder of 0.5m diameter mounted on the top edge as a novel designed barrier.



Fig.3 Fujiwara's idea to reduce noise

Several years later in 1980, D. N. May et al. [2] carried out scale model experiments and found additional attenuation of less than 4dB for T-shaped, Y-shaped and arrow shaped barriers in

cross sectional view. In 1991, D.C. Hothersall [3] conducted numerical simulation based on BEM for these special type barriers and obtained a couple of dBs due to the shape change at the top. The sketch of these barriers in cross sectional view is shown in Fig.4.



Fig.4 A sketch of early idea of edge modified barriers

Based on Fujiwara's idea, a trial product of absorptive cylinder was manufactured by JH. The efficiency of this cylinder with 0.5 m diameter was tested at a real expressway with a barrier of 3.0m height [4]. The level difference in A-weighted sound pressure level between before and after the mounting was measured. The measurements were made for one night each. Figure 5 shows the cross sectional distribution of the level difference with and without the cylinder. One can see that the additional noise attenuation of 2dB is obtained at a distance of less than 15m from the barrier.



Fig.5 Cross sectional distribution of level differences with and without absorptive cylinder.

In general, the effect of noise barrier is fluctuated by the traffic flows and meteorological condition. In order to check the fluctuation of noise attenuation by the cylinder, long term measurements (7 nights each) were performed. Figure 6 shows the average $L_{Aeq, 10min.}$ and the standard deviation. The reduction of 2dB is observed at 6.6m from the barrier, but no reduction is obtained at 30m.



Fig.6 Results for 7 nights before and after the installation of the absorptive cylinder.

2.4 Barriers in 1990's

(1) Mushroom type

From an aesthetic point of view, barriers or walls are unwanted by both drivers and inhabitants. Therefore, it is important not only to reduce the noise but also to mitigate the visual impact of barriers. Next developed is a device similar to the absorptive cylinder, but the shape is modified to be well-formed, that is Mushroom type. The cylinder type and the mushroom type are compared in Fig.7. The photos at a real expressway are shown in Fig.8. It is shown that the visual impression is rather good in comparison with Cylinder type.



Fig. 7 Cylinder type and Mushroom type.



Fig.8 Photo of Mushroom type at real highway

An acoustical test on noise reduction was carried out at a viaduct with a barrier of 3 m height [5]. The insertion loss of the Mushroom type was observed and almost the same results were obtained as that of the absorptive cylinder. Figure 9 shows the insertion loss vs. time of day. It is shown 2dB reduction is obtained both at the distance of 5m and 20m from the barrier.

Figure 10 shows the insertion loss of 1/1 octave band frequency (7 nights average) at the distance of 5 m from the viaduct. The insertion loss increases as frequency increases.



Fig.9 Insertion loss (7 nights average) vs. time



Fig.10 Insertion loss of 1/1 octave band frequency at 5 m from the road (7 nights average)

Our next interest focused on the usage of the empty space inside the noise reducing device. Can we make use of the inside space of the Mushroom for something? The answer was a surprising one. The idea was to put soil and water into the space and raise plant at the opening of the top position. This means we make the noise reducing device to be a planting box. The design is shown in Fig.11. The photo of the trial product for acoustical test is shown in Fig.12. The test results showed that the Mushroom type planting box had the same noise reducing ability as the original one [6]. However, due to the maintenance problem such as trimming and water feeding, the planting box type was not adopted to actual expressways.



Fig.11 Mushroom type with the ability of planting box.



Fig.12 Photo of Mushroom as planting box.

(2) Competition of research and development

In 1993, Japanese government held a competition for novel designed noise barrier with greater performance of noise reduction ability. In this case, barrier height was limited to 3m. More than 10 manufactures made entry in the competition, but most of them developed the absorption treatment on the surface of the barrier. Only a few participants developed noise reducing device which apply to the barrier top edge. They worked on its shape, size and absorption treatment. Unfortunately, there was no effective barrier other than barrier with Mushroom or Cylinder type. The competition ended in failure.

On the other hand, researchers developed next novel barriers with non-absorptive materials on the

top. The idea was to realize acoustical soft surface at the top edge, i.e., to use acoustical tube with a length of a 1/4 wave length. Another idea was to realize a barrier with multiple diffraction edges on the top. Figure 13 shows some examples published in 1995 [7] and 1996 [8-9].

There is another type of device which is called interference type [10-11]. It has been applied to noise barriers of Shinkansen Superexpress Railway. In application to road traffic noise G. R. Watts [12] tested the performance at TRL's noise barrier test facility with the device attached to a 3 m high metal barrier. It was shown the performance was less than 2 dB.



Fig.13 Barriers without absorptive treatment on the top edge published in Japanese. Type (a) and (b) are published in English [7], [8].

2.5 Commercial products after 2000's

From the late 1990's, Japanese industries started research works to develop good quality noise

barriers. Examples of edge-modified barriers marketed in Japan are shown in Fig.14 [13]. There are so many types of edge modified barriers developed by industries. The first four barriers (ad) are absorptive types which have the same concept as Fujiwara's findings. Among these, the device (a) is known as Mushroom type that we have already seen. The second five barriers (e-i) are interference or multi-edge types which have multi diffraction edges. The third two barriers (j-k) are resonance types which have acoustical tube with 1/4 wave length in depth. The last one is an Active Noise Control type which has microphones and loud speakers to control the sound pressure at the edge position.

Most of the noise reducing devices is not used nowadays, but some devices are often applied to expressways. In particular Type (a), (g), (h) and (i) are popular now. Photos of representative barriers with noise reducing device are shown in Figs. 15-17.



Fig.15 Mushroom type (NEXCO)



Fig. 14 Examples of edge-modified barriers marketed in Japan (Okubo 2008). Cross sectional views with approximate dimensions in mm. Absorption type (a-d), interference or multi-edge type (e-i), resonance type (j-k) and ANC type (l).



Fig.16 Interference or multi-edge type (NEXCO)



Fig.17 Resonance type (Nagoya Expressway Public Corporation.

3. Concluding remarks

From the 1980's to 2000's, much effort had been paid to develop various kinds of edge modified barriers. It has been seen that most of the devices with a width of around 500mm have the additional noise reduction of around 2dB. The size of the device is limited by the clearance limit for existing road. On the other hand, recent new expressway accepts large size device i.e., Type (g-h) in Fig.14. This is an advantage to design more various devices and have the possibility to obtain more noise reduction than small sized devices.

Unfortunately, research projects decrease recently. Required recently are barriers with cost performance, good looking, and other added values as well as noise reduction efficiencies.

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