ENVIRONMENTAL QUALITY STANDARDS AND DEVELOPMENT OF NOISE REDUCTION TECHNIQUE FOR SHINKANSEN RAILWAY

PACS REFERENCE: 43.50.Lj

ZENDA Yasuo; NAGAKURA Kiyoshi
Railway Technical Research Institute
2-8-38, Hikari-cho, Kokubunji-shi, Tokyo 185-8540 JAPAN
Tel: (81) 42-573-7353
Fax: (81) 42-573-7353
E-mail: zenda@rtri.or.jp; naga@rtri.or.jp

ABSTRACT
When Shinkansen was opened in 1964, its wayside noise caused a strong impact on environment preservation. Therefore, the Environment Agency issued environmental quality standards for Shinkansen Super-express railway noise in 1975. The values specified in decibels ($L_{pA,Smax}$) in these standards are 70dB or less mainly for residential areas and 75dB or less for other areas. Because the wayside noise level was nearly 80dB, the government required railway operators to temporarily achieve the so-called "75dB-countermeasure" in 1985. Since then, a number of noise reduction measures have been developed, including the bus line to eliminate the arc noise from pantographs, low noise pantograph and smooth surface car bodies to reduce aerodynamic noise. As a result, the wayside noise is now 75dB. This paper briefly introduces the environmental quality standards and government policies and describes the changes of Shinkansen noise by the development of noise reduction technique.

ENVIRONNMENTAL QUALITY STANDARDS

Environment Quality Standards for Shinkansen Noise

The Shinkansen railway whose speed exceeded 200km/h was opened in 1964. After that, its wayside noise caused a strong social demand for environmental preservation. Questionnaire surveys to wayside residents showed that the proportion of those who appealed some influence of Shinkansen noise was 30% when the noise was 70-75dB(A) in $L_{pA,Smax}$. Based on that result, The Environment Agency laid down the environment quality standards for Shinkansen noise in 1975 as shown in Table 1.

The values of the environmental quality standards are established for each category of area shown in the Table. Prefectural governors shall designate the category of area.

Table 1 Environmental Quality Standards for Shinkansen Noise

Category of area	Standards value (in dB)
Residential area	70 or less
Commercial and industrial area	75 or less

The environmental quality standards values referred to in Table 1 above are measured and evaluated by the following method.

(1) Measurement should be carried out by recording the peak noise level of each of 20 successive trains passing in either direction in principle.

(2) Measurement should be carried out outdoor and in principle at the height of 1.2 m above the ground, at the points that are considered to represent the Shinkansen railway noise levels in the area concerned, and those where the noise is posing a problem.

(3) Any period when there are special weather conditions or when it is deemed the speed of the trains is lower than normal shall be avoided in selecting a measurement time.

(4) The Shinkansen railway noise should be evaluated by the energy mean value of the higher half of the measured peak noise levels.

(5) The measuring instrument used shall be a noise meter with A-weighted calibration and slow dynamic response.

(6) The environmental quality standards shall apply to Shinkansen railway noise from 6 a.m. to 12 midnight.

Temporary 75 dB Countermeasures for Shinkansen Noise

With understanding and co-operation among nation, local public bodies and wayside residents, countermeasures for noise sources, sound insulation for houses, land plan along the wayside and so on are necessary to promote reducing Shinkansen noise. However, the function of these countermeasures was not always harmoniously effective. So, the government required railway operators to achieve the so-called "Temporary 75 dB Countermeasure" as shown in Table 2 to implement the standards. Those areas are selected based on the presence of wayside houses, and expanded from densely inhabited areas to less dense areas. On the other hand, the Hokuriku Shinkansen, which opened in 1997, was supposed to achieve 75 dB from the beginning of its operation in all areas except uninhabited areas.

Table 2 Temporary 75 dB countermeasures

Phase	Deadline	Areas for 75 dB countermeasures	
		Tokaido, Sanyo Shinkansen	Tohoku, Jyoetsu Shinkansen
1	March 31, 1994	Areas crowded with houses	Areas assembled with houses
2	March 31, 1997	Areas assembled with houses	Areas treated the same as area assembled with houses
3	March 31, 2003	Areas treated the same as area assembled with houses	Areas for location of houses except areas scattered with houses

Guidelines for the Conventional Railway Noise

Standards for the conventional railway noise were also considered when the standards for Shinkansen noise were established. But the adoption of standards was postponed because there were so many problems to be studied, such as the methods for evaluation of noise and influence on people who live near the railways.

In the 1990, since the noise problem of conventional lines became serious, the Environment Agency published the "Guidelines for Noise Measures with regard to Construction and/or Large-scale Improvement of conventional railways" in 1995. Guideline values desirable to be attained for the preservation of the living environment and for the prevention of noise issues beforehand are shown in Table 3.

Table 3 Guidelines of noise levels for conventional railways

Newly constructed railways	Day time (7-22) L_{Aeq} 60 dB(A) Night time (22-7) L_{Aeq} 55 dB(A)
Large-scale improvement of existing conventional railways	Status of noise exposure shall be improved, compared with that in the past

In these guidelines, unlike the evaluation of Shinkansen noise with the peak noise level, an equivalent continuous A-weighted sound pressure level is selected as an evaluation index, which reflects the recent trend of evaluation of noise. The measurement point is 12.5m horizontally distant from the center of a near side track, and the height of 1.2m above the ground.

TRANSITION OF SHINKANSEN NOISE

Countermeasures for Shinkansen Noise

Various countermeasures have been implemented to reduce the Shinkansen noise since its commercial operation. As a result, the noise level at the wayside of the Shinkansen has been changed dramatically. In this section, we introduce the advance of noise reduction technology and the transition of the Shinkansen noise. Here we call the noise level defined in the environmental quality standards for Shinkansen noise "the noise value" , which was calculated by using the "Prediction model of Shinkansen noise[1)]" under the conditions shown in Table 4.

Table 4 Conditions of calculation

Conditions		Tokaido Line	Sanyo Line
Structure	Type	Concrete bridge	Concrete bridge
	Height	8m	8m
Track		Ballast	Slab
Sound barrier	Type	Straight type	Straight type
	Height from R.L.	1.2m	2.0m

Figure 1 shows the transition of the noise value evaluated at a point at a distance of 25m away from the track (the point P_{25}) and the maximum train velocity on the Tokaido and Sanyo Lines. This Figure shows the advance of noise reduction

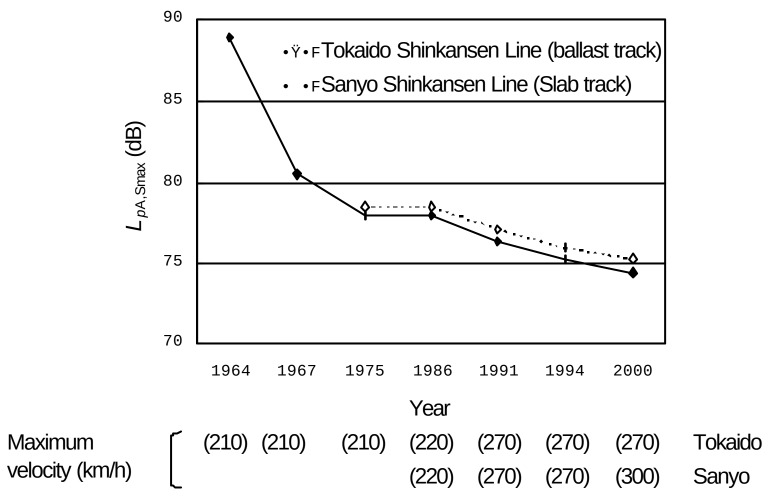

Figure 1 Transition of noise value and maximum train velocity on Shinkansen lines

technology that enabled speed-up of Shinkansen without increasing the noise value.

<u>Tokaido Shinkansen line</u>

When the Tokaido Shinkansen Line commenced operation in 1964, the noise value was about 90dB(A). The main component of Shinkansen noise at that time was rolling noise. In response to the urgent need to reduce the wayside noise, sound barriers were constructed along the track. This reduced the noise value to 80-82dB(A).

In 1971, ballast mats were applied and the contribution of the concrete bridge structure noise became negligible as a result. However its original ratio to the total noise was not so large that the noise value did not change remarkably.

In 1973, cast iron abrasive blocks were replaced by composite abrasive blocks in order to improve the adhesion between wheel and rail. Incidentally, it was found that the corrugations on the wheel treads disappeared, since abrasive composite blocks were used and the rolling noise was reduced by 4dB. As a result, the noise value was reduced to 78dB. Furthermore, the technique of grinding rail surfaces began to be implemented in 1983 and the rolling noise was reduced by about 5dB. In 1986, the maximum velocity was raised to 220km/h. However, the noise value remained to be 78dB, almost the same as that before the countermeasure of grinding rail surfaces was implemented (maximum velocity = 210km/h).

After the implementation of consecutive countermeasures for the rolling noise, the pantograph noise came to dominate among noise components. The pantograph noise mainly consisted of aerodynamic noise and spark noise and the latter was larger than the former at that time. The aerodynamic noise from the upper parts of cars also came to have a non-negligible contribution to the total noise. In particular, remarkable noise was generated by louver intakes of air conditioners that were distributed continuously on Series 0 cars and locally at double-decker Series 100 cars.

In order to reduce the pantograph noise and aerodynamic noise, several countermeasures were implemented for Series 100 cars. Pantograph shields, which aim controlling the airflow around the pantograph and screening the pantograph noise, were equipped with on Series 100 cars in 1988 and the pantograph noise was reduced by about 5dB. As countermeasures for spark noise, the "bus cable" which electrically connects plural pantographs was used in 1990, and it was found that spark noise almost vanished. The bus cable also enabled the reduction of the number of pantograph also. Furthermore, the shape of the louver intakes of air conditioners was improved. As the result of these consecutive countermeasures, the noise of Series 100 cars was reduced dramatically. At the same time, Series 0 cars were gradually replaced by Series 100 cars, and the noise value was reduced to 75-76dB.

In the latter half of the 1980s, projects of the speed-up of Shinkansen started in response to the social needs and much effort was directed to the study of noise reduction technology. At first, the study was directed to improving Series 100 cars. However, it was found in the process of the study that development of a new car that was designed for low aerodynamic noise was indispensable for high speed operation to 270km/h without increasing the noise level. The first car that was designed for low aerodynamic noise is a Series 300 car. In Series 300 cars, most equipment, such as air conditioners, was moved to the lower part of cars which is screened by a sound barrier, and the upper part was almost smoothened except electric insulators and gaps of cars. As a result, the aerodynamic noise from the upper part of cars was reduced dramatically and the noise level of Series 300 cars at 270km/h run was 75-76dB. At the same time, the number of train sets of Series 0 cars whose noise levels were higher than those of other cars decreased and the noise value was reduced to 75dB in spite of remarkable speed-up.

In the late of the 1990s, Series 500 and Series 700 cars were developed for further speed-up and low noise. Many low noise technologies are used for these cars. A combination of low noise pantographs and small insulator shields is adopted for Series 500 cars and a combination of low noise pantographs, small insulator shields and side-walls for screening pantographs adopted for Series 700 cars. As for the aerodynamic noise from the upper part of cars, the bus cable is connected directly by small joints and the electric insulators are removed. The pantograph noise and aerodynamic noise from the upper part of cars of these cars are smaller than those of Series 300 cars at the beginning of commercial operation, by an amount of 1-4dB and 3-4dB, respectively, and their noise level is 73-74dB at 270km/h. These new technologies are being applied to Series 300 cars and contribute to the noise reduction of Series 300 cars. Furthermore, Series 0, whose noise level is higher than that of other cars, disappeared from the Tokaido Line. The noise value has now been reduced to 74-75dB.

Sanyo Shinkansen line

On the Sanyo Shinkansen Line, which started operation in 1972 and extended to Hakata in 1975, sound barriers were equipped as standard and slab tracks were widely adopted (about 70% of the line between Okayama and Hakata). Cars and the maximum velocity were the same as those of Tokaido Shinkansen Line, namely Series 0 cars ran at the speed of 210km/h. The noise value at the beginning of commercial operation in 1975 was about 78-79dB, which was much lower than that at the beginning of commercial operation of Tokaido Shinkansen Line because sound barriers were equipped as standard and the cast iron abrasive blocks had already been replaced by composite abrasive blocks. However, this noise value was slightly higher than that on Tokaido Shinkansen Line in 1975 because the rolling noise is higher on slab tracks than on ballast tracks.

The countermeasures for noise reduction were almost the same as those for Tokaido Shinkansen Line. Today newly developed cars, namely, Series 500 and Series 700 cars are running at the speed of 300km/h and 285km/h, respectively, and the noise value is about 75dB.

Transition of Noise Level of Individual Components

The Shinkansen noise consists of various noise sources. In order to reduce the wayside noise level effectively, it is important to understand the contribution of each noise source to the total noise and to apply countermeasures to the source that has a main contribution.

Figure 2 shows the transition of energy of each noise component observed at the point P_{25} during the pass of a train set[2)]. The area denotes the energy of each noise component. The values in Figure 2 are those of a train set whose velocity was the highest at the time and on the line. The conditions of structures and tracks are the same as those in section 2.1.We can find that countermeasures have been applied mainly to the component that had the largest contribution at each stage. In the case of remarkable speed-up, such as at the start of Series 300 operation, countermeasures are applied further to the aerodynamic noise and pantograph noise, whose sound power highly depends on the train speed. As a result the ratio of these noise to the total noise remains almost the same as those before speed-up. By the way, on the slab tracks (Sanyo Shinkansen Line), the noise from the lower part of cars remains to have a large contribution to the total noise and it seems that no countermeasures have been applied to it. This is because Figure 2 is estimated under the conditions shown in Table 4, e.g. the fixed straight type sound barrier. In fact, countermeasures for the noise from the lower part of cars, such as sound barriers with absorbing materials and inverted-L type sound barriers were applied in slab track sections.

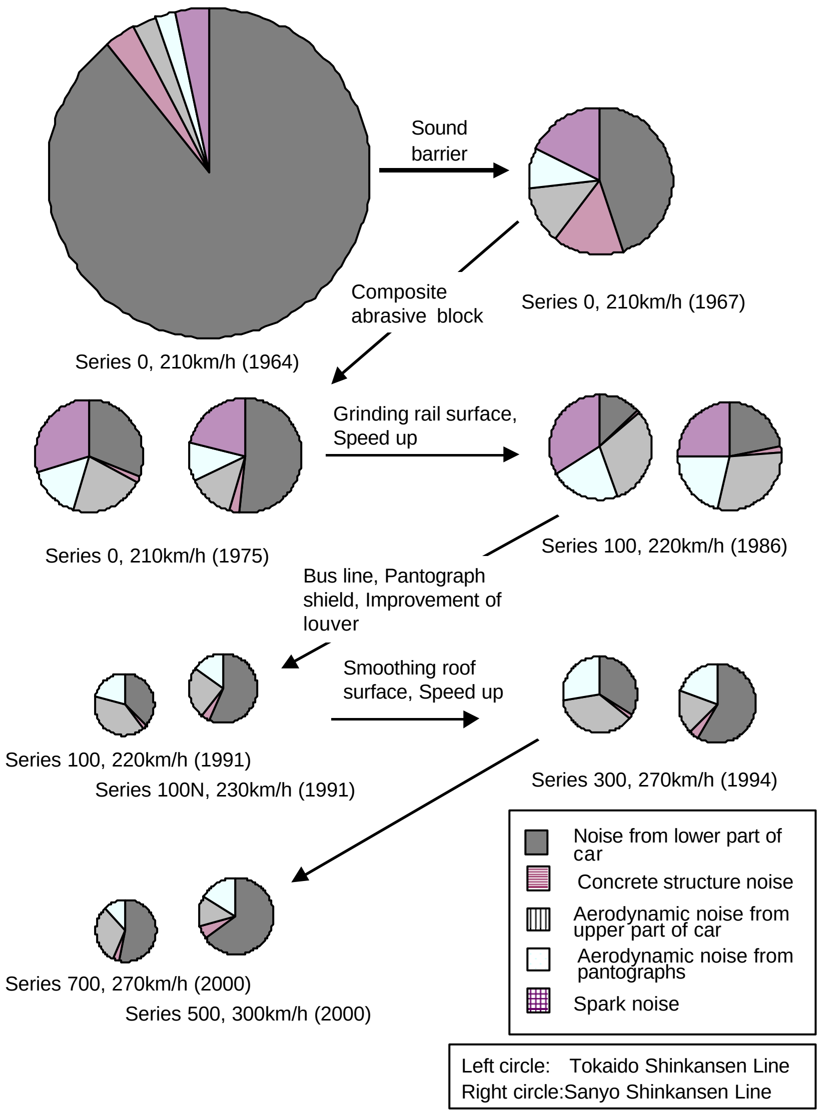

Figure 2 Transition of energy of each noise component observed at point P_{25}

CONCLUSIONS

The values specified in decibels ($L_{pA,Smax}$) in environmental quality standards for Shinkansen noise are 70dB or less mainly for residential areas and 75dB or less for other areas. Since Shinkansen was opened, a number of noise reduction measures have been developed. As a result, the wayside noise is now 75dB, and successive efforts have been carried out to achieve 70dB as next step.

BIBLIOGRAPHICAL REFERENCES

1) NAGAKURA K. ZENDA Y.: Method of Predicting Wayside Noise Level of Shinkansen, 7th Western Pacific Regional Acoustics Conference, 2000

2) KITAGAWA T., NAGAKURA K.: Aerodynamic Noise generated by Shinkansen Cars, Journal of Sound and Vibration (2000)231(3)