NIPPON STEEL TECHNICAL REPORT No. 81 JANUARY 2000

UDC 628 . 517 . 2 : 625 . 74

Sound Absorption Panel for Roads

Hirohiko NOGAWA*1 Morihiro MATSUMOTO*2

Abstract

Noise from automobile reflects off of the ceilings and walls in overpasses and canals, and may cause noise pollution in residential areas along the streets. As conventional measures, like sound insulation walls, do not work well in these areas, we started developing a new sound absorption board in order to reduce this noise pollution by them to the ceilings and walls of roads. The mechanism of the well-known sound absorbing characteristic of mineral wool is that it causes a loss of friction inside the material. The board we developed is a kind of mineral wool sandwich panel with dual metal facings with a thickness of 100mm. The direction of mineral wool fiber is parallel to the direction of incoming sound. This material is endlessly affixed to both sides of the steel plates using a sandwiching structure and while it is lightweight enough to allow easy installation, it has also high strength.

1. Preface

In developing a new type of sound absorption panel, a metal-sided sandwich structure was taken as the basic design concept and the following points were laid down as targets:

(1) A benefit of remarkable reduction of reflected sound is brought about to the areas along motorways by installation of the new sound absorption panels incorporating a new technology at adequate locations around the roads. More specifically, an average sound absorption coefficient at oblique incidences not less than 0.9 is envisaged.

(2) The panels have adequate strength and safety features and should not impose excessive loads to the existing structures onto which they are mounted.

(3) Being pleasant to look at.

(4) Easy installation and maintenance.

(5) A sandwich structure is employed wherein a core of a sound absorption material, a front board and a rear board are formed into one unit by adhesive.

(6) The panel can be manufactured on an continuous line.

An illustration of installed panels and its concept are shown in **Figs. 1 and 2**, respectively. The developed panel comprises a mineral wool layer with vertically running fibers as the sound absorption core, a perforated metal sheet as the front board and a sound insulation layer which serves as the rear board and walkway for inspection. It was confirmed through preliminary tests that sound absorption coefficient of mineral wool with vertically running fibers was better by several percents at every frequency range than conventional one with horizontally running fibers, that the value of the sound absorption coefficient of the sound absorption layer hit a maximum at a thickness around 75 - 100 mm, and that strength of the panel was enhanced when the fibers were arranged along the thick-

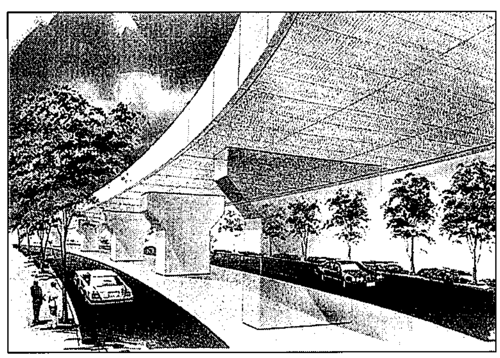


Fig. 1 An artistic illustration of installed panels

*1 Nitto Boseki Co.,Ltd.

*2 Daido Steel Sheet Corporation

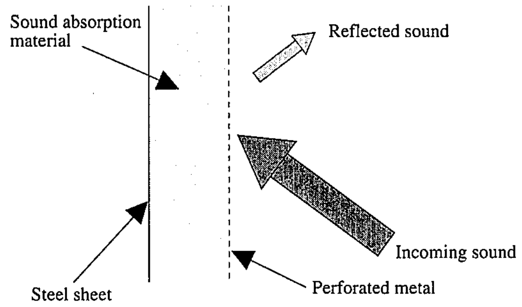


Fig. 2 Design of sound absorption panel

ness direction (vertically). The above knowledge served as the bases of the development.

2. Evaluation of Sound Absorption Performance

2.1 Preliminary tests

Investigations were made on effects of density and thickness of the mineral wool and fiber direction on the sound absorption efficiency. The effects of the shape of the front board were also studied. Specimens of the sound absorption core 100 × 100 mm were prepared and the sound absorption coefficient at normal incidence was measured using a sound tube, then the value obtained was converted into the average sound absorption coefficient at oblique incidences (See **Fig. 3**). In the first place, sound propagation coefficient and characteristic impedance of the mineral wool were measured by 2-microphone method using sound tube, complex reflection coefficient was calculated from the measured value, and then the sound absorption coefficient at oblique incidence for each incidence angle was estimated.

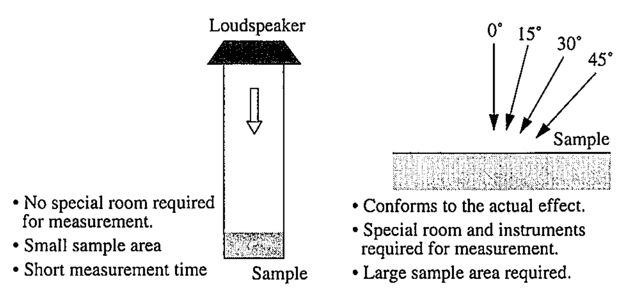
2.1.1 Density, thickness and fiber direction of mineral wool

Effects of mineral wool density, thickness and fiber direction on the sound absorption efficiency were evaluated (See **Table 1**) changing the specification of specimens as follows, without using the front board:

Evaluation item	Specification of specimens	Range where result was good
Density:	80 - 150 kg/m^3	80 - 100 kg/m^3
Thickness:	50 - 200 mm	75 mm or more
Fiber direction:	Vertical/Horizontal	Vertical

2.1.2 Effects of the front board

Effects of the shape of the front board were studied changing the specification as follows (See **Table 2** and **Fig. 4**):



Sound absorption coefficient at normal incidence using sound tube **Average sound absorption coefficient at four oblique incidence**

Fig. 3 Measurement methods of sound absorption coefficient

Table 1 Effects of mineral wool on sound absorption coefficient at oblique incidence

Thickness (mm)		50	75	100	125	150	175	200
Horizontal fiber density	80kg/m^3	0.908	0.922	0.914	0.909	0.914	0.909	0.909
	100kg/m^3	0.900	0.872	0.863	0.864	0.866	0.866	0.866
	120kg/m^3	0.867	0.850	0.844	0.844	0.845	0.845	0.845
	150kg/m^3	0.793	0.786	0.786	0.787	0.786	0.786	0.786
Vertical fiber density	80kg/m^3	0.867	0.933	0.938	0.932	0.929	0.928	0.928
	100kg/m^3	0.908	0.920	0.909	0.906	0.906	0.907	0.907
	120kg/m^3	0.883	0.886	0.883	0.881	0.881	0.881	0.881
	150kg/m^3	0.809	0.791	0.791	0.791	0.791	0.791	0.791

Table 2 Effects of front board on sound absorption coefficient at oblique incidence

Perforation pattern (mm)	Ratio of perforated area	Average sound absorption coefficient at oblique incidence
No front board	1.0	0.892
2ϕ × 3P	0.402	0.885
3ϕ × 4P	0.509	0.891
6ϕ × 9P	0.402	0.891
7ϕ × 10P	0.444	0.898
8ϕ × 10P	0.579	0.895
9ϕ × 12P	0.509	0.900
10ϕ × 13P	0.536	0.897
10ϕ × 15P	0.402	0.904
12ϕ × 15P	0.579	0.893

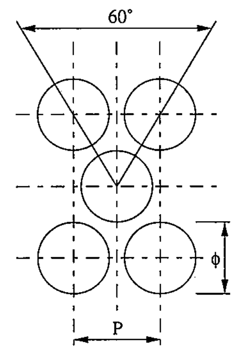


Fig. 4 Perforation work

Study item	Specification of specimens	Range where result was good
Ratio of perforated area:	0.4 - 0.6	No significant difference.
Hole diameter (ϕ):	2 - 12 mm	Ditto.
Hole pitch (P):	3 - 15 mm	Ditto.

The mineral wool used in this study was: density 100 kg/m^3, thickness 100 mm, fiber direction vertical.

2.2 Measurement of sound absorption coefficient at oblique incidence using panels

The sound absorption coefficient at oblique incidence was measured on two different prototype panels using the values obtained from the above investigations.

2.2.1 Measurement method

- Environment: Hemi- anechoic chamber (7 × 8 × 6 m)
- Panel installation: More than 20 m^2 of the panel was placed on the floor.
- Sound reflection was measured at 4 different angles of incidence (0°, 15°, 30° and 45°). The frequency range was 400 - 4,000 Hz.

2.2.2 Result

As shown in **Table 3**, Panel No.1 achieved an average sound absorption coefficient at oblique incidence of 0.9, the target value.

3. Specification of Developed Panel

Based on the result obtained through the measurement described in 2.2 above, a basic specification of the panel was worked out as

Table 3 Average sound absorption coefficient at oblique incidence of test produced panels

No.	Rock wool density (kg/m³)	Panel thickness (mm)	Perforation pattern (mm)	Ratio of perforated area (%)	Average sound absorption coefficient at oblique incidence
1	80	100	9ϕ × 12P	50.9	0.90
2	100	75	9ϕ × 12P	50.9	0.87

Table 4 Panel components

No.	Component	Material	Specification	Remark
①	Perforted metal	SUS 304 Fluoro resin coating	Thickness: 0.4 mm	Perforation pattern 9ϕ × 12P (mm)
②	Rear insulation board	Pre-painted galvanized sheet	Thickness: 0.5 mm	
③	Sound absorption core	Mineral wool with vertical fiber	Density: 80 kg/m³	
	Fiber direction is parallel to incoming sound. Panel size and weight: 100 × 1,000 × length (mm), 16 kg/m²			

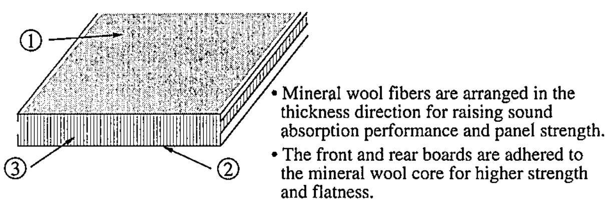


Fig. 5 General view of the panel

shown in **Table 4** and **Fig. 5** using the core which showed the average sound absorption coefficient at oblique incidence of 0.9.

4. Properties of Developed Panel

Various performance items were verified based on the panel specification introduced in Section 3 above.

4.1 Sound absorption property

The average sound absorption coefficient at oblique incidence is 0.9, but it was observed that sound absorption at frequencies above 1,000 Hz was slightly better than in the lower frequency range as shown in **Fig. 6**.

4.2 Panel strength

Allowable bending stress was calculated based on bending test results and then allowable wind load per unit area was estimated. The bending test was done in accordance with the Simple Bending Test under JIS A 1414-1994. The test results are shown in **Table 5** and **Fig. 7**.

4.3 Durability

4.3.1 Salt spray test

Corrosion resistance of the front board and change of adhesion of the sound absorption core with the front and rear boards were investigated by salt spray test as described in **Table 6**.

- Test method: JIS Z 2371
  Sample size: 100 thick × 70 × 150 mm
  Salt water spray was applied to the front board.
- Results: No problem observed after 2,000 h.

4.3.2 Fluorescent UV lamp test

Effects of ultraviolet on material deterioration leading to change in sound absorption property and adhesion of the sound absorption core with the front and rear boards were investigated by fluorescent UV lamp test as described in **Table 7**.

- Test method: JIS K 7350-3
- Sample size: 25 mm thick × 30 mmϕ, 25 mm thick × 100 mmϕ
- UV was irradiated on the perforated metal face and, after the exposure, change of the sound absorption coefficient was evaluated by measuring the sound absorption coefficient at normal incidence using a sound tube.

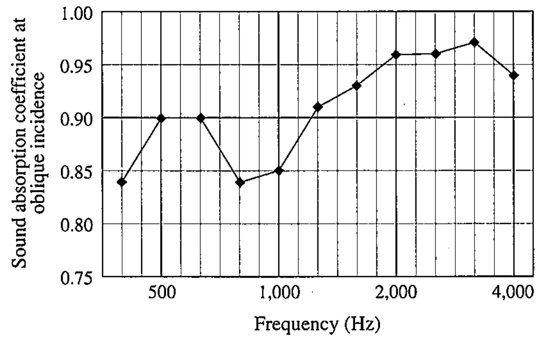


Fig. 6 Sound absorption coefficient at oblique incidence

Table 5 Allowable bending stress

Span L (mm)	Loaded face	Deflection δ_{max} (mm)	Load F (kgf)	Allowable bending stress σ_{max} (kgf/cm²)
2,200	Rear board	12.9	325	199
Allowable bending stress: $\sigma = (FL/8Z)$				
Section modulus: $Z = I/e$ (cm³)				45.0
Where: I: Geometric moment of inertia (cm⁴)				225.2
e; Distance of neutral plane/surface board (cm)				5.0

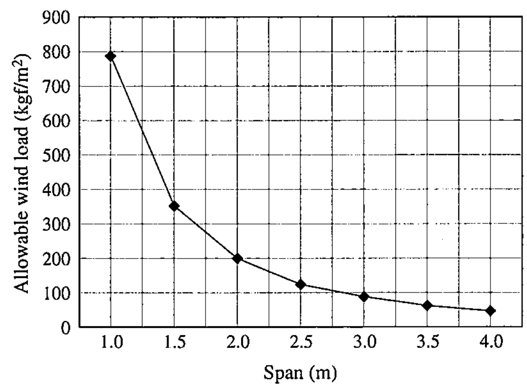


Fig. 7 Relationship between span and allowable wind load

Table 6 Result of salt spray test

Test duration (h)	500	1,000	1,500	2,000
Marks by Rating Number Method	10	10	10	10

Table 7 Sound absorption coefficient at normal incidence after fluorescent UV lamp test

Test duration (h)	0	1,000	1,500	1,750	2,000
Average sound absorption coefficient	0.58	0.56	0.59	0.58	0.60

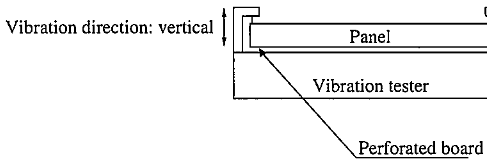


Fig. 8 Vibration test

- Result: No deterioration of sound absorption performance was observed after 2,000 hrs of exposure. Nor was found any change in the adhesion between the sound absorption core and the boards.

4.3.3 Vibration test

In consideration that the sound absorption panels may be mounted on the lower surface of motorway overpasses, the effects of vibration for a long period on the panel were investigated with regards to disintegration of the sound absorption material and separation of the front and rear boards (See **Fig. 8**).

- Test method: JIS Z 0232, i.e. an aluminum frame was fixed to the sound absorption panel and the panel and the frame was suspended at four corners in the same manner as the actual mounting.
- Sample dimension:
  105 mm thick × 1,000 mm wide × 1,445 mm long
- Total weight: 28.5 kg
- Test condition: Vibration: 4 Hz
  Acceleration: 2.9 m/s^2 (0.3 G)
  Direction: vertical
  Duration: 72 h
- Result: No problem observed

5. Discussion

Mineral wool was selected as the sound absorption material and, by arranging the fiber parallel to the direction of sound incidence, good results were obtained either for the sound absorption coefficient at oblique incidence or panel strength. It has been known that the lower the mineral wool density the lower the strength, and thus the minimum mineral wool density for the test of the sound absorption property was set at 80 kg/m^3. It was eventually observed that the sound absorption efficiency was the highest with 80 kg/m^3 density and within a thickness range of 75 - 100 mm.

With regards to the perforation work of the front board, it was found in the tests that the diameter and the pitch of the perforation had little influence on the sound absorption performance as far as the perforation ratio was more than 0.4. It seems reasonable to presume that the sound absorption coefficient is constant when the front board has more than a certain percentage of openings.

In view of corrosion resistance and weatherability, JIS SUS 304 stainless steel sheet is used for the front board and it is coated with a fluoro-resin. Pre-painted galvanized sheet with polyester coating would develop edge creep after a 500hrs salt spray test and be suitable only for indoor uses.

Degeneration of mineral wool and adhesive was tested by fluorescent UV lamp. Sound absorption coefficient was found to have slightly improved after the irradiation, presumably because the binder near the mineral wool surface was disintegrated, but the effect seems to have been limited to the layer near the surface judging from the change of the sound absorption. As for the adhesive, no change was confirmed, as the UV does not seem to have hit it.

6. Conclusions

Development of the sound absorption panel was initiated mainly as a measure for reducing noise pollution caused by reflection of traffic sound at the lower surface of elevated motorways. Since, for this reason, the target value of average sound absorption coefficient at oblique incidence was set as high as 0.9, the panel became as thick as 100 mm. The panel is shaped in simple rectangular parallelepiped as seen in Fig. 5 and can be mounted by a frame and metal fittings to follow the shape of the surface where the panel is mounted. **Photo 1** shows a ceiling-mounting type panel.

Other types of panel for wall application, which requires only a lower sound absorption capacity, are being developed. In this case the panel is thinner and some of them have integral joints for direct mounting. They have already been test produced.

As is made clear through the tests described above, a lightweight sound absorption panel having a high sound absorption capacity and durability has been made available. It is manufactured continuously on a double belt conveyer line and has high strength and good flatness thanks to strong adhesion between the core and the front and rear boards.

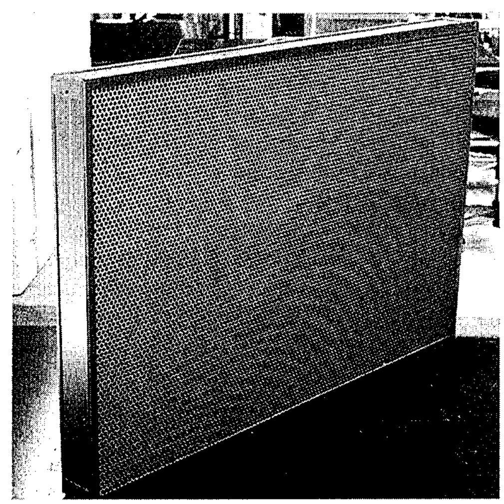


Photo 1 Sound absorption panel for mounting on ceiling