

DESCRIPTION

Title of the Invention: TRANSLUCENT SOUND-ABSORBING PANEL

5 Technical Field

[0001]

The present invention relates to a translucent sound-absorbing panel having translucency and transparency, which reduces noises generated from roads, railroads, factories and the like.

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Background Art

[0002]

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Patent Document 1 discloses a translucent soundproof plate in which a translucent sound-absorbing material which is a film material having a large number of holes formed thereon faces a translucent sound insulating plate through an air layer, as a translucent sound-absorbing plate having translucency and transparency which reduces noises generated from roads, railroads, factories and the like. Furthermore, Patent Document 2 discloses a light-transmitting type film-vibrating sound-absorbing plate in which a transparent resin thin film is sandwiched between an aluminum expanded metal and a transparent perforated resin plate.

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Prior Art Document

Patent Document

[0003]

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Patent Document 1: JP-A-2002-146727

Patent Document 2: JP-A-2007-303080

Summary of the Invention

Problems to be Solved by the Invention

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[0004]

However, in the translucent soundproof plate in Patent Document 1, because the translucent sound-absorbing material which is a film material has low face rigidity, the translucent sound-absorbing material vibrates with respect to incident sound wave,

thereby decreasing relative speed of sound wave passing through hole portions with respect to the hole portions, and deteriorating sound-absorbing performance.

Therefore, it is considered that the translucent sound-absorbing material is reinforced with an expanded metal or the like. However, translucency and transparency are
5 decreased by the addition of the reinforcement material.

[0005]

Furthermore, in the light-transmitting type film-vibrating sound-absorbing plate in Patent Document 2, the aluminum expanded metal sandwiching the transparent resin thin film decreases translucency and transparency.

10 [0006]

If a metal material such as aluminum is formed into, for example, a perforated foil having a thickness of 0.1 mm and is used as an internal sound-absorbing material, the perforated foil is difficult to vibrate due to its high face rigidity, and exhibits sound-absorbing performance. However, if the metal material is used, translucency and
15 transparency are decreased in exchange for the improvement in sound absorbability. Contrary to this, if the metal material is refrained from the use thereof, sound absorbability is decreased in exchange for the improvement in translucency and transparency. Thus, it is difficult to improve all of sound absorbability, translucency and transparency.

20 [0007]

An object of the present invention is to provide a translucent sound-absorbing panel capable of improving sound absorbability and additionally improving translucency and transparency.

[0008]

25 The present invention provides the following translucent sound-absorbing panel.

(1) A translucent sound-absorbing panel, comprising:

a front perforated plate to face a sound source, which comprises a material having translucency and transparency and has a large number of through-holes;

30 a back sound insulating plate which is placed behind the front perforated plate with respect to the sound source and comprises a material having translucency and transparency; and

an internal perforated plate which is placed between the front perforated plate and the back perforated plate so as to separate a space between the front perforated plate and the back perforated plate into a plurality of spaces, comprises a material having translucency and transparency and has a large number of through-holes,

wherein a plate thickness of the internal perforated plate is 0.2 mm or more and 1.5 mm or less.

[0009]

According to the above constitution, if the plate thickness of the internal perforated plate is less than 0.2 mm, face rigidity of the internal perforated plate is decreased and the internal perforated plate vibrates. As a result, relative speed of sound wave passing through the through-holes with respect to the through-holes is decreased and the phenomenon that sound-absorbing performance is deteriorated occurs. On the other hand, if the plate thickness of the internal perforated plate is larger than 1.5 mm, a hole diameter of through-holes that can be formed by perforation at low cost is increased, and sound absorbability is decreased. For the above reasons, the plate thickness of the internal perforated plate is set to 0.2 mm or more and 1.5 mm or less. As a result, face rigidity of the internal perforated plate is improved and the internal perforated plate becomes difficult to vibrate and additionally a hole diameter of the through-holes that can be formed by perforation at low cost is decreased, thereby improving sound absorption coefficient. Furthermore, because a metal material for reinforcement is not used, translucency and transparency are improved. As a result, sound absorbability can be improved, and additionally translucency and transparency can be improved.

[0010]

(2) The translucent sound-absorbing panel according to (1), wherein assuming that an aperture ratio of the internal perforated plate is α , the plate thickness of the internal perforated plate is t , a hole diameter of the through-hole of the internal perforated plate is d , a density of a plate part of the internal perforated plate is ρ and air density is ρ_0 , an area density ratio η which is a value obtained by dividing an area density of the plate part of the internal perforated plate by an area density of air of a part of the through-hole of the internal perforated plate and is represented by the following formula is 1.0 or more.

$$\eta = \rho \cdot t \cdot (1 - \alpha) / (\rho_0 \cdot (t + 0.8 \cdot d) / \alpha) \quad (1)$$

[0011]

According to the above constitution, in the case where the area density ratio η is smaller than 1.0, that is, the mass of a plate part of the internal perforated plate is relatively small as compared with the mass of air in the through-holes, the plate part becomes easy to vibrate, and vibration speed of the plate part becomes large. As a result, the relative speed between the vibration speed of air passing through the through-holes and the vibration speed of the plate part is decreased, and sound absorption effect by viscous damping becomes difficult to be exhibited. Therefore, if the area density η is 1.0 or more, that is, the mass of the plate part of the internal perforated plate is relatively increased as compared with the mass of air in the through-holes, the plate part becomes difficult to vibrate, and vibration speed of the plate part is decreased. As a result, the relative speed between the vibration speed of air passing through the through-holes and the vibration speed of the plate part is increased. The sound absorption effect by viscous damping can be efficiently exhibited by this.

[0012]

(3) The translucent sound-absorbing panel according to (1) or (2), wherein a material of the internal perforated plate is a resin.

According to the above constitution, if the internal perforated plate is made of a resin, cost can be suppressed, and additionally a large number of through-holes can be easily formed by perforation.

[0013]

(4) The translucent sound-absorbing panel according to any one of (1) to (3), wherein a plurality of the internal perforated plates are provided and the internal perforated plates are isolated to each other.

According to the above constitution, if a plurality of the internal perforated plates are provided, sound wave passes through the through-holes of a multiple layer, and thus, sound-absorbing performance can be improved.

[0014]

(5) The translucent sound-absorbing panel according to any one of (1) to (4), further comprising a partition plate which is provided in each of the plurality of spaces and comprises a material having translucency and transparency,

wherein the internal perforated plate is sandwiched by two or more of the partition plates.

According to the above constitution, the internal perforated plate is sandwiched by two or more of the partition plates to suppress vibration of the internal perforated plate, and sound-absorbing performance can be thereby improved. Furthermore, because the partition plate has translucency and transparency, decrease in translucency and transparency can be suppressed as compared with the case where the internal perforated plate is sandwiched between metal materials.

[0015]

(6) The translucent sound-absorbing panel according to (5), wherein a plurality of the partition plates are lined up in a straight line toward the back sound insulating plate from the front perforated plate while sandwiching the internal perforated plate .

According to the above constitution, if a plurality of partition plates is lined up in a straight line, wind load that the front perforated plate receives can be received by the plurality of partition plates and the back sound insulating plate. Therefore, strength of the entire panel can be improved.

[0016]

(7) The translucent sound-absorbing panel according to any one of (1) to (6), wherein a plate thickness of the front perforated plate is 2 mm or more and 3 mm or less.

According to the above constitution, if the plate thickness of the front perforated plate is less than 2 mm, the front perforated plate lacks in strength, and can not satisfy, for example, 300 kg/m^2 which is a reference value of wind load in roads. On the other hand, if the plate thickness of the front perforated plate is larger than 3 mm, cost is increased, and additionally it becomes difficult to form a large number of through-holes by perforation. For the above reasons, the plate thickness of the front perforated plate is set to 2 mm or more and 3 mm or less, and is preferably set to 2 mm. Because strength of the front perforated plate is improved by this, the front perforated plate can satisfy 300 kg/m^2 which is a reference value of wind load in roads. Furthermore, the cost can be suppressed, and additionally a large number of through-holes can be easily formed by perforation.

[0017]

(8) The translucent sound-absorbing panel according to (1) to (7), wherein a material of the front perforated plate is a resin.

According to the above constitution, if the front perforated plate is made of a resin, the cost can be suppressed, and additionally a large number of through-holes can be easily formed by perforation.

[0018]

- 5 (9) The translucent sound-absorbing panel according to any one of (1) to (8), wherein a plate thickness of the sound insulating plate is 5 mm or more and 16 mm or less.

According to the above constitution, if the plate thickness of the back sound insulating plate is less than 5 mm, the entire panel lacks in strength, and additionally sound insulating performance of the back sound insulating plate is decreased, and sound transmission loss of the panel thereby falls below, for example, the standard in roads. On the other hand, if the plate thickness of the back sound insulating plate is larger than 16 mm, the cost is increased. For above reasons, the plate thickness of the back sound insulating plate is set to 5 mm or more and 16 mm or less, and is preferably set to 8 mm. By this, strength of the entire panel can be sufficiently secured and additionally sound insulating performance of the back sound insulating plate is improved. As a result, sound transmission loss of the panel can be improved to meet the reference value or more in roads. Furthermore, cost can be suppressed.

[0019]

- 20 (10) The translucent sound-absorbing panel according to any one of (1) to (9), wherein a material of the back sound insulating plate is a resin.

According to the above constitution, if the back sound insulating plate is made of a resin, cost can be suppressed.

[0020]

- 25 (11) The translucent sound-absorbing panel according to any one of (1) to (10), wherein a large number of the through-holes are densely provided on a partial region of the front perforated plate.

According to the above constitution, in the case where a large number of through-holes are densely provided on a partial region of the front perforated plate, a region which is not perforated in the front perforated plate is increased as compared with the case where a large number of through-holes are provided in a dispersed state, if under the conditions that the number of the through-holes, and the aperture size and aperture ratio in the front perforated plate are the same. As a result, visibility can be

improved as compared with the case where through-holes are provided in a dispersed state.

Advantages of the Invention

5 [0021]

According to the translucent sound-absorbing panel of the present invention, the plate thickness of the internal perforated plate is set to 0.2 mm or more and 1.5 mm or less, and thus, the face rigidity of the internal perforated plate is improved and the internal perforated plate becomes difficult to vibrate, and additionally a hole diameter of
10 through-holes that can be formed by perforation at low cost becomes small. As a result, sound absorption coefficient is improved. Furthermore, because a metal material for reinforcement is not used, translucency and transparency are improved. As a result, sound absorbability can be improved and additionally translucency and transparency can be improved.

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Brief Description of the Drawings

[0022]

FIG. 1 is a perspective view of a translucent sound-absorbing panel.

FIG. 2 is a cross-sectional view of a translucent sound-absorbing panel.

20 FIG. 3 is a perspective view showing a partition plate and a frame member.

FIGs. 4(a) and (b) are views showing a relative speed of sound wave passing though through-holes with respect to the through-holes, and FIG. 4(a) shows the case where an area density ratio η is smaller than 1.0, and FIG. 4(b) shows the case where the area density ratio η is 1.0 or more.

25 FIG. 5 is a plane view showing a front perforated plate.

FIG. 6 is a graph showing sound absorption coefficient of a translucent sound-absorbing panel.

FIG. 7 is a graph showing sound absorption coefficient of a translucent sound-absorbing panel.

30 FIG. 8 is a graph showing sound absorption coefficient of a translucent sound-absorbing panel.

FIG. 9 is a graph showing the relationship between an area density ratio and a sound absorption coefficient ratio.

FIG. 10 is a graph showing the relationship between an area density ratio and a sound absorption coefficient ratio.

Embodiments for Carrying Out the Invention

5 [0023]

The preferred embodiments of the present invention are described below by referring to the drawings.

[0024]

(Translucent sound-absorbing panel)

10 A translucent sound-absorbing panel 1 of the present embodiment has a rectangular and frame-shaped outer frame 7 and an inner frame 8 provided between the center of one short side of the outer frame 7 and the center of the other short side thereof and parallel to long sides of the outer frame 7, as shown in FIG. 1 as a perspective view and FIG. 2 as an A-A cross-sectional view of FIG. 1.

15 [0025]

The outer frame 7 has a length of a long side of 2 m and a length of a short side of 1 m, and is formed in a frame form by combining four straight line frame materials 7a to 7d in a rectangular form. The length of the long side and the length of the short side are not limited to those lengths, and can be appropriately changed. The frame materials 7a to 7d and the inner frame 8 are an extrusion material which has an H-form cross-section and includes aluminum, and corrosion resistance and abrasion resistance are improved by subjecting those to alumite treatment. The frame materials 7a to 7d and the inner frame 8 may include a material having translucency and transparency.

[0026]

25 The translucent sound-absorbing panel 1 faces a sound source not shown in figures, and has a front perforated plate 2 having a large number of through-holes 11, a back sound insulating plate 3 placed behind the front perforated plate 2 with respect to the sound source, and two internal perforated plates 4 (4a and 4b) which has a large number of through-holes 14 (14a and 14b) and is placed between the front perforated plate 2 and the back sound insulating plate 3 so as to separate a space between the front perforated plate 2 and the back sound insulating plate 3 into a plurality of spaces 9. The front perforated plate 2, the back sound insulating plate 3 and two internal

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perforated plates 4a and 4b are isolated to each other through the spaces 9. The number of the internal perforated plates 4 may be 3 or more, and may be 1 or less.

[0027]

5 The front perforated plate 2, the back sound insulating plate 3 and two internal perforated plates 4 (4a and 4b) each are placed inside two frames 10a and 10b formed by the outer frame 7 and the inner frame 8, respectively. In FIG. 1, only a part of each of the front perforated plate 2, the back sound insulating plate 3 and two internal perforated plates 4a and 4b is shown in the frame 10b at a right side in the figure so as to easily understand a depth and the relationship between members. However, actually
10 an opening passing through the translucent sound-absorbing panel 1 from a front side to a back side is not present, and each of the front perforated plate 2, the back sound insulating plate 3 and two internal perforated plates 4 (4a and 4b) is placed inside the two frames 10a and 10b without space, respectively.

[0028]

15 The front perforated plate 2, the back sound insulating plate 3 and the internal perforated plates 4 include a material having translucency and transparency. In the present embodiment, the material of the front perforated plate 2, the back sound insulating plate 3 and the internal perforated plates 4 is polycarbonate. The material of the front perforated plate 2, the back sound insulating plate 3 and the internal perforated
20 plates 4 may be synthetic resins such as vinyl chloride, methacrylic resin, styrol resin, ABS resin, fluorinated ethylene resin and acrylic resin, or rubbers, that are materials having translucency and transparency, or materials having translucency and transparency such as transparent or semi-transparent glasses. Both surfaces of the front perforated plate 2, the back sound insulating plate 3 and the internal perforated
25 plates 4 are subjected to weatherability treatment.

[0029]

Thus, if the internal perforated plates 4 are made of polycarbonate, cost can be suppressed, and additionally a large number of through-holes 14 can be easily formed by perforation. Furthermore, if the front perforated plate 2 is made of polycarbonate,
30 cost can be suppressed, and additionally a large number of through-holes 11 can be easily formed by perforation. Furthermore, if the back sound insulating plate 3 is made of polycarbonate, cost can be suppressed.

[0030]

The through-holes 11 in the front perforated plate 2 cause viscous damping action on air passing through the through-holes 11. Furthermore, the through-holes 14 in the internal perforated plates 4 (4a and 4b) cause viscous damping action on air passing through the through-holes 14. If the viscous damping action is occurred in air passing through the through-holes 11 and 14, air vibration (sound) is converted to heat energy, and damping occurs in air vibration. As a result, sound wave is absorbed in a relatively wide frequency band. If a plurality of internal perforated plates 4a and 4b are provided, sound wave passes through through-holes 14 of a multilayer, and thus, sound-absorbing performance can be further improved.

10 [0031]

The aperture ratios of the front perforated plate 2, the internal perforated plate 4a and the internal perforated plate 4b are set so as to be stepwisely decreased with increasing distance from the sound source. In the present embodiment, the aperture ratio of the front perforated plate 2 is 10% or less, the aperture ratio of the internal perforated plate 4a is 1% or less, and the aperture ratio of the internal perforated plate 4b is 0.5% or less. Thus, if the aperture ratio is set so as to be decreased with increasing distance from the sound source, sound from the sound source can be stepwisely reduced, and as a result, sound in a wide band can be reduced.

[0032]

20 If a plurality of the internal perforated plates 4a and 4b are provided, translucency and transparency are decreased in exchange for the improvement in sound absorbability. For this reason, in the case of emphasizing translucency and transparency rather than sound absorbability, the number of the internal perforated plate 4 may be 1 or 0.

25 [0033]

The through-holes 11 of the front perforated plate 2 and the through-holes 14 (14a and 14b) of the internal perforated plates 4 (4a and 4b) are formed by punching, respectively. Thus, if the through-holes 11 and 14 are formed by punching, a large number of through-holes 11 and 14 can be formed by perforation at low cost. In the case where the through-holes 11 and 14 are perforated by laser or drill, there is a problem that hole parts of the front perforated plate 2 and internal perforated plate 4 which are made of a resin are whitened and visibility is decreased. However, in the case of punching, such a problem does not occur.

[0034]

The translucent sound-absorbing panel 1 has three rectangular and frame-shaped frame members 6 (6a, 6b and 6c) along the inner peripheries of frames 10a and 10b in each of those two frames 10a and 10b. The frame members 6 each include vinyl chloride. Those frame members 6 (6a, 6b and 6c) are placed between the front perforated plate 2 and the internal perforated plate 4a, between the internal perforated plate 4a and the internal perforated plate 4b and between the internal perforated plate 4b and the back sound insulating plate 3, respectively, as shown in FIG. 2, thereby playing a role of positioning the surface perforated plate 2, the back sound insulating plate 3 and two internal perforated plates 4 (4a and 4b), with respect to the outer frame 7 and the inner frame 8, respectively. In the present embodiment, the thickness in a panel thickness direction (up-and-down direction in FIG. 2) of each of the frame members 6 (6a, 6b and 6c) is 25 mm, and the thickness in a panel planar direction (right-and-left direction in FIG. 2) of each of the frame members 6 (6a, 6b and 6c) is 20 mm. By this, a distance between the front perforated plate 2 and the internal perforated plate 4a, a distance between the internal perforated plate 4a and the internal perforated plate 4b and a distance between the internal perforated plate 4b and the back sound insulating plate 3 are set to 25 mm, respectively.

[0035]

The translucent sound-absorbing panel 1 has partition plates 5 (5a, 5b and 5c) provided in each of the plurality of spaces 9. Each of the partition plates 5 includes a material having translucency and transparency. In the present embodiment, the material of the partition plates 5 is polycarbonate. The material of the partition plates 5 may be synthetic resins such as vinyl chloride, methacrylic resin, styrol resin, ABS resin, fluorinated ethylene resin and acrylic resin, or rubbers, that are materials having translucency and transparency, or materials having translucency and transparency such as transparent or semi-transparent glasses. Both surfaces of the partition plates 5 are subjected to weatherability treatment.

[0036]

Regarding the partition plates 5, assuming that three partition plates 5a, 5b and 5c constitute one set, three sets thereof are provided in each of the frame 10a and frame 10b in parallel to a short side of the outer frame 7 as shown in FIG. 1. A long side of the outer frame 7 is divided into four by three sets of the partition plates 5. Two sets

of the partition plates 5 may be provided in each of the frame 10a and the frame 10b so as to divide a long side of the outer frame 7 into three, and four sets of the partition plates 5 may be provided in each of the frame 10a and the frame 10b so as to divide a long side of the outer frame 7 into five.

5 [0037]

Each of the partition plates 5 (5a, 5b and 5c) is supported by the frame members 6 (6a, 6b and 6c). Specifically, as shown in FIG. 3, each of three partition plates 5a is supported by the frame member 6a so that both ends of the partition plates 5a in a longitudinal direction are fit in cuts provided in two facing sides of the frame member 6a, respectively. The partition plates 5b and the partition plates 5c are similarly supported by the frame member 6b and the frame member 6c, respectively.

10 [0038]

As shown in FIG. 2, each of the internal perforated plates 4 is sandwiched by two partition plates 5. Furthermore, outer periphery of each of the internal perforated plates 4a and 4b is sandwiched by two frame members 6. By this, vibration of the internal perforated plates 4 is suppressed. Because the partition plates 5 have translucency and transparency, decrease in translucency and transparency is suppressed as compared with the case where the internal perforated plates 4 are sandwiched by metal materials.

20 [0039]

Three partition plates 5a, 5b and 5c are lined up in a straight line while sandwiching two internal perforated plates 4a and 4b one by one, toward the back sound insulating plate 3 from the front perforated plate 2. The thickness in a direction perpendicular to the lining-up direction (right-and-left direction in FIG. 2) of each partition plate 5 is set to 5 mm or more. If the thickness of each partition plate 5 is smaller than 5 mm (for example, 2 mm), each partition plate 5 falls over by wind load that the front partition plate 2 receives, and both ends of each partition plate 5 gets out of the cuts of the frame member 6. However, if the thickness of each partition plate 5 is 5 mm or more, wind load that the front perforated plate 2 received can be received by a plurality of the partition plates 5a, 5b and 5c and the back sound insulating plate 3.

25 As a result, strength of the entire translucent sound-absorbing panel 1 is improved. In the present embodiment, the thickness of each partition plate 5 in a direction perpendicular to the lining-up direction is 5 mm.

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[0040]

In the above constitution, the plate thickness of the internal perforated plate 4 is set to 0.2 mm or more and 1.5 mm or less. If the plate thickness of the internal perforated plate 4 is less than 0.2 mm, face rigidity of the internal perforated plate 4 is decreased and the internal perforated plate 4 vibrates. As a result, relative speed of sound wave passing through the through-holes 14 with respect to the through-holes 14 is decreased and the phenomenon that sound-absorbing performance is deteriorated occurs. On the other hand, if the plate thickness of the internal perforated plate 4 is larger than 1.5 mm, the hole diameter of the through-holes 14 that can be formed by perforation at low cost is increased and a sound absorption coefficient is decreased. In that respect, if the plate thickness of the internal perforated plate 4 is 0.2 mm or more and 1.5 mm or less, face rigidity of the internal perforated plate 4 is improved and the internal perforated plate 4 becomes difficult to vibrate, and additionally because the hole diameter of the through-holes 14 that can be formed by perforation at low cost is decreased, a sound absorption coefficient is improved. The hole diameter of the through-holes 14 is nearly the same as the plate thickness of the internal perforated plate 4. In the present embodiment, the plate thickness of the internal perforated plate 4a and the internal perforated plate 4b is 0.3 mm, respectively, and the hole diameter of the through-hole 14a and the through-hole 14b is 0.3 mm, respectively. The hole diameter of the through-hole 14a of the internal perforated plate 4a may differ from the hole diameter of the through-hole 14b of the internal perforated plate 4b.

[0041]

In addition, an area density ratio η which is a value obtained by dividing the area density of a plate part of the internal perforated plate 4 by the area density of air of the through-hole 14 part of the internal perforated plate 4 is set to 1.0 or more. Assuming that the aperture ratio of the internal perforated plate 4 is α , the plate thickness of the internal perforated plate 4 is t [m], the hole diameter of the through-holes 14 of the internal perforated plate 4 is d [m], the density of the plate part of the internal perforated plate 4 is ρ [kg/m³], and air density is ρ_0 [kg/cm³], the area density ratio η is represented by the following formula (1). This means that, in the case where a plurality of internal perforated plates are present (for example, 4a and 4b), the area density ratio η of the respective internal perforated plates is 1.0 or more. Furthermore,

in the case where a plurality of through-holes 14 are present, the hole diameter d means the average value thereof.

[0042]

$$\eta = \rho \cdot t \cdot (1 - \alpha) / (\rho_0 \cdot (t + 0.8 \cdot d) / \alpha) \quad (1)$$

5 [0043]

In the case where the area density ratio η is smaller than 1.0, that is, the mass of a plate part of the internal perforated plate 4 is relatively small as compared with the mass of air in the through-holes 14, because the plate part of the internal perforated plate 4 becomes easy to vibrate and vibration speed b of the plate part is increased as shown in FIG. 4(a), relative speed c between vibration speed a of air passing through the through-holes 14 and vibration speed b of the plate part is decreased and sound absorption effect by viscous damping becomes difficult to be efficiently exhibited. Therefore, if the area density ratio η is 1.0 or more, that is, the mass of the plate part of the internal perforated plate 4 is relatively large as compared with the mass of air in the through-holes 14, because the plate part becomes difficult to vibrate and vibration speed b' of the plate part is decreased as shown in FIG. 4(b), relative speed c' between vibration speed a of air passing through the through-holes 14 and vibration speed b' of the plate part is increased. As a result, sound absorption effect by viscous damping is efficiently exhibited.

20 [0044]

The plate thickness of the front perforated plate 2 is set to 2 mm or more and 3 mm or less, and is preferably set to 2 mm. If the plate thickness of the front perforated plate 2 is less than 2 mm, the front perforated plate 2 lacks in strength, and cannot satisfy, for example, 300 kg/m² which is a reference value of wind load in roads. On the other hand, if the plate thickness of the front perforated plate 2 is more than 3 mm, cost is increased, and additionally a large number of the through-holes 11 becomes difficult to be formed by perforation. In this respect, if the plate thickness of the front perforated plate 2 is 2 mm or more and 3 mm or less, and preferably 2 mm, strength of the front perforated plate 2 is improved, and the front perforated plate 2 can satisfy 300 kg/m² which is a reference value of wind load in roads. Furthermore, cost can be suppressed and additionally a large number of the through-holes 11 can be easily formed by perforation. The hole diameter of the through-holes 11 is nearly the same as the plate thickness of the front perforated plate 2. In the present embodiment, the

plate thickness of the front perforated plate 2 is 2mm and the hole diameter of the through-holes 11 is 1.9 mm.

[0045]

The plate thickness of the back sound insulating plate 3 is set to 5 mm or more and 16 mm or less, and is preferably set to 8 mm. If the plate thickness of the back sound insulating plate 3 is less than 5 mm, the entire translucent sound-absorbing panel 1 lacks in strength, and additionally sound insulating performance of the back sound insulating plate 3 is decreased. As a result, sound transmission loss of the translucent sound-absorbing panel 1 falls down, for example, the standard in roads. On the other hand, if the plate thickness of the back sound-insulating plate 3 is larger than 16 mm, cost is increased. In this respect, if the plate thickness of the back sound insulating plate 3 is 5 mm or more and 16 mm or less, and preferably 8 mm, strength of the entire translucent sound-absorbing panel 1 can be sufficiently secured, and additionally sound insulating performance of the back sound insulating plate 3 is improved. As a result, sound transmission loss of the translucent sound-absorbing panel 1 can be improved to meet the reference value or more in roads. Furthermore, cost can be suppressed. In the present embodiment, the plate thickness of the back sound insulting plate 3 is 8 mm.

[0046]

Because the translucent sound-absorbing panel 1 does not use a metal material for reinforcing the surface of the perforated plate at all, translucency and transparency are improved as compared with the case of using a metal material for reinforcement.

[0047]

As shown in FIG. 5, a large number of the through-holes 11 of the front perforated plate 2 may be densely provided on a partial region of the front perforated plate 2. Thus, in the case where a large number of the through-holes 11 of the front perforated plate 2 is densely provided on a partial region of the front perforated plate 2, a region which is not perforated in the front perforated plate 2 is increased as compared with the case where a large number of the through-holes 11 is provided in a dispersed state, if under the conditions that the number of the through-holes 11, and the aperture size and the aperture ratio in the front perforated plate are the same. For this reason, visibility can be improved as compared with the case of providing the through-holes 11 in a dispersed state.

[0048]

(Measurement of sound absorption coefficient)

Sound absorption coefficient of the translucent sound-absorbing panel was measured. Sound absorption coefficient of the translucent sound-absorbing panel in the case where the plate thickness of the front perforated plate 2 was 3 mm and the plate thickness of each of two internal perforated plates 4a and 4b was 0.075 mm is shown in FIG. 6. In FIG. 6, the vertical axis is sound absorption coefficient and the horizontal axis is 1/3 octave center frequency (Hz). The plate thickness of the back sound insulating plate 3 is the equivalent of 8 mm. The plate thickness being 0.075mm in each of two internal perforated plates 4a and 4b is a thickness exhibiting sound-absorbing performance in the case where the internal perforated plate is constituted of a metal material such as aluminum. In the measured value, the sound absorption coefficient is decreased between 500 Hz and 1,250 Hz by the influence of plate vibration as compared with the sound absorption coefficient (calculated value) in the case of assuming that the influence of plate vibration is absent.

[0049]

Measurement results of sound absorption coefficient (measured value) of the translucent sound-absorbing panel in the case where the plate thickness of each of two internal perforated plates 4a and 4b was varied and was set to 0.075 mm, 0.1 mm, 0.2 mm, 0.25 mm and 0.3 mm are shown in FIG. 7. In FIG. 7, the vertical axis is sound absorption coefficient and the horizontal axis is 1/3 octave center frequency (Hz). The plate thickness of the front perforated plate 2 is 3 mm, and the plate thickness of the back sound insulating plate 3 is the equivalent of 8 mm. The sound absorption coefficient of the translucent sound-absorbing panel 1 in the present embodiment in which the plate thickness of each of two internal perforated plates 4a and 4b is 0.2 mm or more is higher than that of the translucent sound-absorbing panel in which the plate thickness of each of two internal perforated plates 4a and 4b is less than 0.2 mm. The reason for this is as follows. By increasing the plate thickness of the internal perforated plates 4a and 4b, face rigidity of the internal perforated plates 4a and 4b is improved and plate vibration is decreased. As a result, relative speed of sound wave passing through the through-holes 14 with respect to the through-holes 14 is increased, and viscous damping action occurs in air passing through the through-holes 14, and sound absorption effect is thereby exhibited.

[0050]

The sound absorption coefficient (calculated value) of the translucent sound-absorbing panel in the case where the plate thickness of each of two internal perforated plates 4 was varied and was set to 0.5 mm, 1 mm, 1.5 mm and 2 mm is shown in FIG. 8. In FIG. 8, the vertical axis is sound absorption coefficient and the horizontal axis is 1/3 octave center frequency (Hz). The plate thickness of the front perforated plate 2 is 3 mm, and the plate thickness of the back sound insulating plate is the equivalent of 8 mm. It is found that the sound absorption coefficient is decreased with increasing the plate thickness of the internal perforated plates 4a and 4b. The reason for this is as follows. As the plate thickness of the internal perforated plates 4a and 4b is increased, the hole diameter of the through-holes 14 is increased due to limitations of processing, and as a result, damping effect by viscous damping action is decreased and the sound absorption coefficient is decreased. To realize the sound absorption of about 0.7 in 400 Hz band and about 0.8 in 1,000 Hz band, it is desirable that the plate thickness of the internal perforated plates 4a and 4b is set to 1.5 mm or less, respectively.

[0051]

As described above, it is desirable that the plate thickness of each of the two internal perforated plates 4a and 4b is 0.2 mm or more and 1.5 mm or less.

[0052]

(Relationship between area density ratio and sound absorption coefficient ratio)

The relationship between the area density ratio η and the sound absorption coefficient ratio was obtained by calculation. Assuming that sound absorption structure is constituted of one sheet of the perforated plate and an air layer, the material of the perforated plate is polycarbonate, the aperture ratio of the perforated plate is 0.20%, the hole diameter of the through-holes is 0.3 mm, and a layer thickness of the air layer behind the perforated plate is 20 mm, the sound-absorbing performance of the sound absorption structure in the case where the area density ratio η shown by the formula (1) was varied by changing the plate thickness of the perforated plate is shown in FIG. 9. In FIG. 9, the vertical axis is the sound absorption coefficient ratio and the horizontal axis is the area density ratio η . The sound absorption coefficient ratio is obtained by dividing the maximum sound absorption coefficient in the case of considering plate vibration in sound absorption by a large number of through-holes by the maximum sound absorption coefficient in the case of considering only sound absorption by a large number of through-holes. Therefore, the sound absorption

coefficient ratio represents the influence of plate vibration to sound absorption by a large number of through-holes, and it shows that in the case where the sound absorption coefficient ratio is less than 1, the sound absorption coefficient is decreased by the influence of plate vibration. As a result of calculation, the case where the sound absorption coefficient ratio is 0.7 or more is the case where the area density ratio η is 0.6 or more. Because the area density ratio η is increased with increasing the plate thickness of the perforated plate, it is found that the sound absorption performance is improved with increasing the plate thickness of the perforated plate.

[0053]

Next, assuming that the sound absorption structure is constituted of one sheet of the perforated plate and an air layer, the material of the perforated plate is aluminum, the aperture ratio of the perforated plate is 0.20%, the hole diameter of the through-holes is 0.1 mm, and the thickness of the air layer behind the perforated plate is 40 mm, the sound-absorbing performance of the sound absorption structure in the case where the area density ratio η shown by the formula (1) was varied by changing the plate thickness of the perforated plate is shown in FIG. 10. As a result of calculation, the case where the sound absorption coefficient ratio is 0.7 or more is the case where the area density ratio η is 1.0 or more.

[0054]

From the above, it is desirable that the plate thickness of the internal perforated plate 4 is set such that the area density ratio η is 1.0 or more. The calculation results shown in FIG. 9 and FIG. 10 are the case where the number of the perforated plate is 1. However, even in the case where two or more perforated plates are combined, the resulting one having larger area density ratio η has similarly high sound absorption performance. The sound-absorbing performance is improved in the range that the area density ratio η is 1.0 or more.

[0055]

(Measurement of total light transmittance)

Total light transmittance of the translucent sound-absorbing panel was measured. The total light transmittance of the translucent sound-absorbing panel 1 in the present embodiment was 60%, where the total light transmittance of a translucent sound-absorbing panel having a structure in which a translucent resin film was reinforced with an expanded metal was 24%. It is found from this fact that

translucency and transparency are improved if a metal material for reinforcement is not used at all.

[0056]

(Effect)

5 As described above, according to the translucent sound-absorbing panel 1 in the present embodiment, the plate thickness of the internal perforated plate 4 is set to 0.2 mm or more and 1.5 mm or less. If the plate thickness of the internal perforated plate 4 is less than 0.2 mm, face rigidity of the internal perforated plate 4 is decreased, and the internal perforated plate 4 vibrates. As a result, relative speed of sound wave
10 passing through-holes 14 with respect to the through-holes 14 is decreased, and the phenomenon that sound-absorbing performance is deteriorated occurs. On the other hand, if the plate thickness of the internal perforated plate 4 is more than 1.5 mm, the hole diameter of the through-holes 14 that can be formed by perforation at low cost becomes large, and the sound absorption coefficient is decreased. For this reason, the
15 plate thickness of the internal perforated plate 4 is set to 0.2 mm or more and 1.5 mm or less. As a result, face rigidity of the internal perforated plate 4 is improved and the internal perforated plate 4 becomes difficult to vibrate and additionally the hole diameter of the through-holes 14 that can be formed by perforation at low cost is decreased, thereby improving the sound absorption coefficient. Furthermore, because
20 a metal material for reinforcement is not used, translucency and transparency are improved. As a result, the sound absorbability can be improved and additionally translucency and transparency can be improved.

[0057]

25 In the case where the area density ratio η is smaller than 1.0, that is, the mass of a plate part of the internal perforated plate is relatively small as compared with the mass of air in the through-holes, the plate part becomes easy to vibrate and vibration speed of the plate part is increased. As a result, relative speed between the vibration speed of air passing through the through-holes and the vibration speed of the plate part is decreased, and the sound absorption effect by viscous damping becomes difficult to
30 be efficiently exhibited. Therefore, if the area density ratio η is 1.0 or more, that is, the mass of the plate part of the internal perforated plate is relatively increased as compared with the mass of air in the through-holes, the plate part becomes difficult to vibrate, and the vibration speed of the plate part is decreased. As a result, relative

speed between the vibration speed of air passing through the through-holes and the vibration speed of the plate part is increased, and the sound absorption effect by viscous damping can be thereby efficiently exhibited.

[0058]

5 Furthermore, if the internal perforated plate 4 is made of a resin (for example, polycarbonate), cost can be suppressed, and additionally a large number of the through-holes 14 can be easily formed by perforation.

[0059]

10 Furthermore, if a plurality of the internal perforated plates 4 is provided, sound wave passes through the through-holes 14 of the multilayer, and as a result, the sound-absorbing performance can be improved.

[0060]

15 Furthermore, if the internal perforated plate 4 is sandwiched by two or more partition plates 5 to thereby suppress vibration of the internal perforated plate 4, the sound-absorbing performance can be improved. Because the partition plate 5 has translucency and transparency, decrease in translucency and transparency can be suppressed as compared with the case of sandwiching the internal perforated plate 4 by metal materials.

[0061]

20 Furthermore, if a plurality of the partition plates 5 is lined up in a straight line, wind load that the front perforated plate 2 received can be received by a plurality of the partition plates 5 and the back sound insulating plate 3. As a result, strength of the entire translucent sound-absorbing panel 1 can be improved.

[0062]

25 Furthermore, the plate thickness of the front perforated plate 2 is set to 2 mm or more and 3 mm or less, and is preferably set to 2 mm. If the plate thickness of the front perforated plate 2 is less than 2 mm, the front perforated plate 2 lacks in strength, and cannot satisfy 300 kg/m^2 which is a reference value of wind load in roads. On the other hand, if the plate thickness of the front perforated plate 2 is larger than 3 mm, cost is increased and additionally a large number of the through-holes 11 becomes difficult to be formed by perforation. For this reason, the plate thickness of the front perforated plate 2 is set to 2 mm or more and 3 mm or less, and is preferably set to 2 mm. Because strength of the front perforated plate 2 is improved by this, the front perforated

30

plate 2 can satisfy 300 kg/m^2 which is a reference value of wind load in roads. Furthermore, cost can be suppressed and additionally a large number of the through-holes 11 can be easily formed by perforation.

[0063]

5 If the front perforated plate 2 is made of a resin (for example, polycarbonate), cost can be suppressed and additionally a large number of the through-holes 11 can be easily formed by perforation.

[0064]

10 The plate thickness of the back sound insulating plate 3 is set to 5 mm or more and 16 mm or less, and is preferably set to 8 mm. If the plate thickness of the back sound insulating plate 3 is less than 5 mm, the entire translucent sound-absorbing panel 1 lacks in strength and additionally sound insulation performance of the back sound insulating plate 3 is decreased, and sound transmission loss of the translucent sound-absorbing panel 1 thereby falls down, for example, the standard in roads. On the other
15 hand, if the plate thickness of the back sound insulating plate 3 is more than 16 mm, cost is increased. For the above reasons, the plate thickness of the back sound insulating plate 3 is set to 5 mm or more and 16 mm or less, and is preferably set to 8 mm. By this, strength of the entire translucent sound-absorbing panel 1 can be sufficiently secured and additionally sound insulation performance of the back sound
20 insulating plate 3 is improved, and sound transmission loss of a panel can be thereby improved to meet a reference value or more in roads. Furthermore, cost can be suppressed.

[0065]

25 Furthermore, if the back sound insulating plate 3 is made of a resin (for example, polycarbonate), cost can be suppressed,

[0066]

30 A large number of the through-holes 11 is densely provided on a partial region of the front perforated plate 2. In the case where a large number of the through-holes 11 is densely provided on a partial region of the front perforated plate 2, a region which is not perforated in the front perforated plate 2 is increased as compared with the case where a large number of the through-holes 11 is provided in a dispersed state, if under the conditions that the number of the through-holes 11, and the aperture size and the aperture ratio in the front perforated plate are the same. For this reason, visibility can

be improved as compared with the case of providing the through-holes 11 in a dispersed state.

[0067]

(Modification example of present embodiment)

5 The embodiment of the present invention is described above, but the embodiment merely exemplifies a specific example and particularly does not limit the present invention, and the design can be appropriately changed in specific constitution and the like. Furthermore, the action and effect described in the embodiment of the invention merely enumerate the most preferred action and effect generated from the present invention, and the action and effect by the present invention are not limited to those described in the embodiment of the present invention.

[0068]

15 For example, in the present embodiment, as shown in FIG. 2, a distance between the front perforated plate 2 and the internal perforated plate 4a, a distance between the internal perforated plate 4a and the internal perforated plate 4b and a distance between the internal perforated plate 4b and the back sound insulting plate 3 are set to 25 mm, respectively. However, the present invention is not limited to this constitution, and the respective distances may differ.

[0069]

20 Furthermore, in the present embodiment, the aperture ratios of the front perforated plate 2, the internal perforated plate 4a and the internal perforated plate 4b are designed so as to be stepwisely decreased with increasing distance from a sound source, but the present invention is not limited to this embodiment. The aperture ratio of the front perforated plate 2 may be the same as the aperture ratio of the internal perforated plate 4a, the aperture ratio of the internal perforated plate 4a may be the same as the aperture ratio of the internal perforated plate 4b, and the aperture ratios of the internal perforated plate 2, the internal perforated plate 4a and the internal perforated plate 4b may be all the same.

[0070]

30 While the present embodiments of the present invention has been described in detail and with reference to specific embodiments thereof, it will be appreciated that the present invention is not limited thereto, and the present invention will be carried out with various modification without departing from the scope of the claims.

This application is based on Japanese Patent Application No. 2011-226316 filed on October 14, 2011, the entire subject matters of which are incorporated herein by reference.

5 Industrial Applicability

[0071]

According to the translucent sound-absorbing panel of the present invention, if the plate thickness of the internal perforated plate is set to 0.2 mm or more and 1.5 mm or less, the face rigidity of the internal perforated plate is improved and the internal
 10 perforated plate becomes difficult to vibrate, and additionally a hole diameter of through-holes that can be formed by perforation at low cost becomes small. As a result, sound absorption coefficient is improved. Furthermore, because a metal material for reinforcement is not used, translucency and transparency are improved. As a result, sound absorbability can be improved and additionally translucency and
 15 transparency can be improved.

Description of Reference Numerals and Signs

[0072]

- 1: Translucent sound-absorbing panel
- 20 2: Front perforated plate
- 3: Back sound insulating plate
- 4a, 4b: Internal perforated plate
- 5a, 5b, 5c: Partition plate
- 6a, 6b, 6c: Frame member
- 25 7: Outer frame
- 8: Inner frame
- 9: Space
- 10a, 10b: Frame
- 11, 14: Through-hole

CLAIMS

1. A translucent sound-absorbing panel, comprising:
 - a front perforated plate to face a sound source, which comprises a material
 - 5 having translucency and transparency and has a large number of through-holes;
 - a back sound insulating plate which is placed behind the front perforated plate with respect to the sound source and comprises a material having translucency and transparency; and
 - an internal perforated plate which is placed between the front perforated plate
 - 10 and the back perforated plate so as to separate a space between the front perforated plate and the back perforated plate into a plurality of spaces, comprises a resin material having translucency and transparency and has a large number of through-holes,
 - wherein assuming that an aperture ratio is α , a plate thickness is t , a hole diameter of the through-hole is d , a density of a plate part is ρ and air density is ρ_0 , the
 - 15 internal perforated plate has an area density ratio η which is a value obtained by dividing an area density of the plate part by an area density of air of a part of the through-hole and is represented by the following formula is 1.0 or more:

$$\eta = \rho \cdot t \cdot (1 - \alpha) / (\rho_0 \cdot (t + 0.8 \cdot d) / \alpha) \quad (1),$$
 - and the plate thickness t is 0.2 mm or more and 1.5 mm or less and the aperture
 - 20 ratio α is 0.5% or less.

2. The translucent sound-absorbing panel according to claim 1, further comprising a front-side internal perforated plate, wherein the front-side internal perforated plate is provided between the front perforated plate and the back sound
- 25 insulating plate and is provided nearer the side of the front perforated plate rather than the side of the internal perforated plate, and has the area density ratio η of 1.0 or more, the plate thickness t of 0.2 mm or more and 1.5 mm or less and the aperture ratio α of 1% or less, the aperture ratio α of the front-side internal perforated plate being larger than the aperture ratio α of the internal perforated plate.

30

3. The translucent sound-absorbing panel according to claim 1 or 2, further comprising a partition plate which is provided in each of the plurality of spaces and comprises a material having translucency and transparency,

wherein the internal perforated plate is sandwiched by two or more of the partition plates.

4. The translucent sound-absorbing panel according to claim 3, wherein
5 a plurality of the partition plates are lined up in a straight line toward the back sound
insulating plate from the front perforated plate while sandwiching the internal
perforated plate .
5. The translucent sound-absorbing panel according to any one of claims
10 1 to 4, wherein a plate thickness of the front perforated plate is 2 mm or more and 3 mm
or less.
6. The translucent sound-absorbing panel according to any one of claims
15 1 to 5, wherein a material of the front perforated plate is a resin.
7. The translucent sound-absorbing panel according to any one of claims
1 to 6, wherein a plate thickness of the sound insulting plate is 5 mm or more and 16
mm or less.
8. The translucent sound-absorbing panel according to any one of claims
20 1 to 7, wherein a material of the back sound insulting plate is a resin.
9. The translucent sound-absorbing panel according to any one of claims
1 to 8, wherein a large number of the through-holes are densely provided on a partial
25 region of the front perforated plate.