

ACOUSTIC WAVE PHASE VARYING APPARATUS

AND SOUND INSULATING WALL

BACKGROUND OF THE INVENTION

Field of the Invention:

The present invention relates to an acoustic wave phase varying apparatus located around a sound source or in a propagation path for advancing or delaying the phase of an acoustic wave; and further to a sound insulating wall (sound barrier) utilizing the acoustic wave phase varying apparatus.

Description of the Related Art:

Fig. 23A is an explanatory view showing a prior sound-insulating wall exemplified by Japanese Patent Publication No. 51-46969. In the illustration, a sound absorbing material 2 is placed along an upper end portion of a sound insulating wall 1. Various types of configurations and fitting constructions are available in terms regards to the sound absorbing material 2 as shown in Figs. 23A to 23G.

In addition, Fig. 24A is an explanatory view of another example of a prior sound insulating wall exemplified by Japanese Patent Laid-Open No. 52-91514. In the illustration, a non-transmission member 3 is installed along an upper end portion of a sound insulating wall 1. The non-transmission member 3 has a structure capable of hindering the transmission of an acoustic wave. Similarly, various types of configurations and fitting constructions are practicable for the non-transmission member 3 as shown in Figs. 24A to 24H.

Furthermore, Fig. 25 is an explanatory view illustration for describing the operation of the sound insulating wall of

Fig. 23A. The sound absorbing material 2 absorbs any acoustic waves 5a emitted from a sound source 4 that strike it directly and any acoustic waves 5b that strike it after being reflected from the sound insulating wall 1. Accordingly, only acoustic waves 5c diffracting over the sound absorbing material 2 constitute acoustic waves running over the sound insulating wall to be radiated toward the outside, thus reducing the sound running over the sound insulating wall.

Still further, Fig. 26 is an explanatory view for describing the operation of the sound insulating wall of Fig. 24A. The non-transmission member 3 reflects any acoustic waves 5d directly strike it and any acoustic waves 5e strike it after being reflected from the sound insulating wall 1. The phases of these acoustic waves 5d and 5e are slightly shifted relative to the phase of acoustic waves 5c diffracted at the non-transmission member 3, due to the difference in path length therebetween. For this reason, the acoustic waves 5d, 5e and the acoustic wave 5c are weakened by interfering with each other, with the result that the sound running over the sound insulating wall is reduced.

However, in the prior sound insulating wall using the aforesaid sound absorbing material 2, the acoustic wave 5c diffracting at the sound absorbing material 2 can not be reduced. Further, in the case of the sound insulating wall using the non-transmission member 3, no great sound reduction effect due to mutual interference can be expected from a phase shift caused only by a difference in path length resulting from the shape thereof.

SUMMARY OF THE INVENTION

The present invention has been achieved with a view toward solving the problems described above, and it is an object of the present invention to provide an acoustic wave phase varying apparatus and a sound insulating wall which are capable of radically shifting the phases of incident acoustic waves to enhance the sound reduction effect due to their mutual interference.

To this end, according to one aspect of the present invention, there is provided an acoustic wave phase varying apparatus comprising a porous member made from a porous material and a sound insulating plate assembly constructed by combining a plurality of sound insulating plates and made to support the porous member and to form a plurality of independent spaces with different volumes at the back of the porous member.

According to another aspect of the present invention, there is provided a sound insulating wall comprising a sound insulating panel provided to stand in the vicinity of a sound source and an acoustic wave phase varying apparatus including a porous member made from a porous material and a sound insulating plate assembly constructed by combining a plurality of sound insulating plates and placed along an upper end portion of the sound insulating panel, the sound insulating plate assembly supporting the porous member and forming a plurality of independent spaces with different volumes behind the porous member.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a cross-sectional view showing a principal portion of a sound insulating wall including an acoustic wave phase varying apparatus according to a first embodiment of the present invention;

Fig. 2 is an explanatory view for describing the operation of the sound insulating wall of Fig. 1;

Fig. 3 is an illustration of one example of a relationship between a frequency f and a difference θ in phase between an incident acoustic wave and a reflected acoustic wave in the acoustic wave phase varying apparatus of Fig. 1;

Fig. 4 is a cross-sectional view showing a principal portion of a sound insulating wall including an acoustic wave phase varying apparatus according to a second embodiment of this invention;

Fig. 5 is an explanatory view for describing the operation of the sound insulating wall of Fig. 4;

Fig. 6 is a cross-sectional view showing a principal portion of an acoustic wave phase varying apparatus according to a third embodiment of this invention;

Fig. 7 is a cross-sectional view showing a principal portion of an acoustic wave phase varying apparatus according to a fourth embodiment of this invention;

Fig. 8 is a cross-sectional view showing a principal portion of an acoustic wave phase varying apparatus according to a fifth embodiment of this invention;

Fig. 9 is a cross-sectional view showing a principal portion of an acoustic wave phase varying apparatus according to a sixth embodiment of this invention;

Fig. 10 is a cross-sectional view showing a principal

portion of an acoustic wave phase varying apparatus according to a seventh embodiment of this invention;

Fig. 11 is a cross-sectional view showing a principal portion of a modification of the apparatus in Fig. 10 ;

Fig. 12 is a cross-sectional view showing a principal portion of an acoustic wave phase varying apparatus according to an eighth embodiment of this invention;

Fig. 13 is a cross-sectional view showing a principal portion of a modification of the apparatus in Fig. 12 ;

Fig. 14 is a cross-sectional view showing a principal portion of an acoustic wave phase varying apparatus according to a ninth embodiment of this invention;

Fig. 15 is a cross-sectional view showing a principal portion of an acoustic wave phase varying apparatus according to a tenth embodiment of this invention;

Fig. 16 is a cross-sectional view showing a principal portion of an acoustic wave phase varying apparatus according to an eleventh embodiment of this invention;

Fig. 17 is a cross-sectional view showing a principal portion of an acoustic wave phase varying apparatus according to a twelfth embodiment of this invention;

Fig. 18 is a plan view showing an arrangement of an acoustic wave phase varying apparatus according to a thirteenth embodiment of this invention;

Fig. 19 is a plan view showing a modification of the apparatus in Fig. 18 ;

Fig. 20 is a plan view showing another modification of the Fig. 18 apparatus;

Fig. 21 is a perspective view schematically showing an acoustic wave phase varying apparatus according to a

fourteenth embodiment of this invention;

Fig. 22 is a perspective view schematically showing a modification of the apparatus in Fig. 21 ;

Figs. 23A to 23G are explanatory views for describing examples of prior sound insulating walls having sound absorbing materials;

Figs. 24A to 24H are explanatory views for describing examples of prior sound insulating walls having non-transmission members;

Fig. 25 is an explanatory view for describing the operation of the sound insulating wall of Fig. 23A; and

Fig. 26 is an explanatory view for describing the operation of the sound insulating wall of Fig. 24A.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The embodiments according to the present invention will now be described with reference to the accompanying drawings.

First Embodiment

Fig. 1 is a cross-sectional view showing a principal portion of a sound insulating wall including an acoustic wave phase varying apparatus according to the First Embodiment of this invention, and Fig. 2 is an illustration for explaining the operation of the sound insulating wall of Fig. 1.

In the illustrations, a sound insulating panel 11 is provided to stand at a side portion of a road over which sound sources (or noise sources) 4 such as motor vehicles pass. A first sound insulating plate 12 is vertically fixed on an upper end portion of the sound insulating panel 11.

In addition, a plurality of second sound insulating plates 13 are horizontally fixedly attached to both side surfaces of the first sound insulating plate 12. The first and second sound insulating plates 12, 13 are made from, for example, steel or plastic plate. Further, the combination of first and second sound insulating plates 12, 13 comprise a sound insulating plate assembly 14.

A cylindrical porous member 15 is located on the outer circumference of the sound insulating plate assembly 14. The porous member 15 extends in the longitudinally directions of the sound insulating panel 11. Further, at the back of the porous member 15 there are defined independent spaces 16 with different volumes. An acoustic wave phase varying apparatus 17 according to the First Embodiment is therefore composed of the porous member 15 and the sound insulating plate assembly 14 additionally serving as a reinforcement. In addition, the acoustic wave phase varying apparatus 17 and the sound insulating panel 11 constitute the sound insulating wall according to the First Embodiment.

The porous member 15 can be made of a material such as plastic, ceramic and foamed metal. For instance, in the case of using plastic for manufacturing the porous member 15, the plastic particulate can be heated to be partially welded to each other. Such a manufacturing method has been disclosed in, for example, Japanese Patent Laid-Open No. 2-289333. Among the plastic materials that may be used are polypropylene resin, acrylate resin, vinyl chloride resin, ABS resin, polycarbonate resin and so on. According to the method of welding the plastic particulates, a porous member

15 with a desirable configuration can be easily formed using a mold.

Next, a description will be made of the operation of this embodiment. In Fig. 2, acoustic waves 18 directly incident on the acoustic wave phase varying apparatus 17 and acoustic waves 19 striking the acoustic wave phase varying apparatus 17 after being reflected from the sound insulating panel 11 pass through the porous member 15 to enter the spaces 16 where they are reflected by the sound insulating plates 12, 13 making up the wall portions of the spaces 16. Subsequently, the acoustic waves pass through the porous member 15 to come out of the acoustic wave phase varying apparatus 17.

When the acoustic waves 18 strike the acoustic wave phase varying apparatus 17 at an incident angle β and then goes out as an acoustic waves 18a, the normal acoustic impedance Z of the acoustic wave phase varying apparatus 17 can be expressed as $Z = \rho a / \cos(\beta) \times (P_i + P_r) / (P_i - P_r)$ where ρa (ρ being air density and a being acoustic velocity in air) represents a characteristic impedance of air, P_i designates a sound pressure of the incident acoustic waves 18, and P_r denotes a sound pressure of the reflected acoustic waves 18a (leaving the acoustic wave phase varying apparatus 17).

From the above equation, the sound pressure reflectance R of the acoustic wave phase varying apparatus 17 can be given by $R = P_r / P_i = (Z \cos(\beta) - \rho a) / (Z \cos(\beta) + \rho a)$. In addition, from this equation, the difference θ in phase between the incident acoustic waves 18 and the reflected acoustic waves 18a can be expressed as $\theta = \arg(R)$.

Furthermore, the porous member 15 of the acoustic wave phase varying apparatus 17 has acoustic characteristics including an acoustic mass m and an acoustic resistance r , while the spaces 16 have acoustic characteristics including an acoustic capacity c , and hence, when the frequency is f , the normal acoustic impedance Z of the acoustic wave phase varying apparatus 17 can be expressed as $Z = r + j2\pi fm + 1/j2\pi fc$. In this instance, $j^2 = -1$.

As mentioned before, the phase difference θ between the incident acoustic waves 18 and the reflected acoustic waves 18a varies with the normal acoustic impedance Z . With the acoustic wave phase varying apparatus 17 according to the First Embodiment, the normal acoustic impedance Z is controllable, thus enabling the phase difference to vary. More specifically, a desirable phase characteristic is obtainable by controlling the acoustic mass m and the acoustic resistance r with the thickness and voids of the porous member 15 and others and further by controlling the acoustic capacity c with the volume of the spaces 16. Further, if the aforesaid plastic particulates are used as the material for porous member 15, the voids are easily controllable with the welding degree between the plastic particulates.

Fig. 3 is an illustration of one example of a relationship between the frequency f and the phase difference θ between the incident acoustic waves 18 and the reflected acoustic waves 18a in the acoustic wave phase varying apparatus 17. In the illustration, the fact that the phase difference θ is 180 degrees or -180 degrees signifies that the incident acoustic waves 18 turn into a

negative-phase condition to reflect as reflected acoustic waves 18a. Thus, when the phase difference θ becomes 180 degrees or -180 degrees, the reflected acoustic waves 18a take on an antiphase relation with acoustic wave 20 diffracting over the acoustic wave phase varying apparatus 17 so that both tend to cancel each other significantly attenuating the acoustic waves as a whole.

As described above, the acoustic wave phase varying apparatus 17 according to the First Embodiment can greatly shift the phase of the incident acoustic wave, with the result that a greater sound reduction effect is obtainable through the mutual interference of the acoustic waves. In addition, since a plurality of independent spaces 16 having different volumes exist behind the porous member 15, it is possible to offer a plurality of phase characteristics suitable for different frequencies and hence to enhance the sound reduction effect in terms of acoustic waves in a wider frequency-range.

Moreover, in the case of employing the partially welded plastic particulates as the porous member 15 material, the formation into various geometries becomes easy to carry out and void control is facilitated.

Furthermore, if an acrylate resin, a vinyl chloride resin, an ABS resin, a polycarbonate resin, or the like which allows the transmission of light is used for the sound insulating plate assembly 14 and the porous member 15, this will prevent the area around an installed sound insulating wall from becoming dark.

Second Embodiment

Fig. 4 is a cross-sectional view showing a principal

portion of a sound insulating wall including an acoustic wave phase varying apparatus according to the Second Embodiment of this invention, and Fig. 5 is an explanatory view of the operation of the Fig. 4 sound insulating wall. Although in the First Embodiment the cross section of the acoustic wave phase varying apparatus 17 has a circular cross-section, in the Second Embodiment an acoustic wave phase varying apparatus 21 has a substantially semi-cylindrical plate-like configuration. In addition, a porous member 15 and a second sound insulating plate 13a existing at the lowermost position and exposed to the outside are joined to define an angular portion (an edge portion) 22. The other arrangements are the same as the First Embodiment.

Next, a description will be made of the operation of the sound insulating wall. The phase of acoustic waves 18 directly incident on the acoustic wave phase varying apparatus 21 is shifted as in the First Embodiment. Further, acoustic wave 23 passing through the angular portion after being reflected from the sound insulating panel 11 are shifted by, for example, 180 degrees in phase due to the phase varying effect caused by the configuration of the angular portion 22. Thus, phase-shifted acoustic waves 18a, 23a and acoustic waves 20 diffracting above the acoustic wave phase varying apparatus 21 tend to cancel each other to attenuate the entire acoustic wave.

When using such an acoustic wave phase varying apparatus, in comparison to the Fig. 1 apparatus with a circular cross section, not only is the entire size of the apparatus reducible, but the manufacturing thereof is also facilitated. In addition, because of the provision of the

angular portion 22, the phase varying effect stemming from the configuration of the angular portion 22 is also obtainable. Moreover, since the angular portion 22 is situated at both sides of the acoustic wave phase varying apparatus 21, the sound reduction effect is achievable no matter what side of the acoustic wave phase varying apparatus 21 a sound source 4 is positioned.

Third Embodiment

Fig. 6 is a cross-sectional view showing a principal portion of an acoustic wave phase varying apparatus according to the Third Embodiment of this invention. In this example, an acoustic wave phase varying apparatus 24 has a substantially sectorial cross section.

As compared with the Second Embodiment, such an apparatus permits a further reduction in total size. In addition, a sound reduction effect is attainable with respect to a sound source at the angular portion 22 side, just as in the Second Embodiment.

Fourth Embodiment

Fig. 7 is a cross-sectional view showing a principal portion of an acoustic wave phase varying apparatus according to the Fourth Embodiment of this invention. Although in the First, Second and Third Embodiments the porous member 15 has a curved configuration, an acoustic wave phase varying apparatus 25 according to the Fourth Embodiment employs a flat plate-like porous member 26.

Since the porous member 26 has a flat plate-like configuration, its manufacture and assembly are facilitated. In addition, because of the formation of an angular portion 22, a sound reduction effect is obtainable similar to the

Third Embodiment.

Fifth Embodiment

Fig. 8 is a cross-sectional view showing a principal portion of an acoustic wave phase varying apparatus according to the Fifth Embodiment of this invention. Although in the above-mentioned embodiments there is only one porous member, an acoustic wave phase varying apparatus 27 according to the Fifth Embodiment uses a plurality of separate porous members 28. Angular portions 29 are formed at portions joining the respective porous member 28 and sound insulating plates 13.

Such an acoustic wave phase varying apparatus 27 not only shifts the phase of the acoustic waves incident on the porous members 28 but also varies the phases thereof with the angular portions 22 and 29, and therefore a great sound reduction effect is attainable.

Although in Fig. 8 the porous members 28 have a flat plate-like configuration, it is also possible that, for example, they have a corrugated or wave-like cross section.

Sixth Embodiment

Fig. 9 is a cross-sectional view showing a principal portion of an acoustic wave phase varying apparatus according to the Sixth Embodiment of this invention. An acoustic wave phase varying apparatus according to the Sixth Embodiment uses a flat plate-like porous member 26. It has a cross-sectional configuration nearly the inverse of that in Fig. 7.

An acoustic wave phase varying apparatus 30 with such a configuration can also provide a sound reduction effect substantially similar to that of the Third Embodiment.

Seventh Embodiment

Figs. 10 and 11 are cross-sectional views showing principal portions of acoustic wave phase varying apparatuses according to the Seventh Embodiment of this invention. In the illustrations, a sound insulating plate assembly 31 comprises first and second sound insulating plates 12, 13, a third sound insulating plate 32 with a circular arc cross section, and two fourth sound insulating plates 33 disposed to extend radially from the third sound insulating plate 32. An acoustic wave phase varying apparatus 34 is composed of the sound insulating plate assembly 31 and a porous member 35 with a circular arc cross section. Although the plate-like porous member 35 is made of a material that is the same as those in the above-mentioned embodiments, its thickness varies. In the porous member 35 of Fig. 10, its thickness varies to become larger toward one end portion, while in the porous member 35 of Fig. 11 its thickness varies to become larger toward the other end portion.

Next, a description will be made of the operation thereof. The porous member 35 of the acoustic wave phase varying apparatus 34 has, as acoustic characteristics, an acoustic mass m and an acoustic resistance r , and a space 16 retains an acoustic capacity c . The variation in thickness of the porous member 35 can be used to adjust the acoustic mass m and the acoustic resistance r , thus providing a desired phase characteristic.

Although in Figs. 10 and 11 the thickness of the porous member 35 continuously varies, it is also appropriate for it to be varied incontinuously.

Eighth Embodiment

Figs. 12 and 13 are cross-sectional views showing principal portions of acoustic wave phase varying apparatus according to the Eighth Embodiment of this invention. In an acoustic wave phase varying apparatus 36 according to this embodiment, porous members 15 each having an even thickness are piled up to change the entire thickness. Fig. 13 illustrates a piling example different from that of Fig. 12. These acoustic wave phase varying apparatuses 36 also offer the same effect as the Seventh Embodiment.

Ninth Embodiment

Fig. 14 is a cross-sectional view showing principal portion of an acoustic wave phase varying apparatus according to the Ninth Embodiment of this invention. In this embodiment, an acoustic wave phase varying apparatus 37 employs, in place of the flat plate-like porous member 28 in Fig. 8, porous members 38, 39 having a curved cross section.

When the porous members 38, 39 are made to have a curved cross section, their essential surface area, i.e., the acoustic wave reception area, becomes larger than the projected area. Accordingly, the apparent acoustic mass m and acoustic resistance r become smaller so that the phase difference characteristic becomes closer to 180 degrees. Accordingly, further excellent sound reduction effects can be attained.

Tenth Embodiment

The cross-sectional configuration of the porous member is not limited to that of Fig. 14, and it is also possible to use a porous member 40 with a cross-sectional configuration, for example, as shown in Fig. 15. Even in

this case, the same effect is obtainable as long as the surface area exceeds the projected area.

Eleventh Embodiment

Fig. 16 is a cross-sectional view showing a principal portion of an acoustic wave phase varying apparatus according to the Eleventh Embodiment of this invention. In an acoustic wave phase varying apparatus 41 according to this embodiment, sound insulating plates constituting bottom portions of spaces 16, i.e., second sound insulating plates 13, are respectively inclined with respect to the horizontal, and their lower end portions are connected to a porous member 15. The other arrangements are the same as those in the Third Embodiment.

In the acoustic wave phase varying apparatus 41, water coming in the spaces 16 after passing through the porous member 15 flows along the second sound insulating plates 13 and then comes out through the porous member 15 in the vicinity of an angular portion 22. Thus, in cases where the acoustic wave phase varying apparatus 41 is applied to a sound insulating wall and installed outdoors, countermeasures against rain water become easy to adapt. Further, the sound reduction effect is the same as that of the Third Embodiment.

Twelfth Embodiment

Fig. 17 is a cross-sectional view showing a principal portion of an acoustic wave phase varying apparatus according to the Twelfth Embodiment of this invention. In an acoustic wave phase varying apparatus 42 according to this embodiment, a lighting device 43 such as a fluorescent lamp is provided within a sound insulating plate assembly

31. In addition, a porous member 15 and the sound insulating plate assembly 31 are made of a transparent or translucent material such as acrylate resin, vinyl chloride resin, ABS resin, polycarbonate resin and so on.

When using the acoustic wave phase varying apparatus thus arranged, the sound insulating wall may also double as lighting equipment. In addition, the sound reduction effect is virtually the same as that of the Third Embodiment.

Thirteenth Embodiment

Fig. 18 is a plan view showing an arrangement of an acoustic wave phase varying apparatus according to the Thirteenth Embodiment of this invention, where the cross-sectional configuration is the same as the Fig. 4 configuration. In an acoustic wave phase varying apparatus 21 according to this embodiment, its entire cross-sectional dimension varies in its longitudinal direction so that the acoustic wave reception surface is enlarged.

Since in the acoustic wave phase varying apparatus 21 the virtual surface area is greater than the projected area, the apparent acoustic mass m and acoustic resistance r are reducible, with the result that the phase difference characteristic becomes closer to 180 degrees so that a more excellent sound reduction effect can be attained.

Although in Fig. 18 the plane shapes of both side portions of the acoustic wave phase varying apparatus 21 assume a saw tooth like configuration, the configuration is not limited thereto, and it is also possible to take a wave-like configuration as shown in Fig. 19. Further, in the acoustic wave phase varying apparatus 24 with the cross-sectional configuration as shown in Fig. 6, the plane shape

of one side portion can be formed as shown in Fig. 20.

Fourteenth Embodiment

Fig. 21 is a perspective view schematically showing an acoustic wave phase varying apparatus according to the Fourteenth Embodiment of this invention. Although in the above-described embodiments an acoustic wave phase varying apparatus constructed separately is attached onto a sound insulating panel, in this embodiment a sound insulating panel 11 section and an acoustic wave phase varying apparatus 24 section are integrally manufactured in advance.

Thus, it is possible to decrease the number of parts and simplify the installation owing to the common use of components.

Fig. 22 is a perspective view schematically showing another example of the Fig. 21 apparatus. In this example, both longitudinal end portions 11a of a sound insulating panel 11 are more extended than the acoustic wave phase varying apparatus 24 section. The resultant sound insulating wall results in easy installation in such a manner that columns (not shown) with an H-shaped cross section are planted at given intervals and both the end portions 11a of the sound insulating panel 11 are fitted into the channels of the H-shaped cross section type columns.

In the case of integrating the acoustic wave phase varying apparatus and the sound insulating panel, the acoustic wave phase varying apparatus section may be changed as illustrated in the above-described embodiments.

Although in the respective embodiments the acoustic wave phase varying apparatus is used for a sound insulating wall,

the acoustic wave phase varying apparatus may also be placed on other structures such as buildings, without a sound insulating panel.



WHAT IS CLAIMED IS:

1. An acoustic wave phase varying apparatus, comprising:
a porous member made from porous material; and
a sound insulating plate assembly constructed by combining a plurality of sound insulating plates and made to support said porous member and to form a plurality of independent spaces with different volumes at the back of said porous member.
2. An acoustic wave phase varying apparatus according to Claim 1 wherein said porous member is made from porous material produced by partially welding a large number of plastic particles.
3. An acoustic wave phase varying apparatus according to Claim 1 wherein said porous member and said sound insulating plates exposed to the outside are joined to each other to form an angular portion.
4. An acoustic wave phase varying apparatus according to Claim 1 wherein said porous member has a plate-like configuration with a varying thickness.
5. An acoustic wave phase varying apparatus according to Claim 1 wherein the thickness of said porous member is varied by changing the number of lamination layers.
6. An acoustic wave phase varying apparatus according to Claim 1 wherein said porous member has a bent cross section.
7. An acoustic wave phase varying apparatus according to Claim 1 wherein the entire cross section of said apparatus varies in dimension in its longitudinal direction so that its acoustic wave reception area is enlarged.
8. An acoustic wave phase varying apparatus according to Claim 1 wherein said sound insulating plate constituting a



bottom portion of said spaces is inclined with respect to a horizontal direction, and a lower end portion thereof is joined to said porous member.

9. An acoustic wave phase varying apparatus according to Claim 1 wherein said porous member and said sound insulating plate assembly are made of a material which allows light to be transmitted therethrough.

10. A sound insulating wall comprising;

a sound insulating panel provided to stand in the vicinity of a sound source; and

an acoustic wave phase varying apparatus including a porous member made from porous material and a sound-insulating plate assembly constructed with a combination of a plurality of sound insulating plates and placed along an upper end portion of said sound insulating panel, said sound insulating plate assembly supporting said porous member and forming a plurality of independent space portions with different volumes behind said porous member.