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A NEW DESIGN OF LIGHTWEIGHT PANEL TO IMPROVE STATIC STRENGTH AND SOUND INSULATION

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ABSTRACT

A new concept of lightweight panel has been developed to improve both static strength and sound insulation properties. The idea has been tested for three different configurations with a flat steel panel of similar surface density as a reference. Results show that the sound reduction index of the complete combination is about $4 - 7$ dB higher than that of the reference one in 1/3 octave band from 250 to 1 kHz. At the same time, the static stiffness is also much higher than that of a flat steel panel with the similar surface density.

1 - INTRODUCTION

Lightweight panels are commonly used nowadays in industry. From acoustic point of view, lightweight is contradictory to the requirement of high sound transmission loss. Some special consideration has to be made in order to compensate this weak point.

On the other hand, in order to increase the static strength of a lightweight structure, sandwich panels or corrugated panels are often used. This may make the situation of sound insulation even worse, since the high bending stiffness results in low coincidence frequency, which is usually in audible frequency range. The idea solution of this problem is to make a structure with a high static stiffness when it is mounted to fulfil stability requirement, and with a low dynamic stiffness to make the coincidence frequency higher.

As a whole, we need to design a lightweight panel with high static strength, and the sound transmission loss of that should be equal to or higher than an isotropic panel with similar surface density. This is the task of this investigation.

2 - THE NEW CONCEPT

It is well known that the sound transmission loss of normal incidence is more than 5 dB higher than that of random incidence (Beranek 1988, [1]). We also know that a cavity connected to an absorptive material will improve the acoustic properties of that material. Those properties may give us some hints when we design a new panel: The structure should attenuate more oblique incident sound waves than the normal incident sound waves. At the same time, it should be lightweight. A bank of parallel thin-walled pipes bonded together perpendicular to a light base panel may do the job. Those pipes will improve the static stiffness of the panel when they are fixed. If they are long enough, only plane waves will exist in the pipes. For short pipes, as in the case, they might also have some positive influence on the properties of the sound transmission loss. Furthermore, these tubes plus the base panel form many open cavities, which will improve the acoustic properties of the panel a lot when the panel is combined to other absorptive materials, as we will see later.

Based on above considerations, we decided to build an open-cell aluminum honeycomb panel, which consists of a honeycomb core bonded to an aluminum face at one side. The open cells have little influence on normal incident sound waves, but may make the oblique sound transmission more difficult. When the edges of the panel are clamped to a structure, the honeycomb core makes the panel very strong to stand a high load. Meanwhile, for the waves with the bending wavelength shorter than the width of the panel, the effective bending stiffness is still, roughly, of the order of the laminate. In that way, we push the coincidence frequency to the high end and increase the sound transmission loss in the interesting frequency range.

3 - TEST SAMPLES AND METHOD

The concept is tested experimentally. Two test panels are designed in the light of the above guidelines. Each sample is of the size of *1.1 m x 2 m*. For the purpose of comparison, a plain steel panel and an ordinary honeycomb panel are also made with the same size. The thickness of the open-cell honeycomb panels is designed such that when the panel is fixed at the edge, the expected maximum static displacement of the commercial honeycomb panel is in between that of the design no. 2 and of the design no. 1 when 1 100 *kg* load is placed at the center. The details of all test panels are listed in Table 1.

Test sample	**Description**	**Thickness**	**Surface density**
Steel panel	Simple 1 *mm* steel plate	1 *mm*	7.85 kg/m^2
Sample 1	1.5 *mm* Al plate bonded to 25 *mm* of Al honeycomb core (9.5 *mm* cells, 59 kg/m^3)	26.5 *mm*	5.5 kg/m^2
Sample 2	1.5 *mm* Al plate bonded to 25 *mm* of Al honeycomb core (6.4 *mm* cells, 83 kg/m^3)	26.5 *mm*	6.1 kg/m^2
Honeycomb panel	1 *mm* Al plate bonded to either side of an 8 *mm* Al honeycomb core (6.4 *mm* cells, 83 kg/m^3)	10 *mm*	6.1 kg/m^2

Table 1: Test samples.

All panels are tested in three different configurations: the test panels alone, the test panel plus a woolen absorbent plate, and the test panel plus a woolen absorbent and a plastic sheet (with an air gap). The weight and thickness of the test situations are listed in Table 2.

Test sample	**With absorbent panel (40 *mm*)**		**With absorbent, plastic panel and air gap**	
	Thickness (*mm*)	Density (kg/m^2)	Thickness (*mm*)	Density (kg/m^2)
Steel panel	41	11.95	75	16.15
Sample 1	66.5	9.6	100.5	13.8
Sample 2	66.5	10.2	100.5	14.4
Honeycomb	50	10.2	84	14.4

Table 2: Weight and thickness for different test situations (the density of the woolen absorbent is 4.1 $kg/m^2$and of the plastic panel is 4.2 kg/m^2).

The samples are mounted in between a reverberation room and an anechoic room with the intensity method to measure transmitted sound power. The air-borne sound reduction index is calculated by using the formula (*Nordtest Method NT ACOU 084*)

$$R_I = L_{p1} - 6 - (L_{In} + 10\log(S_m/S)) \text{ dB} \tag{1}$$

Where L_{p1} is the average sound pressure level in the source room and L_{In} is the average sound intensity level over the panel surface measured in the receiving room, S_m is the measurement area and S is the area of the test specimen. Scan method is used to measure the sound intensity (ISO/DIS 9614-2), and a rotating microphone is used to measure sound pressure level in the source room.

4 - RESULTS

The sound reduction indexes of the four panels are shown in Figure 1. The effect of coincidence is clearly seen for the standard honeycomb panel but not for the new designs, although they have roughly the same displacement for the same static load. We may also see that the sound reduction indexes of the new designs are still not as good as that of the reference steel plate, partly due to the difference of the surface densities (see Table 1).

The performance of the open-cell honeycomb panel becomes much better when an absorbent plate is placed in the front of the panel (Figure 2). The cells now act as the back cavities of the absorptive material, which make the material much more effective. The combination of the cavities and the absorbent

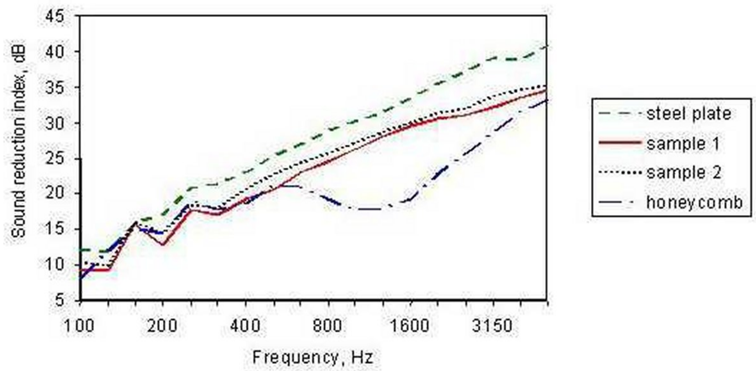

Figure 1: Sound reduction index of the panels only.

may also makes the sound waves to be more "normal" when they reach the base panel. As a result, the sound reduction indexes of the new designs are now higher than that of the reference steel panel when the frequency is below 1.6 kHz. When the frequency is higher than that, the "double wall resonance" starts to reduce the sound reduction index of the open-cell honeycomb panels.

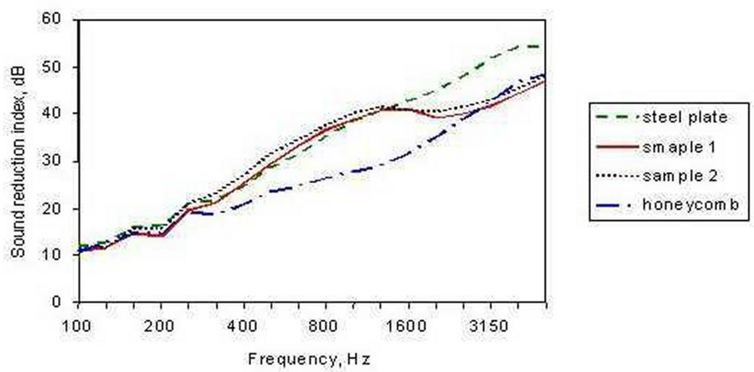

Figure 2: Results of the test panel plus woolen absorbent.

The advantages of the open cells become more evident when a plastic sheet, with a 30-mm air gap in between, is placed at the back of the base panel. The "double wall resonance" is disappeared, and the sound reduction index of the new panel becomes better than that of the reference one in the entire frequency range. On the other hand, the performance of the steel panel and of the standard honeycomb panel is deteriorated, maybe due to the "double wall resonance". At the frequency range from 250 Hz to 1000 Hz, the sound reduction index of the new designs is about $4 - 7$ dB higher than that of the steel plate, although the later is a little heavier.
The weighted apparent sound reduction index R'_W is also calculated according to ISO717-1: 1996. Results are listed in Table 3.

Test situation	**Steel panel**	**Sample 1**	**Sample 2**	**Honeycomb**
Test plate only	29	25	26	21
Test plate plus absorbent	31	31	32	27
Plate + absorbent + plastic sheet	30	31	32	25

Table 3: Weighted apparent sound reduction index R'_W for different situations.

5 - CONCLUSIONS

An open-celled honeycomb panel may achieve good results both in strength and in sound reduction index. The structure of base panel plus open cavities shows a great potential in improving sound reduction index when it is combined to other structures to make more complicated walls.

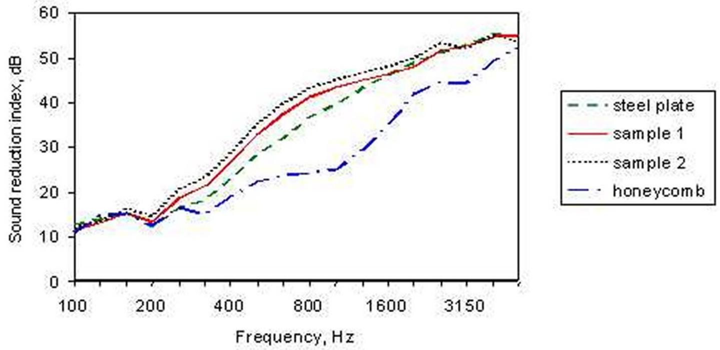

Figure 3: Test results of the complete sets (panel + absorbent + plastic sheet).

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