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## **Sustainable Materials for Sound Absorption and Insulation: Paper ICA2016-201**

### **Sound insulation research of frameless three-layers concrete partitions**

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#### **Abstract**

Recently the frame method of construction of multi-story buildings has been widely developed. In some cases, primarily in Russia, the use of frame walls between flats, which insure required sound insulations, is extremely limited by mentality of residents, who perceive their flats by the principle «my house is my fortress». Due to the limited load on the floor, structures lightweight gypsum or aerated concrete blocks are used for this purpose, but they do not have sufficient soundproofing. Therefore, it is necessary to provide the required sound insulation of walls between flats, which should be made of concrete and have significantly reduced weight and acceptable thickness. For this purpose three-layer frameless barriers were developed. Outer layers of these barriers are made of concrete plates with thickness of 30...50 mm. Total thickness of the barriers do not exceed 160...200 mm. These barriers provide sound insulation of 52...53 dB. The stability of the plates is provided by their form. Below are given the results of research of how thicknesses of the plates and their inner layer, material of the inner layer and density of the concrete plates influence sound insulation.

**Keywords:** sound insulation, concrete blocks

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# Sound insulation research of frameless three-layers concrete partitions

## 1 Introduction

Frame method of construction of high-rise buildings is very common today. In such buildings the walls are almost absent, except stability walls. Monolithic concrete columns are load-bearing elements in such constructions. The choice of materials for the façade is determined by the climatic conditions and aesthetic preferences. A typical construction of such a building is shown in Figure 1.

Maximum floor loading significantly limits the choice of materials for interior walls. It is not a big problem for partitions in apartments and offices, as plasterboard frame walls have low weight. The needed sound insulation of these partitions is achieved by a special multilayer design. General view of this wall type is shown in Figure 2.



**Figure 1: Elements of frame buildings**



**Figure 2: Frame partition**

However, the use of frame walls is not always applicable between apartments or offices, as it does not provide safety requirements for burglary (strength). In Russia, for example, houses where the barriers between apartments are made of a frame walls cannot be built.

Traditional ceramic bricks and concrete blocks have too much weight for mounting on thin floor concrete slabs. Lightweight aerated concrete blocks or bricks with voids do not provide the required insulation at a reasonable thickness (not more than 200 mm). Thus, the design of walls between apartments, which would resolve a number of contradictory requirements, is important. These requirements are:

1. The required sound insulation;
2. Minimum weight;
3. The minimum thickness;
4. Stability at a height of 3.5 m;
5. Resistance to breaking (strength);
6. Simplicity of design and availability of materials.

## 2 Evaluation of acoustic insulation of three-layer walls with hard outer layers

Theoretical determination of sound insulation of multilayered structures, in contrast to single-layer structures, in practical application is difficult. This is because the sound transmission through the outer lines needs to be taken into account when calculating the sound insulation of three-layer walls. This problem was investigated, for example, in [1, 2], which shows that the sound insulation of this construction can be represented by the following formula:

$$R' = R + \Delta R, \quad (1)$$

where  $R$  – sound insulation of single-layer wall,

$\Delta R$  – the value of extra insulation when the second panel is installed.

In work 1 the frequency curve is given, which shows that  $\Delta R$  is a function of boundary frequency  $f_0$ . At the same time boundary frequency depends on the mass of double fencing ( $M_1$ ), the mass between them ( $M_2$ ), the width of the air gap between panels ( $d$ ), the thickness of each panel ( $h_1, h_2$ ), the speed of longitudinal waves in the panel  $c_1$ .

The formula for determining the index of airborne sound insulation of walls consisting of two concrete layers with an air gap, is given in [2]

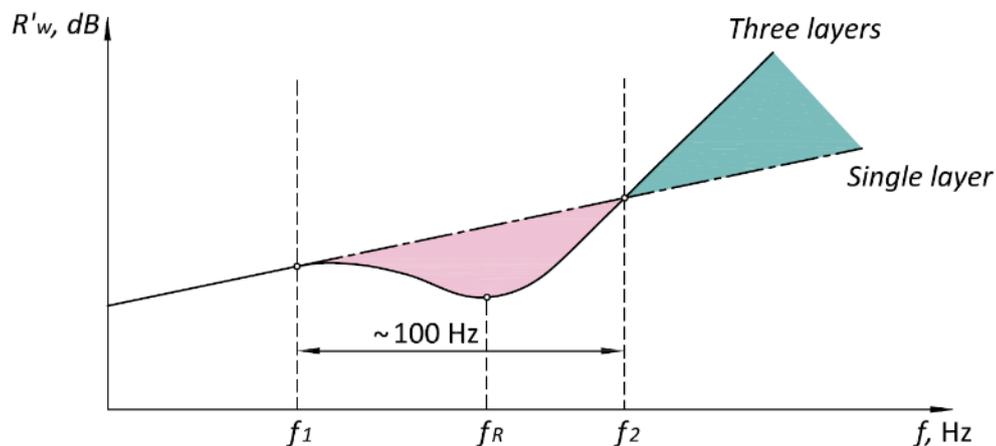
$$R'_{w} = 32 \lg m + 2 \lg d - 17 \text{ dB}; \quad (2)$$

where  $m$  is the surface density of one wall unit, kg/m<sup>2</sup>;  $d$  - thickness of the air gap, sm.

In case when the adjacent walls have different thickness and the difference of their surface densities is not more than 20%, value of  $m$  in [2] is calculated as an arithmetic mean value of the two wall units. If the difference of surface densities is more than 20%, the expression (2) cannot be applied.

### 3 Reserve improve the sound insulation of three-layer walls

It is a known fact that three-layer barriers, having the same thickness and weight, can provide higher sound insulation than single-layer barriers. Figure 3 shows the differences in frequency characteristic of sound insulation single-layer and three-layer structure. It is possible provided if mass of the three-layer structure is maximum, distance between the outer layers is big, dynamic stiffness of the inner layer is low.



**Figure 3: Sound insulation single-layer and three-layer partition**

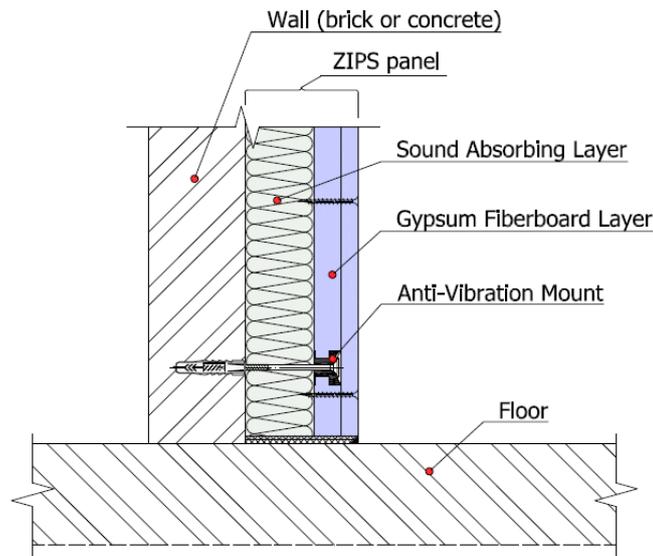
The increase in sound insulation is achieved also due to the mismatches of the frequency of the wave of the outer dense layers. Each of these layers has its own frequency of the wave coincidence, where there is the decline or a plateau in the frequency characteristic of sound insulation. These frequencies are not the same, so, theoretically, the resulting curve of the sound insulation should not be a significant decline or long constant cut. This is the cause of increase of sound insulation of such structures compared to single-layer structures of the same thickness or density. Varying flexural rigidity, which depends on the layer thickness ( $h$ ), elastic modulus ( $E$ ), density ( $M$ ), it is possible to achieve the mismatch of the frequency of the wave coincidence.

In practice, the application of sandwich structures is limited by the possibility to ensure sustainability of each outer layer, which is quite thin (30...80 mm), providing that the wall height is 2.5...3.3 m. To ensure stability of the whole structure, hard links are used. It leads to the fact that the outer layers fluctuate together with almost the same frequency of the wave coincidence. It does not increase insulation. This multilayer structure will have sound insulations close to insulation of the single-layer construction of similar mass.

## 4 The example of three-layer wall

Additional insulation panel ZIPS (The patent of Russian Federation №2140498 of October 14, 1998) is widely used in Russia. It was developed to improve the sound insulation of existing single layer walls of brick or concrete.

ZIPS panel wall application diagram is shown in Figure 4.



**Figure 4: Application diagram of panels additional sound insulation ZIPS**

ZIPS panel consists of an outer dense layer, which is made of two bonded layers of drywall, and an inner layer of mineral wool. The panel is attached to the wall with special anti-vibration mounts. System consisting of wall and ZIPS panels works much like a three-layer wall, except for the inevitable transmission of the sound energy through the attachment points. In this case, the main wall of concrete or brick, sound insulation where you need to improve, has a relatively large mass and thickness (bending rigidity). Hard layer panels ZIPS plays the role of the second walls in three-layer structure. The sound-absorbing layer in ZIPS-panel plays the role of the inner layer of three-layer structure. This allows getting a system where there is a difference in masses, thicknesses and bending rigidities of the outer layers. This leads to increase of sound insulation of this structure with some ratios of these factors.

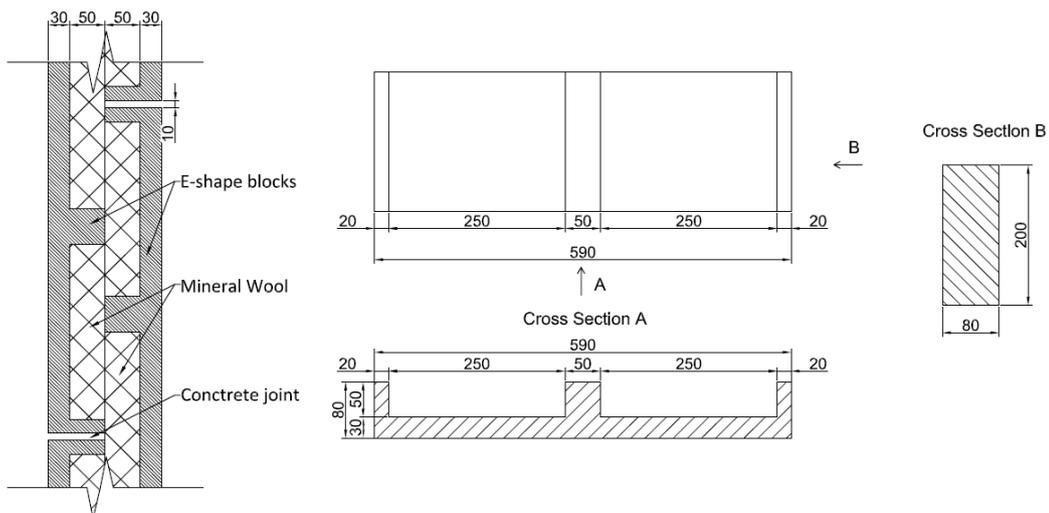
The acoustic effectiveness of the ZIPS panels is 10...15 dB, depending on the thickness of the inner layer material – Table 1. These additional sound insulation values obtained for the base wall of bricks with a thickness of 120 mm and a density of 220 kg / m<sup>2</sup>. The total weight of the structure increased by only 15%, and a thickness of from 44% to 110%. If to improve the sound insulation to increase the thickness (weight) of the base wall twice, the increase of sound insulation would have amounted to no more than 6 dB. That is only 38...68 % of the value of additional insulation, which gives the ZIPS. Panels ZIPS are not effective in new construction, to

increase the cost of construction due to increasing material and labor input. Design of three-layered walls, consisting of simple thin elements is an actual problem.

**Table 1: Characteristics of ZIPS**

Panel	Weight, kg	Thickness, mm	Sound reduction index, dB
ZIPS-Vector (sound absorbing layer 20 mm)	26	53	9-11
ZIPS-III-Ultra (sound absorbing layer 22 mm)	26	55	11-13
ZIPS-Module (sound absorbing layer 50 mm)	26,5	83	12-14
ZIPS-Cinema (sound absorbing layer 100 mm)	28	133	16-18

## 5 A thin concrete plates with integrated frame (E-blocks).



**Figure 5: E-block and the wall, built from E-blocks (top view)**

It solves several problems:

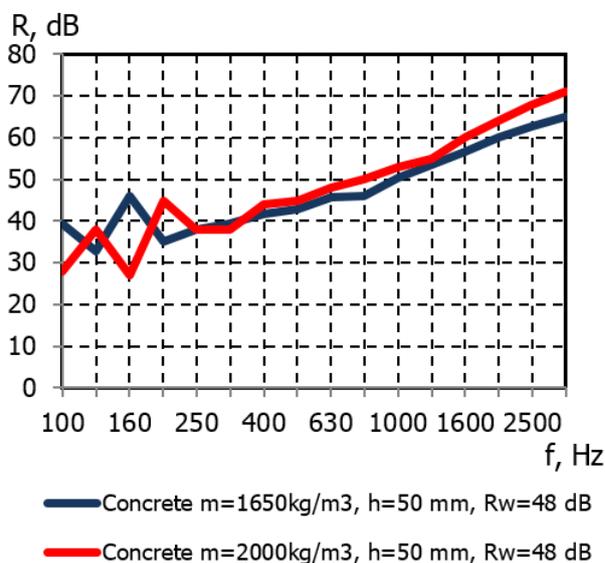
- the sustainability of each vertical layer in the construction with the height of a standard floor (up to 3.3 m);
- improving the sound insulation of each layer with stiffeners due to the increase of flexural rigidity;
- the absence of rigid links between the outer layers;
- the possibility of using the space between the internal layers for routing communications.

Experimental researches of sound insulation of three-layer walls built from the units having an E-shape were conducted in an acoustic chamber of the Nizhny Novgorod University in 2014.

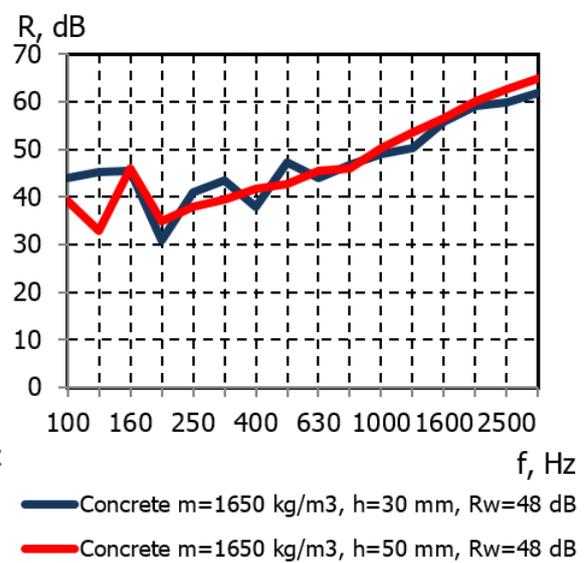
We studied the influence on the sound insulation of the following factors:

- the density of the concrete,  $m$ ;
- the thickness of the outer layers,  $h$ ;
- the material of the inner layer (mineral wool, expanded clay sand, air).

For additional information, we measured the sound insulations of single-layer barriers with stiffeners ribs and without them, as well as sound insulations of triple-layer construction with rigid connections between layers. The results of the research in the form of frequency characteristics of sound insulation and the sound insulation indices of constructions are shown in the figure in Figure 6 -12.



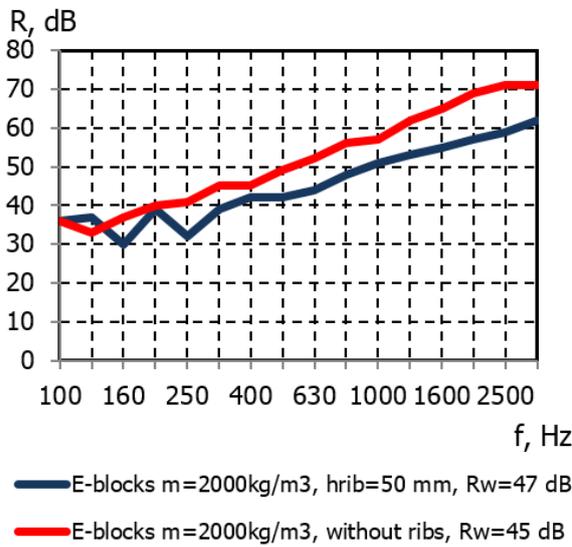
**Figure 6: Dependence of sound insulation from the density of the concrete;  $h_1=h_2$ ;  $H$  mineral wool = 100 mm.**



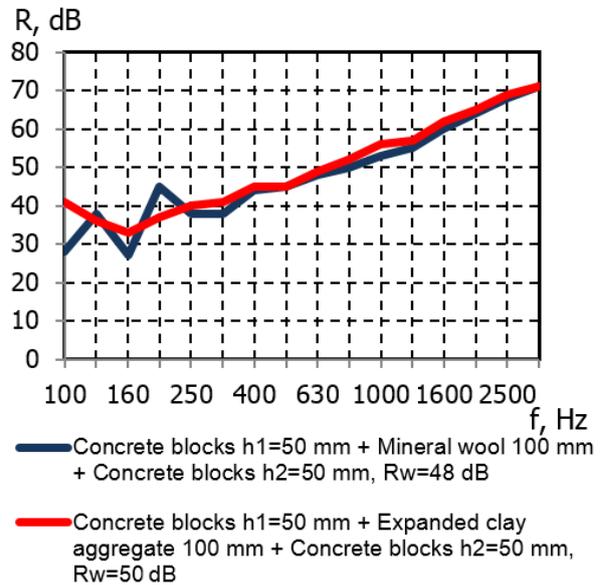
**Figure 7: Dependence of sound insulation on the thickness of the walls of the E-blocks;  $h_1=h_2$ ;  $H$  mineral wool = 100 mm.**

The result of the experiment shows that, in accordance with the law of mass, walls with a greater mass have a higher sound insulation in the frequency domain above the wave coincidence than the one with a smaller mass. Wall with a smaller mass has a greater sound insulation in the frequency of the wave coincidence. As a result, the sound insulation index of both constructions are the same.

The change in wall thickness E-blocks from 30 mm to 50 mm does not increase the sound insulation index.



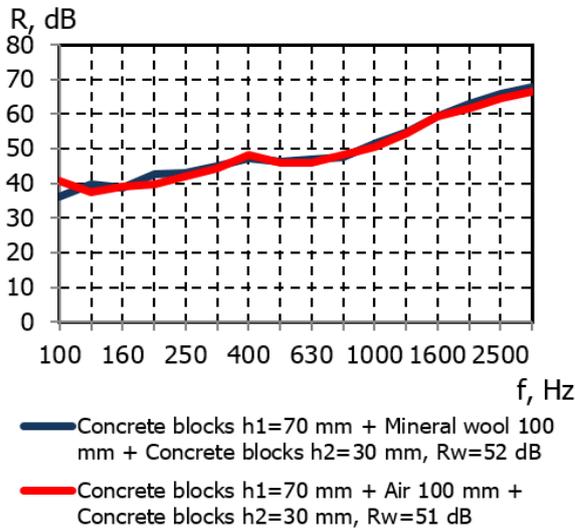
**Figure 8: The influence of ribs of rigidity on sound insulation of single layer construction;  $h_1=h_2=50$  mm.**



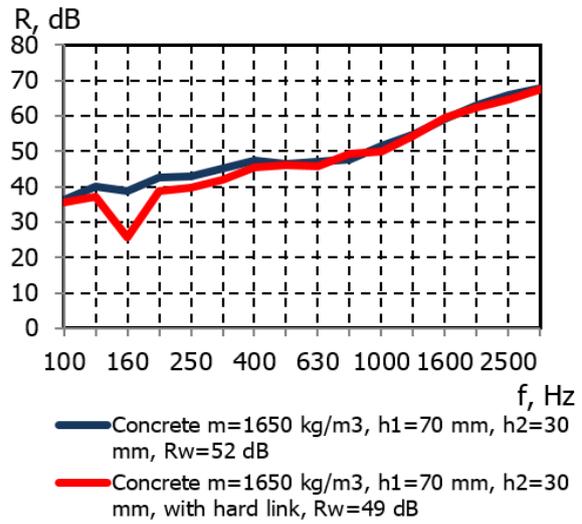
**Figure 9: Dependence of sound insulation from the material of the inner layer**

Integrated into the vertical panel stiffeners ribs by section 50x50 mm and with step 600 mm increase sound insulation single layer wall by 2 dB. Sound insulation panels with ribs is above the sound insulation panels without ribs in almost the whole frequency range. This is due to the increase in wall stiffness with ribs.

The use of expanded clay aggregate instead of mineral wool as an inner layer leads to an increase of the index of sound insulation by 2 dB. The cause of this is a significant increase in the mass of the three-layer wall. As well as the increase internal loss in the inner layer during the oscillation of the whole, structure.



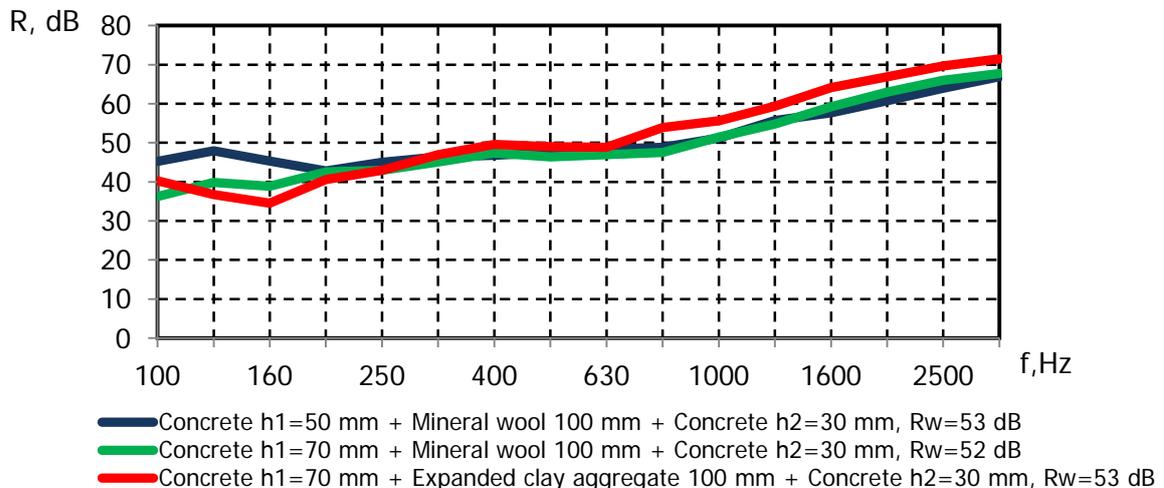
**Figure 10: Sound insulation three-layer wall with the internal layer of mineral wool and air**



**Figure 11: The influence of rigid links between the outer layers for sound insulations**

This experiment showed that in the whole frequency range sound insulations three-layer wall with the internal layer from the air and mineral wool of the same thickness is almost the same. This can be explained by the fact that the elasticity of air and mineral wool do not differ significantly.

This experiment showed that the rigid connection between the outer layers of three-layer wall leads to a significant reduction of sound insulation in the frequency of the wave coincidence. This can be explained by the fact that at these frequencies the three-layer wall oscillates as a single layer.



**Figure 12: The most effective sound insulation constructions**

## 6 Conclusions

The measurement results allow making the following conclusions:

1. Sound insulations of structures made of concrete with a density of 1650 kg / m<sup>3</sup> is higher than of structures made of concrete with density of 2000 kg / m<sup>3</sup>.
2. The wall thickness of the outer layers and their combination affect the sound insulation of the whole structure, thus increasing the thickness of the layers does not always increase the sound insulation.
3. The material of the inner layer affects the sound insulations of constructions. Difference between sound insulations of structures with an inner layer of air and sound absorption mineral wool is not significant. Maximum soundproofing is achieved by using of the inner layer of sand.
4. The stiffening ribs increases the sound insulation of each of the outer layers. The hard links between the layers lead to a decrease in sound insulation of three-layer wall. It almost changes to the level of sound insulation of the single-layer construction.
5. Sound insulation of a three-layer structure with a total thickness of 180...200 mm, with outer layers of 30...70 mm, which has a total thickness of concrete of 80...100 mm, is 52...53 dB; that is equivalent to sound insulation of single layer construction made from concrete of the same thickness and twice mass.
6. The use of three-layer walls of equal thickness and sound insulation compared to single layer constructions is experimentally proved. Their mass must be twice and more times less than of single layer.

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