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Change of Dynamic Stiffness of Open and Closed Cell Resilient Materials after Compressibility Test

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Floating floors are one of the most effective constructions used for impact sound insulation assurance in dwellings. Resilient material between upper layer and the base of the floor are the main element reducing transmission of vibrations through the floor to the adjacent room. Dynamic stiffness and compressibility of resilient materials are the main descriptors characterizing its applicability for impact sound insulation. The change of dynamic stiffness of open and closed cell resilient materials after compressibility test was examined in this research. Stone and glass wool (open cell material) and elastic polystyrene (closed cell material) were tested. The research showed that dynamic stiffness after compressibility test decrease by about 40 % and about 30 % for mineral wool and elastic polystyrene accordingly in comparison with the values before test. Also the research showed that the difference between dynamic stiffness values of the wool and polystyrene after compressibility test decreased. The deference between dynamic stiffness values before compressibility test lied in the range of 20 % – 50 % and after compressibility test only 5 % – 10 % respectively.
Keywords: dynamic stiffness, compressibility, resilient materials.

1. INTRODUCTION

The main requirement for multi-dwelling buildings is to ensure acoustic comfort. A good acoustical environment in multi-dwelling buildings is essential to maintaining a high level satisfaction and health among residents and keep noise at levels that do not disturb their rest or sleep. Building consists of walls, floors and ceilings, which separate different rooms. Building elements having high sound insulation ensures protection from noise. The impact sound is structure borne noise generated by the sources, which are in direct mechanical contact with floors [1, 2].

Floating floors is one of the most effective constructions used for impact sound insulation [1]. It reduces impact sound transmission to rooms below. Different types of floating floors could be used for impact sound insulation: lightweight and heavyweight floors [1 – 7]. The basic idea of floating floors is vibration isolation using vibration absorbing material. Resilient materials are usually used for vibration reduction in such floors. Mineral wool [8] and elasticized polystyrene [9] are the most often used in floating floors construction. Other materials as rubber, wood, cork, carpet waste fibre are also used as elastic layer [1, 10 – 12].

Dynamic stiffness and compressibility are the main descriptors of resilient materials characterizing their acoustic properties and are to be low for effective impact sound insulation. Materials having low dynamic stiffness values effectively reduce transmission of vibration energy through the construction and by that increasing impact sound insulation between rooms. [1, 9, 13].

Unfortunately it was found no information about influence of mechanical deformation on dynamic stiffness values of resilient materials. This led us to perform the measurements enabling to check of such dependence exist and if so, how strong is it.

The change of dynamic stiffness of open and closed cell resilient materials after compressibility test was examined in this research. Stone and glass wool (open cell material) and elastic polystyrene (closed cell material) were tested. The research showed that dynamic stiffness after compressibility test decrease by about 40 % and about 30 % for mineral wool and elastic polystyrene accordingly in comparison with the values before test. Dynamic stiffness and compressibility values of resilient materials are to be low for assurance effective impact sound insulation and its reliability for the long term static load.

2. METHODS AND MATERIALS

Dynamic stiffness and compressibility are the main descriptors of resilient materials used in floating floors. The procedure of determining dynamic stiffness values is given in standard EN 29052-1. Dynamic stiffness of the resilient material per unit area was evaluated on the basis of the resonance frequency measurement of the fundamental vertical vibration of a mass-spring system (Fig. 1).

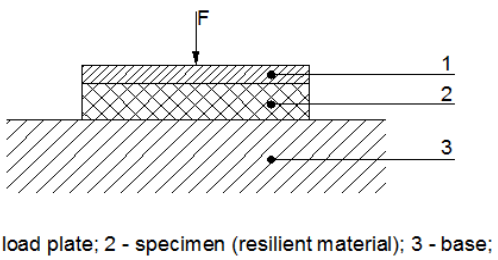

Fig. 1. Mass-spring resonance system

Special system DYPS3 (Ing. Wolfgang Fellner GmbH) for measurement of resonance frequency was used. This system is built in to accordance to the requirements of the standard EN 29052-1. The principal scheme of this measurement system is shown in Fig. 2. The measurement

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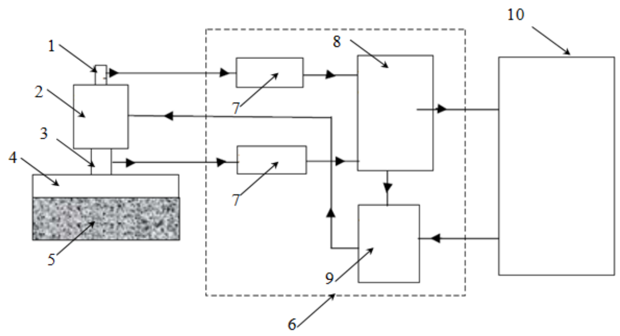
accuracy of the system is ±2 % in the frequency range 10 Hz – 100 Hz.



1 – accelerometer; **2** – shaker; **3** – force transducer; **4** – steel load plate; **5** – test specimen; **6** – Dyps3 case with mains supply; **7** – ICP supply; **8** – A/D converter; **9** – amplifier; **10** – PC

Fig. 2. Block diagram of DYPS3 system

The resonance frequency is determined by varying excitation frequency and excitation force (according EN 29052-1) and calculating the mobility transfer function between the input signal from the force transducer and the output signal from the accelerometer. The resonance frequency was determined using sinusoidal signal and changing input force level from 0.1 N up to 0.4 N.

The specimens (200 mm × 200 mm) were placed between rigid base and load plate (200 kg/m^2). The layer of plaster of Paris was not used on the top of specimens because the surface of specimens was smooth (irregularity less than 3 mm). The joint between the specimen and base was not isolated with petroleum jelly measuring dynamic stiffness of closed cell materials (elasticized polystyrene) because the measured values differ less than 5 %.

The airflow resistivity *r* of open cell resilient materials (stone and glass wool) used in this research was in the range of 10 kPa·s/m^2 ≤ *r* < 100 kPa·s/m^2. According this the dynamic stiffness per unit area was calculated by formula:

$$s' = s_t' + s_a', \text{ (MN/m}^3\text{)}, \quad (1)$$

where s_t' is the apparent dynamic stiffness per unit area; s_a' is the dynamic stiffness per unit area of enclosed air.

Apparent dynamic stiffness per unit area was calculated by following expression:

$$s_t' = 4\pi^2 m_t' f_r', \text{ (MN/m}^3\text{)}, \quad (2)$$

where m_t' is the mass per unit area of the load plate; f_r' is the resonance frequency of mass-spring system.

Apparent dynamic stiffness of air was calculated by formula:

$$s_a' = \frac{p_0}{d\,\varepsilon}, \text{ (MN/m}^3\text{)}, \quad (3)$$

where p_0 is the atmospheric pressure; d is the thickness of specimen; ε is the porosity of material.

For closed cell resilient materials (elasticized polystyrene) the dynamic stiffness is equal to apparent dynamic stiffness:

$$s' = s_t', \text{ (MN/m}^3\text{)}. \quad (4)$$

To evaluate the influence of mechanical deformation of the resilient materials on its dynamic stiffness values compressibility test was performed firstly and after it dynamic stiffness test. The procedure of compressibility test is given in the standard EN 12431. The compressibility test was performed on 200 mm × 200 mm size specimens. Compressibility *c* was calculated by formula:

$$c = d_L - d_B, \text{ (mm)}, \quad (5)$$

where d_L is the thickness under static load 0.25 kPa after 120 s, d_B is the thickness after sequenced cycle of loads: 2 kPa (after 120 s), 50 kPa (after 120 s) and 2 kPa (after 120 s).

For the determination of the thicknesses d_L and d_B universal test machine Zwick/Roell was used. The measurement accuracy of the test machine is ±1 %.

The same specimens were used for both tests (dynamic stiffness and compressibility). In the research materials from the market, which are commonly used for impact sound insulation in Lithuania, were used. Four types of wool and two different types of elasticized polystyrene were tested: stone wool of densities 114 kg/m^3, 113 kg/m^3 and 119 kg/m^3 and glass wool of density 96 kg/m^3, polystyrene of the density 12 kg/m^3 and 18 kg/m^3. Four different thicknesses 20, 30, 40 and 50 mm of the resilient materials were tested. The stone wool specimens were tested only of 30 mm thickness (density 114 kg/m^3) and 20 mm and 30 mm thicknesses (density 113 kg/m^3), glass wool 20 mm and 50 mm thicknesses (density 96 kg/m^3).

3. RESULTS AND DISCUSSION

The dynamic stiffness values are presented in Figs. 3 – 6. The compressibility values are presented in Fig. 7.

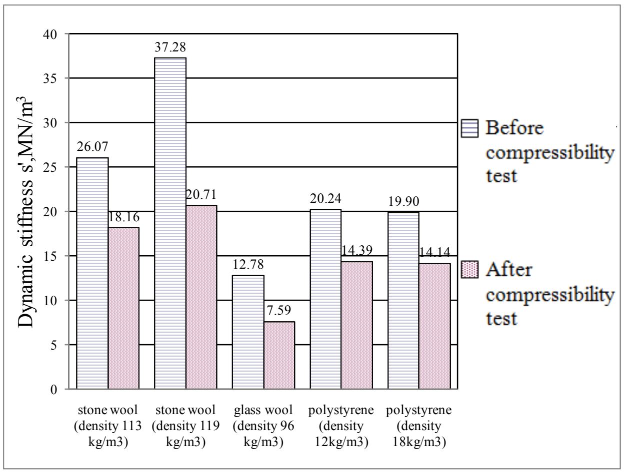


Fig. 3. Comparison of dynamic stiffness values of 20 mm thickness specimens

From Fig. 3 we can see the highest dynamic stiffness was determined of stone wool (density 119 kg/m^3) 37.28 MN/m^3 and lowest of glass wool 12.78 MN/m^3 (the difference is 66 %). Dynamic stiffness values after the compressibility test decreased by about 38 % for wool and 29 % for polystyrene. The highest dynamic stiffness values after the compressibility test were determined of stone wool – 20.71 MN/m^3 and the lowest of glass wool – 7.59 MN/m^3 (the difference about 63 %).

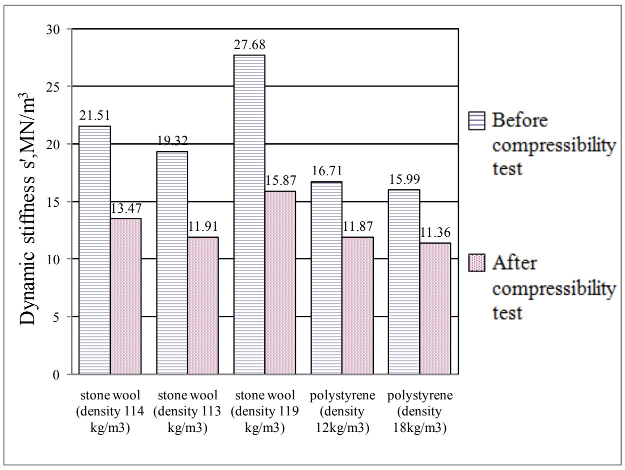


Fig. 4. Comparison of dynamic stiffness values of 30 mm thickness specimens

From the diagram above we can see that the highest dynamic stiffness was determined for stone wool (density 119 kg/m^3) – 27.68 MN/m^3 and lowest for the polystyrene (density 18 kg/m^3) – 15.99 MN/m^3 (the difference is 42 %). The compressibility test identified that the dynamic stiffness values of the wool decreased by about 39 % and the polystyrene about 29 %. The highest dynamic stiffness values after the compressibility test were determined of the stone wool 15.87 MN/m^3 and the lowest of polystyrene 11.36 MN/m^3 (the difference is 28 %).

From Fig. 5 we can see that highest dynamic stiffness value is of stone wool (density 119 kg/m^3) – 20.76 MN/m^3 and lowest of polystyrene (density 18 kg/m^3) – 12.61 MN/m^3 (the difference is 39 %).

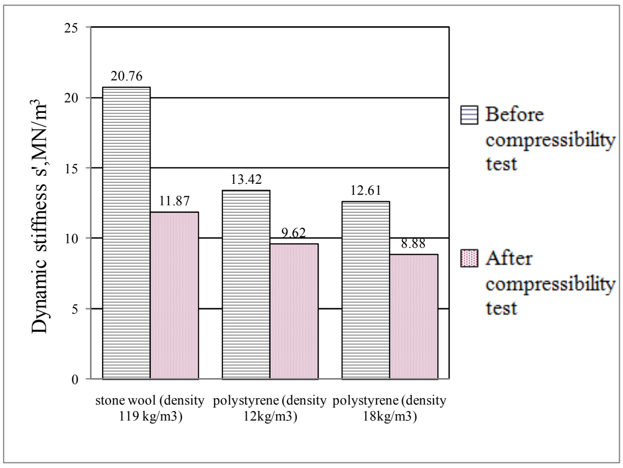


Fig. 5. Comparison of dynamic stiffness values of 40 mm thickness specimens

From the diagram above we can see that dynamic stiffness values of the wool after the compressibility test decreased by about 43 % and the polystyrene by about 29 %. The highest dynamic stiffness values after compressibility test were determined of the stone wool – 11.87 MN/m^3 and the lowest of polystyrene (density 18 kg/m^3) – 8.88 MN/m^3 (the difference is 25 %).

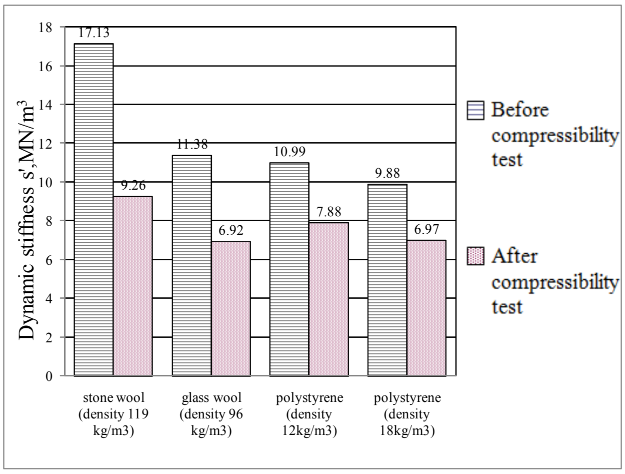


Fig. 6. Comparison of dynamic stiffness values of 50 mm thickness specimens

From the Fig. 6 we can see that highest determined dynamic stiffness value of stone wool (density 119 kg/m^3) is 17.13 MN/m^3 and lowest of polystyrene (density 18 kg/m^3) – 9.88 MN/m^3 (the difference is 42 %). After compressibility test determined dynamic stiffness values of the wool after compressibility test decreased by about 43 % and polystyrene by about 29 %. After the compressibility test the highest dynamic stiffness value of stone wool is 9.26 MN/m^3 and the lowest of polystyrene (density 18 kg/m^3) – 6.97 MN/m^3 and of the glass wool 6.91 MN/m^3 (the difference is 25 %).

The other authors [1, 4, 9] who investigated resilient materials got similar results of dynamic stiffness of materials, which were not mechanically affected.

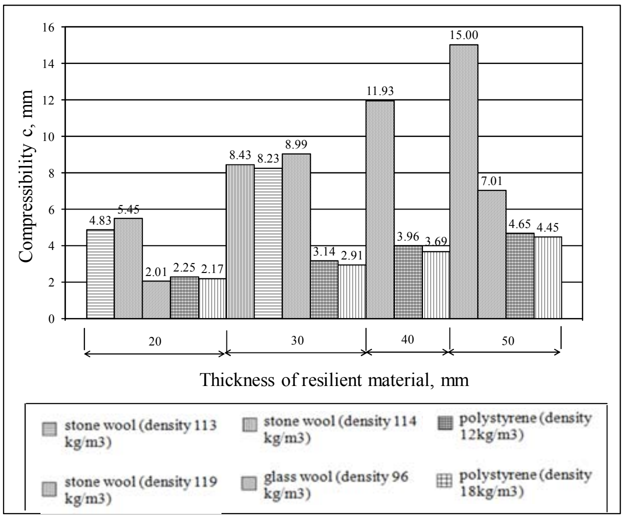


Fig. 7. Comparison of compressibility values of resilient materials

From Figures 3 – 6 we can do conclusion that mechanical deformation of the samples improved dynamic stiffness values of the resilient materials. It could be noticed that the dynamic stiffness values of the wool after compressibility test became similar to dynamic stiffness values of polystyrene before compressibility test. This decrement of dynamic stiffness values is associated with structure changes of resilient materials. The structure changes were noticed using optical microscope. The view was zoomed 40 times. For the stone and glass wool mechanical deformation changes orientation of fibers – we got more fibers oriented in horizontal direction than in vertical. Mechanical deformation of polystyrene changes links between polystyrene cells – mechanical cohesion of the cells becomes weaker.

Finally we can see (Fig. 7) that stone wool compressibility is 2 – 3 times larger than that for glass wool and polystyrene compressibility of the same thickness. Compressibility of the stone wool increased by about 50 % for each 10 mm increment of its thickness and 25 % of polystyrene respectively. It shows that stone wool's deformation is 2 times larger than polystyrene, because of its weaker structural strength.

CONCLUSIONS

1. Dynamic stiffness values of the open cell resilient materials (stone and glass wool) after compressibility test decreased by 40 %.
2. Dynamic stiffness values of the closed cell resilient materials (elasticized polystyrene) after compressibility test decreased by 30 %.
3. The difference between the wool and elasticized polystyrene dynamic stiffness values before compressibility test lie in the range of 20 % – 50 % and after compressibility test only 5 % – 10 %.
4. Density of the tested resilient materials did not influence the percentage decrement of the dynamic stiffness values.
5. The mechanical deformation of resilient materials reduces its dynamic stiffness.

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