Sound transmission of lightweight block walls and panels – Theory and Experiments

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Abstract

Sound transmission either as airborne or structure borne is a potential problem that occurs in buildings either from sources within or from outside. With the expansion of real estate activities in countries like India, the need to attend sound insulation requirements also assumes greater dimensions. The focus of this research is on studying the sound transmission characteristics of building structures made of hollow blocks, neocrete block, aerocon block and prefabricated panels such as Ferrocement panel. The tests were carried out the blocks with and without plastering and their sound reduction index was measured at one-third octave frequencies. In the case of ferrocement panels, different types of systems were tested in the TL suite. Panels with cavity, with cavity ties, with insulation, with stiffeners and with plasterboard were investigated. Sound reduction index of these panels was measured with additional quantities like longitudinal wavespeed, and loss factors (internal and total loss factor). Tests were also conducted on Gypcrete wall panel and Sandwiched wooden panel in a similar way. Theoretical investigations were carried out using Statistical Energy Analysis (SEA) for the above systems. Sound reduction index was then compared between the predicted and the measured values.

1. Experimental Investigations

The sound reduction index for 10cm hollow blocks, 15cm and 20cm respectively. The sound reduction index of the solid wall has a dip at it's critical frequency of 160Hz whereas, the hollow block wall has a broader dip between 50Hz to 250Hz. At higher frequencies, there is another dip at 1250Hz for a hollow block wall which will not appear for a solid wall. The dip is attributed due to the coincident frequency associated with the thin surface layer of the hollow blocks and also 10mm plaster on the surface of the wall.

As expected when the total wall thickness decreases the critical frequency increases and the overall sound insulation decreases. Similar dips appear at the higher frequencies due to the thin surface layers of the block and plaster. All three types of hollow blocks are from the same manufacturer using the same material. Straight webs inside the hollow block provide a higher bending stiffness. Sound reduction index of the neocrete block without the plaster layers. This shows a sound reduction index of 35dB. In this case the dips, occur at the low frequency range of 50 to 125Hz. At 2000Hz, another dip occurs, which can be identified as critical frequency. This is associated with the thickness of the block walls. Total loss factor (TLF) is another parameter affecting the sound reduction index (SRI) of the neocrete blocks. From Fig.4.8 it is seen that the loss factor is high in low frequency regions and tends towards the internal loss factor value of 0.012 at high frequency regions, where the internal loss factor of the blocks dominate.

Sound Transmission with Plaster on Block Walls

Plaster render layers are often applied to walls to seal the face of the blocks. This can increase the total mass of the wall and also increases the air flow resistance leading to improved sound insulation properties. In order to study the effect of plaster layers on the sound insulation of block walls, a plaster of 10mm thick has been applied on all the blocks.

The measured gross densities of the hollow blocks including plaster are 1250kg/m^3 (100mm thick), 1500kg/m^3 (150mm thick), and 1800 kg/m^3 (200mm thick) respectively. The sound reduction index of hollow blocks with plaster layers. The curve shows pronounced dip at a low frequency range of 125-250Hz. At high frequency of 3150Hz there is another dip occurring which can be attributed due to critical frequency. The dip at high frequency is associated with the thin surface layer of the hollow blocks and plaster on each side of the web structure. The SRI of hollow blocks exhibits 32,33,35 dB at 500Hz for 100, 150 and 200mm respectively. A reduction in the thickness of the wall results in the critical frequency increase and a decrease of sound insulation. The blocks exhibit orthotropic behavior, with a wide frequency valley consisting of dips at 125 to 250 Hz. As the frequency increases, the three walls show a higher sound reduction index. All the walls have pronounced dips at 2500 Hz.

For thin walls it can be seen that the wall undergoes pure bending. Bending wavespeed increases with frequency. In the case of thick walls, as the frequency increases one must take into account the shear deformations and rotary inertia. The limit of regarding the wall as thin occurs where the bending wavelength is six times that of the plate thickness. The dips in the sound reduction index curve at high frequencies are due to thickness resonance. The frequency at which these dips occur can be evaluated as $f = \frac{c_L}{2h}$, where c_L is the longitudinal wavespeed and h is the wall thickness. This is evident from the Fig. 4.5 where the dips occur at a frequency of 2000Hz.

Ferrocement Panels

Ferrocement is a kind of composite material in which cement and sand, is reinforced with steel meshes (welded mesh and chicken mesh) dispersed throughout the composite resulting in better structural performance than that of its original constituents, viz., cement, sand, and steel meshes. Ferrocement exhibits certain unique properties such as high tensile strength, better resistance to cracking, and improved durability. It has a higher flexural strength and modulus of elasticity when compared to concrete or timber. Ferrocement panels can be made as thin as timber with better durability characteristics. A semi-skilled mason, with experience in cement mortar plastering can produce aesthetically pleasing thin products.

Panel of size 1.2x1.8m^2 has been cast in-situ and placed on the specimen opening with a thickness of 20mm. The sound reduction index of a single ferrocement panel is 30dB. From Fig. it is seen that the sound reduction index of the panel at low frequency region of 100Hz dips are predominant. This is attributed due to the resonance that occurs in the low frequency region. Critical frequency dips or Coincidence dips occurring in the high frequency region of 1250Hz are due to the thin plate behavior of the panel. The limit of regarding the panel as thin occurs when the bending wavelength is six times the plate thickness given by $f_c = \frac{c_L}{20h}$ for homogenous plates. The longitudinal wavespeed of the single ferrocement panel is 1860m/s. It can be seen that the loss factor is higher at low frequency regions and tends towards the internal loss factor of the panel at high frequency regions. The internal loss factor value of the panel is 0.009. At high frequencies the total loss factor decreases and tends towards the internal loss factor. Panel exhibits a SRI of 30dB at 500Hz.

Subsequently the panel is stiffened with stiffener whose dimensions are 50mm in width and 100mm in depth. Figure shows the sound reduction index of the element. At low frequency regions dips occur at the frequency of 63-125Hz. These dips are predominant due to the panel resonance behavior of the system. Stiffness of the panel results in the increase in sound reduction index. These dips shift from the frequency range observed in the plain panel to the panel with single stiffener. Because of the presence of stiffener the panel resonance occurs at a frequency of 63-125Hz, which occurs due to the panel with single stiffener. It is seen that the total loss factor of the ferrocement panel with stiffener shows higher loss factor at low frequency regions. The total loss factor value is much less when compared to the ferrocement panel. This is again influenced by the presence of the stiffener, which affects the energy absorbing capability of the panel. Due to the filter ringing sound of the panel, higher value of total loss factor was recorded at low frequencies.

Ferrocement panel with Cavity

In case of the panel with cavity system, two ferrocement panels are being separated by a cavity of 25mm. The overall thickness of the panel system is 65mm. Figure shows the sound reduction index of the cavity panel. The cavity panel exhibits a sound reduction value of 40dB. It is seen that the dips are occurring at low frequency region of 80Hz, due to the cavity resonance. Coincidence or Critical frequency dips occur at a frequency of 1600Hz. The critical frequency occurring at high frequency is more related to air-cavity coupling that occurs due to the interaction of air in the cavity system. Cavity system exhibits an SRI of 35dB at 500Hz.

Figure shows the total loss factor of the cavity system. Loss factor is higher at low frequency and tends towards the internal loss factor value at high frequency. In this case the loss factor is high when compared to the other two systems because of the presence of the cavity with insulation system. Longitudinal wavespeed (c_L) of the system is 1868m/s. It is seen that at high frequencies the loss factor tends towards the measured internal loss factor value of 0.009.

THEORETICAL COMPUTATIONS

The theoretical computations have been computed by developing software through Statistical Energy Analysis approach. The programme is written in Visual Basic and the coding is included as Appendix. Visual Basic is one of the powerful GUI (Graphical User Interface) available on a wide range of hardware platforms and operating systems. Visual Basic has evolved from the original Basic language containing statement functions and keywords relating to Windows GUI.

Statistical Energy Analysis permits calculation of energy flow between connected resonant structures such as plates, beams and reverberant sound fields in an enclosure. The term statistical refers that averages are involved and randomness is assumed in excitation, the distribution of resonance frequencies and the matching condition of various modes. Energy is related to the average quantities and power in the system. The principles of energy conservation and reciprocity principles are employed considering the coupled systems. Some of the aspects of Statistical Energy modeling procedures adopted in developing the programme are explained subsequently.

RESULTS AND DISCUSSIONS

The comparison between experimental values of sound reduction index and theoretically/computationally obtained sound reduction indices. The figures show the results of all the different systems studied earlier. For different materials and systems the respective loss factors and internal loss factors which are determined experimentally in this study have been taken into consideration. Some limitations exist at low frequencies because SEA is based on the assumption that the vibration of a structure or the sound field in the room is determined by the resonant vibration of many modes. This is satisfied only when the excitation is of broad band type containing all the frequencies and the structure or room has enough resonating modes within the frequency band of interest. Within a frequency range of 2-3dB variation three or four modes within the frequency band are sufficient. When a structure is excited by a narrow band source with only a few modes associated, the errors obtained through SEA method are more.

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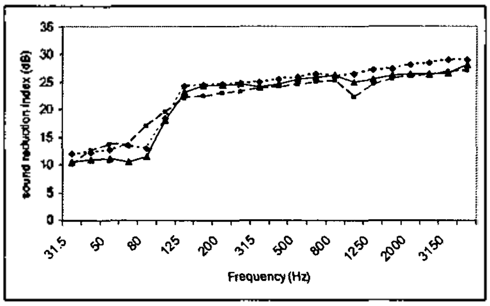

Fig.1. Measured Sound reduction index of hollow blocks without plaster ▲10cm, ■15 cm, ►20cm

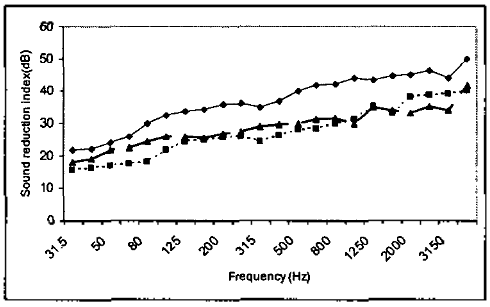

Fig.2. Measured Sound reduction index of hollow blocks with plaster ▲15cm, ■10 cm, ►20cm

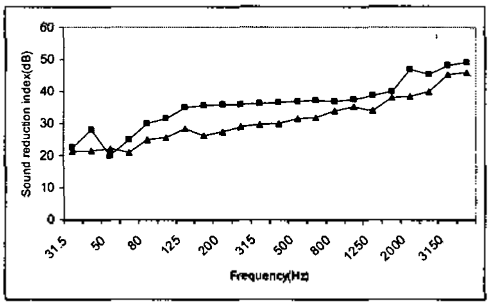

Fig.3. Measured Sound reduction index of neocrete blocks with and without plaster ▲without plaster, ■with plaster