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SOUND TRANSMISSION PERFORMANCE OF COCONUT FIBER IMPREGNATED FERRO-CEMENT AND WOOD WOOL PANELS ON THE LOSS FACTOR OF CONCRETE FLOORS IN MULTISTOREY BUILDINGS

S. Kandaswamy, P.S. Kumar
School of Civil Engineering
SRM Inst. of Science and Technology, Chennai
India

ABSTRACT

Lightweight building materials like ferro-cement panels have been used building as low cost and cost effective construction in the developing countries. Sound transmission studies have been conducted on this panel system with different types of fibers. In this work sound reduction index studies have been conducted on Fiber impregnated ferro-cement panels with and without cavities for their transmission behavior.

The panels have been erected as slabs and lifted and placed in the opening provided between source and receiver rooms. Sound transmission studies have been conducted on panels in the transmission loss suite which has been specially constructed for these set of measurements. It is shown that the presence of lightweight walls (Ferro-cement, cellulose acetate panels) have an influence on the loss factors of concrete floors, especially at low frequencies. Measurements and theoretical calculations also show that the loss factor depends on the design and construction of the walls. It is also shown that the loss factor increase is due to mainly to the energy transmission through the longitudinal waves.

Key words: Sound transmission, Ferro-cement, Wood wool panels, Loss factor, Internal loss factor.

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Introduction

A common design for the load-bearing structure in multi-story buildings is concrete floors and supporting concrete walls. Inside each flat lightweight partition is commonly used. In India, this system is predominant and ferro-cement partitions and cellulose acetate partitions are prevailing, not only in residential buildings but also in office buildings.
It is well known that the sound insulation of concrete floors depends to a great extent on the loss factor. Thus, the possible influence of the lightweight partitions on the loss factor is an interesting area of research. Westcott have previously shown that the influence of non-structural components on the loss factor of floors with long spans is considerable at low frequencies (1).

This is an important conclusion, as vibration problems tend to increase when lighter structures and longer floor spans are used. The reason why lightweight walls influence the loss factor is probably the energy transmission from the studied floor to adjacent floors via the light-weight walls (2-10). The present investigation, deals with the influence of lightweight walls on the loss factor at somewhat higher frequencies than those studied in Westcott's investigation (1), which dealt with the frequencies from 4-50Hz.

The reason why the sound insulation is higher in a building with load-bearing columns than in one with load-bearing walls can be explained as follows. The air-borne sound transmission through a plate can always be regarded as a superposition of two transmission paths, one related to the forced response of the plate and the other to the resonant response (12, 13). The magnitude of the resonant response depends on the loss factor and the size of the plate, whereas the forced response does not depend on these factors.

Both measurements and calculations of the transmission through the lightweight walls are presented. A physical model of the two floors and a wall where constructed for the measurements. The theoretical calculations are in principle based on Cremer's et al. Model for sound bridges in double plate structures but evaluated for longer structures where wave effects are important.

Theoretical Models

The energy in a floor of a multistory building can be transmitted through the partitions to the adjacent floors in two ways, that is, by means of longitudinal and bending waves respectively.

Loss Factor Due to Longitudinal Wave Transmission

For the simplest case with only a single stud between the floors a theoretical model is easy to establish. It will here be based on Cremer's model for sound bridges in double-plate structures. A time factor exp $(j\omega t)$ is assumed throughout but omitted for brevity.

The bending wave in the source plate, plate 1, is supposed to have a transverse velocity v_{10} in the absence of studs. The velocity changes to v_1 because of the presence of stud, and the associated force F_1 can be obtained as

$$F_1 = Z_1(v_{10} - v_1) \tag{1}$$

The floor is assumed to be so large that the well-known expression for the point impedance of an infinite plate can be used:

$$Z_1 = 8\sqrt{B' m_1'} \tag{2}$$

where m'_1 is here the mass per unit surface area and B' the bending stiffness calculated according to the expression

$$B' = \frac{h^3 E_1}{12(1-\mu^2)} \tag{3}$$

where h is the thickness of the plate, μ Poisson's ratio and E_l Young's modulus.
The length and the wave number of the quasi-longitudinal wave in the stud is given by,

$$k_L = \omega\sqrt{\frac{m}{ES}} \tag{4}$$

and Z_L is the associated wave impedance given by

$$Z_L = \sqrt{ESm'} \tag{5}$$

S is the area of the stud, m' mass per unit length and E Young's modulus of the stud.

Since

$$F_2 = Z_2 v_2 \tag{6}$$

where Z_2 is the point impedance of the receiving plate,

$$Z_2 = 8\sqrt{B' m'_2} \tag{7}$$

The loss factor can then be calculated according to the expression

$$\eta = \frac{P_2}{\omega E} \tag{8}$$

where
$$E_1 = m_1' S_s \langle v_{10}^2 \rangle \tag{9}$$

stands for the energy of the source floor. S_s is the plate area per stud and $\langle\ \rangle$ represents the mean value over the relevant area. This finally gives the loss factor as

$$\eta = \frac{Z_2}{2\left[((\frac{Z_L}{Z_1} + \frac{Z_2}{Z_L})\sin k_L d)^2 + ((1 + \frac{Z_2}{Z_1})\cos k_L d)^2 \right] \omega m_1' S_s} \tag{10}$$

If a wall and a stud are placed between the floors the model must be modified.

Several different models of the coupling between the studs, joists and the gypsum panels are possible. In the present case, the studs and the panels are assumed to be perfectly connected to each other. The corresponding change in k_L and Z_L can then be calculated directly. The expression for Z_l and Z_2 are, however, retained. This means that the panels' only effect is to stiffen up the studs. This is thought to be the usual case in practice since the panel ordinarily shorter than the total height of the room. Therefore, the point impedances for the floors can still be used as was done in the previous case.

Loss Factor Due to Bending Wave Transmission

The problem is illustrated as in Fig.4. A bending wave is propagating in the partition between the two floors. If the velocity in the lower, source floor is taken as (Fig.4)
The transverse velocity of the wall can be written as

$$v_2 = v_+ e^{-jkx} + v_- e^{+jkx} + v_{-j} e^{-kx} + v_j e^{kx} \tag{11}$$

The impedance of the floors is assumed to be much larger than those of the partition. In case of studs only, the mobility must be changed to

$$Y'' = (1 - \frac{4j}{\pi} \ln 0.5 k_2 R) \frac{\omega}{16B} \tag{12}$$

where R is the radius of a disk representing the area of contact. The loss factor can now be calculated in the same way as in the preceding case.

Material Characteristics

In this study the coconut shell is been partially used by replacing with aggregates used for construction. The coconut shell of similar age and stored in completely dried condition is used for the study. The crushing machine is designed with sieves of 4.75, 2.36, 1.7 and 1.18 mm is used in order to get shells sizes similar to aggregates used. Table 1 shows the percentage of coconut shell sizes obtained after crushing. Crushed coconut shell fibers passing 2.36 mm sieve are used for this study. 50% of weight of the sand aggregate is been replaced with coconut shell fibers. The coconut shell fibers are cured in water for 24 hrs in order to avoid the water absorption from the required water cement ratio. The cured coconut shell is dried and external water is removed in atmospheric condition before an hour for construction.

Table 1 : Percentage of coconut shell sizes retained after crushing of 500gms of coconut shell in crusher.

S. no	Sieve sizes (mm)	Retained (gms)	Percentage
1.	4.75	325	65
2.	2.36	158	31.6
3.	1.7	15	3
4.	1.18	2	0.4

Cement mortar of 1:1:1 ratio of cement, sand and coconut shell fibers has been used in casting the specimens. The panel is made up of two layers of chicken mesh (22 gauge thick with hexagonal openings) and one layer of weld mesh of 10cm x 10cm opening.

Measurements

The models that were used for the measurements were designed with two precast units of concrete. These units represent the floors. Studs and fiber impregnated ferro-cement, wood wool panels are mounted between the two elements, which where mounted vertically for practical reasons. The partitions have 50mm thick studs and a single layer of ferro-cement panels. The partition is fairly representative for the partitions, usually used inside apartments. The wall is 3000mm high which is a common height in India and contains four studs, which implies that it is 1800mm wide. The concrete units are 160mm thick and 4000*2500mm and 5000*3000mm large, respectively. They are placed on 50mm thick neoprene rubber dampers to reduce the flanking transmission through the floor on which the model is placed. The measurement results show that this flanking transmission is relatively small. However, airborne sound was initially transmitted between the two plates. Therefore, the mineral wool and wood wool panels were added on the plates in order to decrease this type of sound transmission.

Measurement Technique

One of the floors is excited with a vertically mounted tapping machine (Fig.1) and the velocity is measured at four points on the source floor and at six points at the receiving floor. The loss factor can then be calculated according to the expression.

$$\eta = 0.8\eta_R \left\langle \frac{v_R^2}{v_s^2} \right\rangle \tag{13}$$

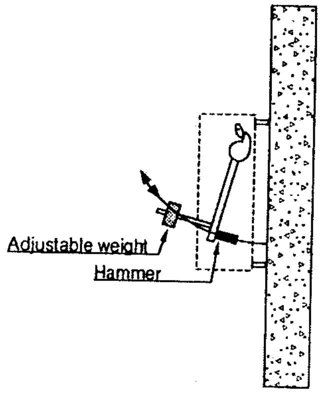

Figure 1 : Modified tapping machine, with five hammers mounted on a wall

The indices R and S stand for the receiving and source floor respectively. η_R is the internal loss factor of the receiving floor. Four measurements have been carried out. In the first one a single stud was used. The stud was long enough to be tightly fitted between the floors. In the second test the stud was cut 10mm shorter and was screwed to the joists, which is the usual procedure when a stud is mounted. Two partitions were also tested. They were 2000mm long and had four studs each. The first partition had long studs tightly fitted between the floors and the second one had 10mm shorter studs. These partitions had a ferro-cement panel on each side.

Results

The calculated loss factor with respect to the longitudinal wave is approximately 6% at 10Hz but drops quickly for higher frequencies when a single stud is used (Fig.2). The loss factor is small at frequencies over 200 Hz except for a couple of peaks. The frequencies of the peak are related to the usual half wavelength resonances of the studs. The loss factor for a wall (Fig.3) is calculated for a 0.5x5m floor strip. The reason for this is that the studs are usually placed 0.6m apart and the walls in a flat are approximately 4m apart. The loss factor is significantly higher for this wall compared with the stud in the previous case. The calculated loss factor due to bending waves is small and can be neglected in comparison with the loss factor due to longitudinal waves. The measurements (Fig.4) show that the loss factor is small when only a single stud is mounted in the ordinary way between the panels. A tightly fitted stud results in a somewhat higher loss factor compared with a screwed stud, which is only to be expected. The difference in the loss factor when a single stud or an entire wall is mounted between the plates is small.

A comparison between measured and calculated loss factor, for the case with a single stud, shows that the agreement is not too good (Fig.5). These curves are normalized to one square meter of the source floor. The agreement is better for the case with a wall between the two concrete units (Fig.6).

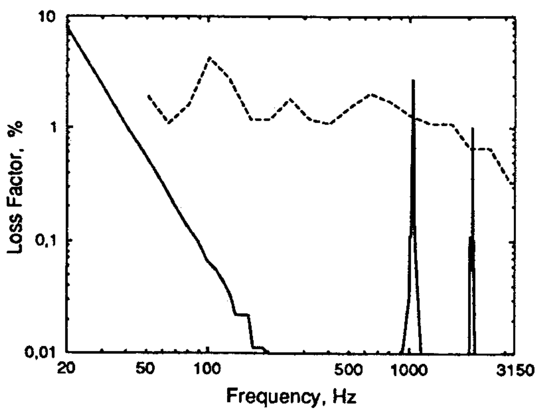

Figure 2 : Calculated loss factor with a single stud between the two plates

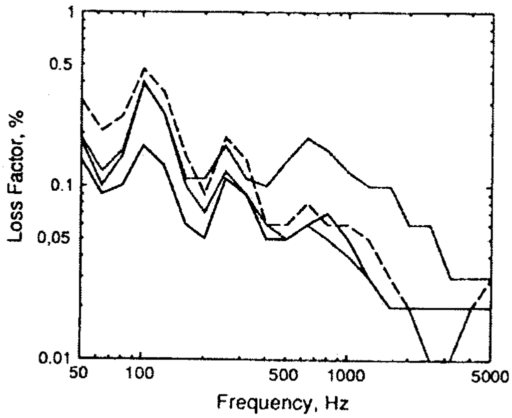

Figure 3 : Measured Loss factors for the source plate with a single stud (------), Fiber impregnated Ferro-cement panel (————), Wood wool panel (-.-.-.), wood wool double panel (.........)

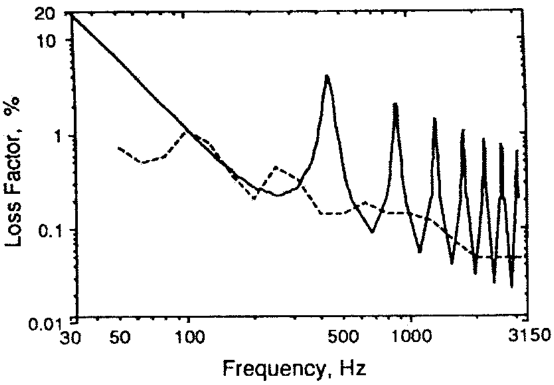

Figure 4 : Measured (————) and Calculated (------) Loss factors for Ferro-cement

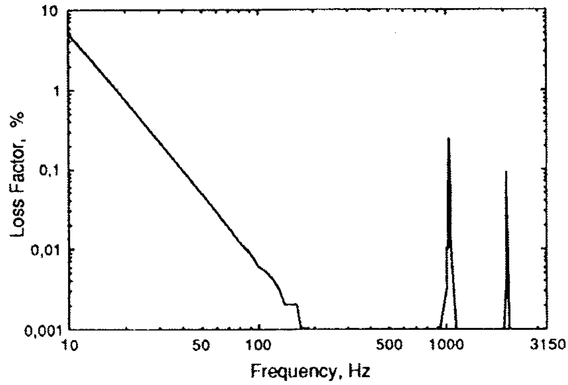

Figure 5 : Measured (————) and Calculated (------) Loss factors for Wood wool panels

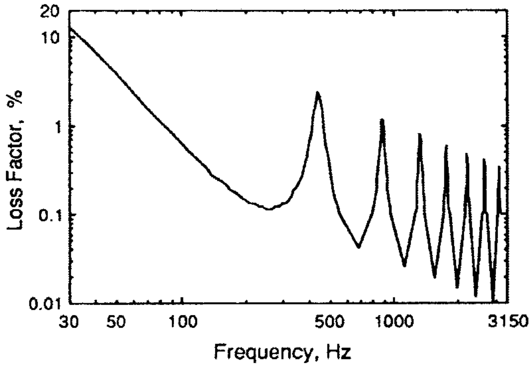

Figure 6 : Calculated loss factor for the panel inserted between two floors

Conclusion

The calculated and measured loss factors show that the presence of a lightweight partition can increase the loss factor of floors in buildings in the low frequency region. This increase is pronounced at very low frequencies and is of the same order of magnitude as that observed by Westcott. At somewhat higher frequencies, around 100Hz the contribution from the partition to the loss factor is of the order of one or a few percent for common configurations, that is one stud per square meter. This contribution will have only a small effect on the sound insulation in common concrete buildings but may be important in buildings with load-bearing columns.

The theoretical results show that the main part of the energy is transmitted through the partitions in the form of longitudinal waves. This is only to be expected as it has been found previously that the transmission from a thick wall to thin wall or beam is mainly governed by the longitudinal waves.

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