Acoustic Evaluation of Floating Floor Applications in Mechanical Rooms

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Summary

Mechanical and electrical equipment rooms are one of the main sources of noise and vibration in buildings. In high-rise buildings, it is usually inevitable to locate equipment rooms in mid-floors rather than placing them far from noise sensitive areas such as basements or separate structures. The noise from the mechanical equipment such as chillers, circulation pumps, and air handling units in these spaces can travel via and through structure to adjacent occupant spaces. Structure-born noise from the machinery excitation transmitted as impact sound and vibration can be isolated by choosing proper vibration isolators. Yet, air-borne and flanking noise transmission from the flooring should still be carefully treated. Installing a floating floor provides high levels of air-borne and flanking sound reduction in such cases. A floating floor is either constructed by using an air gap or a resilient layer. Spring or rubber type mounts are utilized to provide an air gap. A composite sound transmission loss value for such types of floating floor applications are calculated and presented in this paper.

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1. Introduction

High rise multistory buildings involving concrete and steel frames are embarked in many countries. Increase in sound insulation performance requirements result in cost oriented and technically practical solutions [1]. The most effective noise control measure is to locate indoor technical rooms as far away as possible from noise-sensitive areas. However, mechanical equipment rooms in high-rise multistory buildings are typically located on intermediate floors, close to the occupied areas they serve. In such cases, appropriate constructive layers should be selected for walls, ceilings, and floors once the amount of noise is assessed within the mechanical equipment rooms. For floorings, floating concrete floors are usually required to separate mechanical spaces from noise-sensitive spaces that are below the mechanical room [2].

Floating floor is a technical term which implies that the flooring is separated from the structure so that it has no rigid connection with surrounding building elements such as walls, floors and columns. This is achieved by using various insulation materials such as rubber mount isolators, resilient layers, flanking bands and strips. As a term, floating floor may refer to various floor isolation methodologies that can be adopted by using these products. Floorings raised on steel constructions in data centers and laminate parquet floorings installed on resilient layers are also called floating floors, but in our case we will be mostly dealing with concrete slabs raised on rubber mounts or springs as used in most mechanical rooms.

2. Floating Floor Applications in Mechanical Spaces

Insulation for the flooring in mechanical spaces should be chosen according to the equipment type, equipment weight, noise level and adjacent spaces intended purpose of use. Unnecessary and overqualified insulation may result in excess amounts of investment costs. If the main purpose of floor insulation is to overcome impact noise caused by the machinery, then using vibration isolators, resilient layers or rubber pads is probably a better choice since primary objective to install a floating floor with resilient mounts and air cavity is to prevent airborne sound transmission.

2.1. Impact noise insulation performance

Floating floors in mechanical rooms are generally not designed as part of a vibration isolation scheme for plant equipment. Floating floors with resilient mounts consist of concrete slab which is completely disconnected from surrounding building elements by vertical flanking strips to separate it from walls and columns, and resilient mounts to support it above the structural floor. The resilient mounts chosen mostly determine the overall impact noise isolation performance of the floating floor application. Assuming an ideal condition in which flanking transmission are neglected and there are no sound bridges, impact sound insulation improvement can be calculated from,

$$\Delta L_n \approx 10\log_{10}\frac{2.3\rho_{s_1}^2\omega^3\eta_1 c_{L_1} h_1}{ns^2}, \qquad (1)$$

where ρ_{s_1} is the surface weight, η_1 is the internal loss factor, c_{L_1} is the longitudinal wave velocity, h_1 is the thickness of the floating slab, n is the number of resilient mounts per unit area, and s is the stiffness of the mounts used [3]. It is possible to achieve the same or even better impact sound insulation performance with a similar floating floor construction by using a resilient layer instead of rubber mounts. We can consider this case as a locally reacting floating floor. Thus, we can use the following equations for the calculation of improvement in impact noise insulation performance of a floating floor with a resilient layer under ideal circumstances [3].

$$\Delta L_n \approx 20\log_{10}\left[1+\left(\frac{f}{f_0}\right)^2\right], \qquad (2)$$

where f is the frequency. The natural frequency f_0 of the system is,

$$f_0 = \frac{1}{2\pi}\sqrt{\frac{s}{\rho_{s1}}}, \qquad (3)$$

where s is the dynamic stiffness of the resilient layer and ρ_{s1} is the surface weight of the floating slab [3].

Comparing resilient mounts and resilient layers impact noise performance from properties of the available products in the market, it is clear that we can achieve similar impact noise performances by choosing appropriate products according to their mechanical properties (Figure 1). Also, vibration isolation products can be used when the foundation or base

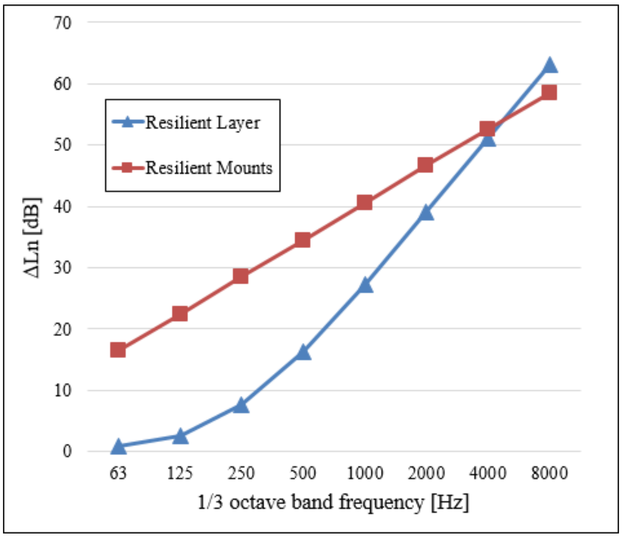

Figure 1. Comparison of improvement in impact noise performances of floating floor systems constructed with a resilient layer and rubber mounts.

of a vibrating machine is to be protected against large unbalanced forces or impulsive forces [4]. However, resilient mounts and elastic underlays performance vary a lot when we are dealing with airborne sound insulation. Even when the so called impact noise, structural vibrations and flanking transmissions are damped by vibration isolation, airborne noise transmission can still be a problem.

2.2. Airborne noise insulation performance

The heavy equipment should be properly supported to account for additional loads such as seismic loads [5]. Therefore, heavy equipment such as a chiller is usually fastened to a plinth base structure which is anchored to the structural load bearing slab in floating floor applications (Figure 2). It is possible to overcome impact noise and vibration transmission caused by the machine by using an elastic or resilient member between the machinery and the foundation. The problem is, it is usually questioned whether the floating floor that surrounding the plinth is doing any good in terms of acoustic insulation since plinth base already creates a short cut for airborne noise transmission through the cross section of the plinth itself.

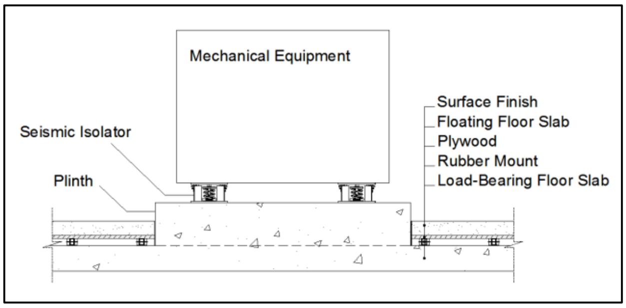

Figure 2. ASHRAE compatible floating floor design for heavy equipment.

Floating floors and plinth base structures have different sound transmission losses. For the ease of our calculations we adopt Goesel's empirical method of double partitions to predict the floating floors sound transmission loss [6]. Calculating the transmission loss of two constituent single partitions R_I and R_{II}, assuming that there are no structure-borne connections, and the gap is filled with porous sound-absorbing material, the airborne sound transmission through the floating floor can be calculated from,

$$R_{FF} \cong R_I + R_{II} + 20\log_{10}\left[\frac{4\pi f \rho_0 c_0}{s}\right], \quad (4)$$

where ρ_0 is the density and c_0 is the speed of sound in air trapped in between the gap, s is the dynamic stiffness per unit area of the gap, d is the gap thickness, and R_{FF} is the overall sound reduction performance of the floating floor system. To calculate isotropic single layered structures sound reduction performances, calculation method described in EN 12354: Annex B is adopted [7]. Assuming that floating floor and plinth structure are exposed to the same average sound intensity on the source side, we can calculate the composite transmission loss from,

$$TL_c = -10\log_{10}\left(\frac{S_{FF}\times 10^{-R_{FF}/10} + S_P\times 10^{-R_P/10}}{S_{FF}+S_P}\right), \quad (5)$$

where S_{FF} is the surface area of floating floor system, S_P is the surface area of the plinth structure, and R_P is the sound transmission loss of plinth base structure.

3. Contribution of Plinth Base Structure to Sound Transmission

We evaluate a mechanical room with the equipment described above installed within. We consider a single rigid base of plinth structure made of concrete with a height of 400mm which is surrounded by a floating concrete slab of 100mm. Load-bearing concrete slab has a 200mm thickness as usual in most mechanical spaces and the air gap between the floating slab and the load-bearing concrete slab is considered to be 50mm. Composite transmission loss is calculated according to the method described for different surface area of plinth structure for a fixed area of 200m2 mechanical space.

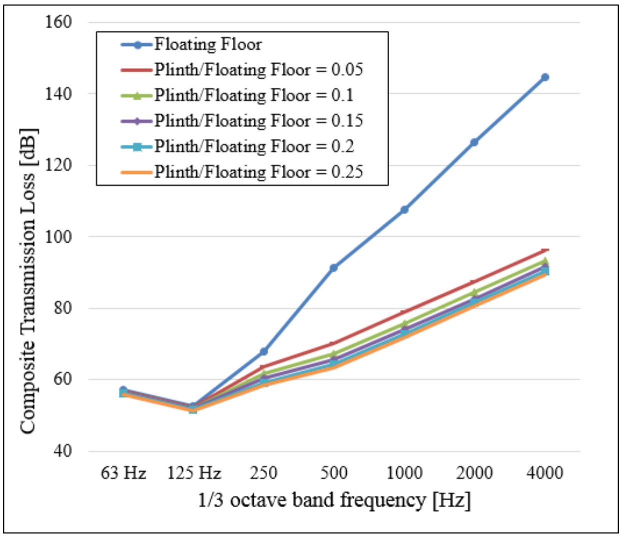

Figure 3. Change in composite transmission loss for varying surface area of plinth structure to a fixed 200m^2 surface area of a floating floor system.

As it appears, there is a considerable difference between the insulation performance of a whole floating floor and a floating floor that encloses a plinth structure (Figure 3). However, once a rigid base of plinth structure is built within a mechanical space, increasing the surface area of the plinth base does not affect insulation performance in a significant way. At this point, the question is whether the performance of floating floors that enclose a plinth base structure is efficient under real working conditions.

Most equipment manufacturers give single value representations of their products noise levels. Unfortunately, we have to work on broad band - or at least one-third octave band - responses of the relevant machinery to design a working isolation system. Therefore, if it is not possible to make measurements on site, having an archive of measurement results of spectral noise levels of common machinery can be an advantage to start with a reasonable design. As an example, we consider a cooling room with a cold water pump, a chiller and an air handling unit (Figure 4). Even though spectral noise characteristics of these three units vary, their combination gives us a flatter response.

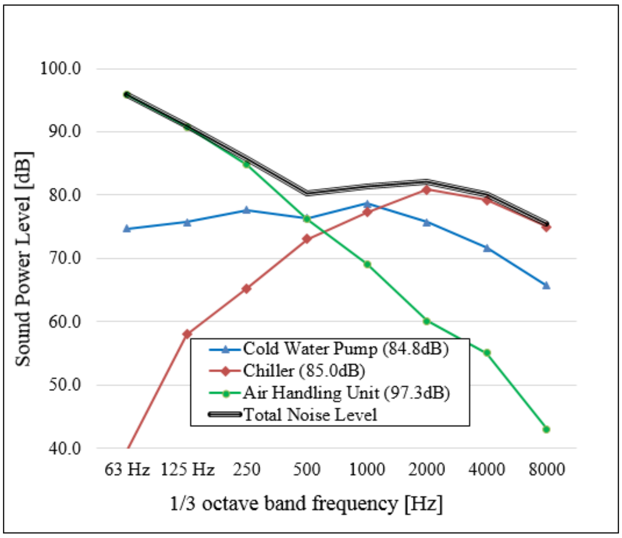

Figure 4. Sound power levels of cooling equipment in a mechanical room

Assuming that the total noise within the mechanical space is transmitted through the flooring to an adjacent space, the difference between the total sound power level (SWL) of the equipment and the composite transmission loss of flooring gives us an idea of sound insulation performance of various floating floor systems with and without plinth base structure. As expected, having a monolithic floating floor is again advantageous. Existence of a plinth base causes an increase in higher frequency noise. However the change of plinth surface area do not affect noise transmission dramatically (Figure 5).

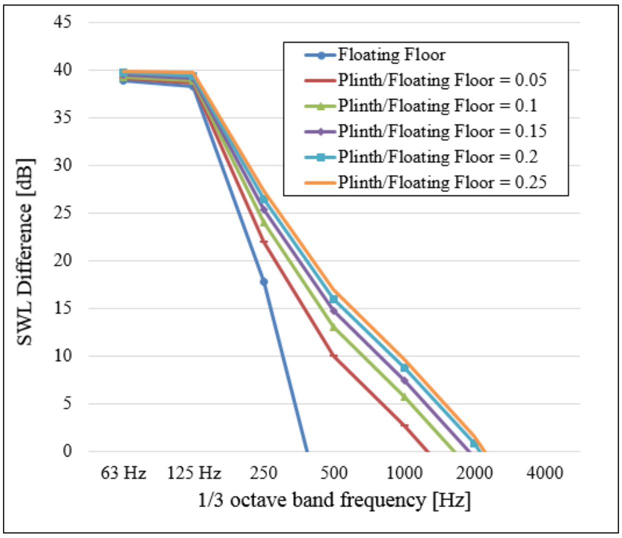

Figure 5. Insulation performance comparison between various floating floor systems.

4. Conclusion

The plinth structures contribution to airborne sound insulation is investigated and with some simple calculations available in literature it has been found that - for a realistic case - the contribution of plinth structure to noise transmission is not negligible as expected. Presence of a plinth base causes a conspicuous increase in noise transmission compared to a monolithic floating floor design. However, if a floating floor design is made considering the equipment noise levels from the beginning and appropriate slab thicknesses and insulation materials are chosen, it is expected that the transmission loss should not vary much according to the changing plinth base surface area. For future work, further analysis and a more detailed model should be developed to investigate floating floors with plinth base structures. It is recommended to investigate more about such composite structures contribution to airborne and impact noise transmission especially in mechanical spaces.

Acknowledgement

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