Measurement of room-to-room airborne sound insulation with an access floor in a dwelling unit of condominium

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Concrete floors of condominium apartments in Japan are preferably covered using wooden access floors. The access floors are usually installed after every partition in each dwelling unit. If the access floor and ceiling are installed before the creation of partitions, one can reduce the waste material and labor involved in the construction. Therefore, one can build housing more efficiently and more "green". However, there is a concern in that the flanking path through under the access floor may reduce the sound insulation performance. In addition, there exists another dominant flanking path that cannot be eliminated by the construction methods—the doors leading into the hallway. Several field measurements of the sound insulation performance were performed with open/closed doors to evaluate the flanking transmission via the doors.
These results show that the flanking path via the doors has a significant effect, particularly in the case of high-frequency noise; however, the effect is not significant in the case of low- and mid-frequency noise. Next, the sound transmission performances of the access floors and ceilings measured in the laboratory were compared with the direct sound transmission through the wall itself. As a conclusion, the field measurement results show that different construction methods have a marginal effect on the airborne sound insulation performance

1 Introduction

Improvements are currently being made in resource circulation and productivity by means of the process control of housing complexes. Advancements in construction procedures have led to changes in the interior and equipment construction; the SI (skeleton-infill) system is one such new construction procedure. Partition walls in dwelling units were previously constructed using wooden access floors by the wall ascending (WA) construction method. However, it may be advantageous to switch to the floor ascending (FA) construction method, as shown in Fig. 1. Using the FA method, when rooms are being remodeled, the covering floor can be retained; at the very least, the furring board can be retained. Thus, the FA system reduces the amount of waste generated and contributes to be extremely precise.

An important factor that must be considered during construction is the sound insulation performance of the housing complex, i.e., sound insulation between units, against noise from outside the units, i.e., road and equipment noises. However, the performance within a unit has also gained importance in recent years. The concerns regarding the performance of FA construction as compared to that of WA are as follows:

1) The airborne sound insulation performance between rooms by the flanking path may be reduced because there is no board in the space under the covering floor.

2) The furring board of the access floor is shared between two rooms. Therefore, structure-borne sounds may transmit through the furring board.

3) Influence of virtual vibrations, i.e., vibrations may be felt due to the movements of individuals in the adjacent room.

A change in the construction procedure may have some impact on the acoustic performance, although these changes are obviously beneficial for resource circulation housing. It is necessary to clarify the extent of the impact. This report presents the results of laboratory and *in situ* experiments that were conducted to clarify the sound insulation performance.

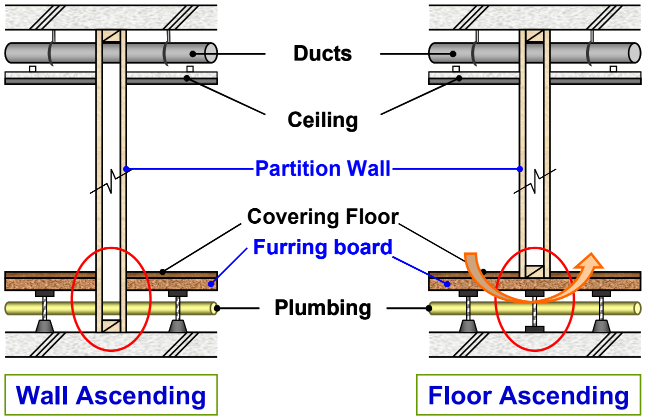
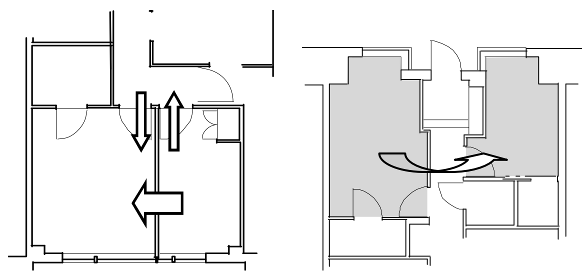


Fig. 1: Two types of sectional views of a partition in a unit of a residential complex.



(a) adjacent (b) beyond corridor

Fig. 2: Typical plans of rooms in the same unit.

Table 1 Measurement condition

Sound source room door	Receiving room door	Symbol of results
close	close	D_{cc}
open	close	D_{oc}
close	open	D_{co}
open	open	D_{oo}

2 Actual condition survey

The sound insulation performance between rooms in the same unit of a housing complex is believed to be influenced by the flanking path through the doors and corridors. Moreover, doors have slits for the purpose of ventilation. This may reduce the sound insulation performance.

We conducted measurements for 26 paths in three housing complexes. The typical plans of the paths are shown in Fig. 2. The partition is a double wall having one or two plasterboards tacked to both sides and the rooms have a finished floor. The sound insulation performance between the rooms was measured for four conditions—opening and shutting the door of the room with a sound source and the room where sound is received[1]. The conditions are listed in Table 1. Moreover, the sound pressure level differences between specific surfaces at a distance of 1 m from the door in the room and in the corridor were measured for both case, i.e., opened and closed doors. The apparent sound insulation loss due to the door could be calculated from the difference between the values for opened and closed doors. Thus, the influence of flanking was evaluated.

An example of the measurement result is shown in Fig. 3. The result indicates that the sound insulation performance is improved with a greater number of closed doors. However, no change is observed, particularly at low frequencies, when only one or two doors are closed. This suggests the possibility that a path other than the doors may affect the performance. The sound insulation performance of doors with slits is around 10–15 dB, as shown in Fig. 4.

We divide the room with a sound source, the room where sound is received, and the passage by means of a virtual plane. Further, we assume a diffuse sound field and also assume that the absorbing power does not change with open or closed doors. The sound insulation performance corresponding to the conditions of open and closed doors is listed in Table 1. If the performance between rooms mainly depends on the path through the door, the relationship among the level differences will be:

$$D_{cc} = D_{co} + D_{oc} - D_{oo} \quad (1)$$

If the right-hand side of the equation exceeds the left-hand side, the effect of sound transmission paths other than the door is not negligible. Figure 5 shows the results of the difference between the right- and left-hand sides of Eqn. (1); these results are obtained by comparing the paths for rooms having adjoining walls and a corridor between the rooms as a buffer area. The reduction in sound insulation performance due to the door is obvious from the results for the case where there exists a corridor between the rooms. However, the performance is also affected by the partition wall.

The sound insulation performance of the wall usually used as a partition wall is shown in Fig. 6. Calculation examples of the sound insulation between adjacent rooms are shown in Fig. 7. The performance between rooms largely depends on the performance of the door in the frequency range of more than 1 kHz. However, at lower frequencies, it is observed that the performance depends on the partition wall.

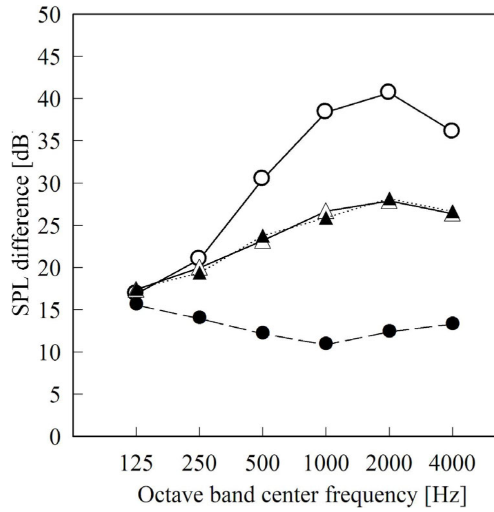


Fig. 3: Level differences with regard to open/closed doors: —○—, both closed; —●—, both opened; —△—,source room opened, receiving room closed; and ·····▲·····, source room closed, receiving room opened.

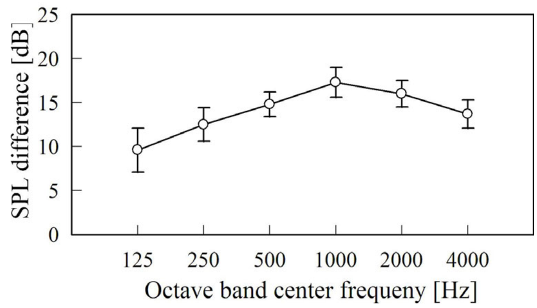


Fig. 4: Average level difference between specific points, ***Dp,*** of door.

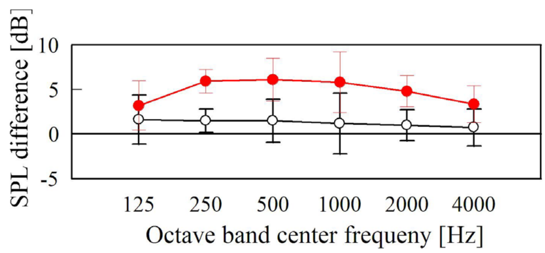


Fig. 5: Errors in Eqn. (1); *filled circle: path beyond corridor (12 data), empty circle: path between adjoining rooms (14 data).*

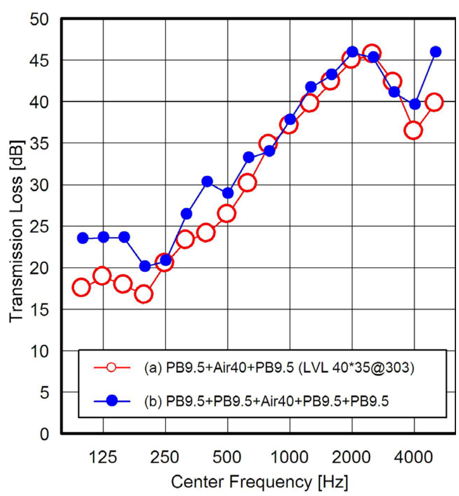


Fig. 6: Sound insulation performance of typical partition wall; *(a) STC-30, Rw-30 and (b) STC-34, Rw-34.*

3 Air-borne sound transmission

In order to clarify the influence of the flanking path of a wooden covering floor constructed by FA system, the sound pressure level difference between rooms was measured in the test facility. The cross section of the test facility and the specimen is shown in Fig. 8. A 140-mm-high wooden covering floor was built on the concrete floor. The plenum under the wooden covering floor was lined only on the concrete surface with fiber-wool. Furthermore, we conducted a test where no lining absorber was used. The objective of this measurement is to determine the sound insulation performances under actual conditions. Therefore, the end-walls of the plenum are also not lined by a sound absorbing material, although ISO 10484-2 requires a lining of a sound absorbing material. The partition wall is a double-layer wall with 50-mm-thick LVL studs and 12.5-mm-thick plaster boards; one side has a single layer and the other has a double layer. The partition was constructed from the covering floor to the undersurface of the upper concrete slab.

In order to understand the influence of the flanking path through under the covering, we also measured the reinforcing sound insulation performance of the partition wall with an additional cover wall. Moreover, we compared the cases where a gap existed between the partition wall and the covering floor with and without a skirt board on the partition wall. The skirt board may improve the floor impact sound at low frequencies, and it functions as an air release for the space below the covering floor.

The measurement result is shown in Fig. 9. The results of the case with an additional cover wall are compared. When the bonded-fiber fabric was paved on the floor slab, the sound pressure level difference between the rooms was Rw-49, and it was greater than 10 dB as compared to the usual partition wall for each frequency. This does not change with the presence of air release from the surrounding.

The sound insulation performance was poor in the case where a bonded-fiber fabric was not lined on the floor slab in the plenum. In particular, the performance worsened in the case with air release to the same extent as the case without an additional cover wall. Therefore, the flanking path through under the covering floor cannot be disregarded in this case.

These results confirm that the performance through under the covering floor exceeds that by the direct path through the partition wall by 10 dB or more. Therefore, the flanking path of the FA can be ignored.

4 Vibration transmission

The acoustics issues related to the FA include airborne sound insulation as well as flanking transmission due to structure-borne sounds and vibrations caused by the movements of individuals in an adjacent room. The base material of the covering floor is consecutive. Here, we present the measurements conducted for a housing complex site with regard to vibration transmission.

The floor impact sound insulation performance when the center of the living room of a unit was excited was measured in FA and WA buildings having three adjacent

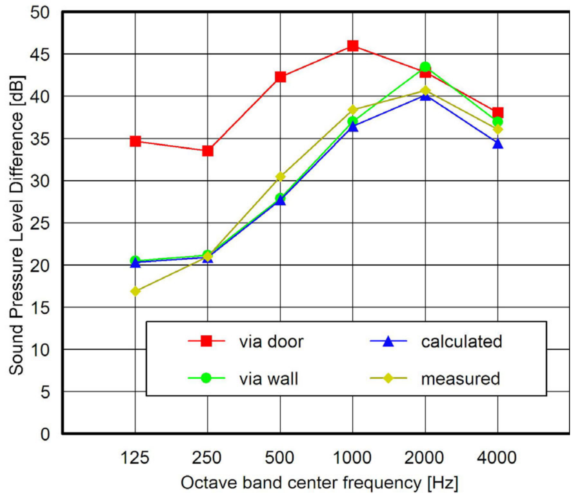


Fig. 7: Comparison between measured values and calculated values.

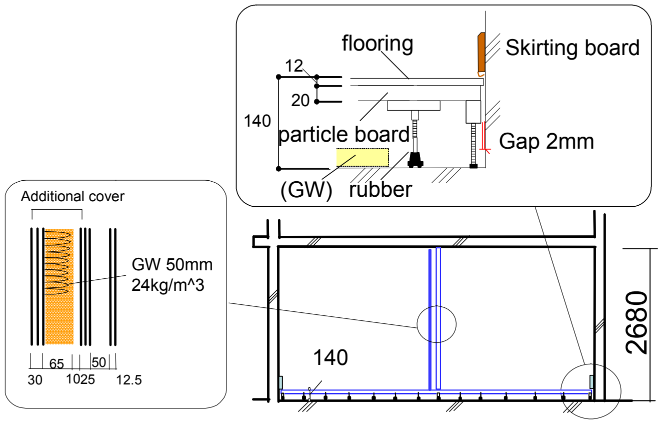


Fig. 8 Cross-sectional view of test facility and specimen

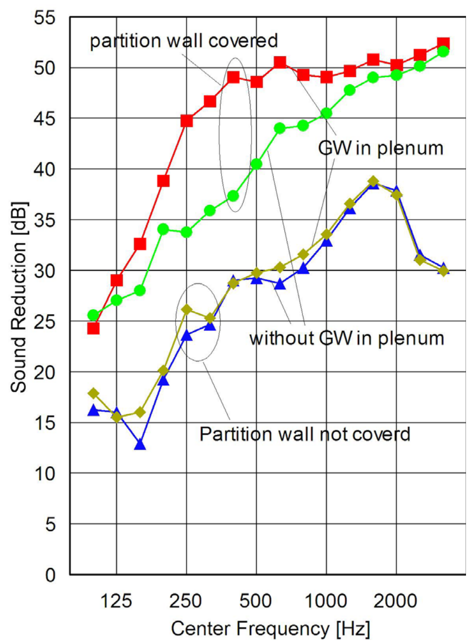


Fig. 9 Apparent transmission losses with regard to the existence of a sound proof cover for the partition and the GW in the plenum of the raised floor.

rooms, as shown in the plan in Fig. 10. The maximum sound pressure level $L_{i,\mathrm{A,Fmax}}$ was measured at the center of the receiving room when a rubber ball (prescribed in JIS A

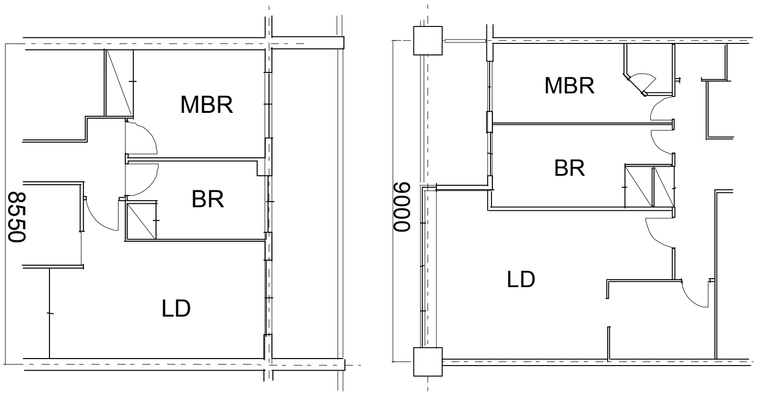
1418-2, from 1-m height), golf ball (from 1-m height), and a 100 yen coin (from 50-cm height) were dropped. The results are shown in Table 2. Furthermore, L_{Aeq} when the tapping machine turns on in the living-dining room was also measured. As compared to the adjacent room and the room next to the adjacent one, a difference of approximately 10 dB can be observed in the results when the golf ball is dropped, although a remarkable difference is not observed when the coin is dropped.

Next, the maximum vibration acceleration level on a covering floor was measured when the ball prescribed in JIS A 1418-2 was dropped from a 10-cm height, imitating the impact force made by heel walking.

The excitation point was set to the center between the support studs at a distance of 30 cm from the partition wall. The measurement results are shown in Fig. 11, which shows a comparison between the vibration source room and adjacent receiving room.

The wooden covering floors are made of steel studs with rubber, a particle board (thickness: 20 mm), and the flooring (thickness: 12 mm); they do not include any additional veneer or damping sheets.

A difference of approximately 20 dB was observed in the case of WA with regard to the vibration acceleration level between the excitation room and the adjacent room. In contrast, it was almost equal in the case of FA because of the common furring board that causes some attenuation with distance.



(a) Wall ascending unit (b) Floor ascending unit

Fig. 10 Plans of units that has three adjoining rooms.

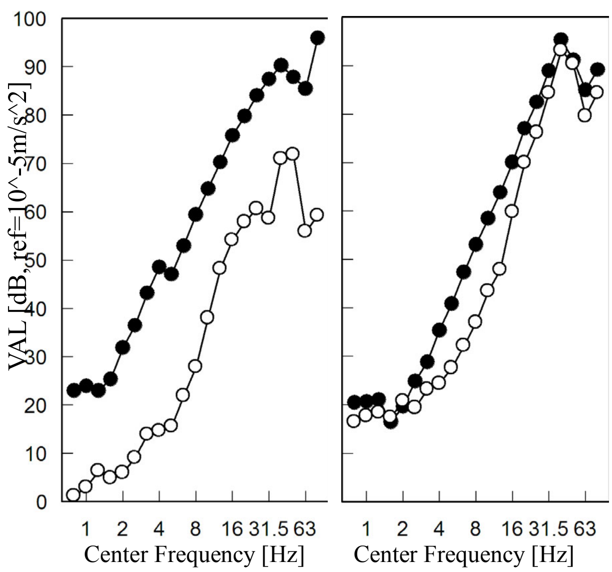
Table 2 Measurement results

(a) Wall ascendant unit

Impact source	LD	BR	MBR
Rubber ball (1 m)	80 dBA	58 dBA	46 dBA
Tapping machine	90 dBA	65 dBA	53 dBA
Golf ball(1 m)	93 dBA	62 dBA	48 dBA
Coin (50 cm)	85 dBA	48 dBA	44 dBA

(b) Floor ascendant unit

Impact source	LD	BR	MBR
Rubber ball (1 m)	83 dBA	61 dBA	57 dBA
Tapping machine	90 dBA	68 dBA	63 dBA
Golf ball(1 m)	88 dBA	65 dBA	59 dBA
Coin (50 cm)	85 dBA	55 dBA	45 dBA



(a) Wall ascendant unit (b) Floor ascendant unit

Fig. 11 Floor vibrations on dropping a JIS rubber ball from a 10-cm height: *filled circle, impact source room: empty circle: adjacent room.*

5 Conclusion

Flanking transmissions between rooms in the same unit were measured in an actual and model residential complex with regard to two construction procedures, namely, the wall ascending and floor ascending methods.

It was revealed that the flanking airborne sound transmission through a doorway and through under the covering floor affects the sound insulation performance of a partition wall. The propagation of structure-borne sounds along the wooden covering floor was also demonstrated. Further, floors made by the FA procedure tend to induce vibrations in the floor of the adjoining room, although it is considered that few of these vibrations actually affect the inhabitants of the adjoining room.

References

[1] K. Kubota, “Flanking transmission of sound along a direct air path out of window”, Onkyo-gijutsu, Vol. 5 (1973), pp. 41 – 47 (in Japanese).

[2] ISO 10848-2:2006 Acoustics – Laboratory measurement of the flanking transmission of airborne and impact sound between adjoining rooms – Part 2: Application to light elements when the junction has a small influence