Measurement of Airborne Sound Insulation of Modular Construction Methods

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***Abstract*— There are a difference between the performance measurement results in the laboratory and the measurement results in the field. This is the reason for the difference in the condition of the measurement site, the difference in construction and installation state of the measurement object depending on the construction or manufacturer. As the industry developed, the construction methods became more diverse. Modular construction methods are growing especially in the field of architecture. This study is a study on the sound insulation performance of modular construction. Based on ISO 140-3 and KS F 2808, we will examine the airborne sound isolation performance of building materials considering the architectural characteristics. Thus, the simulation results and the laboratory measurement results are compared with the wall sound insulation performance of the modular construction method. The influence of the characteristic on the airborne sound performance is analyzed.**

***Index Terms*—modular construction, insulation, airborne sound**

I. Introduction

In order to overcome the disadvantages of the RC method such as the error of construction in the field, the increase of construction waste, and the shortage of the field workforce, the industrialized housing construction method in which the main structural members such as walls and roofs are prefabricated and assembled in the field is suggested as an alternative [1].

Modular houses have standardized frames, walls, windows, and doors produced at factories and assembled and finished at the site, which not only shortens the construction period but also lowers construction costs through mass production. In Korea, recently, the criteria and procedures for recognition of modular housing performance have been streamlined to promote the introduction of modular housing [2].

However, since the performance evaluation standard of the present modular housing standard is the performance evaluation standard based on the PC (Precast Concrete) and the standard of the apartment house performance recognition standard in the housing law, there is a part that does not reflect the characteristic of the modular house, It is necessary to improve the system considering characteristics of modular houses such as performance evaluation of joints between members and members [3].

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In this study, the evaluation method considering the characteristics of the industrialization method is first proposed as the performance evaluation method for the boundary walls.

II. Consideration of Modular Housing Recognition System

A. Modular Housing

Modular housing is a construction method based on factory fabrication by which 50 to 80% of the construction process is completed in factories including a variety of structures, facilities, and building finishes, thereby constructing structures using minimal fabrication at sites. Modular construction minimizes construction time on sites. Thus, it can be reduced the total construction cost including labor and indirect costs as well as construction wastes significantly. Moreover, modular construction has the advantage of facilitating remodeling due to easy partial maintenance and repair and ensuring uniform performance of construction parts and materials. Since 1992, modular housing have been adopted in South Korea and been evaluated as relatively viable methods in terms of schedule shortening, quality improvements, and performance certificate. Modular housing has been actively adopted since 2009 and most methods used in modular construction in Korea have been column-beam steel frame as below Fig. 1. The early markets were school facilities and military units. Now and then, it has expanded into public housing and office buildings [4].

Figure 1. Modular housing in Korea

B. Type of Construction Method of Modular Housing

Modular housing refers to the construction method of producing unit boxes in factories which contain structural materials, interior materials, various facilities, etc. and constructing buildings on the site with the minimum assembly process [5]. It can save labor cost and achieve

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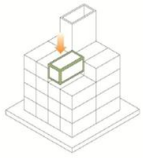
good residence performance because the houses are manufactured in factories and field work can be minimized. Moreover, construction waste can be reduced through the minimization of on-site construction work. Unit modular architecture is simple to assemble and disassemble like Lego blocks and affords easy partial maintenance and replacement and repair of aged parts. Therefore, extension remodeling after change of building use is convenient [6].

Another advantage is that it is a method based on industrialized architecture that can achieve equal performance of the materials. Modular housing can be classified by structure and structural system as shown in Table 1 below.

TABLE I. TYPE OF CONSTRUCTION METHOD OF MODULAR HOUSING

Rahmen (Lamination)	Stud panel (Lamination)	Infill
		
Columns and Beam Structural Systems	Stud Structural System	Insert the unit in the structure

C. Modular Housing Certification System

Modular housing means a house constructed by industrialization methods such as a prefabricated construction according to performance standards and production standards set by the ministry of Land, Infrastructure and Transport in Korea., all or part of the main structural parts.

The certification system for modular housing was introduced for the first time in December 1992, and the performance and production standards of modular housing were partially revised in April 2012. The main framework is divided into performance standards and production standards. Performance standards are divided into single-family houses and multi-family homes in table 2 below.

TABLE II. PERFORMANCE STANDARDS

House	Apartment house
Structure safety Ventilation airtight Thermal environment Durability	Structure safety Ventilation airtight Thermal environment Durability Fireproof Evacuation safety Fall prevention Sound environment

D. Performance Evaluation of Modular Housing

The criteria for the recognition of apartment housing performance in industrialized housing can be classified into seven categories: structural safety performance, fire resistance and fire performance, ventilation performance and airtight performance, thermal environmental performance, sound environmental performance, durability performance, evacuation safety performance and fall prevention performance is.

In this study, only the performance of sound insulation is evaluated.

The performance evaluation of the sound environment is evaluated to be largely based on the noise blocking performance of the intergenerational boundary wall and the blocking performance of the floor impact sound. First, the structure of the inter-generational boundary wall should comply with the structural standard of the boundary wall in accordance with Article 14 (1) and (2) of Regulation on Housing Construction Standard, etc., and the sound insulation performance shall be expressed by the spectrum transmission loss (Rw+C) is 48 or more, it is judged as grade 3 and it passes the recognition standard. The measurement method is defined only by the wall between the two rooms of the building. Unlike the RC house, it is impossible to accurately evaluate the acoustic loss occurrence of the industrial housing resulting from joining two or more unit units.

Therefore, we will make laboratory measurements on the fabricated boundary between the modules and the module, and also see the characteristics of the sound insulation performance for the finishing type.

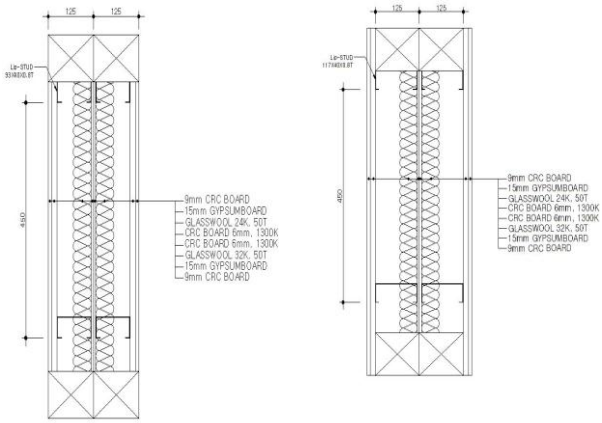
III. PERFORMANCE EVALUATION OF PARTITION WALL BETWEEN HOUSING UNITS

Industrialized houses are likely to lower the sound insulation performance at the joints between structures.

If you follow the existing experimental method, there is a high possibility of increasing the dissatisfaction level of the residents due to the performance evaluation that cannot consider the specificity of the prefabricated construction method.

In this study, the evaluation of sound insulation performance of a single wall was evaluated using INSUL.

Evaluation of the sound insulation performance of the combined wall between modules was made in the laboratory [7].



(a) none-covered column Structure (b) covered column Structure

Figure 2. Section of wall structure

There are two methods to manufacture the wall of modular housing as Fig. 2.

In order to evaluate the performance of the combined partition wall-to-wall housing units, the wall finishes were divided into unsealed, sealed, finishing of board.

A *Performance Evaluation of Partition Wall Between Housing units of Industrialized Houses*

The sound insulation test in accordance with KS F 2808, the results are shown in Fig. 3.

The wall, except for the wall with the board, showed a resonance frequency at 200 Hz and a typical coincidence region of the panel at 400 to 4000 Hz.

The simulation results are similar to those of a typical sandwich panel [8].

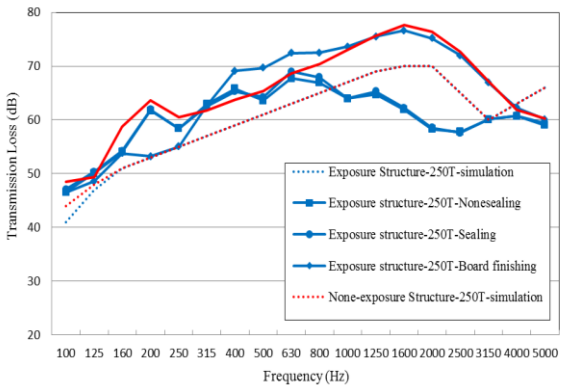


Figure 3. Evaluation of sound insulation performance of partition wall between housing units

The results of the sound insulation performance according to whether or not the sealing was performed were not significantly different. However, finishing of board showed different characteristics.

It is seen that the sound insulation characteristics of the structure exposed type to the board and the sound insulation characteristics of the wall type of the non-exposed type of the structure are similar to each other, and it can be seen that the sound insulation characteristics vary depending on the finishing method and the condition of the joint portion between the modules there was.

B *Evaluation of Sound Insulation Performance of Between Rooms in Industrial Houses*

It is also important to realize the sound insulation performance that distinguishes the public space from the private space [9]. Therefore, the sound insulation performance of the industrial house was evaluated.

The configuration of the between rooms is based on the configuration of partition wall between housing units shown in Fig 3.

The experimental method is the same as the evaluation of the partition wall between housing units. The results are shown in Fig 4.

It can be seen that the sound insulation performance of the room wall is about 20 dB lower than that of the partition wall between housing units.

Since the material is not changed but thickness is reduced, the sound insulation characteristics are similar to the partition wall between housing units.

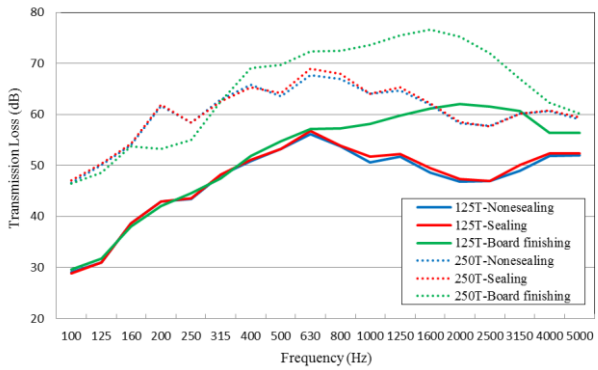


Figure 4. Evaluation of partition wall between rooms sound insulation performance

IV. Conclusion

Since the regulations for the approval of industrialized housing were originally set for the recognition of PC industrialized housing in the 1990s, there is a limit to evaluate the industrialized housing that has been developed with various structures at present.

Reinforce concrete construction are not wetted, and there are no junctions between concrete and concrete in the site.

However, as shown in Fig. 4, modular housing has a point of junction in the process of assembling and integrating up to two or more unit units in the factory after unit is manufactured in the factory.

Thickness is difficult to guarantee that the performance evaluation result is obtained as in the experimental result after combining two or more modules even if the inter-generational boundary wall sound insulation performance is high. In the evaluation of sound insulation, even if the most of the wall materials are designed with good sound insulation performance, the sound insulation characteristics depend on some openings, gaps, and the way in which the gaps are treated.

Since the industrialized housing is not yet a concrete law, the performance evaluation system also conforms to RC house performance evaluation standard. Therefore, it is necessary to propose a performance evaluation method for the activation of the industrialized housing and the accurate performance verification of the residential performance.

Especially, it is considered appropriate to evaluate the sound insulation performance of the structure including the finishing method around the bonding area of the real wall, which is the boundary wall between the generations.

This study is limited to the boundary walls between the generations and their finishing methods. Therefore, we plan to conduct a comparative study with the wet-type method in future studies and to evaluate the performance of the floor impact sound through mock-up with at least four structures by combining two or more structures.

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