Construction and Building Materials 93 (2015) 542–550

Contents lists available at ScienceDirect

Construction and Building Materials

journal homepage: www.elsevier.com/locate/conbuildmat

Acoustic insulation performance of improved airtight windows

Hyeon Ku Park [a,*], Hang Kim [b]

[a] Biohousing Research Center, Chonnam National University, Gwangju, Republic of Korea
[b] Korea Marine Equipment Research Institute, Youngdo, Republic of Korea

HIGHLIGHTS

- The airtightness improved structure was tested on the acoustic performance.
- Test results for old window showed very high performance as much of the new window.
- Test structure could be very effective to most of apartments and buildings.
- The airtight structure can preserve natural resource use and reduce CO_2 emission.

ARTICLE INFO

Article history:
Received 10 December 2013
Received in revised form 28 March 2015
Accepted 1 May 2015
Available online 24 June 2015

Keywords:
Airtight
Window
Environmental performance
Acoustic insulation
Energy saving

ABSTRACT

Windows are used not only for lighting and thermal insulation, but also for sound attenuation. Most window frames installed in apartments are composed of either aluminum or polyvinylchloride. In general, windows in Korea consist of an outer frame forming the opening and a window frame attached to the glass, with enough clearance at the top and bottom to join them together. This space at the top and the bottom for the sliding type is the main factor affecting thermal and acoustic performance. In addition, the precision of the fit between the frames and deterioration of the mohair attached to the window frame affect environmental performance. There is however somewhat gap because the inner frame should be installed within the outer frame in the field. The goal of this study is to improve environmental conditions in residences by increasing the airtightness of windows to counteract deterioration of performance due to aging window frames and mohair. The results indicate that these attachments can attenuate sound effectively and can be regarded to reduce energy and natural resource use by attaching them to deteriorated windows or in apartments needed to be reinforced.

1. Introduction

In Korea, the windows in apartments and houses consist mainly of aluminum and polyvinylchloride (PVC). The windows in the front balcony play a particularly important role in sound and heat insulation, as well as letting in sunlight. In general, loss of energy in buildings occurs through walls, roofs, and windows, and the amount of heat loss through the windows is 20–40% of the total. Noise from outside is transmitted indoors mainly through the walls, and in particular through windows that have poor sound insulation compared with heavier materials such as concrete.

Windows in Korea are typically composed of an outside frame that forms the opening and an inside frame (hereinafter "window frame") that contains the glass. When inserting the window frame into the outside frame, a small amount of clearance is required at the top and bottom of the frame. This space between the outside frame and the window frame is the main factor affecting heat and sound insulation performance. The precision with which the window frame was installed and the degree of deterioration of the mohair used in the window frame are also factors that strongly affect the environmental performance of a window.

Data from the Korea Statistics Office in 2010 indicate that detached houses represent 28% of households, apartments 59%, and townhouses and other multi-household homes 14%. The percentage of apartments is increasing over time, from 48% in 2000 and 53% in 2005. Because the majority of residents live in apartments with many windows on the external wall (39% of the surface), improvement of the environmental performance [1] of these windows would make an important contribution to the quality of life of the residents.

Research on the environmental performance of windows has mainly been focused on evaluation of the thermal environment including ventilation [2,3], indoor air quality [4] and sound

* Corresponding author. Tel.: +82 (062)530 1914; fax: +82 (062)530 0915.
E-mail address: soundpark@cricmail.net (H.K. Park).

http://dx.doi.org/10.1016/j.conbuildmat.2015.05.058
0950-0618/

attenuation [5], and research on the design of high-performance windows like double skin facade has been conducted [6], Loffler has designed new type of windows to increase solar gain and to decrease energy consumption [7]. Recently, research on the loss of energy through windows [8,9] and evaluation of associated CO_2 emissions has been conducted in studies related to global warming [10]. As the repair cycle and repair rate of windows and glass are 10 years and 2%, respectively, it is expected that performance may deteriorate with age.

In this study, the sound insulation of typical windows were evaluated the sound insulation, and it was examined whether indoor sound can be improved and how much improved through retrofitting the existing window. It is very important to reform or reinforce the existing building elements in the energy saving as well as economical aspect like pointed out from the research of Meijer et. al.[11]. In Korea, standards for outside noise in apartments, such as Article 2 of the Enforcement Decree of the Environmental Policy Framework Act and Article 9 of the Regulations on Standards for Housing Construction, stipulate that the noise levels in apartment houses shall be under 65 dBA, and if it is not less than that level, the standard shall be satisfied through installation of sound-proofing such as soundproof walls. For 6-story or higher buildings, indoor noise must be not more than 45 dBA, and when the noise levels outside an apartment house along an urban road are 70–80 dBA [12], noise levels of 25–35 dB or higher should be insulated along the external wall including the windows. The arithmetic averages of the sound insulation performance of windows measured in the laboratory are typically 20–30 dB for single-paned windows and 30–40 dB for double-paned windows [13]. However, sound insulation performance may vary due to the type of outside sound source in laboratory experiments, differences in construction when measured in the field, and deterioration in performance of older windows. Because repairing a window each time its performance deteriorates may be costly and wasteful of resources, finding a reasonably economical approach to improving performance is important.

With these reasons, this study aims to improve environmental conditions in residences by increasing the airtightness of windows to counteract deterioration of performance due to aging window frames and mohair. In this study, we developed and installed airtight structures on typical windows in Korea to maintain airtightness of the space between the window frame and the outside frame, and evaluated improvements in sound insulation. For domestic use, the results of this study suggest that this would be an effective approach for windows with low performance, such as those in existing apartment houses built when standards for heat insulation of windows were lower, when windows are severely aged, or when remodeling is required. Retrofitting with a structure such as that tested in this study provides an efficient plan for resource savings and CO_2 reduction in a cost-effective manner.

2. Development of window airtightness structures

Deterioration of sound insulation in windows occurs due to the gap formed between the outside frame and the window frame, and eventually results in an increase in indoor energy consumption due to lack of airtightness and reduction in thermal performance.

Fundamentally, improving the airtightness of windows requires designing the window frame to have an airtight structure. A patent search was conducted to survey techniques for improving the airtightness of windows. The vast number of window-related patents were reduced to those closely related to this study by searching using the terms "airtightness," "system," "window," and "gap." Fifty cases were found after searching for patents on http://www.kipris.or.kr and considering only patents applied for since 2000. After reclassifying these patents by the method of application to windows, techniques for improving airtightness and reducing gaps were mainly designed to reduce the gap between the sliding window frames, and techniques for minimizing the gap by attaching additional materials to the window frame were the most frequent (21 of 50 cases). Reviewing the attachment methods in more detail, attaching additional material to the bottom face was the most common method (11 patents), followed by attachment to the lateral face (6 patents), two methods using both the lateral and bottom faces, and two methods using the frame connection area (Table 1).

Thus, in this study, a method using the matched part of the bottom and lateral faces of the window frame with a relatively simple installation approach was selected as the subject method, and changes in sound insulation performance were compared and analyzed by applying this method.

Fig. 1 shows cross-sectional diagrams of the airtight structures installed on the window frames, and Photo 1 shows the structure installed during the laboratory experiment. The left panels of Fig. 1 show the cross-section of the airtight installed structure in the vertical direction, and the right panels show the structure installed on the left and right sides of the window frame. Larger gaps are present in the vertical direction; thus, these were judged to affect performance more. Therefore, the experiment was first conducted with installation in the vertical manner, and additional structures were installed in the horizontal direction when changes in sound insulation performance were observed.

Fig. 2 shows a conceptual diagram of installation of the horizontal airtight structure (vertical part) and the vertical airtight structure (horizontal part) on the subject window, as well as the gap-sealing structure on the vertical section of the window frame. Especially usability could be decreased due to airtightness, thus it is now being observed in the construction field by attaching this specimen and the way to improve the usability would be applied, keeping its environmental performance.

3. Laboratory measurement of the sound insulation and airtightness performance of windows

3.1. Structures of the experimental windows

In the experiment, the sound insulation performance of dual windows, airtight dual windows, single windows and airtight single windows was measured and compared. The structures were classified into new and old types and the deterioration of sound insulation with mohair loss and improvements due to airtight structure installation were examined. In addition, air-tightness test was performed to analyze the relationship between air-tightness and sound insulation for some types that was considered to have lowest and highest performance.

The sound insulation of windows is affected by various factors, such as the composition of the window frame and glass, precision of the installation, etc., and some research has been conducted correlating these factors with sound insulation [14]. In the present study, an older structure with mohair on one side, which is vulnerable to loss due to outside air and noise, along with those with mohair installed on both sides of the window frame, were set up to measure the loss of mohair and deterioration of sound insulation with window aging. Windows are bound to age with time and the performance of old windows deteriorates greatly. This is largely because the mohair installed on the window frame is lost, reducing window airtightness due to long use.

Measurement of the sound insulation performance of the windows was conducted in the laboratory using windows constructed of aluminum and PVC as typical window materials and with the glass most widely used in apartment houses (Table 2). The glass