Applied Acoustics 120 (2017) 148–157

Contents lists available at ScienceDirect

Applied Acoustics

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

Levels and sources of neighbour noise in heavyweight residential buildings in Korea

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ARTICLE INFO

Article history:
Received 11 August 2016
Received in revised form 6 January 2017
Accepted 11 January 2017
Available online 30 January 2017

Keywords:
Indoor environment
Neighbour noise
Noise level
Noise source
Residential building

ABSTRACT

Indoor noise level is a significant factor for occupants' health, comfort, and psychological well-being in residential buildings; hence the World Health Organization (WHO) recommends guidelines for residential buildings based on the 24-h sound levels. However, only few studies have examined 24-h noise levels and sources from neighbours. Consequently, 24-h noise measurement is necessary for understanding noise level and acoustic comfort in homes. Field measurements were performed in 26 residential apartments in Korea to investigate levels and types of noise from neighbours. Noise recordings were carried out at each residence in unoccupied conditions. The recordings were analysed at 1 min intervals in terms of the A-weighted equivalent (L_{Aeq}) and maximum sound pressure levels (L_{AFmax}) for three different time periods during the day. It was found that 20 apartments met the recommended WHO guidelines during the daytime (07:00–23:00). However, at night (23:00–07:00), eight apartments were in excess of the WHO guideline value in terms of L_{Aeq} while L_{AFmax} exceeded the WHO limit level in 22 apartments during the night. Human footsteps, movement of furniture, and dropping of small items were found to be major sources accounting for approximately 80% of all the noise events. L_{AFmax} of children's jumping and dropping small items were greater than others. Adults' walking showed larger variation of noise levels than other sources. Moreover, it was found that indoor noise levels were not affected by slab thickness and major noise sources.

1. Introduction

Noise has been considered as a threat to public health and well-being [1]. Several studies have reported that chronic exposure to noise can cause annoyance, sleep disturbance, and health problems. Miedema [2] argued the significant effect of transportation noise on the prevalence of noise annoyance. It has been known that noise has not only auditory health effects (e.g., hearing loss, noise-induced hair-cell damage) but also various non-auditory health risks such as daytime sleepiness or it can impair cognitive performance in schoolchildren [3,4]. It was also reported that aircraft and road traffic noise has a high impact on cardiovascular health (e.g., high blood pressure, ischemic heart diseases) [5].

However, the majority of work has mainly focused on environmental noise such as road traffic noise and railway noise. In contrast, few studies have investigated the impact of neighbour noise on residents' psychophysiological well-being. Maschke et al. [6] conducted a cross-national questionnaire surveys in eight European cities and found that annoyance caused by neighbour noise increased health risks in the cardio-vascular system. But noise exposure level at home is unknown because they did not perform noise measurement. Pujol et al. [7] investigated children's exposure to noise at home in an urban area by measuring long-term indoor noise levels at homes. They were mainly concerned with noise from outside rather than indoor noise sources, and noise sources were not identified during the measurements [7]. Therefore, it is still unknown which indoor noise sources contribute to noise levels in residential buildings.

In order to examine the health effects of environmental noise exposure, 24-h noise measurements have commonly been conducted [8,9]. Several noise descriptors such as day-night level (DNL) and day-evening-night level (DENL) have been introduced to describe overall noise exposure for 24 h. Noise measurements for 24 h or working hours have also been occasionally performed in non-residential buildings such as hospitals and offices [10,11]. On the other hand, very little data exists describing 24-h noise exposure and most previous studies on residential buildings measured only short-term indoor noise levels. Jeon et al. [12] measured

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http://dx.doi.org/10.1016/j.apacoust.2017.01.012
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noise levels while the apartment was empty and the windows were closed. Lai et al. [13] measured the noise levels for 15 min in 32 residential apartments and the average noise levels for 15 min were found to be 67.1 dBA with a variation from 52 to 77.9 dBA. Noise levels for one hour were also measured in urban residential buildings under a natural ventilation condition [14]. Similarly, Pujol et al. [7] measured the noise levels in bedrooms and the main rooms to analyse children's exposure to environmental noise at home. They found the averages of noise levels for day, evening, and night in 44 dwellings were 51.3, 53.6, and 36.9 dBA, respectively. However, short-term field measurements only represent a snapshot condition of an indoor built environment at a specific time. In addition, the World Health Organization (WHO) recommends guidelines for residential buildings in terms of the average sound levels for 16 h (daytime) and eight hours (night) [1]. Therefore, 24-h noise measurement in residential buildings is required to improve our understanding of noise level and acoustic comfort at homes.

The majority of dwelling types in South Korea are multi-story and heavyweight (i.e. reinforced concrete) apartment buildings [15]. In multi-story buildings, residents are easily exposed to a number of noises from their neighbours, thus a large number of complaints regarding dwelling noise have been raised by apartment residents [15]. In order to resolve noise problems in apartment buildings, multi-layered floor structures, consisting of a concrete slab, resilient isolator, lightweight concrete, and finishing mortar, have been used. In addition, the Korean Government strengthened the domestic regulations in 2005 and 2007 by increasing the concrete slab thickness to 180 mm and 210 mm, respectively [16] because the slab thickness of the apartments mostly ranged between 135 mm and 150 mm before 2005. Empirical studies [17,18] supported the decision of the Korean Government reporting that the impact sound insulation of the floors had improved with the increases of the concrete slab thickness. According to Jeong et al. [18], a 30 mm increase of slab thickness led to an increase of heavyweight impact sound insulation of 2 dB. However, contrary to expectations, the complaints of neighbours' noises have still increased; number of complaints about floor impact sound recorded in the Ministry of Environment of Korean Government increased from 114 in 2005 to 341 in 2010. However, the complaints were also raised from residents living in old apartments built before 2005, so it is still unknown whether or not increased slab thickness is effective in reducing indoor noise levels in real buildings.

The present study aims to determine noise levels and noise sources from neighbours in residential buildings. It is hypothesised that noise levels are influenced by noise sources and that indoor noise levels are hypothesised to be affected by slab thickness. To validate these hypotheses, 24-h noise measurements were conducted in the living rooms of 26 residential apartments. During the measurements, the apartments were empty and windows were closed to minimise the influence of outdoor noise on indoor noise levels. The recording were analysed in terms of the equivalent and maximum noise levels (L_{Aeq} and L_{AFmax}, respectively) based on three time periods of the day: day (07:00–19:00), evening (19:00–23:00), and night (23:00–07:00). Furthermore, noise sources from neighbours were identified by listening to the recordings and the levels of each noise source were analysed.

2. Method

2.1. Sites

Twenty-six reinforced concrete apartments were selected for the 24-h noise recordings. Of these, 15 were in Seoul and others were located in cities nearby Seoul. As listed in Table 1, the net floor areas of the apartments ranged from 42.0 to 212.5 m^2. The number of bedrooms in each home varied from two to five. The house age also varied; the oldest apartment was built 32 years ago and the latest one was just 3 years old. Slab thicknesses of the apartment buildings varied from 135 mm to 210 mm; the apartments built before the domestic regulation was strengthened in 2005 had slab thickness of 135 mm and 150 mm. Sizes of groups were quite similar; 14 sites were classified into Group 1, while Group 2 had 12 sites. This distinction was made because the Korean Government introduced a domestic regulation requiring construction companies to increase the concrete floor slab thickness by 30 mm at that time. Most homes under measurement were away from traffic roads, which provides a relatively consistent environmental noise condition.

2.2. Procedure

Noise levels in living rooms were measured under unoccupied conditions from the morning to the following morning for 24-h periods while the residents were vacated. The windows in the living rooms and balconies of all the homes were closed during the measurements to minimise the effects of outdoor noise. All the windows were double glazed and the balconies were adjacent to the living rooms at all sites; thus, it was expected that the influence of outdoor noise on indoor noise levels is limited. The measurements were performed only during weekdays to avoid influences of neighbour's daily activities on the recordings. The noise was recorded using a half-inch free field microphone (B&K Type 4189) positioned at a sitting position in the living rooms. The microphone was directly connected to the noise monitoring system (DUO, 01 dB) which has the calibrated recording feature as all-in-one device. The noise levels were monitored continuously for 24 h and noise was recorded whenever the noise level exceeded 30 dBA (L_{Aeq}) at a sample rate of 51.2 kHz. The recordings were then transferred to a laptop computer. Before the data collection, the entire measurement system was calibrated using an acoustic calibrator (B&K Type 4280).

2.3. Data analysis

One-minute interval noise level data were exported from the noise monitoring system (DUO, 01 dB). The data were then processed using dBTrait software from 01dBmetravib. According to the WHO guidelines [1], all noise events for 1 min, and 2) A-weighted maximum sound pressure level (L_{AFmax}) of the noise event. The L_{AFmax} was calculated using the 'fast' time constant for analyses of the recorded noises. The WHO guideline recommends the noise levels for daytime (07:00–23:00) and night time (23:00–07:00); however, in the present study, 24-h period is classified into the day (07:00–19:00), evening (19:00–23:00), and night (23:00–07:00) according to ISO 1996-2 [19].

In order to identify the noise source, the occurrence of the noise events was defined as an event exceeding the WHO recommended values for day and night noise in dwellings. During the daytime, the recommended values are 35 dBA (L_{Aeq}), while the values for the night are 30 dBA (L_{Aeq}) and 45 dBA (L_{AFmax}). The present study also set the threshold L_{AFmax} value for the daytime as 50 dBA, which is adopted from the domestic guidelines of the Korean Government. Firstly, the noise levels exceeding the recommended value were identified based on the one-minute interval noise level data. Secondly, the noise sources and lengths of the noise events were then manually recognised by listening to small sections of the recordings and visually observing time histories as an interval of 125 ms. All airborne and structure-borne noise events were identified; of structure-borne noise sources, heavyweight and