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Public housing lifecycle cost analysis for optimal insulation standards in South Korea

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ABSTRACT

The objective of this study is to identify heat transmission coefficients that can be incorporated into the design of public housing to reduce lifecycle costs for residential facilities. This was accomplished by analyzing existing costs and estimated costs associated with insulation for public housing works. The hypothesis was that the current insulation standards outlined would reflect relevant climatic characteristics of various districts and economic impacts associated with housing. As a part of the investigation, cluster analysis was performed to divide the Central Zone (ZoneC), which was designated to be part of the Energy Saving Design Standard of Korea for the Southern and Jeju Zones (Zones S and J). The main results show that the proper Housing Insulation Capacity Improvement Rates (HICIR) in Zone C2 and Zone C3 are 50–60% and 45–55%, respectively, and that the lifespan should be long enough to adapt to the higher standards of insulation. The outcome and framework of this research are a set of heat transmission coefficients that can be effectively applied to the design and construction of housing and that could be applied to other regions similar to South Korea.

1. Introduction

South Korea does not have any available energy source except for renewable energy and it depends on importing energy resources from foreign countries. Therefore, South Korea could not avoid the staggering changes caused by the oil shock in 1973. The government established mandatory insulation standards for new buildings. In South Korea, 23% of all energy consumption is used for buildings [1]. Since then, the South Korean government has been constantly interested in energy savings associated with housing.

South Korean standards have steadily been increasing for building insulation regarding external walls, floors, and roofs [2]. The standards have also become more detailed regionally. There were no regional classifications in the standards enacted in 1980, but specific standards for Jeju Island (Zone J) were established in 1984. Since 1987, there are different standards for the Jeju, Southern, and Central Zones (Zones J, S, and C). The climatic differences within Zone J and S are of little importance, but the one within Zone C is notable due to its variations in altitude, heating degree days, and minimum temperatures. In spite of the considerable climatic differences within Zone C, public facilities uniformly adopt the same standards. Hence, more specific standards should be established based on the original standards and considering the climatic conditions of parts of the zone and increasing the level of insulation. Generally, constructability and economic feasibility are simultaneously considered to identify the level of insulation enhancement. According to recent research, the constructability is no longer problematic, but economic feasibility is still an essential factor because there is a critical point to increase the insulation level, and linear effects are not guaranteed.

The experience of housing engineers and the opinion of home owners are critical in most cases for determining insulation levels. However, the lifespan of public residential facilities is shorter than those of civilians because of inadequate maintenance caused by frequent movements of the occupants as well as discordance between occupants and owners. In addition, the owners of residential facilities prefer lower initial investments such as construction costs and to minimize operating expenses such as utilities. In contrast, occupants expect heating-cost savings and do not have any interest in the construction cost. Therefore, it is necessary to estimate objective and quantitative outcomes to determine agreeable insulation

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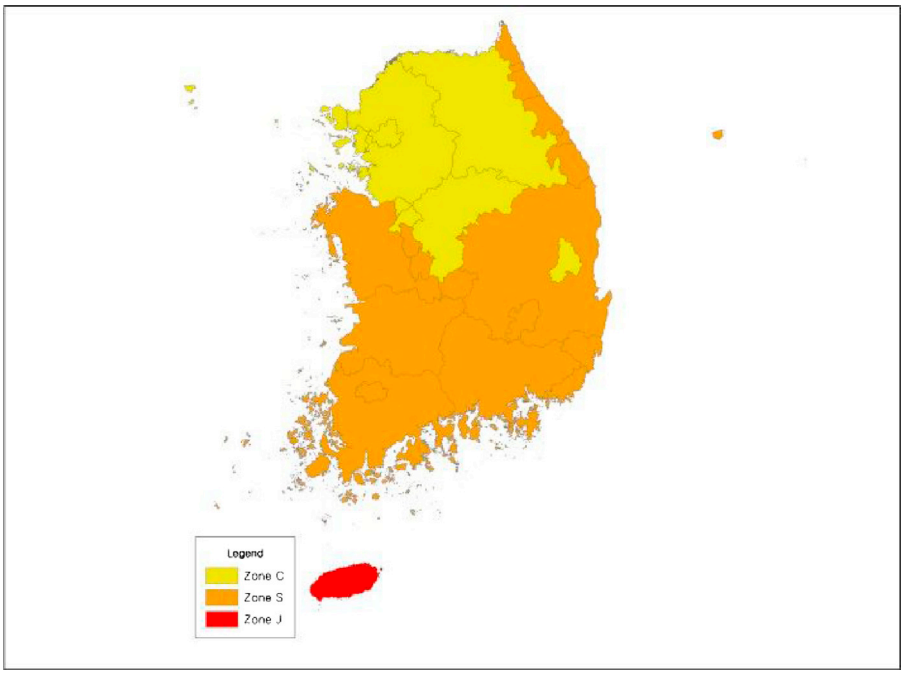

Fig. 1. Climate zones classified in the Energy Saving Designing Standards, South Korea.

levels for public residential facilities for both stakeholders based on subjective experience.

The climatic environment of the mountainous zones in Eastern Korea in Zone C is dramatically different from other parts in the zone. However, residential facilities must all identically follow the insulation standards for Zone C. These insufficient standards can result in excessive heating expenses and unpleasant effects such as dew condensation and mold. Thus, this study identifies new climate zones for Zone C by conducting relevant statistical analyses and estimates insulation standards of public residential facilities in South Korea for lifecycle cost savings.

The following procedures are processed to address this objective. Climatic data for each sub-region are collected by the Korea Meteorological Agency, and the residential characteristics of military housing were investigated using questionnaires. In addition, the drawings of the housing are analyzed to choose a standard model for energy performance simulations. Next, energy simulations are performed to estimate the heating loads, heat transmission coefficients, and regional climatic attributes. The outcomes of the simulations are a combination of the cost of installing insulation reinforcement and the annual savings in heating costs. The cost of installing insulation reinforcement is expressed with the present worth, while the saved heating cost is estimated annually. The relationship between the extent of insulation improvement and these two costs is determined through a regression analysis. Insulation reinforcement levels are then evaluated to minimize the lifecycle cost or to meet the payback return period for choosing agreeable insulation standards for the heat transmission coefficients of each sub-region.

2. Study setting and objective

2.1. Study setting

This study assesses the heat transmission coefficients for the insulation of public housing units to establish insulation design requirements for lifecycle cost savings. The assessments are based on differing requirements for the various zones. The energy standards defined in the Energy Saving Design Standards of Korea were used in this study as a baseline [3,4]. It was hypothesized that a simulation could be used to improve the energy savings that were previously established [5]. Based on the heating degree days, Zone C was divided into sub-regions: Zone C1, C2, and C3 [6,7]. The costs associated with installing insulation reinforcement were established, and the annual heat savings were estimated using an energy simulation. Lastly, regional insulation improvements were assessed using regression and optimization analysis.

The optimization model was designed to identify the optimum levels of housing insulation more accurately and provide new statistically valid determinations for insulation standards. Generally, the current insulation standards for heat transmission coefficients have been justified based on constructability and economic feasibility, which makes it difficult to identify the best values for insulation standards due to the wide acceptable ranges for these values [8].

The final outcomes were evaluated based on empirical climatic and residential data that appropriately address the unique and varying conditions. The Ministry of Land, Infrastructure and Transport (MLTS) did not consider the eastern mountainous area as a residential zone when they enacted the Energy Saving Designing Standard of Korea and included them in the coldest zone, Zone C. Zones C, S, and J are illustrated in Fig. 1 [9,10].

2.2. Objective

In South Korea, apartments are the most prevalent type of housing, representing about 60% of housing and 75% of multi-family residential types. There are many different types of apartments with different size (ranging from 20 to +330 m^2), shape (tower/flat/community types), and height (low-, medium-, and high-rise). Thus, it is not easy to provide generalized results with the data from all types of multi-family residential housing. However, most Korean military apartments are similar apartments with areas of 50–80 m^2 in medium-rise buildings. Because of their similarity, we used data from Korean military apartments to obtain a homogeneous sample, which provides more reliable results. The regional scope was limited to Zone C. Climatic differences within Zone S and J are ignorable, unlike in Zone C.