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Field study seeking for affordable measures to improve living environment of urban gers located in Ulaanbaatar, Mongolia

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Field study seeking affordable methods to improve the living environment of urban *gers* located in Ulaanbaatar, Mongolia

A thesis submitted to Kyushu University in partial fulfillment of the requirement for the degree of Doctor of Engineering (DR. ENG.)

Uelun-Ujin Purev

January 2022

Declaration

I, Uelun-Ujin Purev, hereby declare that this thesis titled “Field study seeking affordable methods to improve the living environment of urban *gers* located in Ulaanbaatar, Mongolia,” submitted in partial fulfillment of the requirements for the degree of Doctoral of Engineering, (Dr. Eng.) is my original research work and all the materials that been used from other sources have been properly and fully acknowledged.

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January 2022

Abstract

In Ulaanbaatar, the capital of Mongolia, the rapid increase in population in recent years has resulted in a delay in the development of infrastructure, and as of 2010, only 32% of all households were living in apartments with adequate infrastructure, while the remainder were living in *ger* areas that lack public services such as water and sewage. The *ger* areas are predominantly located at the northern boundaries of Ulaanbaatar and consist of detached houses (called *baisins*) and *gers* that are built by the residents. A *ger* is a nomadic mobile home with a circular plan and wooden frame and is covered using wool felted sheets; despite its simple structure, currently, *gers* are widely occupied by urban dwellers in Ulaanbaatar. Meanwhile, Ulaanbaatar is also currently suffering from serious air pollution caused by combustion gases that are emitted from the coal stoves used in *baisins* and *gers*. Consequently, replacing coal stoves with clean electric heating systems is an urgent issue; however, if all households in the poorly insulated *gers* switched to electric heating, the electricity demand would significantly exceed the current capacity. To achieve a smooth transition from coal stoves to electric heaters to reduce air pollution, the heating load in *gers* must be reduced on a large scale, according to the income level of the residents.

With this background, this thesis presents a series of studies based on a detailed field survey of *gers* that are occupied by settlers in Ulaanbaatar to develop affordable retrofitting methods for improved insulation in *gers* in accordance with the local conditions; moreover, this research attempts to clarify the actual indoor thermal environment of *gers* based on field measurements in winter.

In Chapter 1, the background of this study, problems in rapid urbanization, and solid fuel use in Ulaanbaatar, Mongolia, are described, and the objectives and structure of this thesis are presented.

In Chapter 2, the results of a survey conducted on 49 *gers* and 67 *ger* residents in the *ger* district of Ulaanbaatar are reported. The results show that the design and materials used in the *gers* are highly standardized; moreover, although *gers* can be easily reused by replacing or transferring parts, the residents have minimal knowledge on the insulation properties of felt sheets. While 85% of the respondents positively rated the indoor thermal environment as comfortable, most respondents said that it was sometimes too hot or too cold in winter, indicating the occurrence of significant temporal fluctuations in the indoor temperature. Furthermore, the heat loss coefficients

of the *ger* envelope, which were estimated from the answers on coal consumption in the *ger*, were reported to be significantly high when compared to those of detached houses in Hokkaido, which is a cold region in Japan. In addition to the above aspects, a survey of the manufacturers and sellers of various components of the *ger* indicated that the price of a typical *ger* is 2.5 million Mongolian tugrik (MNT; approximately 150,000 Japanese yen), which is one-fortieth of the price of a multi-family apartment with an equivalent floor area; consequently, *gers* are considerably affordable for low-income households.

In Chapter 3, based on the results of the conducted survey, which is described in Chapter 2, the author describes the development and demonstration results of a retrofit method for improving *ger* insulation that can be implemented on a large scale. The method involves insulation panels, which are fabric-covered insulation material, that are attached to the inner surface of the *ger* envelope using ropes. The joints of the panels are attached using Velcro to prevent air leakage, which allows the occupants to easily remove/attach the panels. Moreover, a prefabricated windbreak was proposed to reduce the inflow of external air when the door is opened. Further, the author installed and tested the developed system in winter in a *ger* in Ulaanbaatar and collected feedback from the residents and local authorities.

Chapter 4 reports the results of indoor thermal environment measurements that were obtained over a period of 30 days in two *gers* during winter under normal living conditions. In the latter period of the measurement, one of the *gers* was equipped with the retrofitted insulation system, which is described in Chapter 3, and the coal stove was replaced by electric heaters. The results provide detailed characteristics of the spatiotemporal variability of the indoor air temperature in comparison with a baseline *ger* without the retrofitted insulation and using a coal stove for heating. In general, the room temperature in the *ger* varies significantly over time because of the doors are opened frequently for the use of outdoor toilets and the output of the stove is unstable; moreover, because of the low airtightness of the *ger* envelope, the vertical temperature difference in the room was also large, resulting in long periods outside the thermal comfort zone when the measured results were judged on the basis of indoor air temperature alone. Further, it is also shown that the large heating power of the stoves that are widely used in *gers* is essential to ensure thermal comfort by countering the weakness of the low insulation and airtightness of *gers*.

Chapter 5 provides an overview and findings of each chapter and outlines the challenges for future large-scale implementation of retrofits for improved insulation in urban *gers*.

In summary, this thesis aimed to address the problems in controlling the air temperature in urban *gers* in Ulaanbaatar and the issues of indoor air pollution caused by the usage of coal stoves through a detailed field survey, field measurements, and by proposing a new retrofitting system tailored to the local conditions of urban *gers*, which demonstrates a significant contribution to the field of building environment engineering.

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