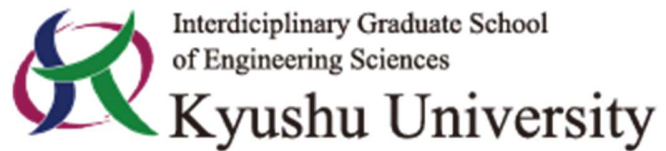


Field study seeking for affordable measures to
improve living environment of urban gers
located in Ulaanbaatar, Mongolia

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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.

Uelun-Ujin Purev

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.

Table of Contents

Abstract.....	iii
Acknowledgements.....	1
Chapter-1 Introduction	1
1.1 Research background	4
1.1.1 Household fuel combustion.....	4
1.1.2 Action to shift clean energy	6
1.1.3 Previous studies related to ger district and urban ger	7
1.2 Research objectives	10
1.3 Outline of the thesis.....	11
Reference	13
Chapter-2 Field Survey on urban ger housing.....	19
2.1 Introduction	19
2.2 Outline of field survey.....	20
2.2.1 Questionnaire-based survey of the residents of urban gers.....	20
2.2.2 Survey on the sales and manufacture of gers	22
2.3 Results of interviews conducted with ger residents	26
2.3.1 Profile of surveyed gers and households.....	26
2.3.2 Accessibility of infrastructure and public service of surveyed gers.....	28
2.3.3 Structure and size of the gers	32
2.3.4 Compositions of ger envelopes	35
2.3.5 Composition of floor material	38
2.3.6 Lifespan of ger	41
2.3.7 Manner in which current gers were obtained and factors influencing the purchase decision of esgii	43
2.4 Result of the survey of urban gers: Interior space usage and space heating	44
2.4.1 Use of interior space.....	44
2.4.2 Types of space heating devices and the behaviour of occupants related stove usage	48

2.4.3 Perception of the resident regarding the coal stoves	50
2.4.4 Fuel consumption in the surveyed gers	53
2.4.5 Winter clothing worn by residents of ger	54
2.4.6 Perception of the residents regarding indoor thermal comfort in winter	56
2.4.7 Motivation of the residents to improve quality of life	57
2.5 Result of market survey	58
2.6 Discussion	60
2.7 Conclusion	61
Reference	63
Chapter-3 Development of Retrofitting Method for Improved Insulation in Urban Gers	66
3.1 Introduction	66
3.2 Baseline conditions of urban gers	67
3.2.1 Standard design and material	67
3.2.2 Construction and dismantling processes	70
3.2.3 Financial requirement	73
3.3 Developed system	73
3.3.1 Insulation panels	73
3.3.2 Selection of materials and manufacturers	79
3.3.3 Windbreak room	84
3.3.4 Price of the developed system.....	85
3.3.5 Expected reduction of heating demand.....	85
3.4 Demonstration test of the developed retrofitting method.....	87
3.4.1 Retrofitting installation at an urban ger	87
3.4.2 Perception of the occupants and neighboring households towards retrofitting	92
3.5 Conclusion	92
Reference	93
Chapter-4 Field measurement of the Indoor Thermal Condition of Urban Gers in Winter	95

4.1 Introduction	95
4.2 Methodology	96
4.2.1 Location	96
4.2.2 Measurement period	98
4.2.3 Conditions of the measured gers	99
4.2.4 Instrumentation	105
4.2.5 Estimation method of heating power of coal stoves	108
4.2.6 Estimation of mean radiant temperre and operative temperture	109
4.3 Result of field measurements	111
4.3.1 Climate conditions	111
4.3.2 Detailed temporal patterns of indoor temperature during Term I	114
4.3.3 Detailed temporal patterns of indoor temperature of Term II and Term III	118
4.3.4 Range of the indoor temperature under the different outdoor air temperatures	128
4.3.5 Heating energy consumption.....	130
4.3.6 Spatial heterogeneity of indoor air temperature	132
4.3.7 Surface temperature of baseline ger envelope and floor	134
4.3.8 Surface temperature of ger envelope and floor of retrofitted ger	136
4.3.9 Thermal exposure of occupants at baseline gers (Term I)	136
4.3.10 Operative temperature of retrofitted ger with electric heater	139
4.4 Conclusions	140
Reference	142
Chapter-5 Conclusions and Future work	144
5.1 Conclusions	144
5.2 Future work	147
5.2 Appendix 1	148