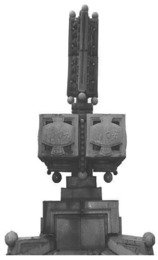
Online ISSN 2436-5513

Intercultural Understanding



Vol.11

Koshien Hall, Mukogawa Women's University: Designed as a hotel by Arata Endo in 1930, it functioned as Koshien Hotel until 1944. As a disciple of Frank Lloyd Wright, Endo had worked on the design of the Imperial Hotel completed in 1923. Endo's design of the Koshien Hotel clearly reflects the strong influence of Wright's Imperial Hotel. In 1965 the Koshien Hotel underwent renovations and now houses the Department of Architecture as well as the Institute of Turkish Culture Studies of Mukogawa Women's University.

Institute of Turkish Culture Studies
Mukogawa Women's University

Intercultural Understanding
Vol.11

Online ISSN 2436-5513

Editor:
Institute of Turkish Culture Studies, Mukogawa Women's University
1-13, Tozaki-cho, Nishinomiya, Hyogo, 663-8121, Japan
E-mail: itcs@mukogawa-u.ac.jp
Publisher:
Mukogawa Women's University

Issued March 2022

Intercultural Understanding Vol.11

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Examining Thermal Problems in Three Types of Emergency Housing in Japan

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Keywords: emergency housing, field measurement, indoor thermal environment, interview survey, trailer home

Abstract: This study analyzes thermal problems in three different types of emergency housing: prefabricated, wooden, and trailer homes. We investigated the thermal environment of each housing type by interviewing residents and measuring the indoor air temperature and humidity inside each house during winter and summer. Prefabricated housing had several issues that needed improvement owing to possessing low airtightness and multiple heat bridges. Wooden housing had very few thermal problems, primarily owing to high insulation performance and resident lifestyles. Finally, the long and narrow interior spaces of trailer homes made air circulation and air conditioning difficult. The findings presented here will provide valuable and fundamental information for proposing ways to improve the living environment of disaster victims in emergency housing, making them more comfortable without interfering with the rapid supply system.

1. Introduction

In Japan, where natural disasters such as earthquakes and heavy rain occur frequently, temporary housing is necessary for those who have lost their homes. However, it is difficult for temporary housing to cope with all types of weather conditions because of the varying regional climates in Japan. Therefore, standardized building materials with certain specifications are used and readily available. In the immediate aftermath of a large-scale disaster, such as the Great East Japan Earthquake of 2011, it is difficult to maintain adequate environmental performance, such as heat insulation, at the time of construction, owing to the need to build as quickly, at as low cost, and in as large a quantity as possible.

The environmental performance of temporary housing in Japan has significantly improved. Table 1 reports the changes in the insulation specifications of temporary housing utilized following large-scale disasters from 1991 to 2018 (Cabinet Office, Government of Japan, 2021, May). Despite the improved performance over the past 30 years, residents are still concerned about the thermal problems and solutions of temporary housing. Therefore, continued efforts are required to enhance housing performance.

Recently, many people have lived in temporary housing for several years following large-scale disasters. The longer people live in temporary homes, the more critical their living environments become. In Japan, the policy on temporary housing supply states that the maximum provisional period of temporary housing is two years, and extensions upon application are permitted. In 2016, five years after the Great East Japan Earthquake of March 2011, one-third of the households living in prefabricated temporary housing remained residents of temporary housing (Mitsubishi Research Institute, 2018). Even now, more than ten years after the disaster, some people still live in temporary homes. Therefore, it is crucial to improve the living environment in temporary housing (Reconstruction Agency, 2021, August).

Various studies have been conducted worldwide regarding the indoor environment of temporary housing and shelters after disasters or war. Albadra et al. (2020) investigated air quality such as VOCs inside temporary shelters in the ten locations with different climates and cultures such as Peru and Ethiopia. They showed that the indoor air quality was extremely harmful because many people live in narrow spaces, and also indicated that the condition could be improved by introducing the air flow effectively. In Japan, after the Great East Japan Earthquake in 2011, much research has been conducted on improving the indoor thermal environment in, especially prefabricated, temporary housing. In addition to the thermal environment, some studies have been conducted on indoor air quality (Shinohara, et al., 2013, January and December. 2018, February).

In temporary shelters after a massive earthquake in Nepal in 2015, seasonal changes in the indoor thermal environment and acceptable temperature range were revealed (Rita Thapa et al., 2016 and 2018). It has also been demonstrated that the addition of polyethylene foam and clothing to walls and roofs can reduce the heat loss coefficient during winter (Rita Thapa et al. 2019). Research on bamboo wood temporary shelters after the 2013 earthquake in Lushan, China, suggested that thermal performance could be improved using inexpensive materials (Ying Yu et al., 2016). In addition, a study on the thermal comfort of shelters in refugee camps in the Middle East underlined the significant adaptability of refugees; however, it also highlighted the need to review ventilation systems and improve the insulation of shelters. (D. Albadra, 2017). After the 2008 Wenchuan earthquake in China, many temporary settlements with high building density consisting of prefabricated housing were built. Huang et al. (2015) revealed

Table 1. Changes in standard specifications regarding environmental performance of temporary housing in Japan

Disaster		Unzen-Fugendake Eruption Disaster (1991)	Hokkaido Southwest Offshore Earthquake (1993)	Great Hanshin-Awaji Earthquake (1995)	Usu Eruption (2000)	Niigata Chuetsu Earthquake (2004)	Iwate-Miyagi Nairiku Earthquake (2008)
Site		Nagasaki	Hokkaido	Hyogo	Hokkaido	Niigata	Iwate, Miyagi
Climate		Moderate	Cold	Moderate	Cold	Cold	Cold
Insu-lation*1	Ceiling	100 mm	100 mm	50 mm	100 mm	100 mm	100 mm
	Wall	-	50 mm + 50 mm (doubled wall)	20~30 mm	50 mm	50 mm	50 mm
	Floor	Nothing	100 mm	Nothing	100 mm	100 mm	100 mm
Partition between households		-	PB 12 mm	PB 9.5 mm	PB 9.5 mm And GW 50 mm	PB 9.5 mm and GW 50 mm	PB 9.5 mm and GW 50 mm
Double sash		Nothing	Do	Nothing	Nothing	Do (after construction)	Do (after construction)
damp-proofing		-	-	Nothing	Do	Do	Do
Sick house measures**2		Nothing	Nothing	Nothing	F★★★★	F★★★★	F★★★★
Cooling and heating equipment		Cooler	Nothing	AC (after construction)	FF-type kerosene heater***3	AC	AC

Disaster		Great East Japan Earthquake (2011)			Typhoon No.12 Disaster (2011)	Heavy Rain in Northern Kyushu (2012)		Kumamoto Earthquake (2016)	West Japan Heavy Rain (2018)	Hokkaido Eastern Iburi Earthquake (2018)
Site		Iwate	Miyagi	Fukushima	Wakayama	Fukuoka	Kumamoto	Kumamoto	Hiroshima, Okayama, Ehime	Hokkaido
Climate		Cold	Cold	Cold	Moderate	Moderate	Moderate	Moderate	Moderate	Cold
Insu-lation*	Ceiling	100 mm			100 mm	GW 100 mm	GW 100 mm	100 mm	100 mm	HGW 175 mm
	Wall	50 mm (+ 50 mm after construction)	50 mm	50 mm	50 mm	GW 50 mm	GW 100 mm	50 mm	50 mm	HGW 100 mm
	Floor	50 mm			100 mm	XPS 60 mm	XPS 50 mm	50 mm	50 mm	HGW 100 mm
Partition between households		PB 9.5 mm + 12.5 mm and GW 50 mm	PB 9.5 mm and GW 50 mm	PB 9.5 mm and GW 50 mm	PB 9.5 mm and GW 50 mm	PB 9.5 mm + 12.5 mm and GW 50 mm	PB 12.5 mm + 12.5 mm (both sides) and GW 100 mm	PB 9.5 mm + 12.5 mm and GW 50 mm	PB 9.5 mm + 12.5 mm and GW 50 mm	PB 9.5 mm + 12.5 mm and HGW 50 mm
Double sash		Do (after construction)			Nothing	Nothing	Nothing (pair glass)	Do	Nothing	Do (Inner sash: pair glass)
damp-proofing		Floor polyethylene sheet			Do	Do	Nothing	Do	Do	Do (also ceiling and inner wall)
Sick house measures**2		F★★★★			F★★★★	F★★★★	F★★★★	F★★★★	F★★★★	F★★★★
Cooling and heating equipment		AC			AC	AC	AC	AC	AC	FF-type kerosene heater***3

GW: glass wool, PB: plasterboard, XPS: extruded polystyrene form

*1 Areas not marked with insulation material are considered to be glass wool.

**2 F★★★★: Interior material with low formaldehyde emission rate and not applicable to interior finish restrictions in Japan's Building Standards Act.

***3 FF: forced supply exhaust type

the summer heat and poor natural ventilation inside and outside houses by measuring the air temperature and air velocity.

Some new technologies for temporary housing have also been discussed. Salvalai et al. (2015) showed the thermal performance and the effect of reducing heating load of a new lightweight emergency architecture using a multilayer insulator. PCM-based solutions for the thermal stability of temporary buildings have been examined (Beom Yeol Yun et al., 2022).

Thus, the thermal environments in temporary housing and shelters have been researched extensively, and some methods of improving these aspects have corresponded to the climatic and cultural conditions in each region. Today, three types of temporary housing structures are commonly used: prefabricated, wooden, and trailer.

-Prefabricated Houses

Prefabricated temporary housing has a light-gauge steel structure, it can be used for a field office at a construction site. It is quickly constructed in large quantities because the building parts are manufactured in factories and assembled at the construction site. This is the most common type of temporary housing in Japan. It is especially prevalent when the scale of the disaster is immense. While the supply speed is fast, the effect of thermal bridges is usually significant because of the housing structure. Moreover, it is difficult to ensure sufficient airtightness.

-Wooden Houses

Currently, wooden structures are used for temporary housing as well. Local carpenters are involved in construction work, and local lumber can be used for construction, contributing to the economic recovery of the disaster area. After the Great East Japan Earthquake and Tsunami, wooden housing became increasingly popular in Japan after disasters. Many wooden homes are built when the disaster scale is relatively limited and few units are needed (Fuchigami, 2021). Accordingly, it is challenging to construct numerous wooden homes in a short period of time.

-Trailer Homes

Recently, trailer homes as temporary housing have become increasingly popular in Japan. The term “trailer home” is a Japanese–English term for a towable mobile dwelling unit with an axle, no engine, and cannot be self-driven. Trailer homes are factory-made, quickly constructed, low-cost, and reusable. The finished product is brought to the site by towing and installed by adjusting its level with jacks. There, it connects to electricity, gas, and water. If prepared properly, the installation can be done in a day. In addition, trailer homes are mobile and reusable, able to provide disaster relief housing in multiple areas. Trailer homes became a temporary emergency housing for the first time in Kurashiki, Okayama prefecture, after the West Japan Heavy Rain Disaster in 2018. It has been used as temporary housing for the victims of the 2018 Hokkaido Iburi East Earthquake as well. However, in Japan today, trailer homes remain not widely used, owing to their low supply. Therefore, it is difficult to provide trailer homes as temporary housing following disasters. Some research has been conducted on formaldehyde levels and other factors in trailers after Hurricanes Katrina and Rita (M. W. Murphy, 2013). However, research on the thermal environments of trailer homes is lacking.

Several types of temporary housing structures were provided in Kurashiki, including the three types previously described. Each type of temporary housing has distinct advantages and disadvantages regarding its supply-chain. Immediately after a disaster, selecting and providing the appropriate housing type is critical according to unique circumstances, scale, and location.

Understanding the thermal environmental characteristics and problems of different types of temporary housing can help improve the overall quality of disaster relief. As stated, research in this area is sparse. Only a few studies have examined the thermal environment characteristics of different temporary housing types in the same climatic region. This study identifies the characteristics and challenges related to thermal environments of three different temporary housing types within the same area. We interviewed temporary housing residents living in the three different housing types and measured the air temperature and humidity during winter and summer in Kurashiki, which was damaged by the West Japan Heavy Rain Disaster in 2018.

2. Method of field survey

2.1. OUTLINE OF SURVEY SITE

In July 2018, heavy rains caused widespread and simultaneous flooding and landslides, particularly in western Japan. According to a report from the Ministry of Land, Infrastructure, Transport, and Tourism (2018, September), 20,663 houses were washed out or partially destroyed. A total of 29,766 houses were flooded and 223 people died throughout Japan. In Kurashiki, 5,977 houses were washed out or partially destroyed, and 52 people died owing to embankment breaches in several rivers and landslides. After the disaster, Kurashiki built 158 prefabricated houses, 57 wooden houses, and 51 trailer homes (Disaster Prevention and Crisis Management Office, Kurashiki City, 2020, October).

Fig.1 shows the annual average weather data for the past 30 years (1991–2020) in Kurashiki from the Japan Meteorological Agency.

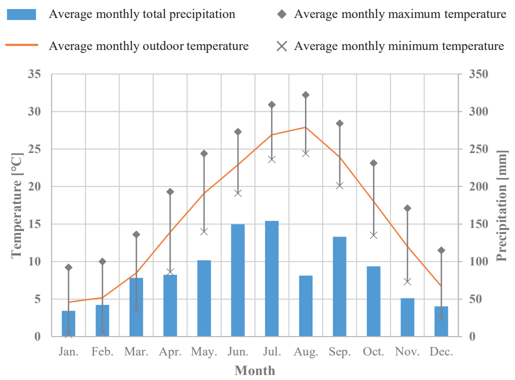

Figure 1. Annual average weather data over the past 30 years (1991–2020) in Kurashiki

In Kurashiki, the average annual air temperature is 15.8°C, and it rains throughout the year, especially during the rainy season from June to July. During winter, it snows occasionally but rarely piles up.

2.2. SURVEYED HOUSES AND RESIDENTS

Fig. 2 shows the appearances and plans of the surveyed houses. Table 2 lists the insulation specifications for each type of temporary housing considered in this survey. The thermal insulation specifications for each housing type meet the Japanese Energy Efficiency Standards for residential buildings for exterior skin performance (Institute for Building Environment and Energy Conservation, 2016, April).

Prefabricated temporary housing applications have only one air conditioner in the living room. Ventilation fans are installed in the kitchen, bathroom, and toilet. There are air supply outlets in the living room and Japanese-style room. In wooden house applications, the room with an air conditioner is used as the bedroom, and the other room without air conditioning serves as the utility room and is rarely used. The trailer homes are equipped

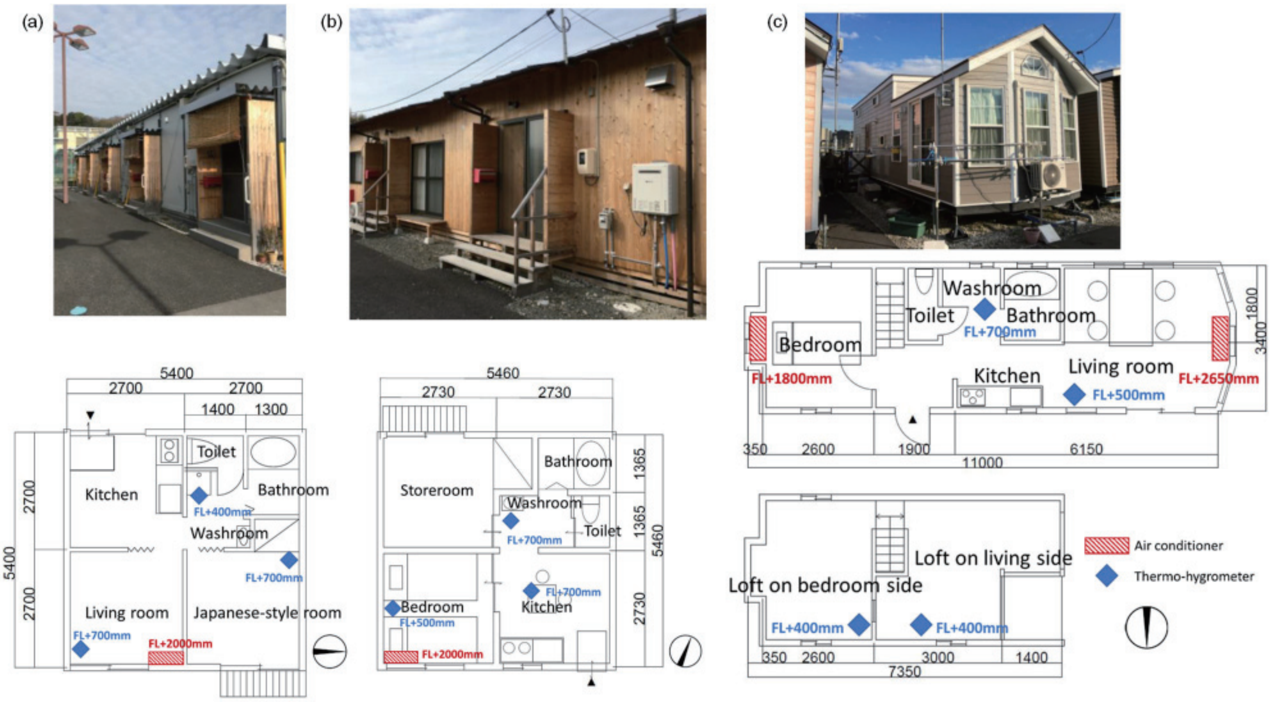

Figure 2. Appearance and floor plan of surveyed emergency housing (left: prefabricated house, center: wooden house, right: trailer home)

Table 2. Insulation specifications of three types of temporary housing

	Prefabricated house	Wooden house	Trailer home
Ceiling or roof	Ceiling: GW 100mm	Ceiling: HGW 100 mm	Roof: GW 100 mm
Wall	‣Exterior: PUF 40 mm and GW 50 mm ‣Separation: GB 12.5 + 9.5 mm and GW 50 mm	HGW 100 mm	GW 100 mm
Floor	XPS 40 mm	XPS 100 mm (50 mm double)	GW 42 mm
Window	Aluminum sash and single glass	Aluminum sash and pair glass	PVC sash and Low-E pair glass
Front door	‣Upper: Figured glass ‣Lower: Spandrel wall panel	Upper: Figured glass	‣Frame: wooden ‣Door: wood insulation laminated structure

GW: glass wool, HGW: high performance glass wool,
PUF: Polyurethane form, GB: gypsum board,
XPS: extruded polystyrene foam, PVC: polyvinyl chloride

with two air conditioners: one for the living room and another for the bedroom. Ventilation fans are located in the kitchen, bathroom, toilet, and loft on the living room side.

The prefabricated house is home to a couple, and the wooden house belongs to the parent and her child. The trailer home houses a family, that is, a couple with a child. The first-floor bedroom is closed during the daytime so that the husband can sleep.

In this survey, we asked the residents about their lifestyles. They provided a subjective evaluation of the thermal environment in their homes during winter and summer. We inquired about particularly hot and cold areas in their homes, air conditioning use, ventilation fans, and what measures were taken against heat and cold. They were also asked about condensation, mold, and drafts during winter, and if they had complaints about solar radiation during summer.

2.3. OUTLINE OF MEASUREMENTS

Several air temperature and humidity meters (HOBO UX100-011A, ONSET) were installed in the three temporary housing applications (prefabricated, wooden, and trailer homes). The air temperature and relative humidity were recorded every 10 min from December 3 to August 30, 2020. The locations of the air temperature and humidity meters are indicated in the floor plans presented in Fig. 2. In the prefabricated house and trailer home, the residents installed the measuring devices themselves, indicating the locations on the floor plans. Because some of the measuring instruments in the prefabricated house were installed near the wall, they may not have accurately captured the air temperature and humidity. Therefore, measurement results from the prefabricated home should be carefully evaluated. The graph shows the measured air temperature and humidity ratio calculated from air temperature and relative humidity.

3. Results

3.1. INTERVIEW SURVEY

Tables 3 and 4 list the interview results.

3.1.1. Prefabricated house

During winter, the living room was heated all day at a high air temperature of 28 °C. However, the house remained cold in several areas. Residents commented that it was cold near windows and floorboards. In the prefabricated housing, the ventilation fans in the toilet and bathroom were continuously running to prevent condensation and mold. Nevertheless, condensation and mold were observed. Furthermore, the residents stated that there were cold drafts coming from the entrance door and ventilation fans. To reduce the intrusion of cold air, they placed urethane mats near the locations where they felt the drafts.

During summer, solar radiation is the primary heat source in a prefabricated house. As shown in the floor plan presented in Fig. 2(a), the west solar radiation enters the kitchen and bathroom, creating warmth. An exposed steel column in the toilet becomes very hot in the evenings because of solar heat. Steel pillars can become too hot to touch and harm the residents.

3.1.2. Wooden house

The results showed that wooden housing residents had fewer complaints about thermal conditions throughout summer and winter. During summer, the only hot place was the kitchen while cooking, and during winter, no cold areas, condensation, mold, or drafts were observed.

3.1.3. Trailer home

During winter, areas far from the air conditioner appeared particularly cold. Owing to the cold floor, the residents put down rugs and wore slippers. During summer, the excess heat from solar radiation was a problem. The residents reported that the loft area was particularly hot and felt the direct effect of solar radiation on the roof. They cope with this issue by opening windows and closing curtains to ensure ventilation while reducing the solar heat in the living room.

3.2. AIR TEMPERATURE AND HUMIDITY

The results for sunny days with particularly low air temperatures during winter and high air temperatures during summer over the measurement period are presented in Figs. 3–8. We obtained the outdoor air temperature data from the Japan Meteorological Agency (JMA) in Kurashiki City. The humidity ratio was calculated using the outside air temperature and relative humidity measured at the site.

3.2.1. Winter

Table 3. Winter conditions–Interview lists and results (AC: air conditioner)

Interview list / structure types	**Prefabricated house**	**Wooden house**	**Trailer home**
Cold areas	・Japanese-style room (with no AC) ・Toilet・Near the windows ・Coldness of the floor	Nothing	・Loft on the bedroom side, bathroom and washroom ・Coldness of the floor
Heat setting	AC heating set at 28℃ all day	AC heating set at 24.5℃ all times except when out	AC heating set at 23℃ all day in living room, 24℃ setting during daytime in bedroom
Ventilation	・Ventilation fan: constant use in toilet and bathroom, used when cooking in the kitchen ・Air supply outlet: closed	・All ventilation fans used intermittently ・Air supply outlet: open	・All ventilation fans used intermittently ・Air supply outlet: open
Condensation and mold growth	・Condensation on the front door and all windows ・Mold on tatami mats and behind the curtains	Nothing	Condensation on windows in bedroom, loft above the bedroom, and kitchen
Cold drafts	From the kitchen ventilation fan in early morning, gaps in the front door and windows	Nothing	From bottom of the window in living room
Measures against the cold	・Place urethane mats on the floor ・Place urethane mats wherever drafts occur	Nothing	・Place urethane mats against the window where drafts occur ・Place rug mats on the floor ・Wear slippers

Table 4. Summer conditions–Interview lists and results (AC: air conditioner)

Interview list / Structure types	**Prefabricated house**	**Wooden house**	**Trailer home**
Hot areas	・Western-facing room ・The toilet's exposed steel pillar gets very hot due to sunlight.	Kitchen when cooking (a little hot)	・Feel the radiant heat from the ceiling in lofts ・Livingroom during daytime ・Bedroom in evenings
AC setting	AC set at 26℃ and full-time fan use except when out	AC set at 24℃ at all times except when out	AC set at 26℃ in evenings to next mornings in the living room, set at 20℃ during daytime
Ventilation	・Ventilation fan: constant use in toilet and bathroom, use when cooking in the kitchen ・Air supply outlet: open	・All ventilation fans used intermittently ・Air supply outlet: open	・Intermittent use: ventilation fans in toilet, bathroom, and kitchen ・Constant use: ventilation fan in the loft on the living room side ・Air supply outlet: open
Solar radiation heat complaints	Too much west sunlight	Nothing	Too much western sunlight to the living room
Measures against the heat	・Bamboo screen installed to shade solar radiation from the west ・A fan between rooms to circulate cool air from the air conditioner.	Nothing	Close curtains for shading solar radiation and open windows for ventilation

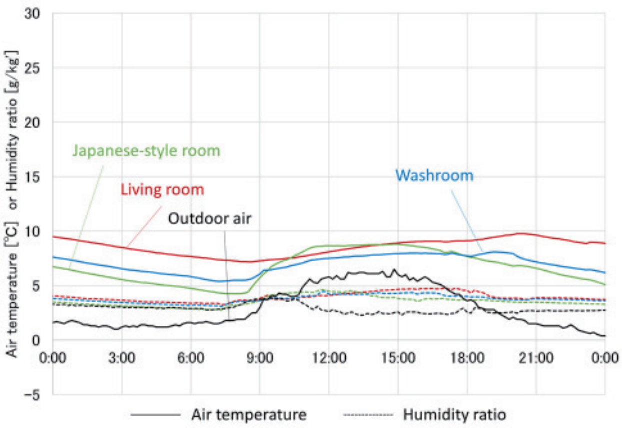

Figure 3. Air temperature and humidity ratio measured inside the prefabricated house during winter (February 6, 2020)

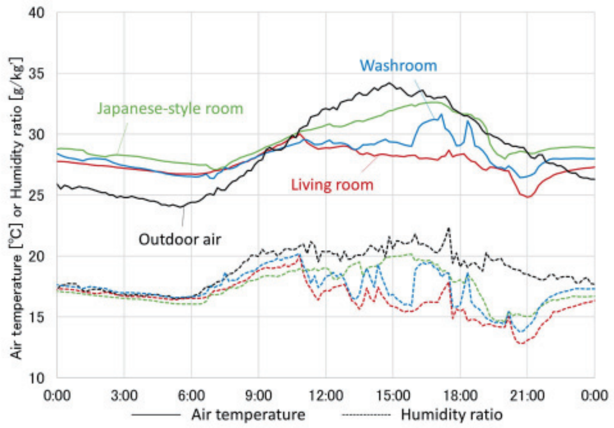

Figure 4. Air temperature and humidity ratio measured inside the prefabricated house during summer (August 5, 2020)

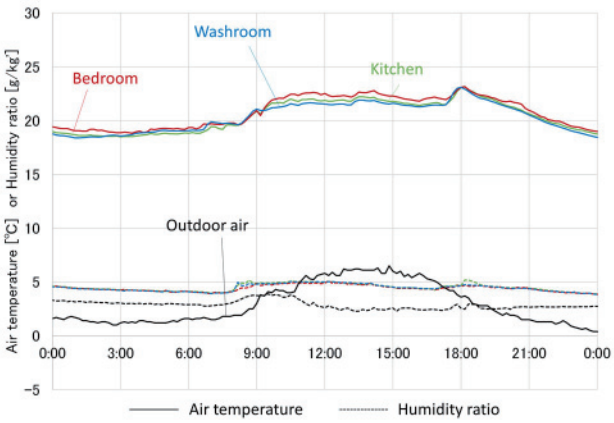

Figure 5. Air temperature and humidity ratio measured inside the wooden house during winter (February 6, 2020)

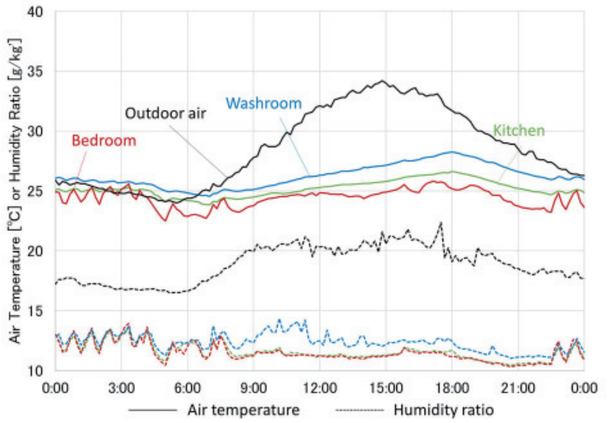

Figure 6. Air temperature and humidity ratio measured inside the wooden house during summer (August 5, 2020)

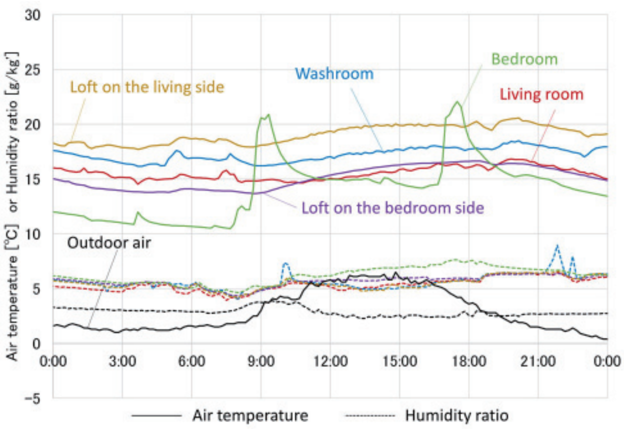

Figure 7. Air temperature and humidity ratio measured inside the trailer home during winter (February 6, 2020)

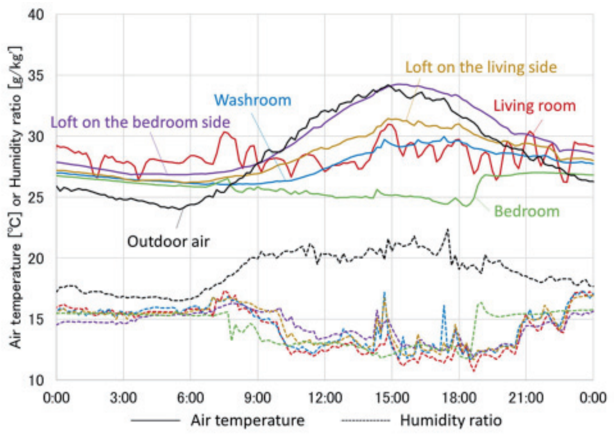

Figure 8. Air temperature and humidity ratio measured inside the trailer home during summer (August 5, 2020)

(a) Prefabricated house

The measured air temperatures in prefabricated housing were low. As previously mentioned, the results may not accurately reflect the actual room air temperature owing to the the measurement instruments being positioned near the walls and windows. The instruments may have been installed at a relatively low height, resulting in lower air temperatures. However, even accounting for this, the thermal environment in prefabricated houses is insufficient for residents' health and comfort.

In this type of housing, the heating system was set high during winter (28°C); however, the actual measurement results indicated an indoor air temperature below 10°C throughout the day. The further the distance was from the living room, the lower was the air temperature. In addition, the humidity ratio in the rooms was close to that measured outside the house.

(b) Wooden house

The air temperature and humidity measurements indicated very few problems in the thermal environment of wooden housing during winter. The three living areas the residents commonly used remained at approximately 20 °C even on low temperature days, and the humidity ratio difference between the inside and outside of the house was maintained.

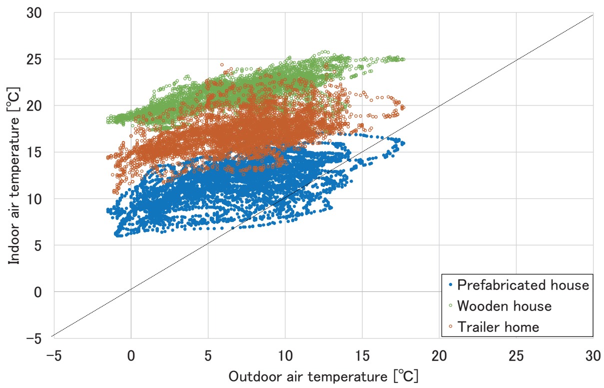

Figure 9. Scatter diagram of indoor air temperature versus outside temperature for each temporary housing during winter (January 20 to February 20, 2020)

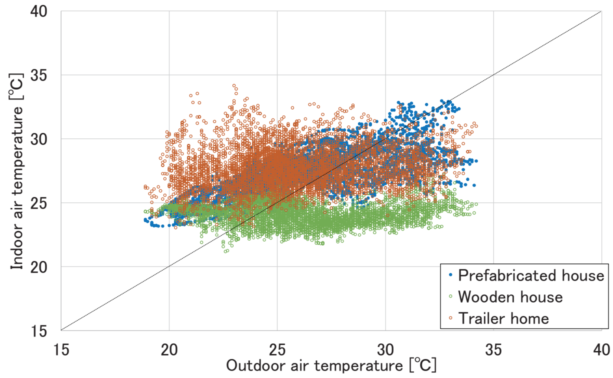

Figure 10. Scatter diagram of indoor air temperature versus outside temperature for each temporary housing during summer (July 9 to August 9, 2020)

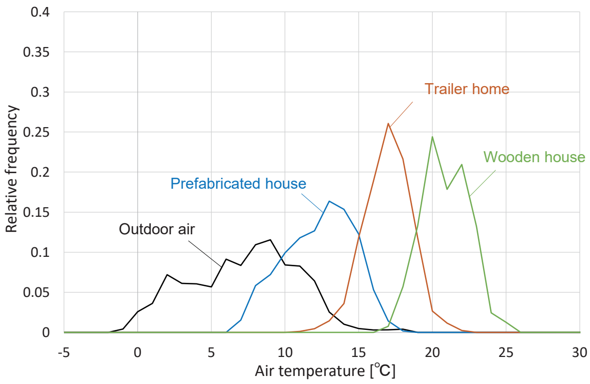

Figure 11. Relative frequency distribution of air temperature in the air-conditioned room of each temporary housing during winter (January 20 to February 20, 2020)

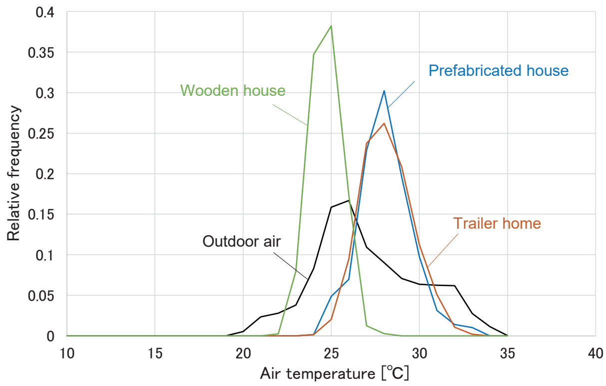

Figure 12. Relative frequency distribution of air temperature in the air-conditioned room of each temporary housing during summer (July 9 to August 9, 2020)

(c) Trailer home

The results indicated that the trailer home had an air temperature difference of approximately 5°C between the loft on the living side and loft on the bedroom side. Furthermore, the living room air temperature was lower than that of the upstairs loft on the living side and washroom, even though the living room was a heated room.

3.2.2. Summer

(1) Prefabricated house

The results showed that the bedroom air temperature, without air conditioning, tended to be higher. At approximately 11:00, the washroom and living room air temperatures decreased by cooling, while the Japanese-style room air temperature continued to rise. Conversely, the indoor air temperature exceeded the outdoor air temperature during the night and early morning.

(2) Wooden house

In the wooden house during summer, the room air temperature was maintained at approximately 25°C, even on days with high air temperatures. The results demonstrated almost no air temperature difference between the rooms.

(3) Trailer home

During summer, the loft area air temperature exceeded 30 °C, especially on the bedroom side, which rose to 34 °C during daytime. In addition, the air temperature difference between the two upstairs loft spaces reached a maximum of approximately 4 °C. The living room was air-conditioned, but the air temperature was sometimes lower in the washroom. Moreover, the room air temperature was higher inside than outside during night and early morning.

4. Discussion

4.1. ENVIRONMENTAL FACTORS AND POSSIBLE COUNTERMEASURES AGAINST THERMAL PROBLEMS

Our goal was to understand the characteristics and issues of winter and summer thermal environments in three types of emergency housing in the same climatic region. We collected subjective evaluations from residents and objective calculations by measuring air temperatures and humidity in a prefabricated, wooden, and trailer type temporary housing in Kurashiki. To understand the summer thermal environment, we measured air temperature and humidity changes on sunny and hot days. Conversely, to measure the winter thermal environment, we extracted and evaluated the changes in air temperature and humidity on sunny and cold days. To specify the differences among the three types of houses, scatter diagrams (Figs. 9 and 10) and relative frequency distributions (Figs. 11 and 12) were constructed for the winter and summer periods. The temperatures shown in these figures are the air temperatures in the air-conditioned living rooms in each house. The winter period was defined as lasting from January 20 to February 20, 2020, and the summer period was defined as lasting from July 9 to August 9, 2020. During winter, the air temperature in each house differed significantly. The difference between the average temperature of the wooden house (20.4°C) and prefabricated house (11.8°C) reached as much as 8°C. The average temperature in the trailer home was 16.5°C. Furthermore, the temperature range in the prefabricated house was relatively wide, and the minimum temperature was much lower than those measured in the other two houses. During summer, prefabricated house and trailer home showed approximately the same air temperature distribution, with an average temperature of 27.6°C. In both houses, the set cooling temperature was maintained at 26°C.On the other hand, in wooden house, the average temperature was 24.2°C, which was approximately the same as the set temperature of 24°C.

4.1.1. Prefabricated house

In prefabricated house, the main cause of the strenuous thermal environment, which is cold during winter and hot during summer, can be attributed to low thermal performance.

During winter, the low air temperature inside the prefabricated housing most likely resulted from the low airtightness and thermal bridge effects. Drafts from the kitchen ventilation fan and other openings let cold inside the house. Drafts can be reduced by lining the openings where they occur and by installing thick drapes on the windows. In addition, constantly running the ventilation fans in the toilet and bathroom may not have been sufficient to prevent condensation and mold, but rather an of cold air. Therefore, it may be necessary to review the practicality of running a ventilation fan.

During summer, the temperature difference between the living room and Japanese-style room after operating the air conditioner may be owing to closing the partition curtain to improve the cooling efficiency in the living room. Alternatively, if the curtain was open, it would be difficult for the cooled air to reach the Japanese-style room, which would make the living room hotter. In addition, it may be possible to live more comfortably by promoting more ventilation at relatively cooler periods throughout the day. The results indicate that it is possible to create a comfortable thermal environment by making lifestyle changes according to the outdoor conditions. However, exposed steel pillars heated by solar radiation pose an injury risk to the residents. The bare pillars should be covered to reduce heat gain and ensure safety.

Finally, during both seasons, it was difficult to channel air-conditioned air into the Japanese-style room that was not air-conditioned. This is a critical issue for the health of residents. Therefore, it is necessary to reconsider the effective use of circulators.

4.1.2. Wooden house

In the wooden house, occupant evaluation and air temperature and humidity measurements suggested that the thermal environment was stable. The reason for this consistency may be the high level of airtightness of wooden structures, high thermal insulation performance, and fact that the thermal bridges are less prominent than those occurring in lightweight steel constructions. In addition, the small living area of this housing style may have contributed to its increased heating and cooling efficiency. However, because family structure and resident lifestyles vary, we do not suggest that residents limit their living areas. Furthermore, not all wooden houses would provide the stable thermal environment depicted by the results of this study. Therefore, to obtain the general characteristics and issues of the thermal environment of wooden houses, it will be necessary to conduct more surveys of temporary wooden houses with different family structures and lifestyles and in areas with disparate climatic conditions.

4.1.3. Trailer home

In the trailer home, it was difficult to channel air-conditioned air toward the back of the loft during both winter and summer. This was because trailer homes pack residential functions into long and narrow spaces. Circulators must promote air circulation more effectively in the rooms. In addition, we need to solve the issue of cold floors during winter, which occurs because of the hollow space under the floorboards. Closing the hollow space and laying mats or providing insulation on or under the floor would make a significant difference in keeping the floors warm. By addressing the cold floor issue, we reduced the vertical air temperature difference in the room.

During summer, the distribution of air temperature is higher than that of the outdoor air temperature, suggesting that the air temperature tends to be higher during the day due to solar radiation and does not decrease over nighttime. Therefore, measures against heat absorption owing to solar radiation are critical. Because trailer homes do not have attic spaces, the effect of solar radiation on roofs is particularly intense. Therefore, it may be necessary to reinforce the thermal insulation of the roof and select materials to reduce the rate of solar radiation absorption. Furthermore, trailer homes are limited in width to comply with the “wide load” road rules when driving the house to its destination (taken from Japan RV and Trailer House Association). They have few or no eaves, making it difficult to shade them from solar radiation. However, when used as temporary housing, additional eaves and other sun-shielding materials cannot be fixed directly to the housing because the original condition must be maintained and returned at the end of the service period. Therefore, trailer homes should be designed for temporary use only and by installing boards in advance to attach additional eaves and other components as needed.

4.2. SUMMARY OF SURVEY RESULTS

As described above, differences exist in the thermal environments of different temporary housing types built in the same climatic region. Although the thermal environment was very stable in the wooden house, several issues were found in other types of housing. However, this does not mean that there should be fewer prefabricated houses and trailer homes and more wooden houses built. During a disaster, it is often necessary to construct as many units as possible, as quickly as possible. Prefabricated housing can be supplied in much larger quantities than wooden houses. Additionally, trailer homes are highly mobile and reusable. They can be moved from one site to another depending on the disaster recovery situation (Tsuchiya, et al., 2019). In summary, each type of temporary housing has unique advantages and disadvantages, and it is critical to select the appropriate type according to the scale and location of the disaster. This study aimed to examine all three types of temporary housing to analyze the living environment comfort of disaster victims.

5. Conclusions

To understand and compare the seasonal and thermal characteristics of the three types of emergency temporary housing provided to disaster victims, we gathered subjective and objective data to determine the most comfortable option. Our subjective evaluations were conducted by the residents. Our objective evaluations entailed taking air temperature and humidity measurements inside a prefabricated house, wooden house, and trailer home built after the West Japan Heavy Rain Disaster in 2018.

The survey results showed that there are several ways to improve the thermal environment of prefabricated housing. Heat and cold can be attributed to low thermal performance and air circulation difficulties. In the wooden house, the residents' evaluations and air temperature and humidity measurements indicated to a stable thermal environment. We found that this was primarily because of the airtightness, high thermal insulation performance, small influence of thermal bridges, and small living area of the residents. In the trailer home, the long, narrow space made air circulation difficult during winter and summer. The floor was cold during winter because of the hollow space under the floor caused by jacking the structure above the ground. During summer, the sun's heat affected the environment. Improving the use of air circulators, closing or insulating the gap under the floor, improving roof insulation, and reducing solar radiation absorption are viable options for mitigating complaints. In summary, the characteristics and issues of the thermal environment varied depending on the structure of temporary housing in a given climatic region.

This study contributes to improving the living standards of disaster victims in temporary housing by outlining how to achieve a more physically comfortable environment. We considered the advantages and disadvantages of each temporary housing type. By selecting and supplying the appropriate housing type with respect to the disaster scale and location, we can reduce the damage to resident health and aid disaster recovery.

Furthermore, this research contributes to speeding up disaster rescue efforts by leveraging the advantages of trailer homes through identifying the issues and characteristics of their thermal environments and promoting their production as temporary housing for disaster victims. As a next step, as Song et al. (2016) pointed out, each type of temporary housing should be assessed also from the viewpoint of life-cycle energy.

Notably, prefabricated housing measurement results require careful evaluation. Some measurements were insufficient because of the installation position of the measurement equipment used in this study. In addition, as this study only surveyed one case for each temporary housing type. Therefore, it is necessary to expand the survey scope in the future to generalize the findings.

In future research, we will verify the effectiveness of the improvement measures for thermal environment issues in each temporary housing type identified in this study through experiments and computational fluid dynamics analyses. We plan to visit an increased number of temporary housing sites to observe more general thermal environmental characteristics and issues. Finally, we aim to expand the target area and continue our research to present appropriate ways of living and operating under various climatic conditions.

Acknowledgements

The authors express their appreciation to the residents of each surveyed house for their kindness and cooperation. We also thank the Housing Division of Kurashiki City for their assistance. We are grateful to Prof. Norio Maki of the Disaster Prevention Research Institute, Kyoto University for his useful comments on emergency temporary housing, and to the Japan RV and Trailer House Association for their technical advice. This project was partially supported by JSPS KAKENHI (Grant Number JP21H04583).

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Intercultural Understanding, volume 11, pages 12-19

Furniture Stereotypes Interrogated: Undertaking Design Research Yields Design Ideas

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Keywords: Living room, stereotype, furniture, industrial design, user research, design education

Abstract: Whether looking at furniture retail stores or reading advice from interior design guide books, we can recognize that middle-class living rooms are normatively divided into sitting and dining zones, furnished by relevant furniture stereotypes, such as dining tables and chairs, display cabinets, couch and armchair sets, centre tables, etc. Even the focal point of the living room is pre-determined: a television or a fireplace. Professional actors such as designers and manufacturers require the user to undertake a set of generic activities like watching television, eating, hosting, relaxing. During my elective course, students were expected to undertake surveys for undermining how respondents conduct their everyday lives and which activities their respondents would like to perform in their living rooms. Research analysis presented a wide range of responses from unconventional ones which included defining new activities and abandonment of certain stereotypes to more conformist ones like complying with the current mass-market layouts.

1. Introduction

'Stereotype' is defined as "a fixed idea or image that many people have of a particular type of person or thing, but which is often not true in reality."[1] We can see the embodiment of this definition in the context of furniture stereotypes. Looking at the furniture industry and analysing retail furniture stores, or observing how people acquire their living room furniture, we confront some norms for defining living rooms and some stereotypes regarding its furnishing. Defining the living room by two main zones, such as dining and sitting (or lounge) zones, is a common norm consolidated by producers and designers. Furniture stereotypes are also determined for decorating these zones. Many users define and decorate their living rooms with this vocabulary. To provide a short historical perspective, dividing the living room into dining and lounging areas could be considered as having evolved from the parlour style (Attfield 2007, Sparke et al. 2009). In that style, there were two main front rooms: a reception room and a dining room (Attfield 2007). After the World Wars, with changing political and economic dynamics, the parlour style started to lose its power and dominance in Europe and the United States (Denby, 1944). With the arrival of the modern style, it became popular for middle-class homes to contain large, open-plan living rooms with two areas (one for dining and one for relaxation) instead of the two separate reception rooms (Attfield 2007). The intention of the modern model of the house in the twentieth century was to rationalize living patterns by providing the most economical and efficient spaces for everyday life (Birdwell-Pheasant and Lawrence-Zuniga 1999: 20). Also, the intention was, ideally, to include minimal spaces for eating, cooking, resting, sleeping, bathing, socializing and leisure pursuits. Therefore, a combined living/dining room became the space for everyday household activities and hosting practices that would fit in the proposed ideal minimal home life (ibid.).

This modern setting and practice dominating domestic interiors also influenced Turkish middle-class homes through the westernization and modernization process (Bozdoğan 2001, Nasır et al. 2015). Many norms and conventions that had defined Turkish lifestyles were shifting in favour of western ones, starting from the Early Republican Era and being accelerated by the globalization flows of the 1980s. Through this transition, when the apartment became mostly a norm for middle-class dwelling, living rooms that combined dining and lounge areas were recognized as a spatial convention. Following that, living room furniture was designed and mediated by complying with the established zones: dining room furniture and sitting room furniture, including their stereotypes, in the context of the Turkish mass market of furniture.

In my elective course titled "Furniture Design and Everyday Life,"[2] which addressed industrial design sophomores, I initiated a "design research" phase. To evaluate the contributions of becoming more empathic with users and gaining insights about the relationship between the living room norms and the actual user experience, I assigned the students to conduct user research to interrogate the furniture stereotypes. Approaches of design thinking and the methods of user-focused design research could be considered as valuable educational objectives and learning outcomes as the normative nature of the living room dominates the furniture market. In this elective course, the stages are constructed in the following order:

1. Studying, depicting and reviewing living room norms in the furniture market
2. Questioning and criticizing the market norms
3. Analysing users' needs and desires in their living room context through surveys and
4. Redesigning living room zones and relevant products based on data retrieved from the inquiries.

This paper involves phase three regarding the design research process and the analysis of the data provided from the respondents with whom the students conducted surveys and made observations. Meanwhile, phase four, articulated in Nasır (2021), necessarily includes the design ideas for living room furniture and zones that the students developed.

As Wormald (2010) indicates, teaching undergraduates about product design should involve directing students' interest in engaging with research on user-focused design. Wormald conducted an extensive study at England's Loughborough University that found that such research has influenced the education of design students. Reasons for including this type of research in undergraduate education programs are that exposure to such research results in improved data acquisition and analysis and in increased opportunities to apply the resulting knowledge. Delft University of Technology is one renowned school that exposes students to research on users throughout its undergraduate program (Stappers and Sleeswijk 2007). It makes sense to teach designers to take users into account, given that designs are intended to serve people (Wormald 2010). Indeed, the curricula of many of the industrial design departments in Turkey's educational institutions—including the university where I taught the elective course referred to earlier—include a course that covers design research (Medipol 2022). Design research methods taught in the required course "Design Research and Theory" provide students with an opportunity to integrate their design research knowledge and to understand what users need and want in their living room settings, and they give students a chance to explore the notion of "stereotype." However, the students were supervised while they undertook their research in the context of their design research process and analysis of the outcomes.

2. The Living Room Discourse from Interior Guide Books and Furniture Retail Store Showrooms

In the context of building and sustaining norms and standards, like in furniture stereotypes, I would like to refer to a concept, 'abstract space', developed by sociologist Henry Lefebvre. To Lefebvre (1991), 'abstract space' is the space of actors like designers, technicians, architects, engineers, manufacturers, politicians and governors. These actors are people other than users, who decide how users 'should' go through their daily practices in alignment with established production units and standards. In that sense, interior design guide books [3] were introduced to students, providing straightforward advices about how a living room *should* be decorated and which units *should* be placed in the determined zones. Chiara et al. (2001) indicates even more explicit affirmations about how users should build a living room. They (ibid.) provided information that is generally spread amongst an array of sources, such as manufacturers' catalogues, literature of a technical nature, books touching on historic styles, and papers and illustrations from different projects. Therefore, such guide books serve as a significant source to observe how a notion of *'abstract space'* is constructed. Chiara and Callender (2007) suggest typical furniture arrangements such as the conversation group (chairs, a sofa and a fireplace), the reading group (a chair, an ottoman, a lamp and a table), the writing or study group (a desk, a lamp, chairs and bookcases), the music group (a piano, a bench and storage space), the game group (a game table and four chairs) and the television group (a television set and seating for several people). They (ibid.) assume that two or three, or all, of the furnishing group units may be included depending on the household's available space and financial means. Irrespective of whether the dining area is a separate room or a designated zone in the living room, they (ibid.) indicate that dining areas must accommodate eating, sitting, serving and possible storage with the help of appropriate furniture. The furniture units that Chiara et al. (2001) list for a dining room or zone are dining tables and chairs, a sideboard, a buffet, a dresser, cupboards, china cabinets and servers. Although they elaborate on the schemes and typical furniture settings for mainly the dining and hosting functions, they also suggest that equipment for these dining functions may be adapted to meet other possible requirements for this space, providing such examples as studying and game playing. They suggest combined living-dining spaces as advantageous arrangements in which less space is used but more intensively.

Through this advice, we see the construction of a typical living room discourse. Stereotypes are placed as given. Generic dining tables or generic couches in more diagram-like drawing styles are illustrated (Chiara et al. 2001, p.59-61). In addition, they (ibid.) recommend that small and medium-size interior design and/or architectural firms use their standards book as a guide to building a quick reference library, consisting of data and specifics related to design. This highly referred book, as its aim is performed, contributes to the production and reproduction of furniture stereotypes. Likewise, Dodswoth and Anderson (2015) introduce a modern living room design, illustrating a sitting group composed of a three-piece suite placed around a central coffee table, oriented according to the positions of the television unit and the fireplace, justifying conventions. Therefore, these generic assumptions make living room furniture a fairly complicated product group. Although each item—whether it is a table or an armchair—is obviously a product (in the field of product design), it is difficult to ignore the fact that furniture units are mostly reproduced in compliance with the norms of interior design conventions. Considering the design process regarding living room furniture taking its references from established conventions and standards, the design of a couch is performed as a unit, which is supposed to find a place in the defined living room configuration, for instance, being one part of a 'three-piece suite'. This process is likely to influence the product design practice to *design* furniture, though gradually in the frame of presumed layouts.

Another window through which we can observe professional actors directing users on how to construct a living room is the furniture mass market. Furniture designers, manufacturers and marketing experts mostly shape the current living room settings and contribute to the common living room discourse. Store showrooms and their web sites are ideal places to observe the ever-lasting furniture stereotypes. An observation of several examples of large-scale furniture retailing manufacturing sites in Turkish cities [4] again demonstrates certain forms of living room furniture stereotypes and spatial conventions. For instance, taking two big-scale furniture sites, Modoko[5] and Masko[6], and the 1128 stores comprising them, addressing middle and upper-middle-class consumers, in regards to what they suggest for constructing a living room, we see mostly the dining zone and sitting zone division as a spatial standard. We also see that the furniture stereotypes of the dining zone are maintained with the main standard of a dining table accommodating several chairs around it, although the number of dining chairs may differ in different stores. Accompanying storage and display units are also presented. Similar normative configurations are presented in the context of sitting zones as well. Sitting zones are generally presented as having a layout including couches, coffee tables and television units. Even the placement of couches is defined by standards, such as the need for three-piece units, which means including modules of one, two and three units. Television units are usually situated as focal points for seated individuals in the household. Finally, the dining zone similarly includes its stereotypical units and sitting zone.

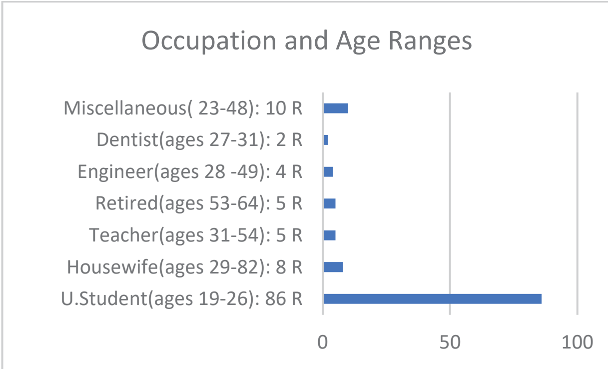
Interior guide books and mass market showrooms promote and construct the ‘standards’ for living room space and furniture. Existing and persisting furniture stereotypes inform us about the standards and conventions of the market and manufacturers. Referring to Lefebvre’s (1991) notion of ‘abstract space’ in the context of living room and furniture designs, all these standardized configurations can be considered ‘abstract living rooms’ of the professional actors in the furniture market. Nevertheless, the critiques geared towards design practices that barely consider users’ everyday life through a top-down viewpoint in the agendas of everyday studies. The authoritarian approaches that aim to change and control everyday life practices have been contested in this field. Everyday life studies commonly focus on the core concepts of everyday life and investigate the capitalist discourse that leverages the everyday practices of people (Lefebvre 1991, Certau 1984). In conventional living room visual culture, the everyday lives of people are considered addressing a set of activities such as sitting, relaxing, watching television, eating, dining and hosting. While the rooted standards function as the repeating units of the furniture stereotypes throughout the capitalist production and consumption cycles, user practices are defined with a limited range. But is it possible to put every single household’s everyday life into normative packages?

3. Undertaking a User-Focused Design Research

After discussing the notion of stereotypes and the established conventions of living rooms, students were informed about current living room settings. But the aim of the course was not taking the stereotypes for granted. A stereotypical understanding of furniture was preventing the design students from thinking outside of the box and creating genuine designs. Before altering stereotypes, a discussion was held regarding how these conventions were founded and how they became common elements that define a living room.

After this stage, it was important to introduce the students to the relationship and the possible contradictions or struggles between the established living norms and the related thoughts and actual experience of the users. In this way, the students were able to gain an awareness of the difference between the *abstract space* of the living rooms and the *lived space* as perceived by the users. This meant students would conduct user-focused design research, which, as has been noted, Wormald (2010) suggested is an essential component of undergraduate design education. We see that Lopes (2008), Lofthouse (2008), and Rodgers and Anusas (2008) also describe having design students conduct research focused on users. According to Lofthouse (2008), even first-year students should conduct such research by observing consumers and identifying problems as part of their process for developing a design project. Wormard (2010) categorizes these activities as a way to quickly gather ethnographic data. The required course “Design Research and Theory,” already mentioned, supported this direction. The course aims to raise awareness of the basic principles of research and to explore the primary methods used in research intended to solve design problems (Medipol 2022). The course content considers the whys and wherefores of design research and examines the methods researchers use to have designers incorporate their findings into the design process (Medipol 2022). After having learned fundamental research methods in “Design Research and Theory,” students would be able to draw on those methods when conducting design research for my elective course. After analysing the furniture market suggestions regarding how to build up a living room and becoming aware of the persisting norms and furniture stereotypes, students started to make inquiries in order to question the existence, validity and conflicts (if any) at the user side.

Table 1. Occupation and age ranges of the respondents
(R stands for respondent)



The students were assigned to collect data in order to gain insights into the respondents’ everyday practices and the current composition of their living room units. The user research phase was designated in such a way that students[7] were supposed to conduct their interviews with 15 respondents. Students were supposed to provide demographic data from the respondents, such as the respondents’ ages and occupations and where they lived. It was important for the students to develop an awareness of the different life stages, occupational levels and work schedules of the respondents in relation to their home routines and the configurations of their living rooms. Because the respondents comprised individuals from the inner social circle of the students, which they could easily access, we reached a sample consisting mostly of Istanbulite university students (Table 1). 91/120 respondents were based in İstanbul, while the rest were from smaller cities like Eskişehir, Kırklareli, İzmit, etc. This type of demographic data would be useful in interpreting the feedback given by different profiles having various dynamics. A university student living with his/her parents and a middle-aged dentist could have different dynamics, demands and preferences for decorating and experiencing their living rooms. Thus, it would make more sense to process any data framed with the comprehensive knowledge of the personal context (age, occupation, etc.) of the given sample.

In the main stage of research, each of the eight students conducted interviews with 15 respondents to gain an understanding of their demands and needs in the context of their current living rooms. The students were mostly autonomous and developed their questionnaires independently. Yet once the finalized questionnaires were collated, we saw that the questions that the students brought in were more or less similar. Therefore, it could be affirmed that the students developed an almost common survey template composed of open-ended questions like the following:

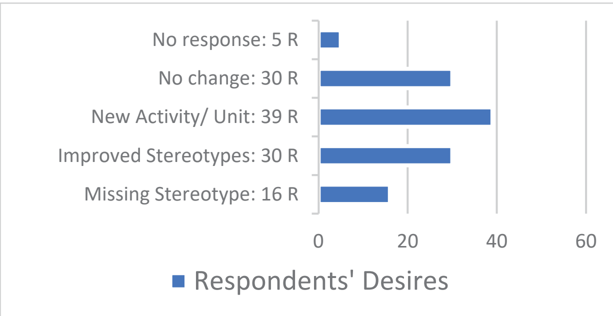
- Which units do the respondents have in their living rooms?
- Which activities are performed in the living rooms of respondents?
- What kind of activities are desired to be performed if there were means in the living rooms?
- Which kind(s) of object(s)/product(s) do the users desire to have in their living rooms?

In addition to the common inquiries, a couple of students also questioned the validity of the current stereotypes, asking if there were any units that the respondents found redundant and would prefer to discard from their current settings, which is explained in the section: Furniture Stereotypes of Abandonment.

3.1. DATA ANALYSIS

We began the data analysis by processing the responses obtained from common questions that all eight students responded to. Relying on the survey analysis, conducted with a total of 120 respondents, the students presented their data in the following class. Each student shared his/her data and fieldwork notes with the whole class, so we created a large pool of data about respondents' aspirations. This enabled each student to see the bigger picture of the subject. As seen in Table 2, respondents presented us with different levels and qualities of desire for change. In total, 39/120 respondents defined a new activity or object as desired other than their current living room practice. Meanwhile, 16/120 respondents pointed to a *missing stereotype* as a desire. Some respondents addressed more unconventional activities like swimming, while some were content with small scale-improvements. Moreover, 30/120 respondents desired no change regarding their living room configurations. Through this phase, the variety of user demands and needs inside and outside the established norms was contemplated.

Table 2. Categories of respondents' desires

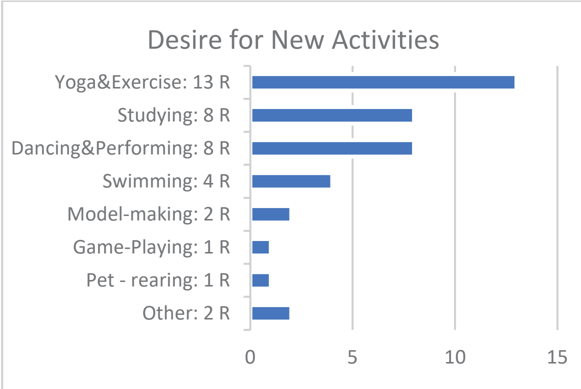


3.1.1. Desire for a New Unit/Activity Out of Respondents' Current Setting

In the context of analysing the activities that the respondents desire, but that are out of the respondents' current setting, we found that 39 respondents defined several everyday activities to take place in their living rooms.

As illustrated in Table 3, through the variety of the desires of different activites, while 13 respondents mentioned having yoga and exercise practices, four respondents visualized swimming in their living rooms. Such activities suggested by respondents are collated and analyzed under such subtitles as "Studying," "Exercising," "Dancing," and "Other performances," which are considered as repeating patterns and frequently referred-to themes throughout the data pool.

Table 3. Respondents' desires for performing new activities in living rooms



Studying: Throughout the analysis, a repeating pattern was that household individuals desired or already performed intellectual activities like studying, completing assignments or even simply surfing on the internet and social media. As P38 (US) puts it: "I'd like a region in which I could study comfortably." P38, who lives in a household of five members, in a home of six rooms, says that the typical act that her family performs in the living room is "hosting." Thus, the usage of the living room depends on guest visits to their house. Although the home has plenty of rooms and also a "back-stage sitting room," P38 considers the lack of a region for studying in the living room as a deficiency. Respondents' desires indicated the need for a *defined* study area that includes comfortable furniture and sufficient storage units for relevant equipment inside the living room. One reason for this desire to study in the living room was because "it is spacious and large" (P63, US). Another reason was the desire to not be far away from family gatherings. The respondents' desires address a more defined study experience, with furniture specifically designated for study activity, rather than appropriating the dining table as a study desk or engaging in other makeover practices.

Exercising: Another important emerging activity that requires consideration is exercising. Some of the respondents would like to exercise in their living rooms. However, in a conventional living room, there might not be enough room for this type of activity, as P80 indicates: "I would like to do yoga but the space is so cluttered and not enough." P110 (US) explains the current activities that he conducts in his living room as "doing exercise, playing PlayStation games and watching television," while the units his parents placed in the living room are sorted as armchairs, a dining table and chairs, a television unit and a centre table. Thus, P110 exercises in a mostly conventional configuration in which he appropriates the space and stereotypes for this activity. As a counterpart case, P94 (US), having a similar conventional setting (armchairs, console table, television unit, dining table and chairs) implies that she prefers to exercise in the living room, as it is large. However, she finds it difficult to constantly carry her workout equipment to the living room. This respondent expressed her appreciation for a solution to this exhausting routine. The cases of P94 and P110 reveal that the living room is already appropriated for engaging in exercise. P67 (US) underlined another issue with exercise practice:

> Student-5: "What kind of activities would you like to perform if there were means in your living room?"
>
> P67: "Nothing for my own, but my brother uses our living room for doing exercise, as it is large. It becomes a nuisance as he makes the room so messy."

We also understand that it is difficult for such a regular household activity to be considered a legitimate one for purposes of assigning permanent space and units to it in the living room. This caused exhaustion on the part of users, as they had to exercise with makeshift and temporary solutions every time. Also, other household members considered the makeshift practices as being disruptive to the current living room setting.

Dancing and other performances: Dancing was another repetitive pattern that the respondents performed or desired to perform inside their living rooms. It was discovered that the respondents who actually danced in their living rooms opened up a convenient space in the current living room setting. Opening up space for dancing and exercising may indicate why the centre tables were often perceived as redundant. P93 (US) considers the units that address her needs in the living room as being "only a few [pieces of] furniture, wall to wall mirrors and giant loudspeakers," for dancing practices. It was understandable that P93 required less furniture to accommodate dancing because her parents had designated a rather cluttered living room consisting of "armchairs, couches, display cabinet, centre table, television unit, smaller tables, dining table and chairs" (P93). In a parallel theme, in which furniture disables bodily performances, we hear P69 (US), who lives with his family and mostly uses his personal room: "I'd like to play drums in the living room but because we don't have sufficient space, I cannot do [that]." While P69 engages in "study and hobbies" in the living room, he needs more space for playing the drums.

As seen in this category, the patterns and necessary data obtained from the everyday lives of the respondents represented differences and diversities from the established living room norms regarding the survey research of each student.

3.1.2. Desire for an Improved Version of a Stereotype

In total, 30/120 respondents responded to the question asking about their desired activity/unit in their living rooms by defining some improved versions of certain stereotypes, for example: "multifunctional couches and wall-mounted table, opened-up when needed" (P97, manager, 52 years old).

The main theme characterizing this category was space-saving. The common suggestions of P99, "a more practical dining table which occupies less volume," and P91, "more compact units which integrate television unit, console and display cabinet which occupy so much space in total," again, addressed space-saving concerns. Seven out of 30 respondents addressed space-saving improvements especially about dining tables, advising that the tables should be smaller, modular or adjustable.

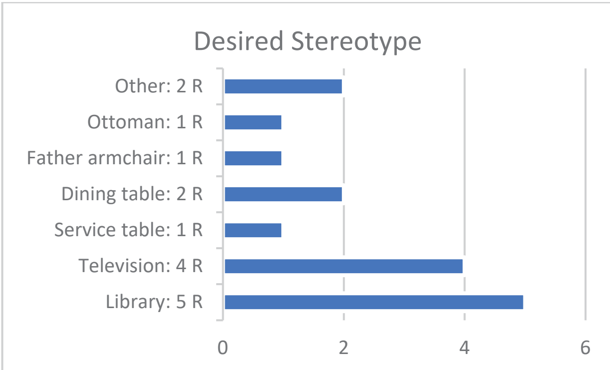
Table 4. Respondents' suggestions for improving living room setting

Unit	Number of respondents addressing this stereotype	Suggested improvement
Dining table	7	Modular, adjustable, smaller versions
Television unit	2	Incorporation with other units, being more functional
Console table	2	Incorporation with other units
Display cabinet	2	Incorporation with other units
Coffee table	4	More of them Wheeled versions Siding with couches Less hazardous
Couches	3	Making them more comfortable, functional
Armchairs	2	Making them larger
Plugs	2	Making them easy to reach
Living room, general	6	Smaller furniture, larger spaces

3.1.3. Desire for the Missing Stereotype

In total, 16/120 respondents implied that they desired some units—but which were among already available furniture stereotypes. The units pronounced as being desired, as illustrated in Table 5, were: library, television, service table, dining table, father armchair and ottoman. SR48 (19, US), who lives with her family, feels the need for a dining table: "A dining table is a major necessity, as you can use [it] comfortably when your guests come." However, this respondent also describes her use of the living room in terms of hosting guests. The missing dining table represents a shortcoming for formal occasions.

Table 5. Respondents' desires for owning the missing stereotypes



The desire for a television is also a very typical activity defining a living room. We included this object although it is not a furniture. But television is usually considered as a focal point of the living room. With its existence as a norm, television directly or indirectly affects the design or layout of other furniture stereotypes, like television units. However, from this desire or 'father armchair', we can at least see that the living room is addressing everyday life. Another significant unit is the library. This could be interpreted as being related to the emerging study activity in the living room context. The units comprising this category were mostly available stereotypes that the mass-market furniture industry already suggests for setting up a living room. The reason why they were desired was simply that they were missing from the living rooms of respondents' homes.

3.1.4. Users' Contentment with their Current Living Room Settings

According to the survey results, 30/120 respondents believed that no change was necessary regarding their living room settings. They did not aspire to a different unit or a practice that would be performed in their rooms. P37 (US, 18), who lives with her family of four, says: "A living room is a living room. Why bother to change? I like it as it is." This respondent also implies that her household does not use the living room on a daily basis; rather, members spend their time mostly in their backstage sitting room: "The total amount time that I spend in the living room is [a] maximum [of] 30 minutes a day." This conformist approach demonstrates to us that it is a significant preference to build up a conventional living room and maintain it—even if one does not use it. Regarding Turkish home culture, it is a common practice to maintain the reception area so that it is clean, tidy and isolated from everyday activities (Nasır et. al. 2019). Besides visualizing a new living room activity zone, it is a taboo for some social groups to even perform conventional activities—like sitting, relaxing and watching television—in the living room. Thirty respondents did not prefer any change or improvement, whether or not they used their living rooms for everyday activities.

3.1.5. Furniture Stereotypes of Abandonment

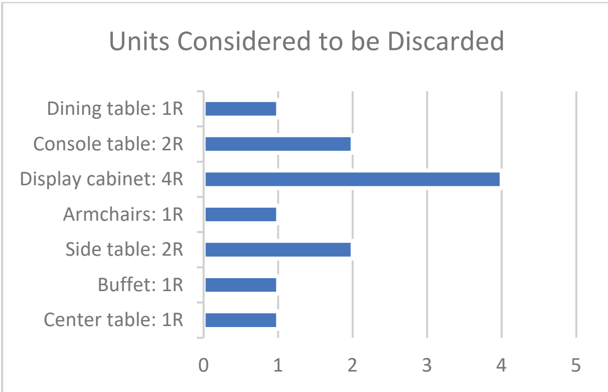
As mentioned in the beginning of the design research phase, the students were assigned to develop their own set of questions in relation with interrogating the stereotypical understanding of the living rooms from their own point of view. Apart from the common questions regarding all of the students' questionnaires, there was another inquiry about the abandonment of stereotype units, which specifically Student-6 and Student-8 were interested in.

- Is there any furniture that you have discarded or would like to discard from your living room?

The questionnaires of most of the students were found as similar, however specifically, Student-6 and Student-8 also scrutinized the existing stereotypes that the respondents wanted to discard from their domestic environment. Although I realized that we would provide the responses from only 30 respondents—which was the total sum of the number of the respondents that two students interviewed—I encouraged the students to fetch the relevant data in our qualitative data analysis session; because even with only 30 respondents, the answers about discarding stereotypes or preferring to discard them would yield a discussion regarding the validity of the stereotypes. Out of the 30 respondents, we found that 20 of them favoured the abandonment of their current furniture, while 10 respondents saw no need for removing any unit. Among the respondents who preferred discarding some units and objects, 12 of them implied certain furniture stereotypes. Regarding these units, display cabinets were prominent in the surveys: "I would remove my display cabinet. I don't think it is essential. It is possible to put the stuff into other places." (P115, male, engineer, 28 years old). The reason for considering discarding units was mostly to provide more space and eliminate clutter: P118 (engineer, 34 years old): "I would remove the dining table, which occupies too much space. I could take it to the kitchen." Other units that the respondents would like to abandon were side tables and coffee tables, console tables and "buffet[s] with a mirror" (P80, university student, 20 years old).

Respondents expressed their desire to discard these units, as the units mostly took up space. However, most of the respondents did not intend to take that action. P83 (20, US[8]), who lives with her parents, explains the situation as: "We have an incompatible side table but we cannot remove it, in case … it gets useful one day." Another respondent, P84 (20, US), who enjoys watching movies, listening to music and exercising in their living room, expresses: "There are things that we should discard but because my mom is keen on them, we cannot get rid of them." Student-6 interpreted this situation as indicating that most households she interviewed kept their conventional configurations in the same order and did not go beyond the current layout. However, recognizing the responses regarding the desire to abandon certain units, she concluded that it was important to make some changes. After the analysis of this initial inquiry, we found a preference for having spacious living rooms over acquiring many stereotypes. We observe a tendency to discard certain stereotypes from the dining room furniture, like display cabinets, console tables, other small tables, etc., more than the sitting group. Through this quest, students gained an idea about the furniture units that the respondents do not need anymore, but keep as a spatial and social norm despite the limitations of the sample. Besides furniture units, other objects that the respondents wanted to discard were carpets, knick-knacks, photographs, vases and candlesticks.

Table 6. Units considered to be discarded



4. Design Research Yielding Design Ideas

The design research process has proven to be successful in terms of both interrogating the notion of stereotype and including a user-centered approach to the students' design process. Outcomes deriving from the research process presented a wide range of responses—from those that point to unconventional demands, which included defining new activities like swimming, dancing, etc., to more conformist tendencies, like complying with the current mass-market layouts in efforts to improve their domestic lives. Having such user data at hand, students were able to reconceptualize furniture units, instead of immediately drawing from a certain stereotype. Lockwood (2010) implies, through his articulation of fundamental notions about design, that using an empathetic approach can both be a source of inspiration and contribute to reaching user insights. Lofthouse (2008) points to the importance of using observation to support problem identification. In conjunction with this approach, students could identify several design problems through their fieldwork and data analysis. Such identifications led the students to create new design ideas for living rooms. Analysing the respondents' desires to conduct study-related activities, Student-2 created a subzone in the living room that would define an artistic activity, and Student-4 focused on designing a new product, called Multy, that addressed users' needs for charging and plugging in their devices, including providing charging slots on the front edge of the unit (Nasır, 2021). Another idea was generated by the fact that some users desire to engage in, and some of them already undertake, exercise and yoga practices in their living rooms, which was difficult because they would have to move items to make room for the practice, or the room could be messy. This was considered a solid design problem and a source of inspiration for a new product or zone for Student-5, Student-6, and Student-8. Another case where the design research yielded fruit was the design idea of Student-7. Unlike most of the design concerns, which address human individuals, Student-7's idea was to redesign and reconsider the living room environment, furniture and units with regard to the pets that live in the home (Nasır, 2021). Therefore, conducting the design research, which resulted in being more knowledgeable about the users and their everyday lives, enabled the students to identify design problems more genuinely instead of immediately drawing from certain furniture stereotypes that the mass market keeps reproducing.

5. Summary

In the theoretical stage of the course, the students initially studied and gained an understanding of the normative structure of living room furniture and zones through an array of sources. Following that, they questioned and developed an understanding of the established norms and stereotypical configurations, based mostly on the critique literature of everyday life and critical design. To have a genuine approach for their design process, students were assigned to undertake surveys that would help them understand how respondents conduct their everyday lives and which activities their respondents perform or would like to perform in their living rooms. Clarke (2011) signifies that the region of design anthropology adheres to the tradition in which corporate, retail-driven associations regarding object culture are questioned. Increasingly, designers are immersing themselves in both social research and creating form. Hence, observational techniques, human focus and an emphasis on the dynamics of the everyday have become prominent subjects regarding contemporary design practice. The research phase undertaken through this course has been mind-opening in many ways. We saw that the affirmations advising which stereotypes a living room *should* include were not considered 'necessary' for every user. The main body of the research analysis revealed that respondents *do* undertake some personal activities in their living rooms. However, there are no defined zones or furniture for them to engage in dancing or working out. Bodily practices like dancing, exercising, or intellectual activities as studying, etc. are performed in a living room setting constructed in compliance with norms, by repurposing the units and adjusting the current configurations, as well as by making use of affordances of tables, chairs and other units. Additionally, some respondents desired to engage in these unconventional activities but could not do so. Finally, whether felt as a desire or conducted through appropriation practices, the students were inspired by their receipt of information from users.

Nevertheless, we also see that what some respondents desired for their living rooms was a missing stereotype, or an improved version of a stereotype or no change at all. The responses revolving around the notion of 'stereotype' show us that the aforementioned respondents mostly comply with the established norms and conventions. These may be interpreted in light of several factors. One of them could be about the power of *'abstract living rooms'* constituted by the mass-market-driven dissemination. Social control pressures households to acquire conventional furniture derived from both the options available in the market and society's judgement regarding an individual has created a proper living room. Both the pressure of social control and the mediation of the furniture industry market may lead masses of people to purchase conventional set-style furniture that mostly addresses sitting, eating and dining functions. Another reason could be that the daily activities of these respondents may not differ from the assumed generic practices.

This research regarding its limits demonstrated many different levels and dimensions about the relationship of users and the stereotypical understanding of constructing living rooms. Furthermore it was a good venue to realize that the required furnishing and conducted practices in respondents' living rooms were not fixed as what the mass-market furniture retail stores were offering. Obviously, more user research would contribute well to the region of living room furniture design, which has been a realm dominated by stereotypes and normative configurations, imposing upon the users which units they should acquire. Region of living rooms had rich potential for informing design research where such a standardized realm and the dynamics of everyday life—public and private qualities of home life—were supposed to clash.

Endnotes

1. Oxford Learner's Dictionaries
2. This course was conducted in the Department of Industrial Design, Faculty of Fine Arts Design and Architecture at İstanbul Medipol University, in the spring semester of the 2016-2017 academic year.
3. For instance, see Binggeli, 2011; Mitton and Nystuen, 2016; and Fisher et al. 2018
4. For the Istanbul context, we can see the 'Modoko' and 'Masko' sites; for the Ankara context, the 'Siteler' site, 2020; for the Izmir context, the 'Kısıkköy' site. (For an extensive review of the furniture industry for the Sakarya context, see Bıçak, 2017).
5. Modoko, established in 1969, accommodates 350 prominent furniture stores as a large furniture site (Modoko 2020).
6. Masko, established in 1984, is larger than Modoko, having 778 furniture stores (Masko 2020).
7. There were actually nine students who took this course. But as the submissions of one of the students were not sufficient for inclusion in this study, overall analysis was undertaken regarding the works of eight students.
8. Abbreviation for 'University Student.'

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Intercultural Understanding, volume 11, pages 20-29

Redefinitions of Mathematical Formulae for Warping Curves Based on Three Design Methods of *Ishigaki* (Stone Walls) at Japanese Castles and Comparison with Photogrammetric Results of Edges of *Ishigaki* at Hikone Castle

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Keywords: average gradient, depth, envelope, height, initial gradient, lower bottom, occluding edge, overhang, upper bottom

Abstract: We redefine three mathematical formulae for warping curves obtained from three documents describing three design methods for the *ishigaki* (stone walls) of Japanese castles as mathematical formulae with the parameters of depth, height, and initial gradient. We also propose redefinitions of the mathematical formulae for the warping curves by selecting a lower third gradient (the average gradient of the lower third of an *ishigaki*) suitable for comparing differences in curves among the three methods and existing *ishigaki* at castles. Furthermore, the conditions under which a warping curve based on each method and an *ishigaki* designed on the basis of the methods do not overhang were compared. Finally, we compared the three redefined curves and the results of photogrammetry conducted near the edges of the *ishigaki* at Hikone Castle. The differences in the characteristics of the three types of curves and the methods were specifically clarified.

1. Introduction

Today, especially in Japan, most retaining walls are constructed with cast-in-place concrete or concrete blocks, and the number of stone walls being constructed has been decreasing. However, stone walls, which can be constructed with materials obtained from nature, have advantages such as a low impact on the natural environment, easy partial restoration, and contribution to the formation of a beautiful landscape. In fact, it has been experimentally confirmed that the strength of stone walls called *ishigaki*, which are built using the *Ano Zumi* method (a form of stone masonry by the *Ano-shu* Guild, a group of stone-wall craftspeople) is superior to that of concrete blocks, and these walls were used in part of the construction of the Shin-Meishin Expressway.

Each of the many *ishigaki* in Japan has an almost uniform gradient from the bottom to the top. However, many of the remaining castles in Japan have warping *ishigaki* with uneven gradients. These *ishigaki* are thought to have been designed to ensure structural strength by reducing the gradient at the bottom, which is subject to greater earth pressure, and to protect against enemies by increasing the gradient at the top, which is subject to less earth pressure. On the other hand, the warping *ishigaki* in castles have been recognized for their historical value due to their beauty, and they have been the subject of preservation and restoration as cultural assets. In designing modern retaining walls and stone walls, it is no longer necessary to consider security against external enemies. However, in designing stone walls that are both beautiful and structurally rational, it is extremely useful to clarify the nature of the warping curve of *ishigaki*.

The designs of the *ishigaki* at castles were considered a military secret at the time of construction, and many of them do not have drawings from that time. Therefore, the design methods became secret traditions known only to a limited number of people. Currently known once-secret documents describing the design methods for warping curves include the *Goto-ke Monjo*, reprinted by the Japan Sea Culture Research Institute, Kanazawa University (1976), the *Sekisho Sho*, reprinted by the Ishikawa Prefectural Research Institute of Kanazawa Castle (2011), and the *Ishigaki Hiden-no-sho*, reprinted by the Kyushu Research Institute for Cultural Properties (2001) and the Ishikawa Prefectural Research Institute of Kanazawa Castle. The design methods in these three documents are different, and the mathematical formulae for the warping curves for each method have already been clarified (Fujii, 2018; Morimoto, Nishida, Nishigata, & Tamano, 2000; Nishida, Nishigata, Tamano, & Morimoto, 2003; Yanai, 1988)[1]. However, because each formula defines a curve by its upper bottom, lower bottom, and height, it has the following problems. (i) Because the upper and lower bottoms cannot be measured directly on the actual *ishigaki*, it is difficult to compare them with the curves. (ii) To change the shape of the curve, two parameters, the upper and lower bottoms, need to be adjusted simultaneously, which is difficult to apply to design. (iii) Because there is no "depth" in the parameters of the defining mathematical formulae, it is difficult to vary a curve while keeping the average gradient constant and compare the dynamical stability due to the shape of the curve.

In this paper, we first redefine each mathematical formula for warping curves defined by using the three parameters of upper bottom, lower bottom, and height based on the *Goto-ke Monjo* (GM), the *Sekisho Sho* (SS), and the *Ishigaki Hiden-no-sho* (IH) using the depth and height of the warping curve and another parameter. As another parameter, we first select an initial gradient (gradient of the curve at the bottom of an *ishigaki*), which is directly obtained from each design method. We also propose redefinitions of the mathematical formulae by selecting a lower third gradient (average gradient of the lower third of an *ishigaki*) that is suitable for comparing the differences in warping curves among the three design methods and existing *ishigaki* in castles.

In addition, even though it is generally believed that *ishigaki* recede toward the top, it is also known that the curve based on the IH always has an overhang at the top (Fujii, 2018). We also clarify the conditions that lead to a lack of an overhang in the GM and SS. However, in practice, even if there is a small overhang in a curve, it can be considered not an overhang in practical use if it is smaller than the height of the stone used for the *ishigaki*. On the basis of this, the conditions under which an *ishigaki* designed by each method do not overhang in practical use are also clarified.

Finally, we compare the three redefined warping curves and the results of photogrammetry previously conducted near the edges of the *ishigaki* at Hikone Castle (Umezaki, Suzuki, Tagawa, & Yoneda, 2021). Thus, we try to investigate the mutual differences in the shape of the curves in accordance with the design methods and the differences with the existing *ishigaki*.

Through the above study, we aim to obtain the basic knowledge necessary to apply the warping curves of *ishigaki* at castles not only to the design of new stone walls but also to various architectural and landscape designs beyond stone walls.

2. Redefinitions of Mathematical Formulae of Warping Curves and Conditions for No Overhang

We will redefine the curves based on the *Goto-ke Monjo* (GM), *Sekishou Sho* (SS), and *Ishigaki Hiden-no-sho* (IH) and compare their conditions for having no overhangs.

2.1. *GOTO-KE MONJO* (GM)

The *Goto-ke Monjo* (GM), which means "Goto Family Documents," consist of ancient documents created by the Goto Family, *ano* (*ishigaki* craftspeople) of the *Kaga-han* (Kaga Domain, based at Kanazawa Castle). Among them, the method systematized in *Yuishi Ichinin-den* (*Issatsu-bon*) in 1824 by Hikosaburo Goto (Ishikawa Prefectural Research Institute of Kanazawa Castle, 2011) is used in this study as the design method of the GM.

2.1.1. Design Method of GM

According to Kigoshi (2007; Ishikawa Prefectural Research Institute of Kanazawa Castle, 2008), Kitagaki (1987), Morimoto et al. (2000), and Nishida et al. (2003), the design method described in the GM can be formulated as follows from (a) to (f). In Figure 1, the upper end of the curve is the origin O; the x-axis heads vertically downward, and the y-axis heads horizontally outward (in front of the *ishigaki*).

(a) Determine the height $h = \mathrm{AC}$, the upper bottom $a = \mathrm{OA}$, and the lower bottom $b = \mathrm{CD}$. The point where line segment AC is divided into 2:1 is $\mathrm{B_0}$.

(b) The sectional shape of the lower third of the *ishigaki*, i.e., $\frac{2}{3}h \le x \le h$, is line DA. Let this sectional shape be line segment $\mathrm{DE_0}$, which is $\mathrm{E_0}\left(\frac{2}{3}h, \frac{2}{3}b - a\right)$, and

$$\mathrm{DE_0}:\ y = \frac{b}{h}x - a. \tag{1}$$

(c) In the top two-thirds of the *ishigaki*, divide line segment $\mathrm{B_0A}$ equally by the natural number n, and let $\mathrm{B_1}, \mathrm{B_2}, \ldots, \mathrm{B}_{n-1}$ be the points closest to $\mathrm{E_0}$ in order.

(d) Let a_0 be the value obtained by dividing a by the sum of the natural numbers from 1 to n,

$$a_0 = \frac{2a}{n(n+1)}. \tag{2}$$

(e) The point that protrudes a_0 from the intersection of the straight line drawn horizontally from $\mathrm{B_1}$ in the direction of the y-axis and straight line $\mathrm{DE_0}$ to the front of the *ishigaki* is $\mathrm{E_1}\left(\frac{2}{3}h\left(1 - \frac{1}{n}\right), \frac{2}{3}b\left(1 - \frac{1}{n}\right) + a_0 - a\right)$. The sectional shape of the part with $\frac{2(n-1)}{3n}h \le x \le \frac{2}{3}h$ is

$$\mathrm{E_0E_1}:\ y = \frac{1}{h}\left(b - \frac{3a}{n+1}\right)x + \frac{2a}{n+1} - a. \tag{3}$$

(f) Similarly, when $2 \le k \le n-1$, the point that protrudes a_0 from the intersection of the straight line drawn horizontally from B_k in the direction of the y-axis and straight line $\mathrm{E}_{k-2}\mathrm{E}_{k-1}$ to the front of the *ishigaki* can be obtained inductively as $\mathrm{E}_k\left(\frac{2}{3}h\left(1 - \frac{k}{n}\right), \frac{2}{3}b\left(1 - \frac{k}{n}\right) + \frac{k(k+1)}{2} - a\right)$. The sectional shape of the part with $\frac{2(n-k)}{3n}h \le x \le \frac{2(n-k+1)}{3n}$ is

$$\mathrm{E}_{k-1}\mathrm{E}_k:\ y = \frac{1}{h}\left(b - 3a\frac{k}{n+1}\right)x + 2a\frac{k}{n+1}\left(1 - \frac{k-1}{2n}\right) - a. \tag{4}$$

If $\mathrm{O} = \mathrm{E}_n$, (4) holds for $1 \le k \le n$. Therefore, the sectional shape $\mathrm{DE_0E_1} \cdots \mathrm{E}_{n-1}\mathrm{O}$ can be determined by (1) and (4).

2.1.2. Derivation of Warping Curve Based on Design Method of GM

Here, by finding the envelope of the sectional shape $\mathrm{E_0E_1} \cdots \mathrm{E}_{n-1}\mathrm{O}$, we obtain a warping curve that approximates the sectional shape between $\mathrm{E_0}$ and O when $n \to \infty$. In (4), if we replace $\frac{k}{n}$ with variable t and let $n \to \infty$, we have

$$y = \frac{1}{h}(b - 3at)x + 2at\left(1 - \frac{t}{2}\right) - a. \tag{5}$$

Multiplying both sides by h and transposing so that the right side is zero, we have

$$hy - (b - 3at)x + 2ah\left(t - \frac{t^2}{2}\right) - ah = 0. \tag{6}$$

Partial differentiation of both sides by t yields

$$3ax + 2ah(1 - t) = 0. \tag{7}$$

If we find t,

$$t = 1 - \frac{3}{2h}x. \tag{8}$$

Substituting this into (5), we have

$$\begin{aligned} y &= a\left(\frac{3}{2h}x - 1\right)^2 + \frac{b}{h}x - a \\ &= \frac{4a}{9h^2}\left\{x - \frac{3}{2}h\left(1 - \frac{b}{3a}\right)\right\}^2 + \frac{2}{3}b - \frac{1}{9a}b^2 - a. \end{aligned} \tag{9}$$

This envelope passes through two points, $\mathrm{E_0}$ and O. From the above, the sectional shape between $\mathrm{E_0}$ and O can be approximated by a quadratic function (Figure 1). Yanai (1988) derived this quadratic function with the origin at point A. It is the same mathematical formula as that in (9) with the $-a$ term removed, and it is the same curve. The same is true for the quadratic function shown by Morimoto et al. (2000) and Nishida et al. (2003)[2]. Let this be the warping curve between $\mathrm{E_0}$ and O.

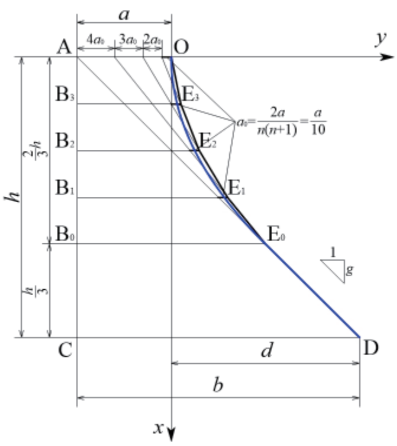

Figure 1. Design method for sectional shape based on *Goto-ke Monjo* (GM, for $n = 4$) and warping curve for $n \to \infty$ (blue)

2.1.3. Redefinition of Mathematical Formula for

Warping Curve of GM

If we rewrite (9) using the depth $d = b - a$ and the gradient of line DE_0 $g = \frac{h}{b}$ (initial gradient) instead of a and b, we have

$$y = \left(\frac{h}{g} - d\right)\left(\frac{3}{2h}x - 1\right)^2 + \frac{1}{g}(x - h) + d$$
$$= \frac{4}{9h}\left(\frac{1}{g} - \frac{d}{h}\right)\left[x - \frac{3}{2}h\left\{1 - \frac{h}{3(h - dg)}\right\}\right]^2 - \frac{h}{3g}\left\{1 + \frac{h}{3(h - dg)}\right\} + d. \quad (10)$$

2.1.4. Conditions for No Overhang for Warping Curve of GM

If the x-coordinate of the vertex of the quadratic function calculated in (9) and (10) is positive, the top of the warping curve overhangs. To prevent the top of the warping curve from overhanging, the x-coordinate of the vertex must be zero or negative. According to (9), the condition for no overhang is

$$\frac{3}{2}h\left(1 - \frac{b}{3a}\right) \leq 0. \quad (11)$$

Because a, b, and h are positive, we have

$$b \geq 3a. \quad (12)$$

Also, if we rewrite the condition in (12) using the initial gradient g instead of the upper and lower bottoms $a = \frac{h}{g} - d$ and $b = \frac{h}{g}$, because a is not positive when $g \geq \frac{h}{d}$,

$$\frac{2h}{3d} \leq g < \frac{h}{d}. \quad (13)$$

Therefore, the initial gradient of GM must be greater than or equal to 2/3 of the average gradient of the entire *ishigaki* to prevent overhang.

2.1.5. Practical Conditions for No Overhang for Ishigaki by GM

In practical use, n in the GM is a finite natural number, and there is no problem if section $E_{n-1}O$ of the topmost *ishigaki* does not overhang (Figure 2). In other words, the slope of line $E_{n-1}E_n$ should be greater than or equal to zero. Therefore, according to (4),

$$\frac{1}{h}\left(b - 3a\frac{n}{n+1}\right) \geq 0. \quad (14)$$

Therefore, if we divide line segment AB_0 into n equal parts, we need to satisfy the condition

$$b \geq 3a\left(1 - \frac{1}{n+1}\right). \quad (15)$$

If we rewrite this condition with d, h, and g, we have

$$\frac{h}{3d}\left(2 - \frac{1}{n}\right) \leq g < \frac{h}{d}. \quad (16)$$

If $n \to \infty$, (15) and (16) coincide with (12) and (13), respectively.

2.2. *SEKISHO SHO* (SS)

The *Sekisho Sho* (SS), which means "Stone Walls Document," is a document compiled in 1755 by the Yuasa Family, *ano* of the *Iwakuni-han* (Iwakini Domain, based at Iwakuni Castle).

2.2.1. Design Method by SS

The SS does not contain a general design method, but it does contain the gradient values for each *ken* (one *ken* is about 1.82 m) from the bottom for each height of the *ishigaki*. Nishida et al. (2003) proposed a design method that agrees with these gradient values with very high accuracy. This design method can be formulated as follows from (a) to (f). In Figure 3, as in Figure 1, the upper end of the curve is the origin O, the x-axis is downward vertical, and the y-axis is outward horizontal (in front of the *ishigaki*).

(a) Determine the height $h = \mathrm{AC}$, the upper bottom $a = \mathrm{OA}$, and the lower bottom $b = \mathrm{CD}$.

(b) Divide line segment AC into equal parts by natural number $n + 1$, and let B_0, B_1, …, B_{n-1} be the points closest to C in order.

(c) The sectional shape of part n+1 from the bottom, i.e., $\frac{n}{n+1}h \leq x \leq h$, is line DA. Let this sectional shape be line segment DE_0, which is $E_0\left(\frac{n}{n+1}h, \frac{n}{n+1}b - a\right)$, and

$$DE_0:\ y = \frac{b}{h}x - a. \quad (17)$$

(d) At $i = 1, 2, \cdots, n$, we define a_i by

$$a_i = \frac{6ai}{n(n+1)(n+2)}. \quad (18)$$

(e) The point that protrudes a_1 from the intersection of the straight line drawn horizontally from B_1 in the direction of the y-axis and straight line DE_0 to the front of the *ishigaki* is $E_1\left(\frac{n-1}{n+1}h, \frac{n-1}{n+1}b + a_1 - a\right)$. The sectional shape of the part with $\frac{n-1}{n+1}h \leq x \leq \frac{n}{n+1}h$ is

$$E_0E_1:\ y = \frac{1}{h}\left\{b - \frac{6a}{n(n+2)}\right\}x + \frac{6a}{(n+1)(n+2)} - a. \quad (19)$$

(f) Similarly, when $2 \leq k \leq n - 1$, the point that protrudes a_k from the intersection of the straight line drawn horizontally from B_k in the direction of the y-axis and straight line $E_{k-2}E_{k-1}$ to the front of the *ishigaki* can be obtained inductively as $E_k\left(\frac{n-k}{n+1}h, \frac{n-k}{n+1}b + \sum_{i=1}^{k}(k - i + 1)a_i - a\right)$. Because

$$\sum_{i=1}^{k}(k - i + 1)a_i = a\frac{k(k+1)(k+2)}{n(n+1)(n+2)}, \quad (20)$$

the sectional shape of the part with $\frac{n-k}{n+1}h \leq x \leq \frac{n-k+1}{n+1}h$ is

$$E_{k-1}E_k:\ y = \frac{1}{h}\left\{b - \frac{3ak(k+1)}{n(n+2)}\right\}x + a\frac{k(k+1)(3n - 2k + 2)}{n(n+1)(n+2)} - a. \quad (21)$$

If $D = E_{-1}$ and $O = E_n$, (21) holds for $0 \leq k \leq n$. Therefore, sectional shape $DE_0E_1 \cdots E_{n-1}O$ can be determined by (21).

2.2.2. Derivation of Warping Curve Based on Design Method of SS

Here, by finding the envelope of sectional shape $DE_0E_1 \cdots E_{n-1}O$, we obtain a warping curve that approximates the sectional shape between D and O when $n \to \infty$. (21) can be transformed as

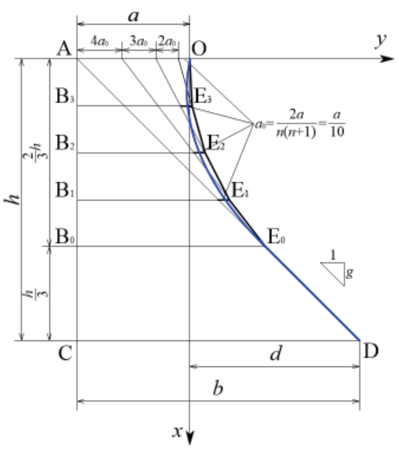

Figure 2. Example of warping curve (blue) based on GM that overhangs but does not hang over sectional shape when $n = 4$

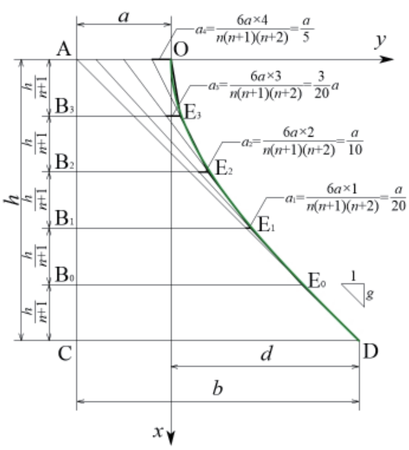

Figure 3. Design method for sectional shape based on *Sekisho Sho* (SS, for $n = 4$) and warping curve for $n \to \infty$ (green)

$$y = \frac{1}{h}\left\{b - \frac{3a\frac{k}{n}\left(\frac{k}{n}+\frac{1}{n}\right)}{1+\frac{2}{n}}\right\}x + a\frac{\frac{k}{n}\left(\frac{k}{n}+\frac{1}{n}\right)\left(3-2\frac{k}{n}+\frac{2}{n}\right)}{\left(1+\frac{1}{n}\right)\left(1+\frac{2}{n}\right)} - a. \quad (21')$$

If we replace $\frac{k}{n}$ with variable t and let $n \to \infty$, we have

$$y = \frac{1}{h}(b - 3at^2)x - at^2(2t-3) - a. \quad (22)$$

Multiplying both sides by h and transposing so that the right side is zero, we have

$$hy - (b - 3at^2)x + aht^2(2t-3) + ah = 0. \quad (23)$$

Partial differentiation of both sides by t yields

$$6atx + ah(6t^2 - 6t) = 0. \quad (24)$$

Because $t = \frac{k}{n}$ is not identically zero,

$$t = 1 - \frac{x}{h}. \quad (25)$$

Substituting this into (22), we have

$$y = -a\left(\frac{x}{h} - 1\right)^3 + \frac{b}{h}x - a. \quad (26)$$

This envelope passes through two points, D and O. From the above, the sectional shape between D and O can be approximated by a quadratic function (Figure 3). Nishida et al. (2003) derived this cubic function almost the same as this one with the origin at point A. It is the same mathematical formula as the one in (26) with the $-a$ term removed[3], and it is the same curve. Let this be the warping curve between D and O.

2.2.3. Redefinition of Mathematical Formula for Warping Curve of SS

If we rewrite (26) using depth $d = b - a$ and the gradient of line DE_0 $g = \frac{h}{b}$ (initial gradient) instead of a and b, we have

$$y = \left(d - \frac{h}{g}\right)\left(\frac{x}{h} - 1\right)^3 + \frac{1}{g}x + d - \frac{h}{g}. \quad (27)$$

The initial gradient of the *ishigaki* is defined as the gradient of one of the $n + 1$ from the bottom of the wall. Therefore, the larger n is, the more difficult it becomes to measure accurately on the actual *ishigaki*.

There is also a problem in treating this initial gradient as equivalent to the initial gradient of the GM, which is the lower third gradient of the *ishigaki*. Therefore, instead of the initial gradient g, we use the average gradient g_t of the lower third of the *ishigaki* (hereinafter referred to as the lower third gradient), which corresponds to the initial gradient of the GM, to represent the warping curve. Specifically, as shown in Figure 4, let E_t be the intersection point between the warping curve and line $x = \frac{2}{3}h$, and let g_t be the reciprocal of the slope of line DE_t. According to (26) and (27), because the y-coordinate of Et is $\frac{2}{3}\left(b - \frac{13}{9}a\right) = \frac{2}{27}\left(13d - \frac{4h}{g}\right)$,

$$g_t = \frac{9h}{9b - a} = \frac{9}{\frac{d}{h} + \frac{8}{g}}. \quad (28)$$

Substituting

$$\frac{1}{g} = \frac{1}{8}\left(\frac{9}{g_t} - \frac{d}{h}\right) \quad (29)$$

into (27), we have

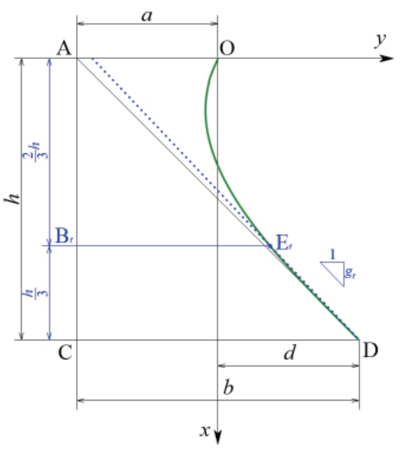

Figure 4. Example of overhang of warping curve (green) based on SS and definition of lower third gradient g_t

$$y = \frac{9}{8}\left(d - \frac{h}{g_t}\right)\left(\frac{x}{h} - 1\right)^3 - \frac{1}{8}\left(\frac{d}{h} - \frac{9}{g_t}\right)x + \frac{9}{8}\left(d - \frac{h}{g_t}\right). \quad (30)$$

2.2.4. Condition for No Overhang for Warping Curve of SS

Differentiating both sides of equation (26) by x, we have

$$\frac{dy}{dx} = -\frac{3a}{h}\left(\frac{x}{h} - 1\right)^2 + \frac{b}{h}. \quad (31)$$

Because $x \leq h$,

$$\frac{d^2y}{dx^2} = -\frac{6a}{h^2}\left(\frac{x}{h} - 1\right) \geq 0. \quad (32)$$

Therefore, $\frac{dy}{dx}$ is monotonically increasing for $0 \leq x \leq h$. Because

$$\left.\frac{dy}{dx}\right|_{x=h} = \frac{b}{h} > 0, \quad (33)$$

the condition that $y \geq 0$ for $0 \leq x \leq h$ is

$$\left.\frac{dy}{dx}\right|_{x=0} = -\frac{3a}{h} + \frac{b}{h} \geq 0. \quad (34)$$

Therefore, we have

$$b \geq 3a. \quad (35)$$

This is the same as (12), indicating that the condition for the top of the *ishigaki* to not overhang is the same as in the GM. If we rewrite the condition using the initial gradient g instead of the upper and lower bottoms a and b, we also get

$$\frac{2h}{3d} \leq g < \frac{h}{d} \quad (36)$$

as in the GM. Further rewriting the condition in (36) using the lower third gradient g_t, we have

$$\frac{9h}{13d} \leq g_t < \frac{h}{d} \quad (37)$$

according to (29). Because $\frac{2h}{3d} < \frac{9h}{13d}$, the condition for no overhang is more severe for the SS than for the GM, where $g = g_t$, when compared with the lower third gradient. The lower third gradient of SS must be greater than or equal to 9/13 of the average gradient of the entire *ishigaki* to avoid overhang.

2.2.5. Practical Condition for No Overhang for Ishigaki by SS

In practical use, n is a finite natural number. Therefore, there is no problem if section $E_{n-1}O$ of the uppermost *ishigaki* does not overhang, i.e., the slope of line $E_{n-1}E_n$ is greater than or equal to zero. According to (21),

$$\frac{1}{h}\left\{b - \frac{3a(n+1)}{n+2}\right\} \geq 0. \quad (38)$$

Therefore, to divide line segment AB0 into n equal parts, i.e., to divide line segment AC into $n + 1$ equal parts, it is sufficient to satisfy the condition

$$b \geq 3a\left(1 - \frac{1}{n+2}\right). \quad (39)$$

If we rewrite this condition with d, h, and g, we have

$$\frac{h}{3d}\left(2 - \frac{1}{n+1}\right) \leq g < \frac{h}{d}. \quad (40)$$

If $n \to \infty$, (39) and (40) coincide with (35) and (36), respectively.

We also consider rewriting the condition in (40) using the lower third gradient. g_t is the lower third gradient of the curve when $n \to \infty$. Because n in (40) is a finite natural number, we find the lower third gradient g_{tn} when n is a finite natural number. Specifically, as shown in Figure 5, let E_{tn} be the intersection point between sectional shape $DE_0E_1 \cdots E_{n-1}O$ and line $x = \frac{2}{3}h$, and let g_{tn} be the reciprocal of the slope of line DE_{tn}. According to (21), the y-coordinate of E_{tn} can be expressed as $\frac{2}{3}b + a\frac{k(k+1)(n-2k)}{n(n+1)(n+2)} - a$, and we have

$$g_{tn} = \frac{h}{b - 3a\dfrac{k(k+1)(n-2k)}{n(n+1)(n+2)}}. \quad (41)$$

Let l be a natural number.

(i) If $n = 3l - 2$,

because E_{tn} lies on line segment $\mathrm{E}_{l-2}\mathrm{E}_{l-1}$ (but with $\mathrm{E}_{-1} = \mathrm{D}$), $k = l - 1 = \frac{n-1}{3}$, and

$$g_{tn} = \frac{9n(n+1)}{\dfrac{2(2n+1)^2}{g} + \dfrac{d}{h}(n-1)(n+2)}. \quad (42)$$

Substituting

$$\frac{1}{g} = \frac{1}{2(2n+1)^2}\left\{\frac{9}{g_{tn}}n(n+1) - \frac{d}{h}(n-1)(n+2)\right\} \quad (43)$$

into (40), we have

$$\frac{h}{3d}\left(2 - \frac{1}{n+1}\right) \leq \frac{2(2n+1)^2}{\dfrac{9}{g_{tn}}n(n+1) - \dfrac{d}{h}(n-1)(n+2)}. \quad (44)$$

Therefore,

$$\frac{9n(n+1)h}{(13n^2+19n+4)d} \leq g_{tn} < \frac{h}{d} \quad (n = 1,4,7,\cdots). \quad (45)$$

The range of g_{tn} obtained here agrees with (37) when n→∞.

(ii) If $n = 3l - 1$,

because $\mathrm{E}_{tn} = \mathrm{E}_{l-1}$, $k = l - 1 = \frac{n-2}{3}$, and

$$g_{tn} = \frac{9n(n+2)}{\dfrac{8(n+1)^2}{g} + \dfrac{d}{h}(n-2)(n+4)}. \quad (46)$$

Substituting

$$\frac{1}{g} = \frac{1}{8(n+1)^2}\left\{\frac{9}{g_{tn}}n(n+2) - \frac{d}{h}(n-2)(n+4)\right\} \quad (47)$$

into (40), we have

$$\frac{h}{3d}\left(2 - \frac{1}{n+1}\right) \leq \frac{8(n+1)^2}{\dfrac{9}{g_{tn}}n(n+2) - \dfrac{d}{h}(n-2)(n+4)}. \quad (48)$$

Therefore,

$$\frac{9n(2n+1)h}{(26n^2+25n+8)d} \leq g_{tn} < \frac{h}{d} \quad (n = 2,5,8,\cdots). \quad (49)$$

The range of g_{tn} obtained here agrees with (37) when n→∞.

(iii) If $n = 3l$,

because E_{tn} lies on line segment $\mathrm{E}_{l-1}\mathrm{E}_{l}$, $k = l = \frac{n}{3}$, and

$$g_{tn} = \frac{9(n+1)(n+2)}{\dfrac{2(2n+3)^2}{g} + \dfrac{d}{h}n(n+3)}. \quad (50)$$

Substituting

$$\frac{1}{g} = \frac{1}{2(2n+3)^2}\left\{\frac{9}{g_{tn}}(n+1)(n+2) - \frac{d}{h}n(n+3)\right\} \quad (51)$$

into (40), we have

$$\frac{h}{3d}\left(2 - \frac{1}{n+1}\right) \leq \frac{2(2n+3)^2}{\dfrac{9}{g_{tn}}(n+1)(n+2) - \dfrac{d}{h}n(n+3)}. \quad (52)$$

Therefore,

$$\frac{9(n+1)(2n+1)h}{(26n^2+51n+27)d} \leq g_{tn} < \frac{h}{d} \quad (n = 3,6,9,\cdots). \quad (53)$$

The range of g_{tn} obtained here agrees with (37) when n→∞.

2.3. *ISHIGAKI HIDEN-NO-SHO* (IH)

The *Ishigaki Hiden-no-sho* (IH), which means "*Ishigaki* Secret Document," was already known in the *Kitagawa-bon*, written in 1743 by Sakubei Kitagawa, *ano* of the Kumamoto-han (Kumamoto Domain, based at Kumamoto Castle; Kyushu Research Institute for Cultural Properties, 2001). In recent years, the *Noguchi-bon*, written in 1680, was also reprinted by the Ishikawa Prefectural Research Institute of Kanazawa Castle (2011). The contents of the two versions are almost identical.

2.3.1. Design Method by IH

According to Kitagaki (1987) and Nishida et al. (2003), the design method described in IH can be formulated as follows from (a) to (f). In Figure 6, as in Figures 1 and 3, the upper end of the curve is the origin O, the x-axis is downward vertical, and the y-axis is outward horizontal (in front of the *ishigaki*).

(a) Determine the height $h = \mathrm{AC}$, the upper bottom $a = \mathrm{OA}$, and the lower bottom $b = \mathrm{CD}$.

(b) Divide line segment AC into equal parts by natural number $n+1$, and let $\mathrm{B}_0, \mathrm{B}_1, \ldots, \mathrm{B}_{n-1}$ be the points closest to C in order.

(c) The sectional shape of part n+1 from the bottom, i.e., $\frac{n}{n+1}h \leq x \leq h$, is line DA. Let this sectional shape be line segment DE_0, which is $\mathrm{E}_0\left(\frac{n}{n+1}h, \frac{n}{n+1}b - a\right)$, and

$$\mathrm{DE}_0\colon\ y = \frac{b}{h}x - a. \quad (54)$$

(d) At $i = 1,2,\cdots,n$, we define a_i by

$$a_i = \frac{a}{n(n-i+1)}. \quad (55)$$

(e) The point that protrudes a_1 from the intersection of the straight line drawn horizontally from B_1 in the direction of the y-axis and straight line DE_0 to the front of the *ishigaki* is $\mathrm{E}_1\left(\frac{n-1}{n+1}h, \frac{n-1}{n+1}b + a_1 - a\right)$. The sectional shape of the part with $\frac{n-1}{n+1}h \leq x \leq \frac{n}{n+1}h$ is

$$\mathrm{E}_0\mathrm{E}_1\colon y = \frac{1}{h}\left\{b - \frac{a}{n}\left(1 + \frac{1}{n}\right)\right\}x + \frac{a}{n} - a. \quad (56)$$

(f) Similarly, when $2 \leq k \leq n-1$, the point that protrudes a_k from the intersection of the straight line drawn horizontally from B_k in the direction of the y-axis and straight line $\mathrm{E}_{k-2}\mathrm{E}_{k-1}$ to the front of the *ishigaki* can be obtained inductively as $\mathrm{E}_k\left(\frac{n-k}{n+1}h, \frac{n-k}{n+1}b + \sum_{i=1}^{k}(k-i+1)a_i - a\right)$. The sectional shape of the part with $\frac{n-k}{n+1}h \leq x \leq \frac{n-k+1}{n+1}h$ is

$$\mathrm{E}_{k-1}\mathrm{E}_k\colon y = \frac{1}{h}\left\{b - a\left(1 + \frac{1}{n}\right)\sum_{i=1}^{k}\frac{1}{n-i+1}\right\}x + a\frac{k}{n} - a. \quad (57)$$

If $\mathrm{D} = \mathrm{E}_{-1}$ and $\mathrm{O} = \mathrm{E}_n$, and we define $\sum_{i=1}^{0}\frac{1}{n-i+1} = 0$, then (57) is valid for $0 \leq k \leq n$. Therefore, sectional shape

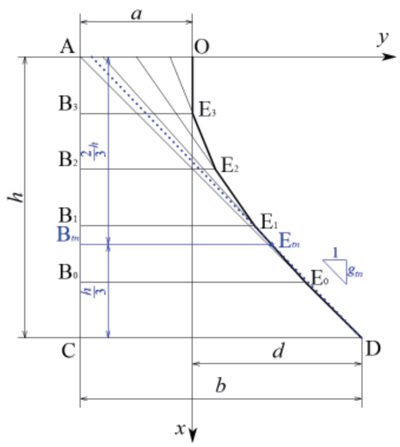

Figure 5. Definition of lower third gradient g_{tn} for case $n = 4$ in sectional shape based on SS

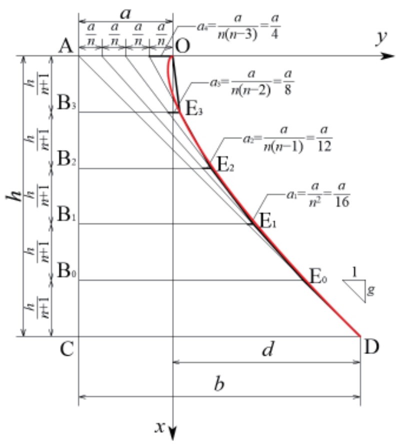

Figure 6. Design method for sectional shape based on *Ishigaki Hiden-no-sho* (IH, for $n = 4$) and warping curve for $n \to \infty$ (red)

$\mathrm{DE_0E_1 \cdots E_{n-1}O}$ can be determined by (57).

2.3.2. Derivation of Warping Curve Based on Design Method of IH

Here, by finding the envelope of sectional shape $\mathrm{DE_0E_1 \cdots E_{n-1}O}$, we obtain a warping curve that approximates the sectional shape between D and O when $n \to \infty$. If $f(x)$ is a Riemann integrable,

$$\lim_{n\to\infty} \frac{b-a}{n}\sum_{j=1}^{n} f\left(a+(b-a)\frac{j}{n}\right) = \int_a^b f(x)dx. \quad (58)$$

If $a = 1, b = n+1, f(x) = \frac{1}{x}$, we have

$$\lim_{n\to\infty}\sum_{j=1}^{n}\frac{1}{j+1} = \lim_{n\to\infty}\log(n+1). \quad (59)$$

If we substitute n for $n-k$ in this equation, we have

$$\lim_{n\to\infty}\sum_{j=1}^{n-k}\frac{1}{j+1} = \lim_{n\to\infty}\log(n-k+1). \quad (60)$$

Therefore,

$$\begin{aligned}\lim_{n\to\infty}&\sum_{i=1}^{k}\frac{1}{n-i+1}\\ &= \lim_{n\to\infty}\left(\sum_{j=1}^{n}\frac{1}{j+1}-\frac{1}{n+1}-\sum_{j=1}^{n-k}\frac{1}{j+1}+\frac{1}{n-k+1}\right)\\ &= \lim_{n\to\infty}\{\log(n+1)-\log(n-k+1)\}\\ &= \lim_{n\to\infty}\log\left(\frac{1+\frac{1}{n}}{1-\frac{k}{n}+\frac{1}{n}}\right). \quad (61)\end{aligned}$$

Now, if we set $\frac{k}{n} = t$ to find the envelope,

$$\lim_{n\to\infty}\sum_{i=1}^{k}\frac{1}{n-i+1} = \log\left(\frac{1}{1-t}\right) = -\log(1-t). \quad (62)$$

Therefore, in (57), if we replace $\frac{k}{n}$ with variable t and let $n \to \infty$, we have

$$y = \frac{1}{h}\{b + a\log(1-t)\}x + at - a. \quad (63)$$

Multiplying both sides by h and transposing so that the right side is zero, we have

$$hy - \{b + a\log(1-t)\}x - aht + ah = 0. \quad (64)$$

Partial differentiation of both sides by t yields

$$\frac{a}{1-t}x - ah = 0. \quad (65)$$

If we find t,

$$t = 1 - \frac{x}{h}. \quad (66)$$

Substituting this into (63), we have

$$y = \frac{1}{h}(b-a)x + \frac{a}{h}x\log\left(\frac{x}{h}\right). \quad (67)$$

This envelope passes through D. Also, (67) is defined in the range of $x > 0$, but according to L'Hôpital's rule,

$$\lim_{x\to+0} x\log\left(\frac{x}{h}\right) = \lim_{x\to+0}\frac{\log\left(\frac{x}{h}\right)}{\frac{1}{x}} = \lim_{x\to+0}\frac{\frac{1}{x}}{-\frac{1}{x^2}} = 0. \quad (68)$$

Therefore, when $x \to +0$, y approaches 0, i.e., the origin O. From the above, the curve defined by (67) is a curve that approximates the sectional shape between D and O (Figure 6).

Yanai (1988) derived this function with the origin at point A. It is the same as the right side of (67) with the addition of term a, and it is the same curve. The same is true for the function shown by Nishida et al. (2003)[4]. Let this be the warping curve between D and O.

2.3.3. Redefinition of Mathematical Formula for Warping Curve of IH

If we rewrite (67) using the depth $d = b - a$ and the gradient of line $\mathrm{DE_0}$ $g = \frac{h}{b}$ (initial gradient) instead of a and b, we have

$$y = \frac{d}{h}x + \left(\frac{1}{g} - \frac{d}{h}\right)x\log\left(\frac{x}{h}\right). \quad (69)$$

In the same way as in the SS, let $\mathrm{E_t}$ be the intersection point between the warping curve and line $x = \frac{2}{3}h$, and let g_t be the reciprocal of the slope of line $\mathrm{DE_t}$ to get the lower third gradient g_t, which corresponds to the initial gradient of the GM. According to (67) and (69), because the y-coordinate of Et is $\frac{2}{3}(b-a) - \frac{2}{3}a\log\left(\frac{3}{2}\right) = \frac{2}{3}d - \frac{2}{3}\left(\frac{h}{g} - d\right)\log\left(\frac{3}{2}\right)$,

$$g_t = \frac{h}{b - a + 2a\log\left(\frac{3}{2}\right)} = \frac{h}{d + 2\left(\frac{h}{g} - d\right)\log\left(\frac{3}{2}\right)}. \quad (70)$$

Substituting

$$\frac{1}{g} = \frac{d}{h} + \frac{\frac{1}{g_t} - \frac{d}{h}}{2\log\left(\frac{3}{2}\right)} \quad (71)$$

into (69), we have

$$y = \frac{d}{h}x + \frac{\frac{1}{g_t} - \frac{d}{h}}{2\log\left(\frac{3}{2}\right)}x\log\left(\frac{x}{h}\right). \quad (72)$$

2.3.4. Practical Condition for No Overhang for Ishigaki by IH

Differentiating both sides of (67) by x,

$$\frac{dy}{dx} = \frac{b}{h} + \frac{a}{h}\log\left(\frac{x}{h}\right). \quad (73)$$

Therefore,

$$\lim_{x\to+0}\frac{dy}{dx} = -\infty. \quad (74)$$

Because the slope of the curve based on the IH is negative near the origin O, as Fujii (2018) already pointed out, the upper part of the curve always overhangs, at least locally. However, for practical use, n is a finite natural number. Therefore, if section $\mathrm{E_{n-1}O}$ of the uppermost *ishigaki* does not overhang, i.e., the slope of line $\mathrm{E_{n-1}E_n}$ is greater than or equal to zero, there is no problem. According to (57),

$$\frac{1}{h}\left\{b - a\left(1+\frac{1}{n}\right)\sum_{i=1}^{n}\frac{1}{n-i+1}\right\} \geq 0. \quad (75)$$

Therefore, to divide line segment $\mathrm{AB_0}$ into n equal parts, i.e., to divide line segment AC into $n+1$ equal parts, it is sufficient to satisfy the condition of

$$b \geq a\left(1+\frac{1}{n}\right)\sum_{i=1}^{n}\frac{1}{i}. \quad (76)$$

Also, if we rewrite the condition using the initial gradient g instead of the upper and lower bottoms a and b, because a is not positive when $g \geq \frac{h}{d}$,

$$\frac{h}{d}\left\{1 - \frac{1}{\left(1+\frac{1}{n}\right)\sum_{i=1}^{n}\frac{1}{i}}\right\} \leq g < \frac{h}{d}. \quad (77)$$

We also consider rewriting the condition in (77) using the lower third gradient. We find the lower third gradient g_{tn} when n is a finite natural number, as in the SS. Specifically, let E_{tn} be the intersection point between sectional shape $\mathrm{DE_0E_1 \cdots E_{n-1}O}$ and line $x = \frac{2}{3}h$, and let g_{tn} be the reciprocal of the slope of line DE_{tn}. According to (57), the y-coordinate of E_{tn} can be expressed as $\frac{2}{3}\left\{b - a\left(1+\frac{1}{n}\right)\sum_{i=1}^{k}\frac{1}{n-i+1}\right\} + a\frac{k}{n} - a$, and we have

$$g_{tn} = \frac{h}{b + a\left(1+\frac{1}{n}\right)\sum_{i=1}^{k}\frac{1}{n-i+1} - 3a\frac{k}{n}}. \quad (78)$$

Let l be a natural number.

(i) If $n = 3l - 2$,

because E_{tn} lies on line segment $E_{l-2}E_{l-1}$ (but with $E_{-1} = D$), $k = l - 1 = \frac{n-1}{3}$. For $k \geq 1$, that is, $n \geq 4$,

$$g_{tn} = \frac{1}{\frac{1}{g} + \left(\frac{1}{g} - \frac{d}{h}\right)\left\{2\left(1+\frac{1}{n}\right)\sum_{i=1}^{\frac{n-1}{3}}\frac{1}{n-i+1} - 1 + \frac{1}{n}\right\}}. \quad (79)$$

Substituting

$$\frac{1}{g} = \frac{1}{\frac{1}{n} + 2\left(1+\frac{1}{n}\right)\sum_{i=\frac{2(n+2)}{3}}^{n}\frac{1}{i}}\left(\frac{1}{g_{tn}} - \frac{d}{h}\right) + \frac{d}{h} \quad (80)$$

into (77), we have

$$\frac{h}{d}\left\{1 - \frac{1}{\left(1+\frac{1}{n}\right)\sum_{i=1}^{n}\frac{1}{i}}\right\} \leq \frac{1}{\frac{1}{\frac{1}{n} + 2\left(1+\frac{1}{n}\right)\sum_{i=\frac{2(n+2)}{3}}^{n}\frac{1}{i}}\left(\frac{1}{g_{tn}} - \frac{d}{h}\right) + \frac{d}{h}}. \quad (81)$$

Therefore,

$$\frac{h}{d}\left(\frac{\sum_{i=1}^{n}\frac{1}{i} - 1 + \frac{1}{n+1}}{3\sum_{i=1}^{n}\frac{1}{i} - 2\sum_{i=1}^{\frac{2n+1}{3}}\frac{1}{i} - 1 + \frac{2}{n+1}}\right) \leq g_{tn} < \frac{h}{d}$$

$$(n = 4, 7, 10, \cdots). \quad (82)$$

If $k = 0$, that is, $n = 1$, because the y-coordinate of E_{t1} is $\frac{2}{3}b - a$,

$$g_{t1} = \frac{h}{b} = g. \quad (83)$$

According to (77),

$$\frac{h}{2d} \leq g_{t1} < \frac{h}{d}. \quad (84)$$

This (84) is equal to (82) with $n = 1$ substituted.

(ii) If $n = 3l - 1$,

because $E_{tn} = E_{l-1}$, $k = l - 1 = \frac{n-2}{3}$. For $k \geq 1$, that is, $n \geq 5$,

$$g_{tn} = \frac{1}{\frac{1}{g} + \left(\frac{1}{g} - \frac{d}{h}\right)\left\{2\left(1+\frac{1}{n}\right)\sum_{i=1}^{\frac{n-2}{3}}\frac{1}{n-i+1} - 1 + \frac{2}{n}\right\}}. \quad (85)$$

Substituting

$$\frac{1}{g} = \frac{1}{\frac{2}{n} + 2\left(1+\frac{1}{n}\right)\sum_{i=\frac{2n+5}{3}}^{n}\frac{1}{i}}\left(\frac{1}{g_{tn}} - \frac{d}{h}\right) + \frac{d}{h} \quad (86)$$

into (77), we have

$$\frac{h}{d}\left\{1 - \frac{1}{\left(1+\frac{1}{n}\right)\sum_{i=1}^{n}\frac{1}{i}}\right\} \leq \frac{1}{\frac{1}{\frac{2}{n} + 2\left(1+\frac{1}{n}\right)\sum_{i=\frac{2n+5}{3}}^{n}\frac{1}{i}}\left(\frac{1}{g_{tn}} - \frac{d}{h}\right) + \frac{d}{h}}. \quad (87)$$

Therefore,

$$\frac{h}{d}\left(\frac{\sum_{i=1}^{n}\frac{1}{i} - 1 + \frac{1}{n+1}}{3\sum_{i=1}^{n}\frac{1}{i} - 2\sum_{i=1}^{\frac{2(n+1)}{3}}\frac{1}{i} - 1 + \frac{3}{n+1}}\right) \leq g_{tn} < \frac{h}{d}.$$

$$(n = 5, 8, 11, \cdots). \quad (88)$$

If $k = 0$, that is, $n = 2$, because the y-coordinate of E_{t2} is $\frac{2}{3}b - a$,

$$g_{t2} = \frac{h}{b} = g. \quad (89)$$

According to (77),

$$\frac{5h}{9d} \leq g_{t2} < \frac{h}{d}. \quad (90)$$

This (90) is equal to (88) with $n = 2$ substituted.

(iii) If $n = 3l$,

because E_{tn} lies on line segment $E_{l-1}E_l$, $k = l = \frac{n}{3}$, and

$$g_{tn} = \frac{1}{\frac{1}{g} + \left(\frac{1}{g} - \frac{d}{h}\right)\left\{2\left(1+\frac{1}{n}\right)\sum_{i=1}^{\frac{n}{3}}\frac{1}{n-i+1} - 1\right\}}. \quad (91)$$

Substituting

$$\frac{1}{g} = \frac{1}{2\left(1+\frac{1}{n}\right)\sum_{i=\frac{2}{3}n+1}^{n}\frac{1}{i}}\left(\frac{1}{g_{tn}} - \frac{d}{h}\right) + \frac{d}{h} \quad (92)$$

into (77), we have

$$\frac{h}{d}\left\{1 - \frac{1}{\left(1+\frac{1}{n}\right)\sum_{i=1}^{n}\frac{1}{i}}\right\} \leq \frac{1}{\frac{1}{2\left(1+\frac{1}{n}\right)\sum_{i=\frac{2}{3}n+1}^{n}\frac{1}{i}}\left(\frac{1}{g_{tn}} - \frac{d}{h}\right) + \frac{d}{h}}. \quad (93)$$

Therefore,

$$\frac{h}{d}\left(\frac{\sum_{i=1}^{n}\frac{1}{i} - 1 + \frac{1}{n+1}}{3\sum_{i=1}^{n}\frac{1}{i} - 2\sum_{i=1}^{\frac{2}{3}n}\frac{1}{i} - 1 + \frac{1}{n+1}}\right) \leq g_{tn} < \frac{h}{d}$$

$$(n = 3, 6, 9, \cdots). \quad (94)$$

3. Comparison of Practical Conditions for No Overhang for *Ishigaki*

Figure 7 shows the results of comparing the conditions of the initial gradient where the top of the *ishigaki* does not overhang in practical use with the lower limit of $\frac{gd}{h}$ (the ratio of the initial gradient to the average gradient of the entire *ishigaki*) obtained by (16), (40), and (77).

One problem that arose during the comparison is that, for example, when designing an *ishigaki* by dividing its entire height into six equal parts, the *Goto-ke Monjo* (GM, Figure 1) divides its upper two-thirds into n equal parts, resulting in $n = 4$, while the *Sekisho Sho* (SS, Figure 3) and *Ishigaki Hiden-no-sho* (IH, Figure 6) divide the entire *ishigaki* into $n + 1$ equal parts, resulting in $n = 5$. As shown in this example, even if an *ishigaki* of the same height is divided into equal parts at the same interval, n differs depending on the design method. Therefore, the number of divisions (m), which indicates the number of divisions of the entire *ishigaki*, was taken as the horizontal axis for comparison. In the SM, $m = \frac{3}{2}n$ was used, and the height of the *ishigaki* was considered to be divided into $\frac{3}{2}n$ equal parts from the top. In the SS and IH, $m = n + 1$ was used.

The GM and SS both have a $\frac{gd}{h}$ of $\frac{2}{3}$ when $n \to \infty$, but the convergence is slower in the GM than in the SS. Therefore, if n is finite, the conditions of the GM are looser than those of the SS. On the other hand, the IH has the biggest $\frac{gd}{h}$ for all n, and the conditions are more severe.

In the same way, the results for the lower third gradient condition, where the top of the *ishigaki* does not overhang in practical use, are compared at the lower limit of $\frac{g_{tn}d}{h}$ (the ratio of the initial gradient to the average gradient of the entire *ishigaki*) in Figure 8. In the GM, $\frac{g_{tn}d}{h} = \frac{gd}{h}$ because the initial gradient and the lower third gradient are equal. The values of the SS are (45), (49), and (53), and the values of the IH are (82), (84), (88), (90), and (94). Comparing with Figure 7, it can also be seen that the conditions for the GM are the loosest, and those for the IH are the strictest, but the conditions for the SS and the IH are stricter than in Figure 7.

4. Comparison with Photogrammetric Results of Edges of *Ishigaki* at Hikone Castle

The three warping curves with the formula redefined for the lower third gradient were compared with the photogrammetric results obtained at three places near the edges of the *ishigaki* at Hikone Castle (Umezaki et al., 2021)[5]. The procedure was as follows from (i) to (iii).

(i) The point clouds of the photogrammetric results near the three edges were parallel projected at the two angles shown in Figure 9. In reality, people observe *ishigaki* from different angles. However, in this paper, we decided to project the *ishigaki* not from the front elevation but from the angle rotated by 30 degrees[6]. By doing so, the curve of the edge of the *ishigaki* not only becomes an occluding edge (Gibson, 1979), but unevenness in the *ishigaki* on the back side does not appear as well, making it easier to observe the edge.

(ii) We measured the depth d and the lower third gradient g_t from the height h shown in the previous report and the projection of the point cloud from the photogrammetry results (Table 1). According to the angle of the projection, d is $\frac{2}{\sqrt{3}}$ times the value measured on the projection plane, and g_t is $\frac{\sqrt{3}}{2}$ times the value because the width of the projection of the *ishigaki* in Figures 10, 11, and 12 is $\frac{\sqrt{3}}{2}$ times its elevation[7].

(iii) Substituting h and the measured d and g_t into (10), (30), and (72), the three kinds of warping curves of each *ishigaki* and the projection were drawn and compared with the point clouds of the photogrammetric results [$g = g_t$ in (10) for GM]. The results of substituting h, d, and g_t of TS-L, NS-L, and TY-L in Table 1 into the equations and comparing them with the point clouds of the photogrammetric results are shown in Figures 10, 11, and 12.

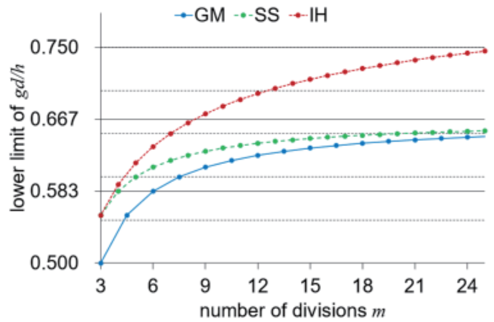

Figure 7. Comparison of initial gradient conditions where *ishigaki* does not overhang for practical use

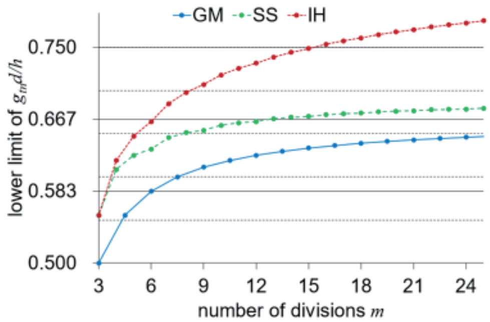

Figure 8. Comparison of lower third gradient conditions where *ishigaki* does not overhang for practical use

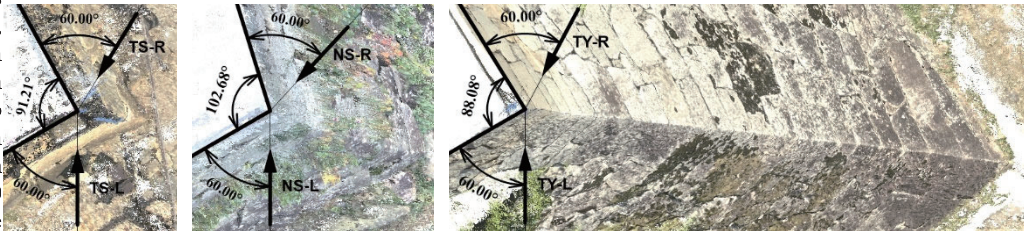

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Figure 9. Plan for each photogrammetric result for each *ishigaki* and angles of projection S=1:100

Table 1. Measurement results for height h, depth d, and lower third gradient g_t of each *ishigaki* and projection

ishigaki-projection	h[mm]	d[mm]	g_t
TS-L	4,239	964	2.753
TS-R		955	2.737
NS-L	5,864	2,400	1.902
NS-R		2,166	2.137
TY-L	10,680	6,960	1.292
TY-R		6,508	1.379

4.1. COMPARISON WITH *ISHIGAKI* OF *TENSHU* (Figure 10)

This *ishigaki* was built between 1604 and 1607 during the construction of Hikone Castle. Most of the stones are roughly split and processed, and there are few hewn stones. It is considered to be one of the earliest *ishigaki* at Hikone Castle (Hikone Educational Bureau, 2010). The photogrammetry was done near the southwest edge.

Because the value of $\frac{g_t d}{h}$ is 0.626 for TS-L and 0.617 for TS-R, which are smaller than $\frac{2}{3} \simeq 0.667$, all three types of warping curves had an overhang. Moreover, because the stones of the edge are stacked in eight tiers, if we assume that the height of the *ishigaki* is divided into eight equal parts and $n = 7$ in (45) and (82), the lower limit of Figure 8 is 0.651 in the SS and 0.698 in the IH. Therefore, the *ishigaki* designed with the SS and IH are considered to overhang even in practical use. The GM does not correspond to the eighth division of the height of the *ishigaki*, but if we assume that it is divided into nine equal parts and $n = 6$ in (16), the lower limit is 0.611, which is smaller than 0.617. Therefore, if we design this *ishigaki* with the GM, it will not have an overhang in practical use.

Due to the low quality of the stone processing, it is difficult to find a curve that is close, but the curve of the edge of this *ishigaki* is relatively closer to the curves in the GM and the SS than to the IH. The distance between the curves in the GM and the SS is less than 10 mm.

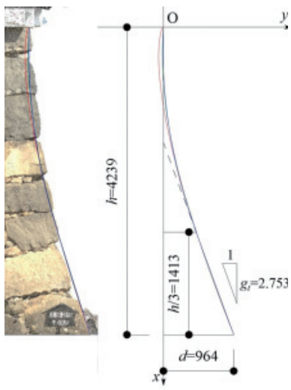

Figure 10. Curves of TS-L (right) and comparison with projection of photogrammetric result (left) S=1:100 (blue: GM, green: SS, red: IH). Width of projection (left) is $\frac{\sqrt{3}}{2} \simeq 0.866$ times that of actual *ishigaki*.

4.2. COMPARISON WITH *ISHIGAKI* OF *NISHINOMARU SANJU YAGURA* (Figure 11)

This *ishigaki* was repaired in 1852. The stones are hewn stone, which is highly processed, but old materials were used. Therefore, the size and shape of the stones are not very consistent (Hikone Educational Bureau, 2010). The photogrammetry was done near the northeast edge.

Because the value of $\frac{g_t d}{h}$ is 0.778 for NS-L and 0.789 for NS-R, which is larger than $\frac{9}{13} \simeq 0.692$, the warping curves based on the GM and the SS do not overhang. Moreover, because the stones of the edge are stacked in 13 tiers, if we assume that the height of the *ishigaki* is divided into 13 equal parts and $n = 12$ in (94) of the IH, the lower limit of Figure 8 is 0.739. Because $\frac{g_t d}{h}$ is larger than this value, the *ishigaki* designed by the SS will also not have an overhang in practical use. Therefore, we can say that no matter which design method is used to design this *ishigaki*, it will not have an overhang in practical use.

The curve of the edge of this *ishigaki* is relatively closer to the curves in the GM and the SS than to the IH. The distance between the curves in the GM and the SS is less than 11 mm.

4.3. COMPARISON WITH *ISHIGAKI* OF *TENBIN YAGURA* (Figure 12)

This *ishigaki* was re-stacked around 1854. Like the *Nishinomaru Sanju Yagura*, hewn stones are used, but the stones are processed into almost rectangular shapes, and the size and shape are relatively consistent. This is the most recent of the *ishigaki* at Hikone Castle from the Edo period (Hikone Educational Bureau, 2010). The photogrammetry was done near the northwest edge.

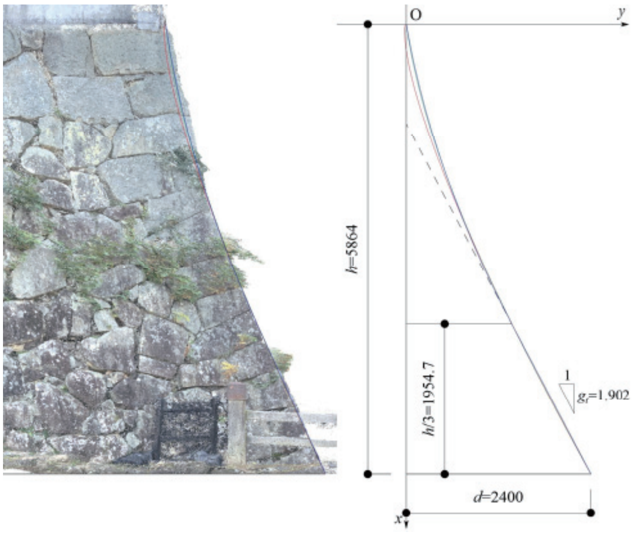

Figure 11. Curves of NS-L (right) and comparison with projection of photogrammetric result (left) S=1:100 (blue: GM, green: SS, red: IH). Width of projection (left) is $\frac{\sqrt{3}}{2} \simeq 0.866$ times that of actual *ishigaki*.

The value of $\frac{g_t d}{h}$ is 0.841 for TY-L and 0.840 for TY-R, which is larger than $\frac{9}{13} \simeq 0.692$. Therefore, the warping curves based on the GM and the SS do not overhang. Moreover, because the stones of the edge are stacked in 25 tiers, if we assume that the height of the *ishigaki* is divided into 25 equal parts and $n = 24$ in (94) of the IH, the lower limit of Figure 8 is 0.781. Because $\frac{g_t d}{h}$ is larger than this value, the *ishigaki* designed with the SS will also not overhang in practical use. Therefore, we can say that no matter which design method is used to design this *ishigaki*, it will not overhang in practical use.

The curve of the edge of the *ishigaki* is close to the curve of the IH except for the top four tiers. At the top, the curve is close to that of the GM and SS. The distance between the curves in the GM and the SS is less than 21 mm.

5. Conclusion

In this paper, we redefined the mathematical formulae for warping curves obtained from three documents describing the design methods of warping curves of *ishigaki* (stone walls) at Japanese castles, *Goto-ke Monjo* (GM), *Sekisho Sho* (SS), and *Ishigaki Hiden-no-sho* (IH), as mathematical formulae with parameters of depth, height, and initial gradient. We also proposed redefinitions of the mathematical formulae for the warping curves by selecting a lower third gradient (the average gradient of the lower third of the *ishigaki*) that is suitable for comparing differences in warping curves among the three design methods and existing *ishigaki* at castles. Furthermore, the conditions under which a warping curve based on each design method and an *ishigaki* designed on the basis of the methods do not overhang were compared. Finally, we compared the three redefined warping curves and the results of photogrammetry previously conducted near the edges of the *ishigaki* at Hikone Castle. The results of the study revealed the following.

1) In order for a warping curve based on the GM to not overhang, the initial gradient (equal to the lower third gradient) must be greater than

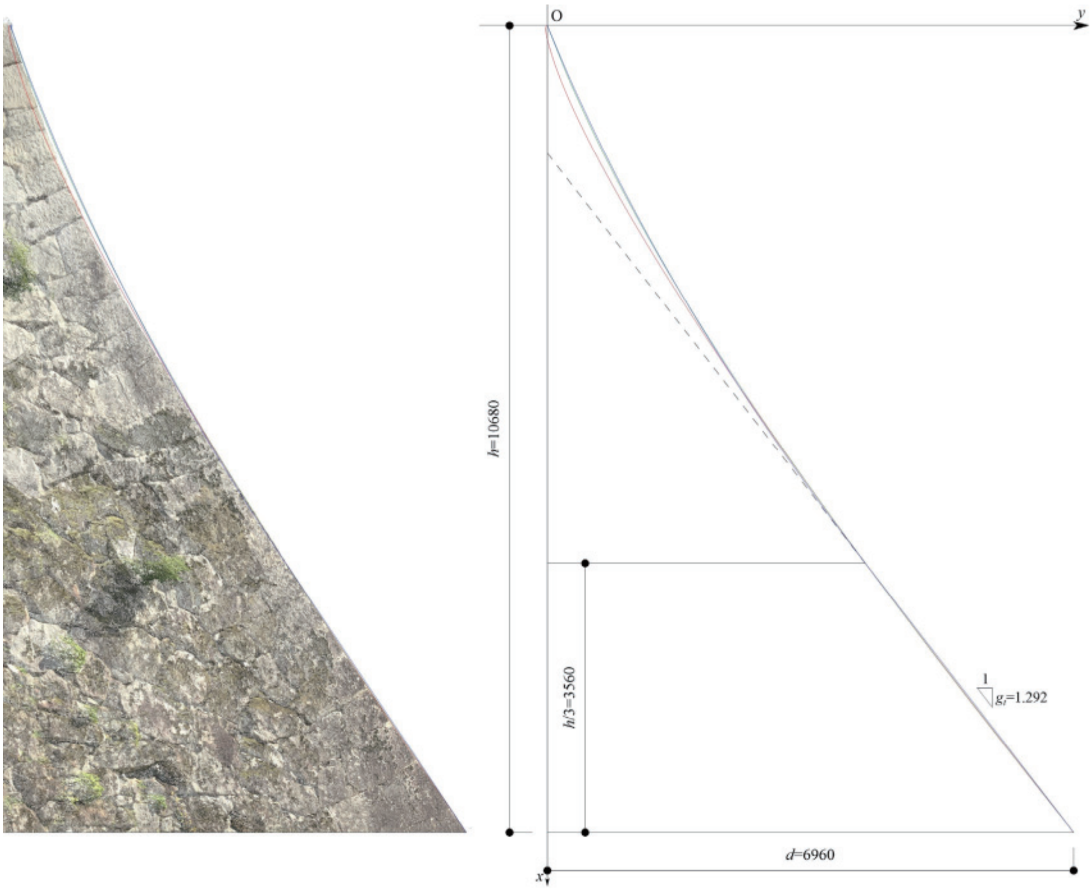

Figure 12. Curves of TY-L (right) and comparison with projection of photogrammetric result (left) S=1:100 (blue: GM, green: SS, red: IH). Width of projection (left) is $\frac{\sqrt{3}}{2} \simeq 0.866$ times that of actual *ishigaki*.

or equal to the average gradient of the entire *ishigaki*.
2) In order for a warping curve based on the SS to not overhang, the initial gradient must be greater than or equal to 2/3, or the lower third of the gradient must be greater than or equal to 9/13 of the average gradient of the entire *ishigaki*.
3) Comparing the conditions under which the tops of an *ishigaki* designed on the basis of each design method do not overhang, the conditions of the GM are the loosest, and those designed with the IH are the severest. The conditions in the SS and IH are more severe when compared with the same lower third gradient than when compared with the same initial gradient.
4) Substituting the depth, height, and lower third gradient of the three edges of the *ishigaki* at Hikone Castle into the mathematical formulae for the warping curves in the GM and the SS, we found that the two curves are close together, with only 10-21 mm separating them at most.
5) Under the conditions of the *ishigaki* of the *Tenshu*, the warping curve overhangs in all the design methods. However, considering the number of tiers of the *ishigaki*, the curve does not overhang in practical use only when it is designed on the basis of the GM.
6) Under the conditions of the *ishigaki* of the *Nishinomaru Sanju Yagura* and *Tenbin Yagura*, only the warping curves with the IH overhang, but considering the number of tiers of the *ishigaki*, none of the design methods cause overhangs in practical use.
7) The warping curves of the *ishigaki* of the *Tenshu* and the *Nishinomaru Sanju Yagura* are closer to the curves in the GM and the SS. The curve of the *ishigaki* of the *Tenbin Yagura*, which is the most recent *ishigaki* at Hikone Castle, is closer to the curve of the IH except for the uppermost four tiers.

Acknowledgements

This work was supported by JSPS KAKENHI Grant Numbers JP20K12520, JP21K13799, and JST CREST Grant Number JPMJCR1911.

Endnotes

1. Nishida et al. (2003), in their English abstract, refer to *Goto-ke Monjo* as *Gotou-ke Monjyo* and *Sekisho Sho* as *Sekishou-sho*.
2. The design method presented in the commentary by Bin Kinai at the end of the reprinted *Goto-ke Monjo* (Japan Sea Culture Research Institute, Kanazawa University, 1976) is different from that of this paper. In later years, Kinai (1988) presented two types of warping curves based on his design method, which are completely different from (9). However, Kinai's design method divides the upper bottom equally (see Figure 6). This idea is not shown in the *Goto-ke Monjo* and cannot be considered correct, as already pointed out by Morimoto et al. (2000).
3. Nishida et al. (2003) used $h_2 = \frac{n}{n+1}h$ and set $y = a\left(1 - \frac{x}{h_2}\right)^3 + \frac{b}{h}x$. Because $\lim_{n\to\infty} h_2 = h$, the mathematical formula becomes the same as (26) if we add term $-a$.
4. Nishida et al. (2003) used $h_2 = \frac{n}{n+1}h$ and set $y = \frac{a}{h_2}\left(\log\frac{x}{h_2} - 1\right) + \frac{b}{h}x + a$. Because $\lim_{n\to\infty} h_2 = h$, the mathematical formula becomes the same as (67) if we delete term $+a$.
5. Photogrammetry was conducted using Agisoft Metashape Professional. The photographs used for the photogrammetry were 100 of the *Tenshu*, 78 of the *Nishinomaru Sanju Yagura*, and 72 of the *Tenbin Yagura*, all of which were taken in November 2020.
6. In the previous paper (Umezaki et al. 2021), the angle of the projection was determined for each *ishigaki*. However, the angle is unified for all *ishigaki* in this paper.
7. The height h is the same as previously reported (Umezaki et al. 2021), but the depth d and the lower third gradient g_t were newly measured. Therefore, the upper bottom a and lower bottom b calculated from these values and the value of $g = g_t$ do not agree with the values estimated by the method based on the GM in the previous report. a and b cannot be measured directly from the photogrammetric results, but d and g_t can be measured. Therefore, the precision of measurements is considered to be improved.

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Intercultural Understanding, volume 11, pages 30-34

Environmental Factors and Material Characteristics Influencing the Deterioration of the Nikka Stone in the Former Koshien Hotel

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Keywords: Nikka stone, Tatsuyama stone, Defect state, Material properties, Hygrothermal properties, Environmental condition.

Abstract: Herein, we investigated the physical properties and microenvironments of the tuffs to identify the ways to conserve the two types of tuffs, Nikka and Tatsuyama, utilized in the former Koshien Hotel. We found that the deterioration properties were affected by the swelling of clay minerals in the stones, water transfer within the material, changes in surface temperature due to solar and nocturnal radiation, and differences in wet conditions caused by rainfall. Our findings specifically indicate that the deterioration of the Nikka stone is caused by freezing and that of the Tatsuyama stone is caused by repeated wetting and drying.

1. Introduction

The former Koshien Hotel in Nishinomiya City, Hyogo Prefecture, is a piece of modern architecture designed by Arata Endo and completed in 1930. After extensive renovations to repurpose the building as an educational facility, it is presently used by the Faculty of Architecture at the Mukogawa Women's University. The Nikka stone (from Komatsu, Ishikawa Prefecture), a tuff with a tint of yellow, is an essential aspect of this decorative building and is utilized on the exterior and interior. Currently, the Nikka stone that is used on the exterior is deteriorating in various ways. The Nikka stone is a valuable material that is no longer available because the quarries where it was mined have closed. Consequently, it is vital to determine why the stone is deteriorating and find ways to slow the progress. When the building was renovated, some stones were replaced by the yellow Tatsuyama stone (from Takasago, Hyogo Prefecture); however, this stone has also deteriorated.

These two types of stone are visually similar and difficult to distinguish. However, their defect states are different. Previously, the authors researched the deterioration properties of the stone used for the exterior of the former Koshien Hotel and identified two types of defects, i.e., large deficits and thin detachments. In that study, the authors attributed the difference in the defect states to the location or the microenvironment surrounding the stone (Uno & Noguchi, 2015). Moreover, it was proved that major defects were frequently observed in the Nikka stone and that thin detachment occurred in the Tatsuyama stone (Uno, Iba & Yamada, 2020). These findings suggest that, in addition to the environmental influence, material and hygrothermal properties have a significant effect on the state of deterioration.

Therefore, this study attempts to clarify the difference between the defect states of exterior of the Nikka and Tatsuyama stones with reference to the surrounding microenvironment and the stone's material properties. Therefore, we investigated the microenvironments of the deteriorated stone and the material and hygrothermal properties. Additionally, we estimated the deterioration mechanism for each stone.

2. Material and hygrothermal properties of the Nikka and Tatsuyama stones

The material properties of the samples examined are listed in Table 1, and the items measured in terms of hygrothermal properties are listed in Table 2.

2.1. STONE MATERIAL COMPONENTS

The components of the stone were qualitatively and quantitatively analyzed via X-ray diffraction analysis and thin section examination. Table 3 shows the main minerals that make up each type of stone.

The examination of the thin sections fragments revealed that Nikka stones are primarily formed of mordenite, a volcanic glass substitute for pumice, and contain traces of swellable clay minerals (smectites). The Tatsuyama stone is primarily comprised of quartz and albite, with traces of swellable clay minerals similar to those found in Nikka stones. Swellable clay minerals comprised overlappedplate-like crystals. They expand because of the absorption of water molecules between the plate-like crystals, which contract under dry conditions (Shirozu 2010). This expansion and shrinkage reduces the strength of the stone.

2.2. DENSITY AND PORE SIZE DISTRIBUTION

Images of the outer appearance of the Nikka and Tatsuyama stones are shown in Figure 1, and their physical properties are listed in Table 4. Pore size distribution is plotted in Figure 2.

It is evident from Figure 1 that the Nikka stone is more porous than the Tatsuyama stone. The holes in the Nikka stone are a few millimeters wide, whereas the Tatsuyama stone is quite dense. The dry density of Nikka stones, which contain many voids, is approximately half that of the Tatsuyama stones. In terms of water absorption ratio, which indicates the saturated moisture content of stones, the absorption ratio of the low-density Nikka stone is twelve times greater than that of the Tatsuyama stones.

Table 1 Material properties and measurement methods

Items	Measurement methods
Stone material components	Thin sections of stone were examined with a polarized microscope to confirm the constituent minerals and tissues[1].
Minerals in stone	Clay minerals that cannot be identified using a microscope were quantitatively identified using X-ray diffraction analysis by the indeterminate orientation method and the fixed orientation approach with constant orientation and ethylene glycol EG treatment[1].
Density	Dry densities were measured. The value was obtained after the sample was completely dried at 105°C (Yamada *et. al.*, 2020).
Pore size distribution	The mercury intrusion method was used to determine pore size distribution[2] (JIS-R1655) (Yamada *et. al.*, 2020).

[1] Analysis by Palynosurvey Co., [2] Analysis by Sumika Chemical Analysis Service, Ltd.

Table 2 Thermal and moisture properties and measurement methods

Items	Measurement methods
Thermal conductivity	Thermal conductivity of dry and wet samples was determined using the hot wire technique (ISO 2007).
Water absorption ratio	Water absorption ratio was calculated from the ratio of the water weight in the sample to the air-dry weight of the sample (Yamada *et. al.*, 2021). The water weight in the sample is calculated from the differences between the dry and wet weights. The wet weight is measured after over 750 hours in water. Water absorption ratio is related to the saturated moisture content, i.e., the ratio of the water content in the pores at saturation under atmospheric pressure to the dry weight.
Moisture diffusivity	Moisture diffusivity was calculated from mini disk infiltrometer measurements (Yamada *et.al.*, 2020).

Table 3 Constituent minerals in the Nikka and Tatsuyama stones[1]

	Nikka stone	Tatsuyama stone
Primary constituents	Mordenite	Quarts, albite
Other minerals	Quarts, albite	Orthoclase
Trace minerals	Amphibole, zircon, muscovite, mica-smectite, chlorite-Smectite, etc.	Muscovite, allanite, epidote, titanite, zircon, montmorillonite, etc.

[1] Analysis by Palynosurvey Co.

Table 4 Physical properties of Nikka and Tatsuyama stones (Yamada *et. al.*, 2020)

Physical properties		Nikka stone	Tatsuyama stone
Dry density [kg/m^3]		1180	2260
Thermal conductivity [W/mK]	Dry	0.481	2.03
	Wet	1.14	2.83
Water absorption ratio [%]		39.2	3.40
Void ratio [m^3/m^3] a: derived from the saturated moisture content under atmospheric pressure and dry density. b: derived from the measured cumulative pore volume.		a 0.485 b 0.412	a 0.0844 b 0.147
Saturated moisture diffusivity [cm/s]		2.20×10^{-4}	1.44×10^{-5}

The pore size distribution in the Nikka stone ranges from less than 0.01 μm to more than 100 μm in diameter, with a mode of approximately 0.2 μm. The pore size distribution range of the Tatsuyama stone is ~ ≤0.04 μm, and the maximum value is ~ 0.06–0.07 μm.

2.3. MOISTURE DIFFUSIVITY

The moisture diffusivity is shown in Figure 3, and the saturated moisture diffusivity is given in Table 4.

Under wet conditions, the saturated moisture diffusivity of the Nikka stone is around fifteen times greater than that of the Tatsuyama stone; however, under dry conditions, the opposite is true. From the observations of the dried Tatsuyama stone, the initial stage of water absorption was found to be extremely high. This is due to the large moisture diffusivity of the Tatsuyama stone at low moisture contents.

2.4. THERMAL CONDUCTIVITY

The Nikka and Tatsuyama thermal conductivities are given in Table 4. Under wet and dry conditions, the difference in the thermal conductivity of the Tatsuyama stone is small. However, the thermal conductivity of the Nikka stone is 2.4 times higher when it is wet than when it is dry.

Figure 1 Outer appearance of the Nikka stone (left) and the Tatsuyama stone (right)

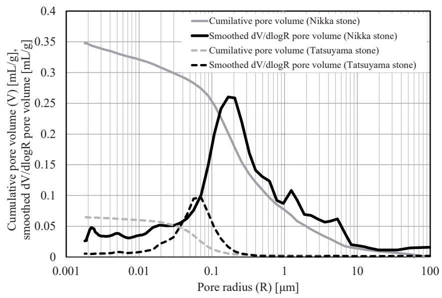

Figure 2 Pore size distribution of the Nikka stone (solid line) and the Tatsuyama stone (dashed line) (Yamada *et. al.*, 2020)

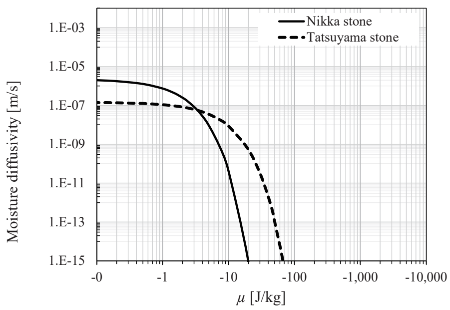

Figure 3 Moisture diffusivity of the Nikka stone (solid line) and the Tatsuyama stone (dashed line) (Yamada *et. al.*, 2020)

3. Defects

Numerous defects were evident in the Nikka stone's horizontal plane, such as the coping stones and stair treads (Figure 4, left). The width of the defects ranged from a few centimeters to a dozen centimeters. The defects were approximately ten millimeters thick. Conversely, with the Tatsuyama stone, the deterioration like the flaking of few-millimeters-thickness on the horizontal and vertical surfaces of the stone beneath the eaves where there was little exposure to rain was observed (Figure 4, right). The deterioration was slight in the area not under the eaves, where the Tatsuyama stone becomes wet in rain.

4. Microenvironment around the stone

4.1. MONITORING SITES

The Nikka and Tatsuyama stones are categorized as the same type of tuff. However, the Nikka and Tatsuyama stones used in the former Koshien Hotel deteriorated differently under similar climatic conditions. To identify the reasons for these differences, we investigated the environmental factors that impacted them.

Figure 4 Defects of the stone materials
(left: Nikka stone, right: Tatsuyama stone)

Central stairs of rooftop on 3rd floor

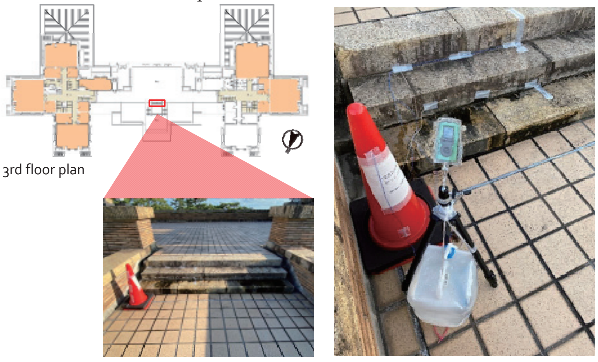

Figure 5 Nikka stone microenvironment survey (central stairs of rooftop on the third floor); the measured point in the 3rd floor plan (left) and condition (right)

West stairs of south terrace on 1st floor

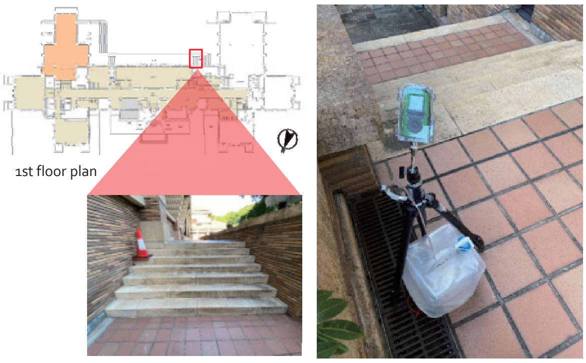

Figure 6 Tatsuyama stone microenvironment survey (south terrace west stairs on the first floor) the measured point in the 1st floor plan (left) and condition (right)

We evaluated the stone's wetness during rainfall, exposure to sunlight on sunny days, and the surface temperature of the deteriorated and sound stones. The outside air temperature was measured on the roof of a separate building near the site. Several measurements were conducted from October 12th 2020 to January 4th 2021. Here, the results between December 29th 2020 and January 1st 2021 are shown.

The third-floor roof terrace was selected as the survey site for the Nikka stone. The measurement point was a north-facing staircase in the center of the terrace (Figure 5). There is no roof at this site, and hence, the horizontal surface of the staircase becomes wet quickly in rain. The stone in the upper part of the staircase has little deterioration; however, previously, cracks have been observed in stones in the lower part of the staircase (Uno & Noguchi, 2015, Isoi, 2021).

The west staircase of the south terrace on the first floor was selected as the survey site for the Tatsuyama stone. The Tatsuyama stone was measured on the west-facing staircase, which has eaves on the north side of the staircase (building side, left section of photo in Figure 6) and a deciduous tree and a low wall on the south side. There is a separate building on the west side. There are evident defects (flaking) under the eaves on the north side of the stairs; however, this rarely occurs at points that are not beneath the eaves.

Figures 7 and 8, respectively, show the air and surface temperatures of the Nikka and Tatsuyama stones in winter.

4.2. NIKKA STONE MEASUREMENT RESULTS

We observed the wet conditions during and after rainfall and found that the water collected under the terrace tile and the tiles flowed to the lower Nikka stone staircase via the back of the upper stair stone. The water from the back side of the stone continued to flow for a few days after it stopped raining.

The surface temperature (Figure 7, left) was lower than the air temperature in both the upper stair (no deterioration) and lower stair (deteriorated) at night. This decline of the surface temperature the stairs is due to nocturnal radiation. During the day, the surface temperature in the upper stair was higher than the air temperature but equal to the air temperature in the lower stair. The differences in surface temperature can be attributed to the exposure to sunlight; the upper stair exposure to the sunlight throughout the day, whereas the exposure of the lower stair to sunlight is only in the afternoon. Here, it is reasonable to assume that, during the day, the temperature in the lower stair (deteriorated)—with less of sunlight and small storage of heat—does not increase much compared to that in the upper stair; thus, at night, the surface temperature of the lower stair also becomes lower than that of the upper stair.

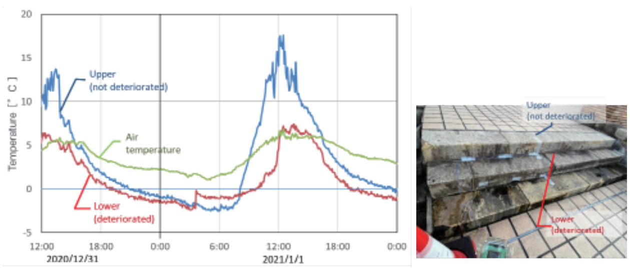

Figure 7 Surface temperature of the deteriorated and not deteriorated Nikka stones (left) and measurement points (right)

From approximately 19:00 to 20:00 on December 31st 2020, (Figure 7 left), the temperature in both the upper and lower stairs was below the freezing point. The lower stair experienced a significant temperature spike of 2°C at 3:40 a.m. on January 1st 2021. This suggests that, after two days of rainfall, the internal water in the stone froze. Observations made a week later determined that cracking had progressed significantly.

4.3. TATSUYAMA STONE MEASUREMENT RESULTS

At the survey site of the Tatsuyama stone, i.e., the stone in the west stairs of the south terrace, during extended rainfall and particularly on windy days, the sound areas (without eaves) became wet, and, subsequently, water flowed under the eaves (deteriorated). Sunlight from the south reached beneath the eaves; however, in sound areas not under the eaves, sunlight is limited by the shadows cast by trees.

According to the measurement results (Figure 8, left), the temperature in the deteriorated area increased on sunny days where the area beneath the eaves was exposed to sunlight. The sound area without eaves was rarely exposed to direct sunlight because it was shaded on the south. Consequently, the temperature did not change significantly. At approximately 12:40 on December 30th, a brief period of precipitation occurred. At the deteriorated area under the eaves, the surface temperature varied by ~6°C before and after the rainfall. It was confirmed that rainfall and sunlight had a significant effect on the surface temperature at the deteriorated site. However, no temperature change was observed in the area without deterioration.

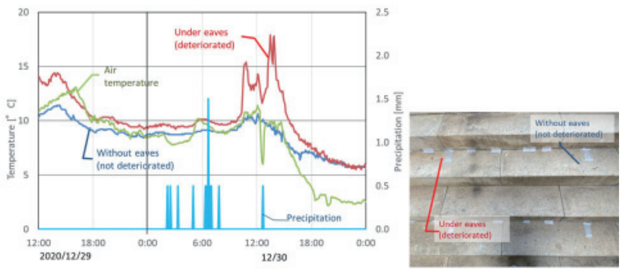

Figure 8 Surface temperature of the deteriorated and not deteriorated Tatsuyama stones (left) and measurement points (right)

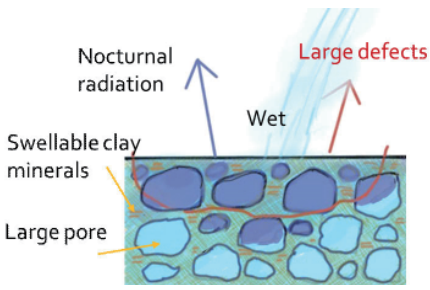

Figure 9 Deterioration mechanism of the Nikka stone

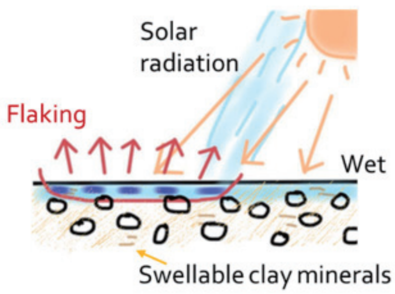

Figure 10 Deterioration mechanism of the Tatsuyama stone

5. Relationship between deterioration and physical properties of stone materials and the microenvironment

5.1. COMMON PROPERTIES OF THE NIKKA AND TATSUYAMA STONES

Both stones contain trace amounts of swellable clay minerals. With repeated water absorption and drying, these swellable clay minerals become brittle. Thus, both stones tend to deteriorate in areas where the moisture content frequently changes.

5.2. DETERIORATION MECHANISM OF THE NIKKA STONE

The Nikka stone includes trace amounts of swellable clay minerals; therefore, frequent water absorption and drying reduces its strength. There are large and small voids in the Nikka stone, and a large defect may emerge if the solid becomes weak in areas with numerous voids. Because the water absorption ratio and saturated moisture diffusivity are large, once water absorption occurs, a significant amount of water diffuses into the deep part of the stone. Since thermal conductivity is not large in the dry condition, the temperature drop inside the stone is small; however, when wet, the temperature drop not only on the surface but also inside the stone. Additionally, ice may form at relatively high temperatures in large-diameter pores, which occur frequently in the Nikka stone.

A diagram of the deterioration mechanism of the Nikka stone is presented in Figure 9. In this investigation, we found that significant deterioration occurred in areas where rainwater was easily absorbed, where the increase in temperature was small during the day, and where the temperature decreased at night due to nocturnal radiation. After a rainfall, the large pores in the Nikka stone contain water. When this water in the pores freezes, it expands and creates pressure, damaging the fragile parenchyma. The large defects are believed to be due to the formation of ice in the internal pores rather than on the surface of the stone.

5.3. DETERIORATION MECHANISM OF THE TATSUYAMA STONE

A diagram of the deterioration mechanism of the Tatsuyama stone is presented in Figure 10. After moisture adsorption, internal absorption is slow. At damaged parts beneath the eaves, the wetness time caused by rainfall is short, and only a thin layer of the surface is wet. When the thin layer is exposed to the sun, the surface temperature of the stone varies significantly, and the surface become dry. The flaking only occurred near the surface because the thin surface layer would experience repeated wetting and drying.

6. Conclusion

To conserve the two types of tuffs utilized in the former Koshien Hotel, we examined the factors affecting the deterioration of the Nikka and Tatsuyama stones by investigating the physical properties and microenvironments of the stone. Our findings suggest that the swelling of clay minerals in the stone, water transfer within the material, surface temperature changes due to solar and nocturnal radiation, and differences in wet conditions caused by rainfall affected the deterioration properties.

In this paper, we investigated the factors and mechanism which caused the stone deterioration, based on the stone material and hygrothermal properties and the measurement results. In order to prove the results, it is necessary to add the reproducibility of the mechanism by the numerical model. In addition, the stone physical properties relating the compression/tension strength should be obtained to show the deterioration of the stone. In the future, we intend to use hygrothermal analysis to obtain a better understanding of the temperature and humidity inside the stone due to boundary condition differences, and the strength of the stone, and to clarify the deterioration mechanism of the stone corresponding to the actual measured results. Additionally, we also intend to explore environmental controls and conservation methods for historic buildings, according to the properties of the stone.

Acknowledgements

This work was supported by JSPS KAKENHI Grant Number 20K04821.

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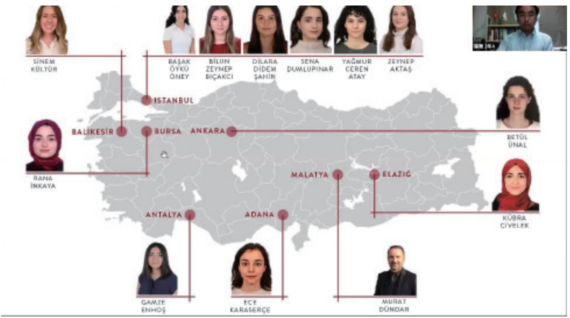
ACTIVITY REPORTS OF THE INSTITUTE OF TURKISH CULTURE STUDIES

Inter Cultural Studies of Architecture (ICSA) in Japan 2020

Based on the general exchange agreement between Mukogawa Women's University (MWU) and Bahçeşehir University (BAU), ICSA in Japan, a short-term study exchange program for BAU students to study together at MWU, has been held annually. However, under the influence of COVID-19, ICSA in Japan 2020 was conducted online for the first time, from July 3 to 28, 2020.

As in the previous programs, BAU students tackled second-, third- and fourth-year MWU student design projects. By participating in this program, they gained knowledge, learned techniques, and increased their awareness of architectural design. On Saturday, MWU faculty members gave online lectures in place of the fieldwork trips that had been offered in previous years. The welcome ceremony was held at the beginning of the program, and the completion and farewell ceremony were held at the end. These gatherings brought together students and faculty from MWU's Department of Architecture and Landscape Architecture.

Participants
Professors: Professor Murat Dündar, Assistant Professor Sinem Kültür,
Teaching Assistant Betül Ünal
Students: Başak Öykü Öney, Bilun Zeynep Bıçakcı, Dilara Didem Şahin, Ece Karaserçe,
Gamze Enhoş, Kübra Civelek, Rana İnkaya, Sena Dumlupınar,
Yağmur Ceren Atay, Zeynep Aktaş

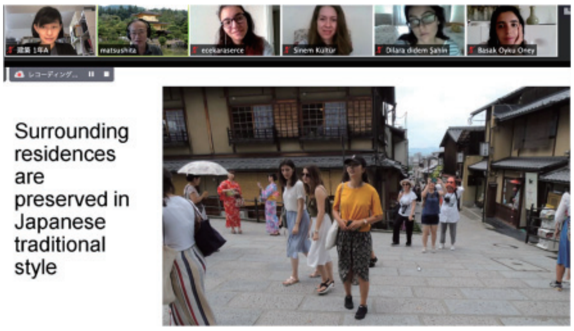


At the welcome ceremony on July 3, each BAU student introduced her own hometown.

At the welcome reception, MWU student representatives gave welcome speeches in English or Turkish. The slides show photos from last year's ICSA in Japan.

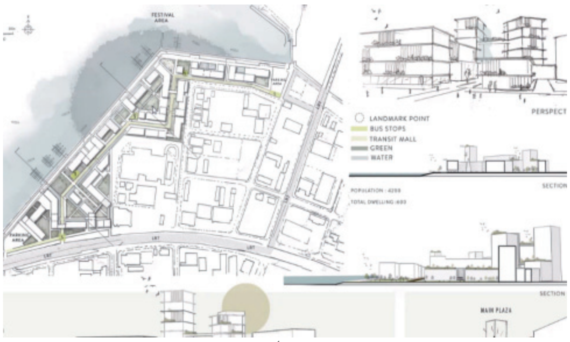
Scene of an online design studio (second-year design project: Design of small-scale Architectural space through combination of planes).

Online lecture on the design of Hanshin Naruo Station.

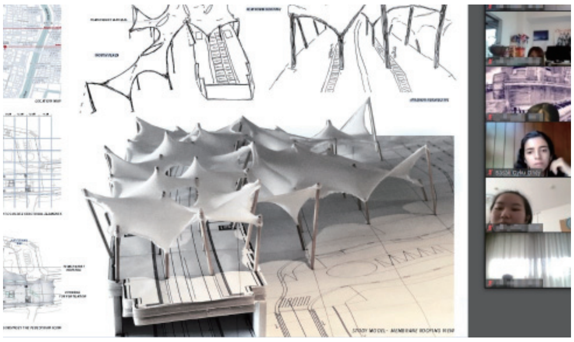


Online lecture on architecture and townscapes of Kyoto.

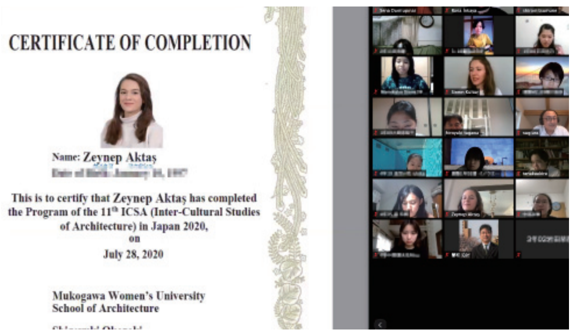
Courtesy call on Chancellor Ryo Okawara and President Kazuyoshi Seguchi of MWU on July 27.



Presentation at the jury (fourth-year design project: Paradise along waterfront).



Discussion between MWU and BAU students during the jury (third-year design project: Rebuilding Hanshin Naruo Station with a membrane-structured roof).



Scene from the certificate presentation at the completion ceremony on July 28.

Group photo at the farewell ceremony.

Two International Students from Turkey Have Earned Their Doctoral Degrees

Date：August 25 (Tuesday), 2020

The Mukogawa Women’s University Graduate School of Architecture Doctoral Commencement Ceremony (for students who entered the program in September) was held at Koshien Kaikan West Hall, where two international students from Turkey received their doctoral degrees. The ceremony was conducted while implementing measures to prevent the spread of COVID-19.

Dr. Okazaki, Dean of the Graduate School, awarded them diplomas, and each of them expressed their gratitude in fluent Japanese. Both have been in Japan for more than five years and both will move back to Turkey to use their knowledge and skills. As invaluable assets who will serve as bridges between Japan and Turkey, we sincerely wish them great success in the future.

Şahin Gonca Hande (left)

【Title of Doctoral Dissertation】
A Study on Spatial Composition of Ryoanji Stone Garden through Three-dimensional Analysis

Bozkurt Beyza Nur (right)

【Title of Doctoral Dissertation】
Comparative Study on Spatial Characteristics of Traditional Farmhouses in Japan and Turkey through Behavior Analysis
－Case Studies of Fukui Prefecture and Eastern Black Sea Region－

An International Student from Turkey Has Arrived

Date：December 2 (Wednesday), 2020

An international student from Turkey has arrived. Her name is Ms. Ulker. She will try to enter the master's program in Architecture at the Graduate School of Architecture in April 2021.

She was originally scheduled to come to Japan in April 2020, but due to the spread of COVID-19, her visit was postponed. She has been an online research student at the university since October 2020. She was finally able to come to Mukogawa Women's University in December 2020 after completing the two-week quarantine period in accordance with the Residence Track requirement.

She loves Japan, and she is especially interested in Japanese vernacular architecture, such as Gassho-zukuri villages in Shirakawa-go and Gokayama. She is currently making great efforts to study Japanese. Please give her a warm welcome.

Ms. Ülker Yeşim Gül

ITCS Seminar (2020 Academic Year)

The Development of Anatolian Dome Structure

Date： **March 12 (Friday), 2021, 13:30～16:00**
Venue： **Online**
Lecturers： **Dr. Masashi Morita (Associate Professor, Yokohama National University)**

The seminar of the Institute of Turkish Culture Studies of the 2020 academic year was held online on Friday, March 12, 2021. This time, we invited Dr. Masashi Morita, Associate Professor, Division of Urban Innovation, Faculty of Urban Innovation, Yokohama National University, to give a lecture titled “The Development of Anatolian Dome Structure.”

The first part of the lecture discussed dome structures in pre-Islamic Anatolia. As characteristics from ancient times to the pre-Christian era, he introduced examples of domes placed on a flat surface and pendentives and squinches that permit the placing of a dome over a rectangular room. Next, as a development under the Christian culture, he discussed Byzantine and Armenian architecture domes.

The second part of the lecture focused on domes in Anatolia under Islamic culture. He explained the dome structures of tomb architecture, which he has been working on for nearly 20 years. He also discussed the types, ages, and regional characteristics of dome structures with triangular flat surfaces, which are unique to Turkey, in detail. At the end of the lecture, he gave a brief overview of the dome structure in mosque architecture, which he is currently studying.

During the subsequent question and answer session, we had an active discussion. This lecture provided an invaluable opportunity to gain an overall understanding of the characteristics of the Anatolian dome.

Seminar Poster

Annual Events Apr. 2020- Mar. 2021

Date	Events
July 3-28, 2020	**Inter Cultural Studies of Architecture (ICSA) in Japan 2020**
August 25, 2020	**Two International Students from Turkey Have Earned Their Doctoral Degrees.**
December 2, 2020	**An International Student from Turkey Has Arrived.**
March 12, 2021	**ITCS Seminar (FY2020)** "*The Development of Anatolian Dome Structure*" (Dr. Masashi Morita, Associate Professor, Division of Urban Innovation, Faculty of Urban Innovation, Yokohama National University)

※The restriction of activities was forced by the prevention of the spread of the new coronavirus.

OUTLINE OF THE INSTITUTE OF TURKISH CULTURE STUDIES

Organization

Position	Affiliation	Title	Name
Director	Department of Architecture	Professor	Shigeyuki Okazaki
Researcher	Department of Architecture	Professor	Shigeki Tosu
		Professor	Chikashi Yamamoto
		Professor	Tetsu Nakae
		Professor	Kazuhiko Yanagisawa
		Professor	Toshitomo Suzuki
		Professor	Hiroyuki Tagawa
	Department of Landscape Architecture	Professor	Junichiro Ishida
		Professor	Azusa Uemachi
		Professor	Noritoshi Sugiura
		Professor	Shigeki Sugita
		Professor	Haruyoshi Sowa
		Professor	Yusei Tazaki
		Professor	Koji Yoneda
	Department of Architecture	Associate Professor	Fumie Ooi
		Associate Professor	Tomoko Uno
		Associate Professor	Akira Tanaka
		Associate Professor	Junko Miyano
		Associate Professor	Hideaki Tembata
		Associate Professor	Keisuke Inomata
	Department of Landscape Architecture	Associate Professor	Junko Morimoto
	Department of Architecture	Lecturer	Aya Yamaguchi
	Department of Architecture	Assistant Professor	Yuuka Nakamura
	Department of Landscape Architecture	Assistant Professor	Yuna Tanaka
	Department of Architecture	Visiting Professor	Kunihiko Honjo
Visiting Researcher	Bahçeşehir University (Turkey) Faculty of Architecture and Design	Professor	Murat Dündar
Assistant	Department of Architecture	Assistant	Rimako Funato
		Assistant	Moeko Ikezawa
	Institute of Turkish Culture Studies	Assistant	Yuka Kawasaki

Reviewers of *Intercultural Understanding*

Name	Title and Affiliation
Yasushi Asami	Professor, The University of Tokyo, Japan
Mitsuo Takada	Professor Emeritus at Kyoto University, Japan
Shuichi Hokoi	Professor Emeritus at Kyoto University, Japan
Kosaku Maeda	Professor Emeritus at Wako University, Japan
Minako Mizuno Yamanlar	Representative of NPO The Japanese-Turkish Friendship Association, Japan
Kazuya Yamauchi	Professor, Teikyo University, Japan
Hironobu Yoshida	Professor Emeritus at Kyoto University, Japan
Murat Dündar	Professor, Bahçeşehir University, Turkey
Murat Şahin	Associate Professor, Özyeğin University, Turkey
Renk Dimli Oraklıbel	Assistant Professor, Bahçeşehir University, Turkey
Kazuhiko Yanagisawa	Professor, Mukogawa Women's University, Japan
Toshitomo Suzuki	Professor, Mukogawa Women's University, Japan

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Rules and Regulations of the Institute of Turkish Culture Studies (ITCS) at Mukogawa Women's University

(Establishment)
Article 1 The Institute of Turkish Culture Studies (hereinafter "the Institute") shall be located in Mukogawa Women's University (hereinafter referred to as "the University").
(2) The Institute shall be operated under the administration of the University's School of Architecture for the time being.

(Objective)
Article 2 The objective of the Institute is as follows:
(i) to conduct comparative studies on life, technology, and culture centered on the architecture of Japan and Turkey as the east and west starting points of the Silk Road, and to clarify the cultural base common to both countries beyond their differences in history, climate, and so forth.
(ii) to conduct, by pursuit of the above-mentioned aims, extensive studies on life, technology, and culture centered on the architecture of neighboring Silk Road countries, clarify similarities among them, and contribute to new mutual understandings that promote the peace and prosperity of the Silk Road region.
(iii) to support international exchange of students predominately in the field of the human environment and conduct international educational activities in the fields of architecture and human environment based on the achievements of the studies mentioned in (i) and (ii).
(iv) to discuss internationally the achievements in research and education mentioned in the preceding three items, introduce (*or* transmit) them to the world in various ways at every occasion, and share common values with people around the world.

(Operation)
Article 3 The operations of the Institute to achieve the above-mentioned objectives are as follows:
(i) to conduct studies in cooperation with the Research Center of Japanese Culture Studies, Bahçeşehir University, Istanbul.
(ii) to hold an international workshop, the "Inter Cultural Studies of Architecture in Japan (ICSA in Japan)," where architecture and human environment students of the world, centered around Turkey, are invited every year in principle to support a similar workshop, the "Inter Cultural Studies of Architecture in Istanbul" that is held at the Research Center of Japanese Culture Studies at Bahçeşehir University, and to send teachers and students of the University's School of Architecture for research and educational activities.
(iii) to hold seminars, introduce research achievements, exhibit, and organize lectures concerning life, technology, and culture, centered around architecture, to which researchers, business persons, and residents who belong to the field of studies conducted by the Institute are invited.
(iv) to hold permanent and special exhibitions on the life, technology, and culture of neighboring Silk Road countries, centered around Turkey.
(v) to conduct public relations activities, such as publication of the research and educational achievements of the Institute, symposiums, and so forth.
(vi) other operations required to accomplish the aims specified in the preceding article.

(Organization)
Article 4 The Institute may establish research departments with respect to differences in research fields to perform relevant activities.

(Director)
Article 5 The Institute shall install a director.
(2) The chancellor shall appoint the director from among professors.
(3) The director shall be appointed for a period of two years and may be reappointed.
(4) The director handles the operations of the Institute under the president's direction.

(Vice Director and Head of Research Department)
Article 6 The Institute may install a vice director and heads of research in each department referred to in Article 4.
(2) The chancellor shall appoint the vice director and heads of the research departments from among the faculty. The latter positions may be substituted with adjunct teaching staff.
(3) The vice director assists the director and engages in the administrative operations.
(4) The vice director fills in for the director under the director's direction.
(5) Each head controls his research department and engages in research under the director's direction.

(Senior Researcher)
Article 7 The Institute may install senior researchers with the chancellor's approval.
(2) The director appoints senior researchers from among the researchers.
(3) The senior researchers will assist their heads and engage in research.

(Researcher)
Article 8 The Institute shall install researchers as required.
(2) Teachers at Bahçeşehir University may be appointed as researchers.
(3) The researchers will engage in research under the director's direction.

(Temporary Researcher)
Article 9 The Institute may install temporary researchers as needed.
(2) The president appoints temporary researchers upon the recommendation of the director.
(3) The period of the appointment shall be less than one year and may be renewed when necessary.
(4) The temporary researchers will engage in specific research or joint research.

(Assistant)
Article 10 The Institute may install assistants.
(2) The assistants will assist in research under the director's direction.

(Steering Committee)
Article 11 The University shall establish a steering committee for the Institute (hereinafter "the steering committee") to deliberate basic policy concerning the Institute's operation.
(2) The steering committee shall consist of a director and a few members chosen from among the vice director, the heads of the research departments, the senior researchers, and researchers.
(3) The president will appoint the members of the steering committee.
(4) The director shall be the chairperson of the steering committee.
(5) The chairperson shall convene and lead the steering committee.
(6) Members shall be appointed for a period of two years and may be reappointed. When a vacancy arises, the successor's term of office shall be the predecessor's remaining term.
(7) Details of the steering committee shall be otherwise laid down.

(Secretariat)
Article 12 The Institute shall install a secretariat.
(2) The secretariat shall consist of a few members and the chief clerk of the School of Architecture shall be the chief of the secretariat.
(3) The members of the secretariat will handle clerical duties under the guidance and supervision of the chief clerk under the director's direction.

(Supplementary Rules and Directions)
Article 13 In addition to what is provided in these rules and directions, necessary matters concerning the administrative operations of the Institute shall be prescribed by the director.

(Modification or Elimination of the Rules and Regulations)
Article 14 Modification or elimination of the rules shall be implemented with the chancellor's prior approval.

Supplementary Provisions
(1) The rules and regulations shall be enforced beginning on July 29, 2009.
(2) From the day the rules and regulations are enforced until March 31, 2011, the term of the appointed directors and members of the steering committee shall begin on the day when they are appointed and end on March 31, 2011, notwithstanding the provisions of Article 5, paragraph (3) and Article 11, paragraph (6).

Intercultural Understanding
Vol.11

Online ISSN 2436-5513

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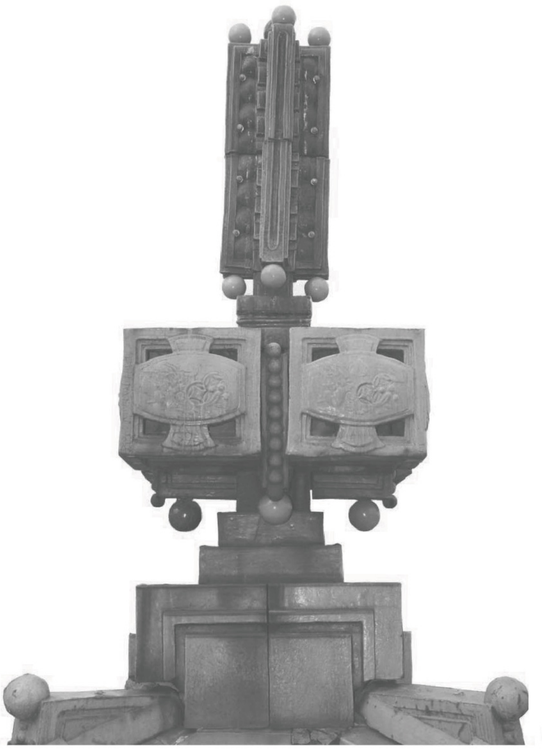
発行者:
武庫川女子大学

令和 4 年 3 月発行



Roof cresting of Koshien Hall: Ceramic cresting with eight legendary mallets sits atop each of the square-shaped roofs. An old Japanese folk legend tells the miracle of a pygmy priest 3cm tall who grew bigger by striking the magic mallet. Daikokuten, one of seven Gods of Wealth, is always portrayed holding the magic mallet in his hand.