

Paper No: Bioclimatic Designs of Glover Residence in Nagasaki, Japan

How it was adapted in the 19th century to suit the hot and humid climate

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Abstract

Glover Residence, completed in 1863, is one of the oldest surviving Western-style houses in Nagasaki, Japan. The Scottish owner, Thomas Blake Glover, came to Nagasaki in 1859 and contributed to the modernization of various Japanese industries. As with many other Western houses in this age, this house is quasi-Colonial style, a mixture of European and Japanese design. This house also incorporates bioclimatic design concepts allowing for adaptation to the local climate, in particular the hot-humid summer in Japan. Some significant characteristics of this wooden house are; 1) a large roof to shield it from sun and rain, 2) rooms surrounded by balconies with deep eaves for sun protection, 3) rooms open outside for sufficient cross-ventilation and, 4) internal thermal mass of soil-finished walls to keep the interior cool. This paper describes and discusses the passive cooling effect of night time ventilation in conjunction with good internal thermal mass and ample shading after the analysis of data obtained through measurements at the site and the results of a series of computer simulation studies.

Keywords: colonial style, local climate, design adaptation, thermal performance

1. Climate and building

Nagasaki, one of the oldest port cities for international trade in Japan since the 16th century, was built at the deep bottom of Nagasaki Bay. Glover house is located on the hillside with a panoramic view of the bay to the west. In contrast, the east side of the house is surrounded by forest. (Fig.1)



Fig 1. Glover Residence (photo in 2007)

The climate in Nagasaki is mild with an average temperature of 6.8 deg Celsius in January and 27.6 deg Celsius in August.

The floor plan of Glover residence is shown in Figure 2. This is the result of four extensions completed after the original construction. (Fig.3) The process of the renovation reveals gradual

adaptation to the local climate. The original construction was completed in 1864 as a guest house and its layout was typical bungalow style, with the main rooms were surrounded with an open-air verandah covered with deep eaves offering protection from the sun and introduced a cool breeze. The kitchen, as it generates heat, was built separately from the main building.

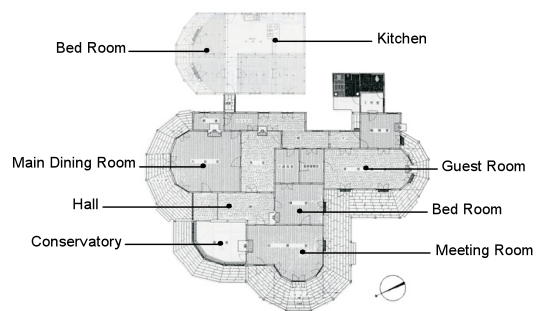


Fig 2. Floor plan of Glover Residence

In the 1877 renovation, a main dining room with an identical verandah was added to the north but the east side verandah was displaced because the building had sufficient shading from the forest in the backyard. When the family began to inhabit the house, fireplaces were installed in the main rooms for heating in the wintertime.

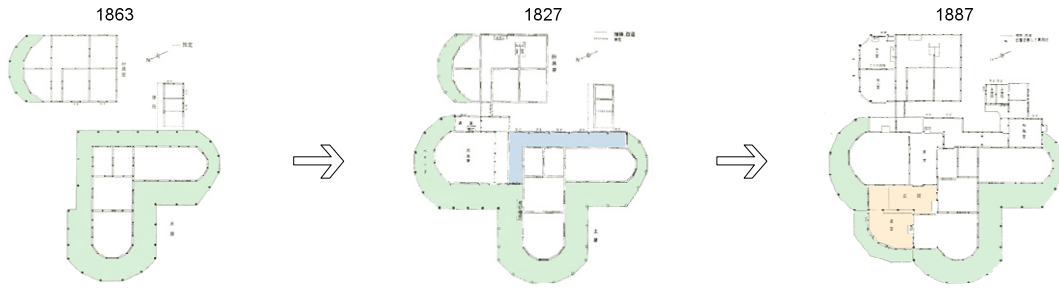


Fig 3. Process of renovation (Colored area is Verandah)

Afterwards, movable walls were additionally installed on the edge of the north-side verandah of the main dining room and a winter garden (conservatory) was built on the north-west corner of the building. Both were built out of consideration to protect the living space against cold winter wind originating from the northern valley. The bungalow style house originated in the tropical climate in Southeast Asia and introduced in this original building primarily, were gradually modified to adapt to the temperate climate in Nagasaki, where both of cooling and heating were required.

Original open verandah (above) was glazed later with glass for cold winter (below)

This kind of climate adaptation could be observed in so called verandah colonial style houses in Japan where the verandah was completely covered with a glass screen. (Fig.4)

2. Passive cooling features

The Passive design features employed in this building are listed in Table 1. It is clear that original main design concept is for passive cooling but careful consideration for wintertime heating can be found in the renovated design.

Table 1. Passive design features in Glove residence

1	verandah	deep eaves	shading
2	roof	attic space	ventilation
3	ceiling	wood lattice	ventilation
4	wall	mud wall	thermal mass
5	openings	French window	cross ventilation
6	floor	crawl space	ventilation/earth contact



Fig 4. Glazed verandah at Hassam Residence (Kobe)

< roof >

The basic concept can be observed in the longitudinal section. (Fig.5) The large roof with deep eaves and high attic space works well as a shading system to prevent solar heat invasion and serves as a ventilation system to enhance the exhaust of hot room air. The verandah ceiling was made from lattice-woven wood pieces that bring in cool air from outside and aids the exhaust of hot air at the top of the attic space in the summer. (Fig. 6)

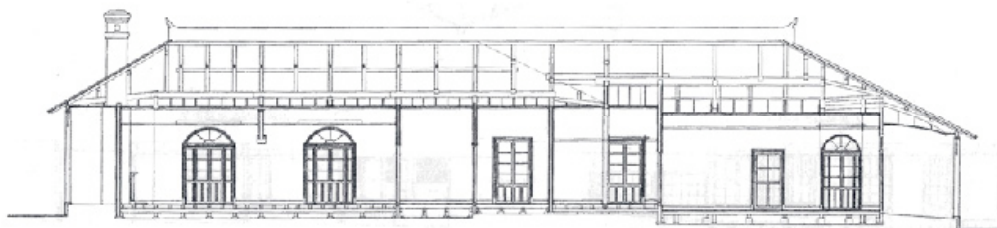


Fig 5. longitudinal section



Fig 6. ceiling with wood lattice

< openings >

Each room faces directly outside and has tall and large openings, sometimes called “French Windows.” They are precisely located in order not to obstruct wind paths for cross ventilation. Each one has an exterior wooden door in addition to the normal glass-fixed door. (Fig.7) At night in the summer, only the wooden doors are closed but the movable louvers mounted on the exterior door are kept open. Therefore, natural ventilation operates sufficiently to cool the inside, safely. They also double as storm windows and insulation windows in the wintertime.



Fig 7. French window with movable louver open to the verandah.

< Elevated floor >

The main floor is wooden and has a crawl space below. The crawl space has small air inlets and outlets for ventilation that work effectively to draw out humidity in the crawl space, keeping it dry. The floor of verandah is the stone finished and is devoid of crawl space.

< Thermal mass >

The wall is a kind of traditional Japanese-style mud wall. The mud paste is laid on a screen made from bamboo and rice straw, previously fixed onto structural members such as wood posts and beams. After the first mud layer dries, the second layer of mud is laid. The thick mud wall, completed after three or four layers are laid, is finished with white plaster. The structure of this

house is post and beam structure and this wooden framed mud wall is regarded as fake stone or brick. Some other colonial style houses in Nagasaki have real stone or brick walls as structural members.

Regardless of structural material authenticity, this thick mud wall has sufficient thermal capacity in order to be effective as good thermal mass for passive cooling. (Fig.8)

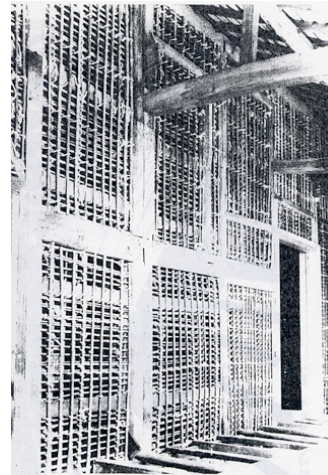


Fig 8. detail of Mud wall. Bamboo screen before pasted with mud.

3. Shading and Daylighting

The shading effect of the deep eaves over the verandah and lighting condition of the rooms were studied using building models. (Fig.9)

< Main dining room >

This part was added in 1877 with a verandah in the north

On an early summer morning, low latitude sunlight from the north-west penetrated the room but was momentary. In the afternoon, most of the direct light was blocked by the verandah eaves. The conservatory located in the west part of the dining room has a glass roof, resulting in moderate light penetration in the late afternoon.

< Meeting room >

This room faces southwest. In the summertime, direct sun only penetrated inside in the late afternoon and to the contrary, in the winter, the room is filled with light in the afternoon. The verandah serves as a good buffer zone and airy space open to the garden with a panoramic view of the bay.

< Guest room >

The east-side verandah in the original plan was closed in the 1887 renovation. The verandah in the southwest controls the light effectively throughout the year. Winter sun reached the room and the summer sun was completely blocked, resulting in it being the most comfortable room in the house.

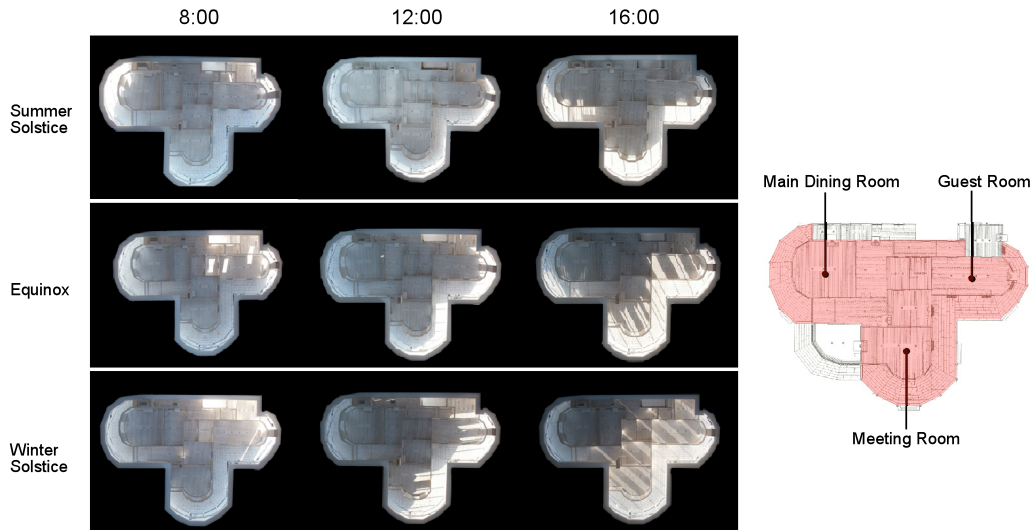


Fig 9. Shading effect of verandah (experiments using model)

4. Ventilation and passive cooling

< simulation analysis >

The effect of passive cooling (night time ventilation) was checked using a computer simulation program developed by the author (<http://qcd.co.jp/>).

In traditional Japanese houses with little thermal mass, it was believed that constant, all day cross-ventilation was the only means of cooling during the summer. However it was expected that the passive cooling effect by nighttime ventilation is significant in buildings such as the Glover residence with abundant thermal mass inside. The calculated results for the meeting room were shown in Fig.10.

The room air fluctuation on typical days in August was shown under four different ventilating modes shown in table 2. The cool storage effect from the nighttime ventilation mode is obvious, where room air change occurred 30 times from 18:00 to 8:00. In comparison, room air change occurred only twice during other hours of the day.

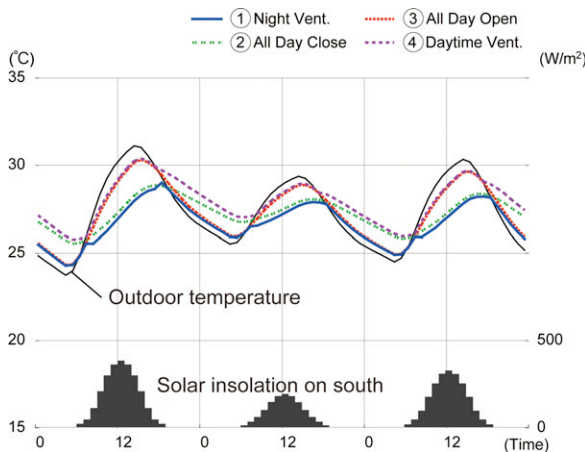


Fig 10. room air temperature fluctuation at meeting room of Glover residence in August (simulated)

The peak room air temperature was 28 degrees Celsius in the afternoon whereas the outdoor air temperature was 31degrees Celsius. The room air temperature dropped at night time to the same level as the outdoor temperature and it was observed that the room stayed cooler than outside temperatures throughout the day.

< measurement and analysis >

Measurements at the site were carried out in September 2007. The weather was fair and it was relatively hot compared to mid-summer weather. The building was used as a museum on that particular day, open in the daytime and closed at night, thus making it impossible to measure the room air under the night ventilation mode. Namely, measurements were only carried out under conditions in which the windows were opened at 9:30 and closed at 21:30. The windows were kept wide open during museum office hours.

The room air fluctuation of the meeting room was shown in Fig.11. It was observed that the room air temperature remained more constant than that

Table 2. Ventilation mode (times of room air change)

	Day (8-18)	Night (18-8)
① Night Vent.	2 times/h	30 times/h
② All Day Close	2 times/h	2 times/h
③ All Day Open	30 times/h	30 times/h
④ Daytime Vent.	30 times/h	2 times/h

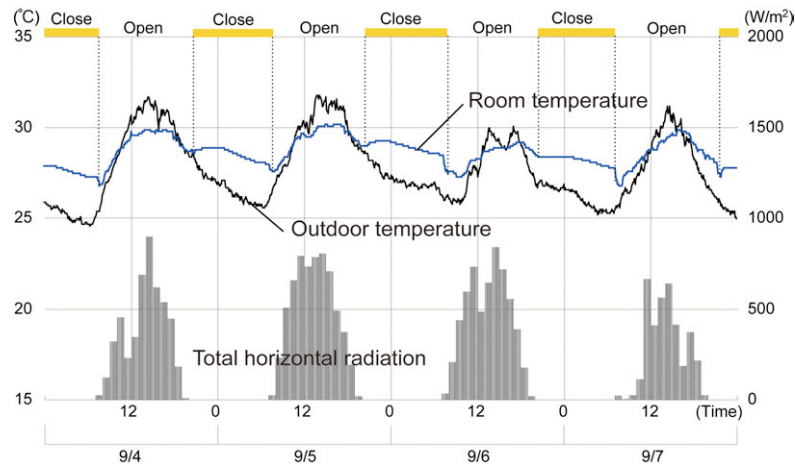


Fig 11. room air temperature fluctuation at meeting room of Glover residence measured through Sept.4-7 (2007)

of the outdoor temperature but the temperature drop of the room ambient air at night was insufficient because the windows were closed at 21:30 when the museum was closed.

The cool storage effect was clearly observed but deemed insignificant due to the irregular ventilation mode.

5. Conclusion

In colonial style houses in Asia, a mixture of design from the main land and that of the colony is observed. It is possible to say that the original design must be changed in order to adapt to the local specific climate of the colony. In the Glover residence in Nagasaki, the advantage of heavy thermal mass, considered a trademark of European houses, was found and expected to work as a passive cooling element in the hot-humid climate, combined with verandah style shading pervasive in many hot-humid Asian countries.

In this paper, the role of thermal mass and shading in passive cooling design were discussed through the measurement and computer simulation studies on the Glover residence as a case study house. The thermal characteristics of Glover residence were clarified and the effect of the proper combination of thermal mass and shading device were confirmed.

6. References

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