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Luminous Performance of Ji-mado as a Daylighting System In Snowy Region

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Summary
The purpose of this study is to have a better understanding how to design daylighting systems and to make clear luminous environment of ji-mado in snowy region. To achieve those, we first classified daylighting systems which have been newly completed in the world. 84 examples were classified into four categories (upper surface, vertical surface, whole building, and lower surface) depending on the control parts of daylight. But there were no control systems of lower surface and no systems of the reflected daylight from snow surface in even snowy region.

From the results of the classification and the previous studies, we second compared luminous environment of typical opening with ji-mado which the reflected daylight from snow surface might be utilized. One of the characteristics of ji-mado is that 80 % of reflected daylight from snow surface corresponds with the indirect factor. There is a possibility that a combination of south facing ji-mado and north facing typical opening might be relatively uniform luminous environment in the snowy region.

1. Background and Purpose
Over the past 10 years daylighting systems such as lightshelf and louvers in double skin wall in especially commercialized buildings have been developed. In addition to establishing comfortable brightness for occupants daylighting systems also reduce electric power consumption as well as passive heating and cooling systems in buildings (O'Connor *et al.*, 1997, Asada and Shukuya, 1999). Nevertheless, installing daylighting systems in buildings in snowy region such as Sapporo is not yet widely practiced. One reason for this is thought the daylighting systems have been developed without considering cold climate with snow coverage. However it is important to reconsider regional and traditional technologies and to re-design daylighting systems for snowy region. For example, in snowy region it is possible to utilize not only downward daylight but also reflected daylight from snow surface in winter season.

"Ji-mado" has been widely practiced in traditional buildings throughout Japan. Ji-mado is one of vertical windows located on the floor surface. "Ji" and "Mado" in Japanese mean ground and window. Its height is almost within a half of wall height. It is often used in Japanese traditional tea-ceremony room, generally Japanese-style room. Ji-mado is for view, for ventilation and for sweeping the dust from the indoor space to the outdoor environment.

There is the habit that we do not use chairs in the Japanese-style room, and that we directly sit on the floor mat, "Tatami". The height of eye level in the case of floor seats lowers as about 0.7 m in comparison with the case of chair seats. It is possible that the human who sits on the floor in the Japanese-style room sufficiently see the framed view of the outside scenery. Because ji-mado is located in the position which is lower than typical opening, ji-mado might lead the reflected daylight from snow surface into the indoor space in winter season.

The purpose of this study is to have a better understanding of daylighting systems which can be well-suited in snowy region. We first classified the daylighting systems which have been completed in the world in less than ten years (Nakano, Nasu and Saito, 2004). In addition, we focused on the effect of luminous performance of ji-mado because we found that it was comfortable to take the reflected daylight into the indoor space thorough ji-mado by the subjective study with the actual scale model (Saito, Nasu, Nakano and Miyakawa, 2004). Finally, we had a luminous measurement in the miniature scale model with a typical opening and a ji-mado. According to the classification and the experimentation, discussion to make clear the effect of utilizing reflected daylight from snow surface in snowy region are described.

2. Classification of Daylighting Systems

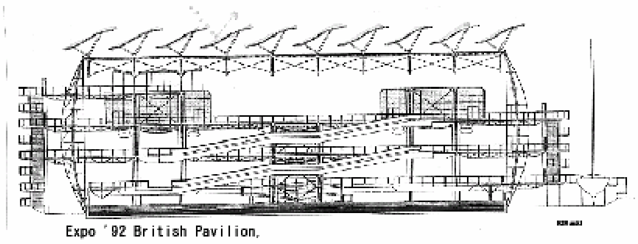
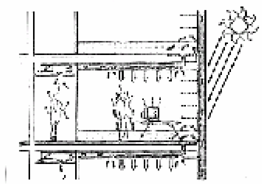
In order to understand the outline of the daylighting strategies in actual architectures in the world, collection of 84 examples and the classification based on the form and the function were performed. Table 1 summarized the classification of all examples into four sections such as upper surface, vertical surface, whole surface, and lower surface of buildings as control parts of daylight.

Upper surface means the systems to control daylight at the roof area of buildings in Table 1. Almost of them can take daylight into the indoor space as well as those accordingly can shade sunlight. Vertical surface also means the system to control daylight at the wall of buildings. As Table 1 indicated, 85% or more of all examples control daylight by vertical surface. It is reasonable to suppose that almost of examples can control daylight at the wall surface. In addition, the vertical surface can control not only to intake the daylight but also to shade indoor space from the sunlight with devices such as eaves or blinds in the double skin wall.

The remaining 13% is upper surface, and less than the remaining 7% is whole surface of buildings. Whole surface means sum of upper surface as a roof and vertical surface as a wall. There was no control system of the daylight by lower surface of buildings.

Table 2 shows the classification in 69 examples of vertical surface into six types as layout of devices of daylighting systems. There are 27 examples in Europe and 8 examples in United Stated and Mexico, and 34 examples in Japan, any other country in Asia and Australia. These can be classified as simple grazing, internal, external, penetrated, integrated, and multi grazing.

Table 1 Classification of daylighting systems in terms of sections as control parts of daylight

Sections	Examples
upper surface	 Expo '92 British Pavilion, Grimshow & partners, Sevilla, Spain, 1992 Shading and reflecting systems above the glass roof
Vertical surface	  Micro electronics park business promotion center Foster & partners, Duisburug, Germany, 1996 Tripple garazed windows with inner horizontal louvers
Whole surface	 New trade fair hall Von Gerkan, Marg & partners in collab-orate with Ian Rithie architects, Leipzip, Germany, 1996 Glass with printed strips
Lower surface	no data

sources from ECO TECH , Thames & Hudson Ltd, UK

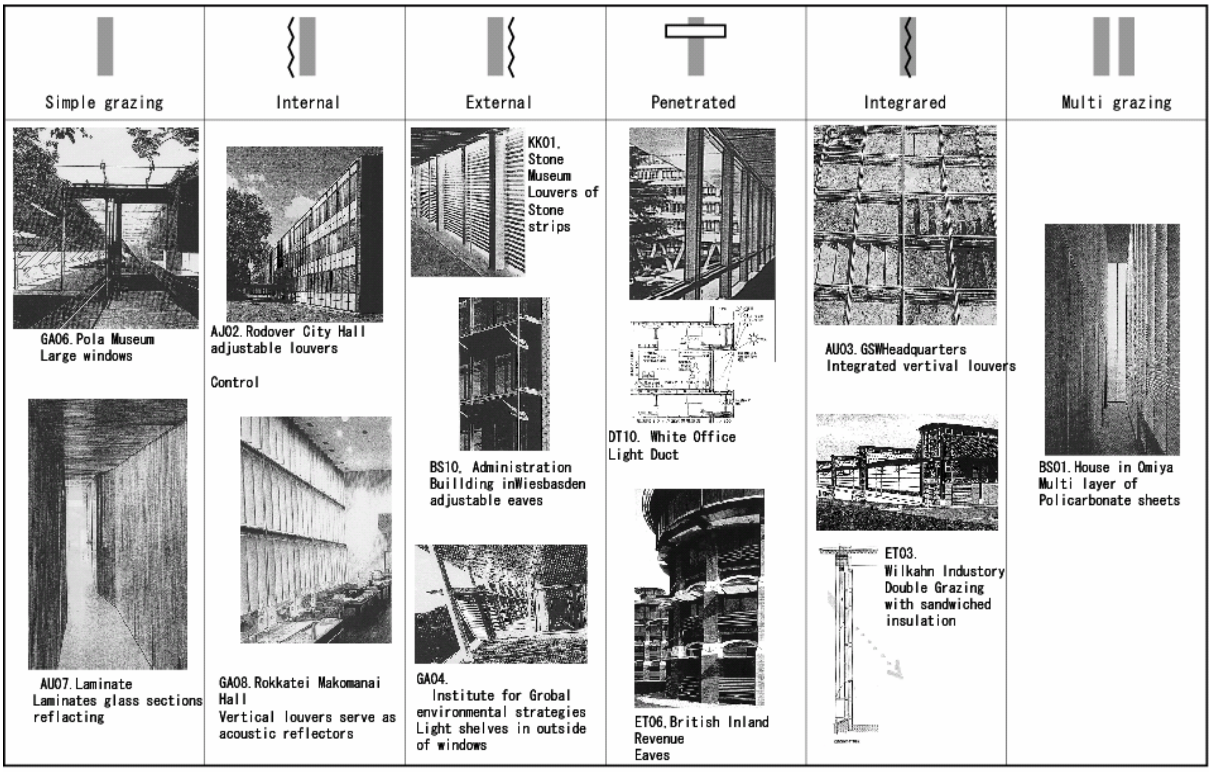
Simple grazing means the buildings which are utilized glass blocks or large windows without any other device. Penetrated means that for example, light shelves and other reflecting devices which are penetrated the wall. Integrated means that the systems such as movable louvers in the windows. Multi grazing means the systems has some control devices in the double or triple skin walls.

External is almost 40% of the vertical surface. Internal, that is the systems prepared in the inner surface of a wall, and the penetrated system formed in both the external wall and the internal wall such as lightshelf and other reflecting devices is 10%, respectively. Penetrated are composed of light shelf and reflective devices such as light duct and eaves. The rate by which the daylight-control system is formed in double stratification of a wall or the sealed wall, those are in integrated and multi grazing, was 30%. This result expresses the tendency for this type of building to increase in number.

Most of the buildings in snowy region such as residential buildings in northern Europe are almost taken in daylight directly by preparing the opening at ceiling or large opening in the buildings without aiming at shading of daylight. This is considered that in northern Europe such as Sweden and Finland, intake solar radiation has a priority to shade it because of cold region. However, the importance of solar shading devices also has already been receiving widespread consideration in Germany and northern Europe countries (Schittich, 2002, Guzowski, 1999).

On the other hand, there were no control systems of lower surface and no systems of the reflected daylight from snow surface in even snowy region. It is assumed that lower opening, that is ji-mado, can shade the directed-downward sunlight and it can take the reflected-upward daylight from snow surface into the indoor space effectively as well. No special shading devices might need to integrate with the grazing if ji-mado was adopted. Furthermore, from our previous studies by the actual model, it was acceptable for subjects to stay the room with the ji-mado (Miyakawa, Nasu, and Saito, 2003). Therefore, we second measured luminous environment of ji-mado compared with the typical opening by the miniature scale model.

Table 2 Classification of building envelope in terms of the layout of controlling devices



Sources from
ET:ECO TECH , Thames & Hudson Ltd. UK
AU:a+u, a+u, Japan
DT:Detail, Shokoku-sha, Japan
BS:Building Skins, edition DETAIL, Geramany
GA:GA JAPAN, ADA edita Tokyo, Japan
KK:Kuma Kengo, Shokoku-sha, Japan
AJ:Arne Jacobsen, Edition GG, Spain

3. Luminous Performance of Ji-mado

3.1 Outline of the Experimentation

A miniature model on a scale of one to ten with two types of openings was made for the experimentation. Figure 1 illustrates a perspective view of the scale model. One is a typical opening and the other is a ji-mado. Figure 2 shows both the sectional views and fisher-eye pictures, respectively. A height of the typical opening and a height of the ji-mado are 0.07 m, respectively. The opening area of the typical opening versus that of ji-mado is 0.078 m^2 versus 0.021 m^2.

We compared luminous environment of the typical window with that of the ji-mado. The experimentation was held in the open air at the Sapporo School of The Arts, Sapporo at latitude 43 degree north in February 25, 2005. The weather was fine and sometimes cloudy, and a time period of the experimentation was from 1:30pm to 2:30pm.

Photo 1 shows a view of the experimentation. The site of the experimentation is widely opened so that minimum influence on reflected daylight from the external wall of the buildings to the model was considered. In this winter season, Sapporo has much snow so that the surrounding was covered with virgin snow. The ambient temperature was around minus 5 degree-C.

As can be seen in Figure 2, downward and upward illuminances at the four horizontal points at the 0.07 m level from the floor surface were measured. Two photometers were set above and below, and they were moved slowly from the back of the scale model to the window side. We measured upward and downward illuminances five times by means of north and south facing openings. Simultaneously the global and the vertical illuminances were also measured each time.

In snowy region it is possible that the reflected daylight from snow surface can be enough led from north facing openings. Therefore, in this experimentation we measured illuminance in the both case of north and south facing openings.

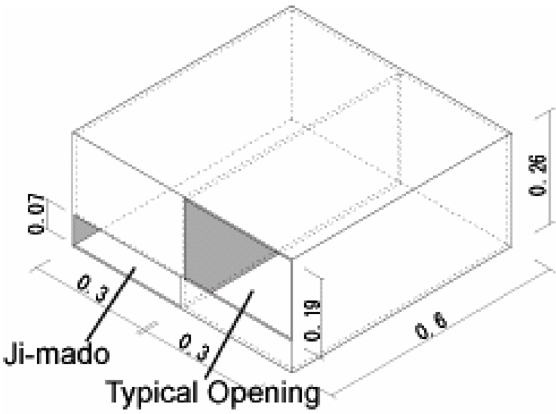


Figure 1 A perspective view of the model [m]

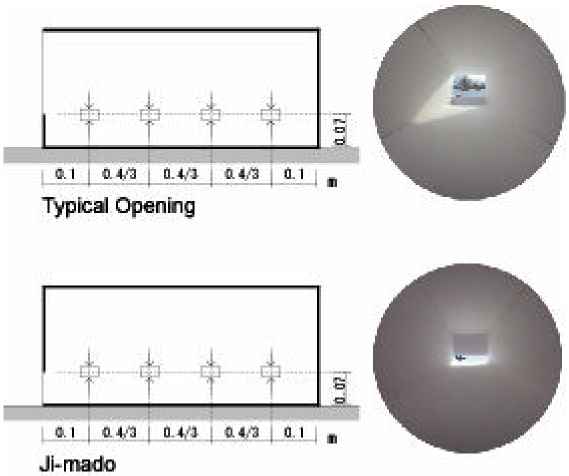


Figure 2 Sectional plan [m] and fish-eye pictures

Photo 1 A View of the experimentation (Feb. 25, 2005, Sapporo, Japan)

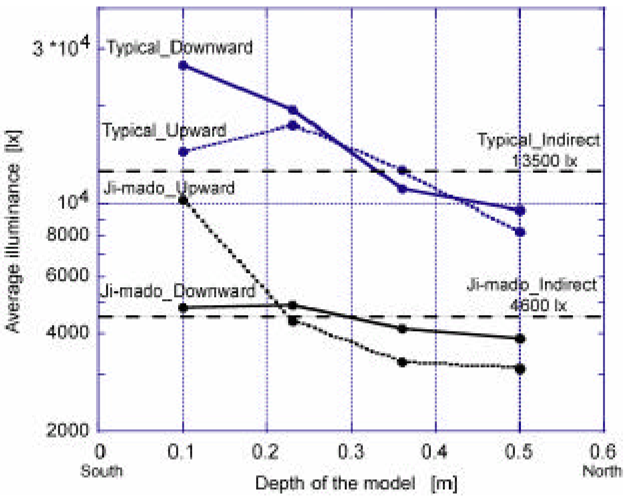


Figure 3 Average illuminance in the case of south facing window

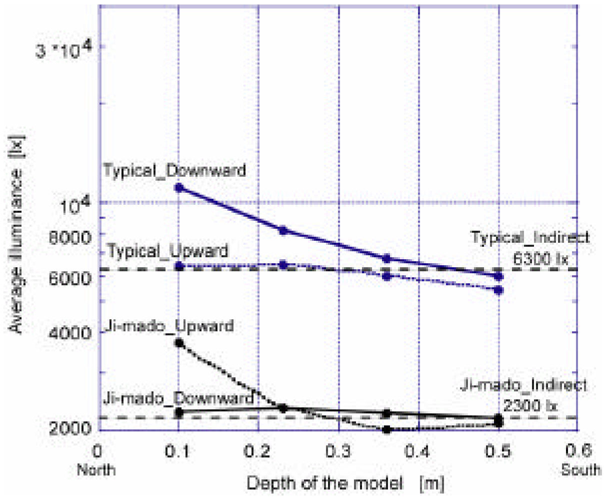


Figure 4 Average illuminance in the case of north facing window

3.2 Results and Discussion

Figure 3 shows the average illuminance per five times in the cases of south facing typical opening and south facing ji-mado. Figure 4 shows those of north facing. The solid lines versus the dotted lines mean downward versus upward illuminance.

As can be seen in Figures 3 and 4, the illuminance in the case the typical opening is higher than those in the case of ji-mado irrespective of north and south. In addition in Figure 3, in the case of typical opening, the downward illuminance at the window side is twice higher than the upward illuminance. On the other hand, in the case of ji-mado the downward illuminance is a half of the upward illuminance. This is denoted the same tendency of north facing opening although there are difference in illuminance in north and south. This means that in the case of ji-mado, controlling the reflected-upward daylight from snow surface at the window side is significant for making indoor luminous environment to be contrast or uniformity.

The indirect illuminance based on the theory of inter reflection was calculated. The ratio of indoor reflectance is assumed to be 0.7 by the brief measurement. The indirect illuminance in the case of south-facing typical opening versus that in the case of south facing ji-mado is 13500 *lx* versus 4600 *lx*. As is the case with south facing, the indirect illuminance in the case of north-facing typical opening versus that in the case of north facing ji-mado is 6300 *lx* versus 2300 *lx*. These mean that the ratio of typical opening to ji-mado of the indirect illuminance is almost equivalent to the ratio of typical opening to ji-mado of the opening area (cf. 0.078 m^2 versus 0.021 m^2). Alternatively if we assumed that the downward illuminance is equal to the total indoor illuminance, almost of total illuminance in the case of ji-mado is occupied the indirect factor. The ratio of indirect to direct can be calculated to be 80 % of total. This result means that ji-mado is the effective device which can provide indirect daylight into the indoor space.

If the site of the experimentation moved to the high latitude more than 43 degree north, the downward illuminance at the window side might decrease and those from the center to back of the room might increase as well because the solar angle becomes lower. Consequently, adopting ji-mado to buildings at high latitude is much more beneficial to be uniform the indoor luminous environment although we need to consider the glare.

In general in snowy region we avoid designing widely north facing openings because of direct gain and heat loss. Moreover, designing a kind of studio or a museum tends to be avoided locating south widely opening because of no influence on direct solar radiation for protecting their interior products. Therefore, we had a case study what the best combination of ji-mado and typical opening is.

Figure 5 shows one of the combinations of illuminance in the case of south facing ji-mado and north-facing typical opening. As can be seen Figures 3 and 4, the indirect illuminance level in the case of south facing ji-mado is approximately two thirds of that in the case of north-facing typical opening. Two lines in Figure 5 were calculated to the sum of south facing ji-mado in Figure 3 and north-facing typical opening in Figure 4. Both downward and upward illuminance becomes closer than those in Figures 3 and 4. This result implies that there is a possibility that a combination of south facing ji-mado and north-facing typical opening might be relatively uniform luminous environment.

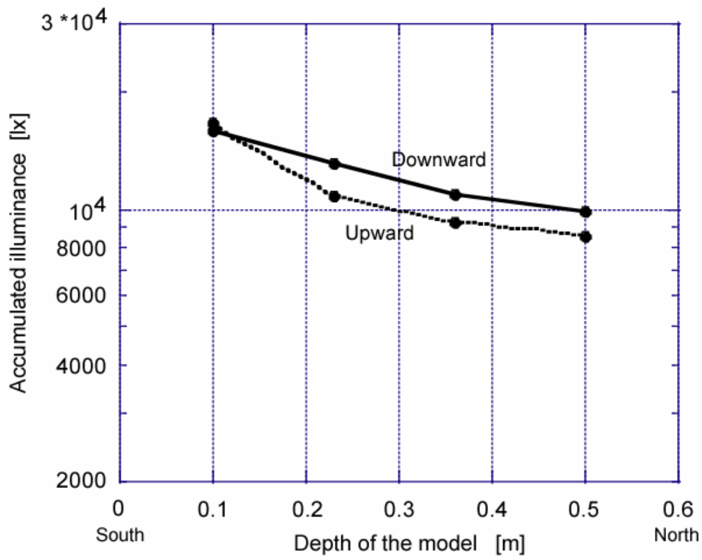


Figure 5 Combination of illuminance in the case of south facing ji-mado and north-facing typical opening

4. Conclusion

From the classification of 84 daylighting systems in the world, they were classified into four categories such as upper surface, vertical surface, whole building, and lower surface depending on the control parts of daylight. But there were no control systems of lower surface and no systems of the reflected daylight from snow surface in even snowy region.

One of the characteristics of ji-mado is that 80 % of daylight from snow surface corresponds with the indirect factor. There is a possibility that a combination of south facing ji-mado and north-facing typical opening can be relatively uniform luminous environment in the snowy region.

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