CLASSIFICATION AND EXPERIMENTATION FOR THE DEVELOPMENT OF DAYLIGHTING SYSTEMS IN COLD AND SNOWY REGIONS

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1. Abstract

The purpose of this study is to have a better understanding how to develop daylighting systems in buildings in cold and snowy regions. To achieve this, classification of daylighting systems which has been completed in the world in less than ten years is described in this paper. In addition, this paper describes the results of illuminance experiment by means of the actual scale model. Eventually, according to both the classification and the experimentation, some sectional examples regarding daylighting systems in Sapporo can be proposed.

84 examples were classified into four sections as a control part of daylight. 80% of all samples control daylight by vertical surface. The remaining 13% is comprised of upper surface, and less than the remaining 7% consisted of whole surface of buildings. There was no control system of the daylight by lower surface of buildings.

40% of the vertical surface has formed the daylight control system in the external wall side. The systems prepared in the inner surface of a wall, the system (the penetrated system is also included) formed in both the external wall and the internal wall is 10%, respectively. The rate by which the daylight control system is formed in double stratification of a wall or the sealed wall is 30%. This result expresses the tendency for this type of building to increase in number.

From the results in the experimentation, one of the characteristics of lower opening is that comfortable daylight can be taken into the interior zone. There is a possibility that lower opening may be well-suited in the north-facing of buildings as well as those can take reflective daylight from snow surface effectively.

2. Introduction

Over the past 10 years, researchers and designers have been seeking alternative strategies for saving energy in buildings. Especially designing or redesigning the building envelope for controlling daylight has been practiced. Various daylighting systems in buildings such as lightshelf and louvers in double skin wall have been developed (Lopin, 2002). In addition to establishing comfortable brightness for occupants daylighting systems also reduce electric power consumption as well as passive solar heating and cooling systems in buildings (O'Connor *et al.*, 1997, Asada and Shukuya, 1999). Nevertheless, installing daylighting systems in buildings in cold and snowy regions such as Sapporo has not yet widely practiced. One reason for this is thought that the daylighting systems have been developed without considering cold climate with snow coverage. However it is important to re-design daylighting systems in cold and snowy regions because they can utilize not only downward daylight from the sun and the sky but also reflective daylight from snow surface.

The purpose of this study is to have a better knowledge of daylighting systems in cold and snowy regions. We first created a classification system from various daylighting systems in the world from literature regarding architectures which have been published in last couple of years (Nasu and Nakano *et al*, 2004). Second, we had a luminous measurement in the actual scale model which has a typical opening. We actually focused on a better understanding how to take the reflective daylight into the indoor space thorough a lower opening (Miyakawa and Saito *et al*, 2003). Finally, according to the classification and the experimentation, we proposed sectional examples regarding daylighting systems in Sapporo.

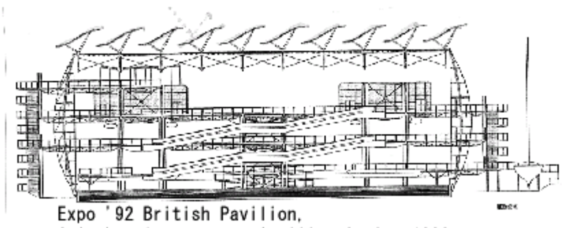
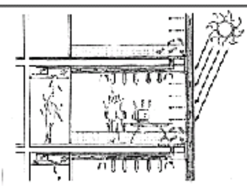
3. Classification of Daylighting Systems

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 a control part of daylight.

Upper surface means the systems to control daylight at the roof area of buildings such as EXPO 92 British Pavilion 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, 80% 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. However for developing the daylighting systems in snowy regions, lower surface or lower opening might become one of important parts in buildings because reflective daylight from snow surface can be taken into the indoor space effectively.

Table 1 Classification in terms of sections as a control part 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 Triple grazed windows with inner horizontal louvers
 Whole surface	 New Trade Fair Hall Von Gerkan, Marg & partners in collaborate with Ian Rithie architects, Leipzip, Germany, 1996 Glass with printed strips
 Lower surface	No data

Sources from ECO TECH , Thames & Hudson Ltd, UK

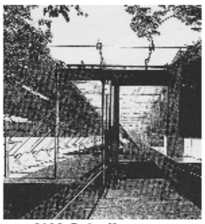
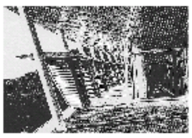
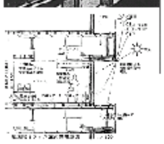
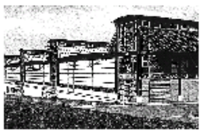
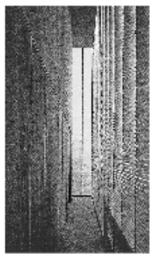
Table 2 shows the classification in 69 examples of vertical surface into six types as layout of devices of daylighting systems. There are 27 examples in Europe and 8 examples in United Stated and Mexico, and 34 examples in Japan, any other country in Asia and Australia. These can be classified as simple grazing, internal, external, penetrated, integrated, and multi grazing. 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 was 30%. This result expresses the tendency for this type of building to increase in number.

In our investigation, most of the buildings in cold and snowy regions such as the residential buildings in northern Europe can take daylight directly by preparing the opening at ceiling or large opening in the buildings without aiming at shading of daylight. However, the importance of solar shading devices also has already received widespread consideration in Germany and northern Europe countries (Schittich, 2002, Guzowski, 1999).

On the other hand in Japan, especially in Sapporo this consideration regarding solar shading has not yet matured so that thermal sensation in the buildings in summer might be sometimes so hot and muggy throughout day and night. We also need to consider daylighting systems from both lighting windows and shielding windows year round. Furthermore, we also need to develop not the devices as horizontal shading but those as vertical shading devices because of snow coverage.

Table 2 Classification of vertical surface in terms of the layout of controlling devices

Simple grazing	Inside	Outside	Penetrated	Integrated	Multi grazing
 GA06. Pola Museum Large windows Kanagawa, Japan  AU07. Laminate Laminates glass sections reflacting Leerdam, Netherlands	 AJ02. Rodover City Hall adjustable louvers Denmark Control  GA08. Rokkatei Makomanai Hall Vertical louvers serve as acoustic reflectors Hokkaido, Japan	 KK01. Stone Museum Louvers of Stone strips, Japan  BS10. Administration Buillding inWiesbasden adjustable eaves Germany  GA04. Institute for Grobal environmental strategies Light shelves in outside of windows, Japan	  DT10. White Office Light Duct  ET06. British Inland Revenue Eaves, London, UK	 AU03. GSWHeadquarters Integrated vertival louvers Berlin, Germany   ET03. Wilkahn Industory Double Grazing with sandwiched insulation Germany	 BS01. House in Okayama Multi layer of Policarbonate sheets Tokyo, Japan

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, Germany
GA:GA JAPAN, ADA edita Tokyo, Japan
KK:Kuma Kengo, Shokoku-sha, Japan
AJ:Arne Jacobsen, Edition GG, Spain

4. Luminous Performance of Lower Opening

The illuminance experimentation in the actual scale model which has four typical openings was made in the department in Sapporo School of the Arts during July in 2002. Figure 1 shows a view of the experimental space. We assumed this model to be a residential room such as a private den. The model has an opening which can be changed to four patterns. An opening was located overlooking and faced due east. Each pattern had no device such as louvers or Venetian blinds for shading.

Four openings can be shown in Figure 2. Four openings were assumed such as simple opening, “Zenkai” in Japanese, opening with back, “Koshi-kabe”, lower-horizontal opening, “Yukimi”, and also half-vertical opening, “Sode-Kabe” were assumed. Lower-horizontal opening, Yukimi, is one of Japanese traditional openings and snow surface can be seen through this opening in winter season. Opening area ratio can be calculated as an opening area divided floor surface.

Figure 2 also shows an average distribution map of indoor illuminance each pattern. Eventually simple opening, “Zenkai” can take largest daylight in any other case. On the other hand, lower-horizontal opening, “Yukimi” is the smallest luminous performance. However, in the case of

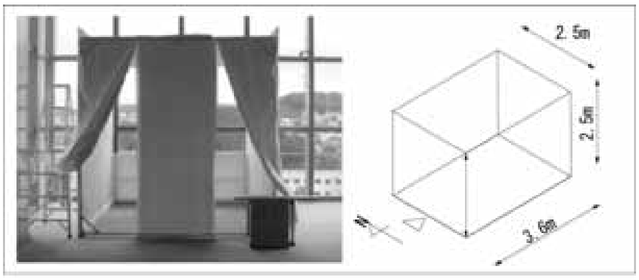


Figure 1 A view of experimental space

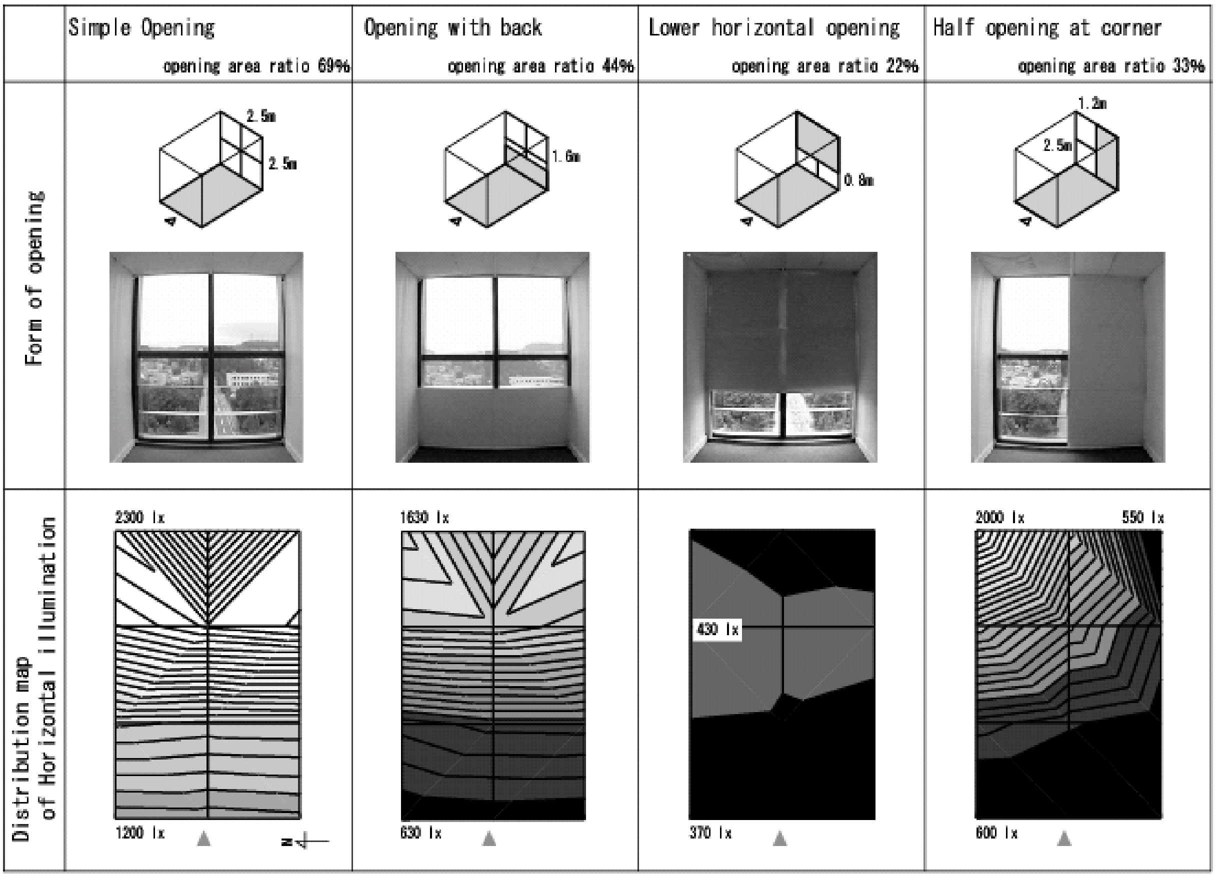


Figure 2 Distribution map of Horizontal illumination in each opening

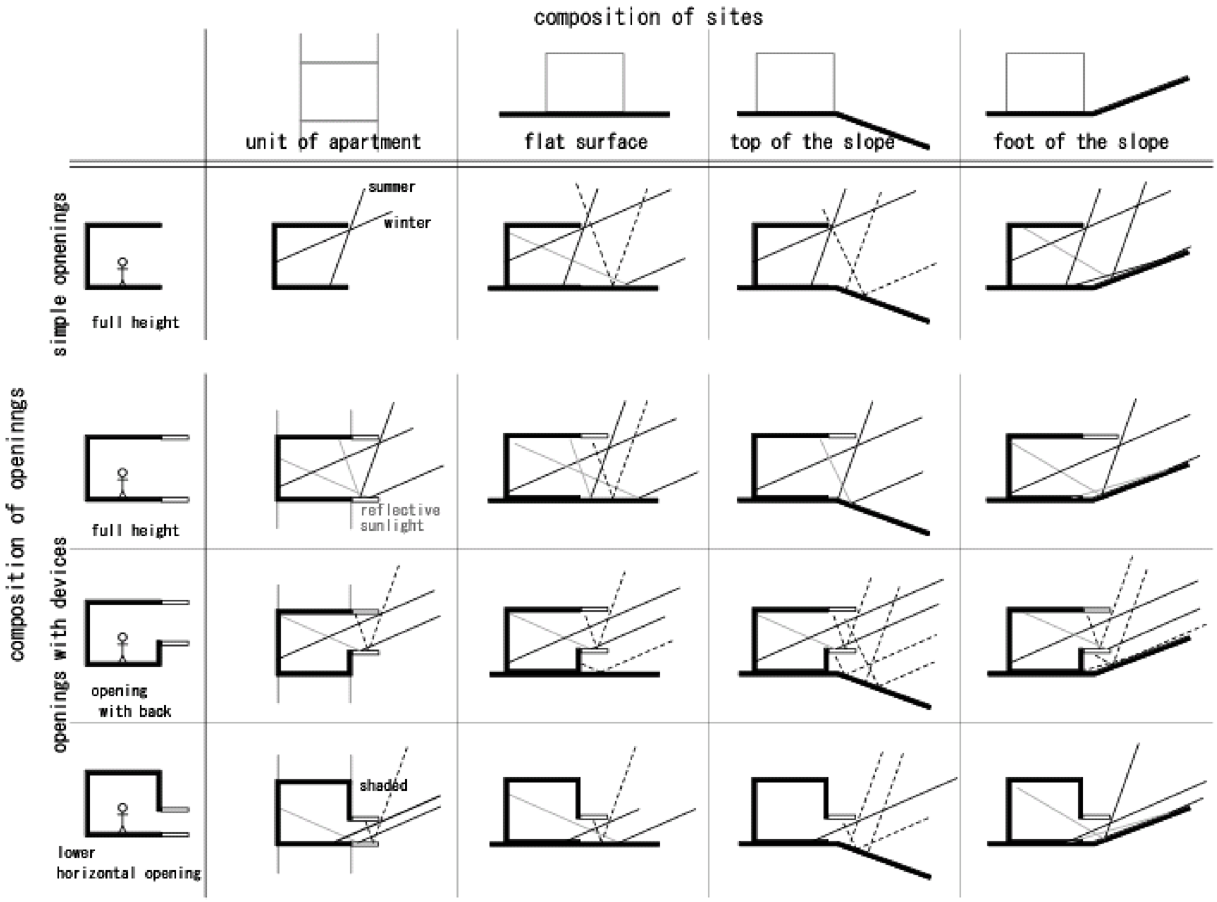


Figure 3 Sectional examples of daylighting systems with composition of opening and site at latitude 43° N (Sapporo)

lower horizontal opening comes into being the smallest uniformity ratio of illuminance. Therefore, it might be considered that occupants in the case of lower opening can not feel glare less than in the case of others. Furthermore, lower opening could be illuminated by 430 lx as only daylight.

According to the classification and the experimentation, sectional examples regarding daylighting systems in Sapporo can be proposed in Figure 3. Daylight can be divided into sunlight and skylight. Sunlight is direct solar radiation so that it can be shown as a solid line. Reflective sunlight is shown as gray line as well. Dotted line means the condition of solar shaded. Skylight is taken into the inside as well.

In cold and snowy regions such as Sapporo, to develop vertical daylighting devices for snow coverage might be important. Furthermore, although there are a few exceptions, characteristics of slope or walls of neighborhood can be utilized to take reflective daylight into the indoor space. In addition to mentioning that luminous performance in the case of south-facing in Figure 3 can be predicted to be stronger than that in the case of north-facing. Therefore, it is a possibility that northern lower opening can take the skylight and the reflective daylight from snow surface as well.

5. Conclusion

It is a possibility that lower openings as daylighting systems in cold and snowy regions can be well adjusted. One reason for this is considered that they can take the skylight and the reflective daylight from the snow surface. Second, there is the smallest uniformity ratio of indoor illuminance in lower opening so that it might be considered that occupants in the case of lower opening can not feel glare less than in the case of others. Developing devices as both daylighting and shading in cold and snowy regions should be thought as vertical devices for snow coverage.

References

a) Books and Books chapters

Guzowski M. (1999): **Daylighting for Sustainable Design**, McGraw Hill, New York, USA.

Schttich C. (2003): **in Detail Solar Architecture**, Birkhauser, Munchen, Germany.

b) Journal papers

Lopin K. M.(2002): **An Overview of Daylighting Systems, Solar Energy** Vol. 73, No. 2, 77–82.

c) Papers presented to conferences

Asada H. and Shukuya M.(1999): Numerical Analysis of Annual Exergy Consumption for Daylighting, Electric-lighting, and Space Heating/Cooling Systems, **Sixth International IBPSA Conference (Building Simulation '99),** Kyoto, Japan, 121-127, September in 1999.

Miyakawa K., Saito M. and Nasu S. (2003): An Experimental Study on the Relationship between Window and Layout of Furniture, **Proceeding of Annual Meeting of Architectural Institute of Japan(AIJ), E-1**, Chubu University, Japan, 1013-1014, September, 2003 (in Japanese).

Nasu S., Nakano M. and Saito M. (2004): Research on Day-lighting systems in Contemporary Architecture, Part 1. Classification in Compositions and Functions of Opening, **Proceedings of Annual Meeting of Architectural Institute of Japan (AIJ)**, **E-1**, Hokkaido University, Japan, 1087-1088, August, 2004 (in Japanese).

d) Other Documents

O' Conner J., Lee E., Rubinstein F., and Selkowitz S (1997): **Tips for Daylighting with Windows**, LBNL-39945, Ernest Orlando Lawrence Berkeley National Laboratory.

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