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Bioclimatic design strategies in temperate climate
Consistency of passive cooling and heating

YUICHIRO KODAMA

Building Research Institute
Tatehara 1, Tsukuba, 305 Japan
phone : +81-298-64-6750 fax : +81-298-64-6775
e-mail : kodama@kenken.go.jp

Abstract

In the temperate climate, the consistency of bioclimatic designs for heating and cooling is essential. However, the traditional Japanese houses which have excellent cooling techniques often disclose their poor thermal performance in the winter time. Since long it has been said that they sacrificed the heating performance in return for the cooling performance, as a result of their choice in the time when the consistency was technically impossible. This principle is often considered as a kind of critical expression of their aesthetic sense to give characteristic forms onto the traditional architecture in Japan.

Obviously, this principle can not be accepted in the extremely cold region, like Hokkaido and they have been struggling to find their ways of building after they had settled to Hokkaido as frontiers. It is spontaneous that they imported new technologies, such as super-insulating and super-air tightening from the northern countries in the recent time.

On the other hand, these new technologies become popular also in hot climate region of Japan because they are believed to be effective to reduce the cooling load of air-conditioning. It is obvious that this is a completely different concept from the traditional concept of bioclimatic design in Japan and sometimes clear contradictions can be observed between them because bioclimatic cooling designs are not always to be effective to reduce the air-conditioning load although they can create the natural pleasant indoor climate. It seems very necessary for the integrated design to coordinate the contrast between concepts.

INTRODUCTION

The Japanese archipelago, which stretches in the north-south direction from North Latitude 26deg to 45deg, has a large variation in climate from subtropical to frigid. This large variation in climate is reflected in a large diversity in heating requirements; no heating is needed on the islands of Okinawa, to the very south, while the annual heating degree day (D18-18) from Honshu to Hokkaido ranges from 1,400 to almost 5,000. This is comparable to the difference between Rome and Moscow. Except for Hokkaido, the summer in Japan is one of high temperatures and high humidity. In midsummer, humid days with temperatures soaring over 30 °C continue for long periods in many regions of Japan.

These high temperatures and humidity in summer have been the main considerations in traditional Japanese house design, which is characterized by a large roof and eaves to block solar radiation, an open interior to enhance ventilation and reduce heating, and integration with the garden and surrounding landscape. Consideration in traditional Japanese house design of the high humidity was important for prolonging the life of the house.

However, this traditional Japanese house design, based on the high temperatures and humidity of the Japanese summer, was not suitable for the cold winter in northern Japan. Most Japanese believe that the traditional Japanese house design is well suited to the Japanese climate. However, many foreigners who have experienced living in a Japanese house in winter do not think so, and it has been pointed out by one anthropologist that the traditional Japanese house design is completely unsuitable for the Japanese climate.

Traditional Japanese house design proved to be especially unsuitable for the harsh winter climate in Hokkaido, in which the heating degree days exceeds 4,000. Attempts to build houses suitable for the harsh Hokkaido climate in the pioneering days by modifying the traditional Japanese house design proved unsuccessful. Instead, ideas were adopted from house designs in cold regions such as Scandinavia and Canada. Superior insulation methods, airtight systems, and ventilation systems in Japanese house design were all first introduced to Hokkaido.

These techniques slowly spread south in Japan, sometimes clashing with traditional house design methods. Such clashes were inevitable. The addition or introduction of partial or superficial design elements that differ from the original basic concept will naturally cause problems. The introduction of superior technology from abroad lead to a new stage in the history of Japanese housing. This paper reviews the design strategies for houses in regions of Japan that have a temperate climate.

TRADITION AND NEW TECHNOLOGY

The two typical types of Japanese traditional houses are "thatched-type dwellings" (reed roofing) and "storehouse-type dwellings". The design characteristics of thatched houses include 1) open spaces, 2) a large roof and large eaves to protect against heat and rain, and 3) the use of construction materials with a small heat capacity. These characteristics are similar to those of dwellings designed for summer that are described in the classical Japanese writing "Tsurezuregusa" (Random Thoughts from My Leisure Hours) by Kenko Hoshi in 13th century.

Storehouse-type dwellings, on the other hand, were originally storehouses that were built with fire-resistant materials to prevent fire spreading from adjacent buildings, although in some areas of Japan, these storehouses were also used as dwellings. The characteristics of these storehouse-type dwellings were 1) closed spaces, 2) double-roof to protect against heat and rain, and 3) thick earthen walls that had a large heat capacity. Thatched-type dwellings far outnumbered the storehouse-type dwellings.

The roofs of Japanese traditional thatched houses were very thick and had provided good insulation. However, the purpose of this thick roof was not to provide warmth in winter but to prevent the penetration of heat and solar radiation in summer. The roofs and walls of thatched houses had good air-permeability, which was not only effective for reducing humidity but also kept the construction materials dry, thereby prolonging the life of the house. The floor of the thatched houses was raised, allowing ventilation under the house. The floor itself also had good air-permeability. The raised-floor structure and permeability of the floor both enhanced the durability of the construction materials and also allowed sufficient ventilation in summer to cool the house.

The open spaces are characterized by high ceilings, sliding doors separating rooms, transoms, a wide opening leading to the garden, and an open veranda under the eaves. These are a result of selecting materials with a natural plant texture, such as straw matting and bamboo hurdles, that resist dampness and have a good cooling effect in summer.

Such types of houses can be found throughout Japan, except for Hokkaido, and are thought to have originated in Southeast Asia. Houses of basically the same style can also be found in cold areas of Japan in which the heating Degree day (D18-18) exceeds 3,000. The lack of insulation against the cold is thought to have been related to the high death rate in winter in such areas of Japan, and statistics show that the death rate in winter decreased with the spread of home heating systems. There was a rapid spread of portable kerosene stoves in Japan in the 1960s, when oil was in abundant supply.

From the 1920s, based on scientific research, attempts were made to enhance the thermal properties of houses to suit climatic conditions. Results of these endeavors can be seen in the experimental house (Choutikukyo) designed by Koji Fujii, a pioneer in research on thermal properties in house design. In addition to the modifications of tradition Japanese house design mentioned previously, glass windows were incorporated into the house design to utilize the heat from solar radiation.

Studies on the enhancement of thermal properties of buildings in regions with a temperate climate increased due to Japans colonization policy during the early years of World War II but were later terminated as the war intensified. Following Japans initial restoration period after the end of World War II came the era of abundant energy supply, and the focus of research shifted from enhancement of the thermal properties of buildings to efficient utilization of energy and appropriate methods of heating. The method of evaluating the performance of buildings also changed due to this shift in research. Interest was not shown again in the enhancement of thermal properties of buildings until after the introduction of passive design in the 1970's.

The common factor in traditional Japanese house design and passive design is their adaptability to changes in the natural environment and the resultant improvements in the interior environment. On the other hand, evaluation of the thermal properties of a building that uses mechanical heating and cooling is based on the amount of the heating or cooling load. Airtightness is a precondition in the latter case. Such a difference in the methods of evaluation is not a problem in cold regions such as Canada but is very significant in the case of a temperature region such as Japan.

THE EFFECTS OF INSULATION AND AIRTIGHTNESS IN WINTER IN A TEMPERATE REGION

Insulation and airtightness techniques in Japan, as mentioned at the start, were first introduced to Hokkaido. The purpose for introducing these techniques was to improve the thermal performance of buildings in Hokkaido to the level of that in Canada. Insulation reduces heat loss, while airtightness not only reduces heat loss but also prevents condensation inside the walls, which can be caused by insulation, as well as enable effective operation of a controlled ventilation system. If we were to consider only an extremely cold climate, then the higher the degrees of insulation and airtightness are, the more effective they will be. The Canadian R2000 house is one example of such a highly insulated and airtight house designed for extremely cold conditions. However, how about a region with a temperate climate? In order to clarify this issue, lets focus the discussion first on winter.

EFFECT OF INSULATION

Insulation enhances the resistance to heat transmission on the exterior surface of the building and is effective for reducing heat loss from the building. Naturally, this effect is greater the greater the difference between indoor and outdoor temperatures is. Economically, the appropriate degree of resistance to heat transmission on the exterior surface of the building should be estimated from the air temperatures of the region in question.

EFFECT OF AIRTIGHTNESS

1. *Reduction of heat loss*
   Heat loss due to ventilation also depends on the difference between indoor and outdoor temperatures. It is estimated that in traditional Japanese houses, which are full of cracks, the room air change rate is more than five times per hour, and a reduction of the infiltration would naturally have a great effect on the reduction of heat loss. However, a reduction of the rate of room air change from 0.5 to 0.1 time per hour would, on the other hand, not be so effective, even less so a reduction from only 0.1 times to 0.05 times or a reduction in the equivalent leakage area from 1 to 0.5 cm^2/m^2 (floor). The only effect this may have would be a very slight improvement in the comfort level due to a draft reduction in the room.
   In a temperate region, which has a smaller difference between indoor and outdoor temperatures, the effect would be even smaller. The amount of infiltration is also affected by the wind speed, but this effect is quite small in temperate regions.
2. *Prevention of condensation inside walls*
   Condensation inside walls was a problem in the early days of insulation due to the use of inappropriate insulation materials, and this resulted in a significant shortening of the life of the building. This problem of condensation can be prevented by installing a vapor barrier layer and ensuring that dampness in the room does not penetrate the walls. The risk of condensation is higher in colder climates, and therefore the airtightness of buildings in cold regions is important. However, in temperate regions, in which there is a lower risk of condensation, what degree of airtightness is necessary ? Installation of a venti-

lation layer on exterior walls to exhaust damp and the use of insulation materials that have humid-absorption and -desorption are effective for preventing condensation. Can an appropriate level of airtightness be established for building in temperate regions ? Further studies are needed do develop various new methods of construction.

3. *Effective operation of controlled ventilation*
If the degree of airtightness is low, effective operation of a controlled ventilation system is impossible. This is because, even though polluted air may effectively be expelled from the building, the direction and amount of airflow can not be effectively controlled if there are cracks in the building that disturb the flow and pressure of air. A high level of airtightness is especially important for the effective operation of high-level ventilation systems such as the heat exchange-type central ventilation system. However, if there are few pollutants and also a small difference between the indoor and outdoor temperatures, there is not a great need for a high-level ventilation system. There is the view that an elaborate control system is not needed for houses, and simple ventilation systems should be developed for houses in temperate regions.

The above three points are essential for airtightness of houses in cold regions. However, what about houses in temperate regions?

EFFECTS OF INSULATION AND AIRTIGHTNESS IN SUMMER IN TEMPERATE REGIONS

A common misunderstanding concerning a highly insulated and airtight house is that a high degree of insulation and airtightness will reduce the load of mechanical cooling.

EFFECT OF INSULATION

As mentioned previously, one of the design characteristics of a traditional Japanese house is blockage of heat from solar radiation. The thick thatched roof and large eaves prevented penetration of heat from solar radiation. However, the thick thatched roof and large eaves may have been effective for blocking heat from solar radiation in summer, but they did not have an insulating effect in winter. On the other hand, the well-insulated parts of the house did contribute to blocking heat from solar radiation in summer. Insulating materials in the roof and ceiling were also effective for blocking heat from solar radiation in summer, but a greater heat resistance for summer was more desirable than heat resistance for winter. Also, looking at the back flow of heat through the exterior surface that was not subject to solar radiation, under conditions in summer in which the difference between indoor and outdoor temperatures is only a few degrees, the effect of insulation on reducing the cooling load is not so great. The sun-breaking effect around windows has a much greater effect on reducing the cooling load.

EFFECT OF AIRTIGHTNESS

In places where there is a large inflow of fresh air, air conditioning is not effective. Increasing the degree of airtightness by reducing the equivalent leakage area from, say, 5 cm^2 to 2 cm^2 would only have a very small effect on reducing the cooling load. This is because, as in the case of insulation, if the difference between indoor and outdoor temperatures is only a few degrees, the effect of a small decrease in the amount of air inflow would be small. A high degree of airtightness, like insulation, is effective for winter, not summer.

This does not mean, as is sometimes thought, that the cooling load would be increased in a highly insulated and airtight house. The important thing is to block out solar radiation. If this is not done, only the heat that is trapped in a highly insulated and airtight house may increase the cooling load.

The effects of insulation and airtightness have been investigated using heating load and cooling load as indices, but in temperate regions, it has been shown that changing the mode of the building from a cooling mode to a passive cooling mode is very effective for reducing the necessary cooling period. In a cooling mode, the building is sealed, while in a passive cooling mode, a natural cooling effect can be obtained from cross ventilation or nighttime ventilation by opening or closing windows according to outdoor conditions. In other words, in a temperate region, changing the mode of the building, that is, allowing the building to be opened is just as important as insulation and airtightness. Being able to seal the building is necessary in a temperate region, but allowing the building to be opened is also an important condition for building design.

CONCLUSION

Everyone is now well aware of the seriousness of the global environmental problems. All human activities, whether they be efforts to conserve energy or reduce the use of resources, are related to the global environmental issues now facing us. Various policies to counter these environmental problems have been devised, and there are various options available for individual building design, which is probably a desirable situation. The choice does not have to be limited to catalogue stereotype energy-conservation measures but should be considered on an individual level.

As far as durability, which is a key word in building design now, is concerned, a lesson should be taken from the "diversity" of ecology. Diversity in building design may greatly increase the resistance to natural regional differences.

Unfortunately, there has not been much consideration of diversity in building design. Rather, there has been a tendency to simplify systems or to adhere to only one system in order to increase efficiency. Energy-consuming mechanical heating and cooling systems were built after the 1960s, when energy was in abundant supply, and the focus later shifted to energy conservation of the system when energy supplies became limited.

One example is energy conservation in heating and cooling. Different design strategies should be required for constructing a building with good thermal efficiency that has 24-hour air conditioning and a building that does not rely heavily on air conditioning but low energy passive cooling and heating. One example of the former case is a house like a spaceship. The house is tightly sealed so as not to be affected by any changes in the external environment. In the latter case, in contrast, changes in the natural environment are utilized to create modified indoor climate by planning the flow in the building. For efficient utilization of changes in solar conditions, wind and humidity, integration of internal and external environments is an important point in the design.

In terms of energy conservation, the focus of the design for blocking out the external environment is the opposite to that for integrating the external environment. If we assume that energy consumption is the same in both cases, then the impact on the environment is the same in both cases. The difference lies in the quality of comfort. Thus, the issue is not which mode is correct but which should be chosen. The image of what type of town is desirable is important in deciding which mode to choose.

The quality of comfort may be the final deciding factor. What we will need to reconsider in the future is the relationship between environment and building and the relationship between nature and man-made environment.

This is not saying that artificial environment technology is unnecessary. In fact, buildings today would not be possible without this technology. This powerful technology should be used when necessary. However, living spaces constructed solely with this technology are not desirable.

Living spaces in the future should be designed with the focus on the correspondence between man and the nature, or the natural- and the built environment. Development of technology based on this type is desirable especially for Japan and Asia, which have temperate climates.

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