Translucent thermal insulation walls for houses in Japan

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ABSTRACT

Translucent thermal insulation walls for Japanese houses have been designed to allow solar radiation and daylight to pass through the walls into the house (Fig. 1） in order to reduce the amount of energy required for heating and lighting and to create a comfortable lighting environment. The walls are made of translucent or transparent materials such as glass and thermal insulation material.

The walls have been developed with consideration given to conditions of various regional climates and housing lots. Computer simulations showed that light transmittance should be higher than 20% to reduce daytime lighting energy by half in the case of a small housing lot in Tokyo. Total solar energy transmittance is the most important factor for reducing energy required for heating. The higher total solar energy transmittance is, the greater is the reduction in energy required for heating. Simulations conducted for the cold region and the moderate climate region in Japan showed that the use of translucent thermal insulation walls enables 20%-40% reduction in total energy, including energy for heating, cooling and daytime lighting.

1. INTRODUCTION

There is a demand for reduction in energy for heating in houses in almost all areas of Japan. However, increase in thermal insulation and improvement in space heating system efficiency have not had any immediate or significant effects on the amount of energy used for heating. Reasons for this include an increase in indoor temperature in winter for the occupants' comfort, increase in floor area per house, and increase in the number of households despite a decrease in the number of persons in a family.

Windows in many houses in Japan cannot provide sufficient daylight because of the small and shady housing lots (Fig. 2) and because of the use of low light transmittance window

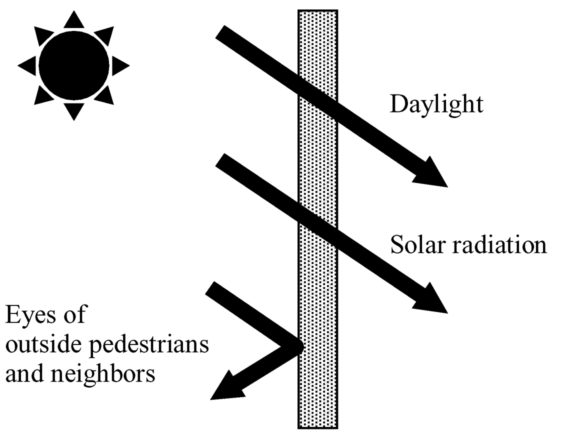


Fig.1 Translucent thermal insulation walls

Fig.2 A small housing lot in Tokyo

systems (such as lace curtains and rolling screens) to block the views of outside pedestrians and neighbors. Large windows are not effective for improving visual comfort and cause an increase in energy for heating.

Translucent thermal insulation walls for Japanese houses have been developed as a means for reducing total energy consumption and providing daylight. These walls reduce heating energy and increase cooling energy by solar radiation gain, and they provide daylight while blocking the view of outside pedestrians and neighbors.

This paper presents results of computer simulations carried out to determine the performance of translucent thermal insulation walls from the viewpoint of energy conservation.

2. SIMULATION MODEL

Figure 3 shows the model used for simulations of energy for heating, cooling and daytime lighting. This model was used for the study to make the Japanese energy conservation standard. The model is based on the average floor area and average volume of houses in Japan and on a typical house plan in Japan. Translucent thermal insulation walls are used for 70% of the surface area of exterior walls (except windows). Housing lot" Type I" is common in and around Tokyo, and" Type II" is common in other parts of Japan.

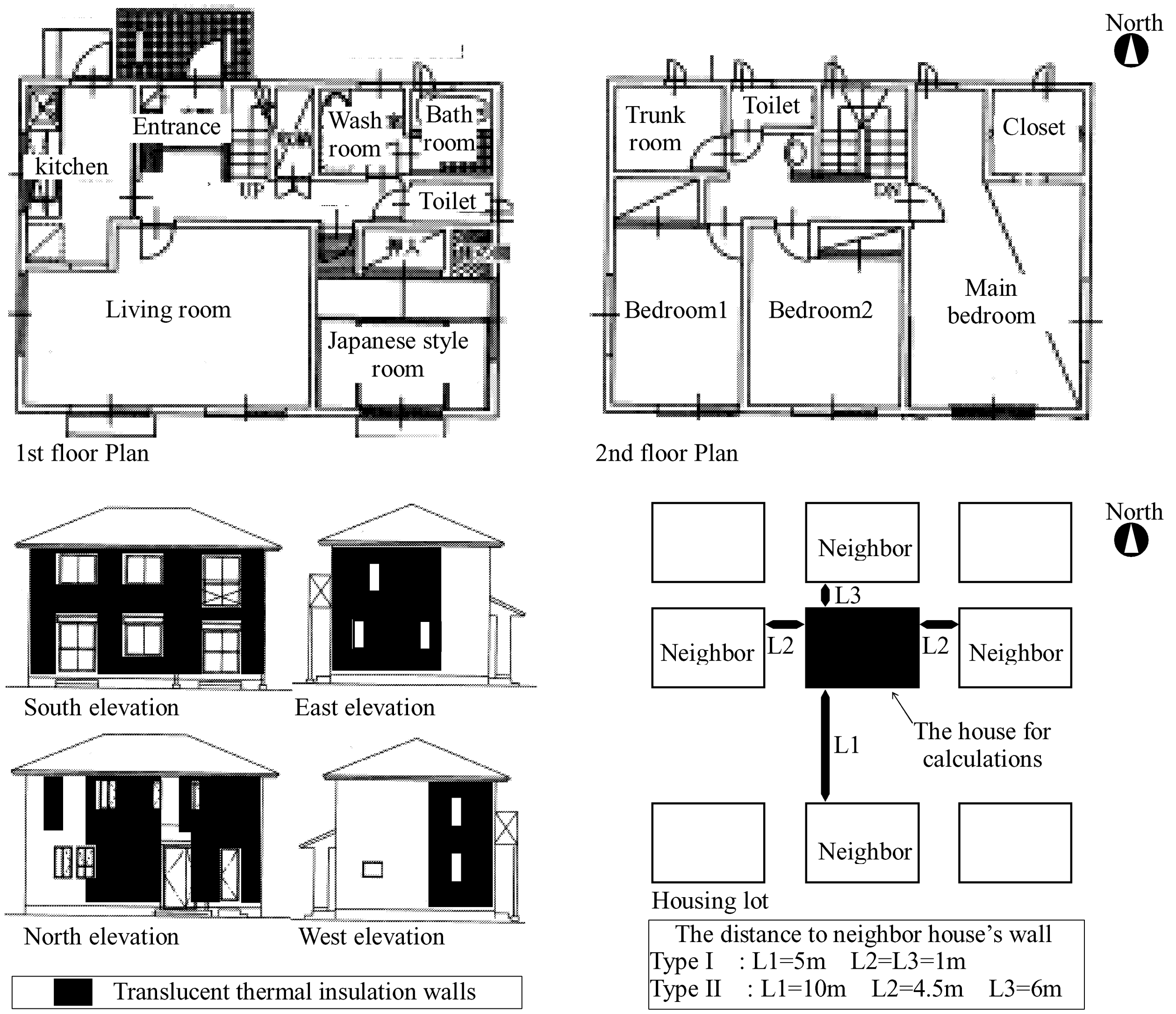


Fig.3 House and housing lot model used for simulation

3. LIGHT TRANSMITTANCE

3.1 CONDITIONS OF THE SIMULATION

The light transmittance of translucent thermal insulation walls is assumed to be in the range of 0-50%, and the light transmittance of windows with lace curtains is 30%. Translucent thermal insulation walls and windows have isotropic diffuse transmission.

In the case in which the floor illuminance of the center point of each room is lower than the value of illuminance in Table 1, electric power is consumed for artificial light. Energy for daytime lighting means total electric power used for all rooms for one year in the daytime (solar altitude over 10 degrees).

3.2 PRIMARY ENERGY

Figure 4 shows the relationship between light transmittance and primary energy for daytime lighting. The higher light transmittance is, the greater is the energy reduction. Compared with walls that have 0% light transmittance (translucent thermal insulation walls not used), walls that have about 20% light transmittance reduce primary energy usage by half. Light transmittance should therefore be more than 20% in order to reduce energy consumption.

4. TOTAL SOLAR ENERGY TRANSMITTANCE AND THERMAL TRANSMITTANCE

4.1 WALLS

Figure 5 shows specifications of translucent insulation walls. The walls are made of three sheets of glass and translucent thermal insulation material. These wall specifications are based on results of studies on lighting environment (reference), earthquake resistance and fire resistance.

Table1 Illuminance term for artificial light use and energy for artificial lighting

	Illuminance [lx]	Energy for artificial lighting [MJ]																
		time																
		6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
Living room	150	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18			1.18	1.18	1.18	1.18	1.18	1.18	1.18
Japanese style room	150																	0.69
Kitchen	75	0.59	0.59	0.59				0.59	0.59				0.59	0.59	0.59			
Wash room, Bath room	75	0.39	0.39	0.39												0.39	0.39	0.39
Entrance	30	0.59	0.59	0.59								0.59	0.59	0.59	0.59	0.59	0.59	0.59
Main bed room	10	0.79															0.79	0.79
Bed room1	150		0.69													0.69	1.28	
Bed room2	150		0.69													0.69	1.28	

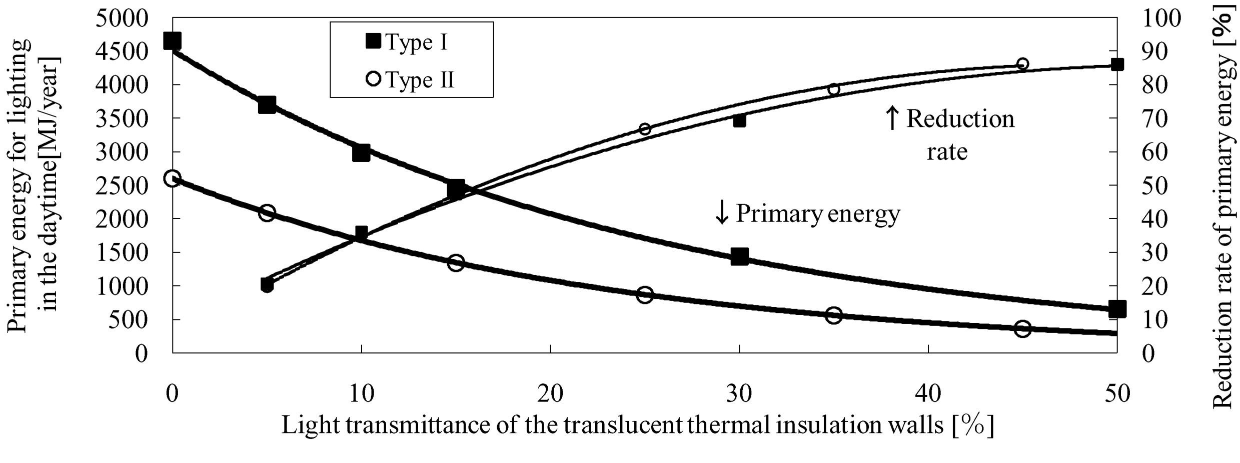
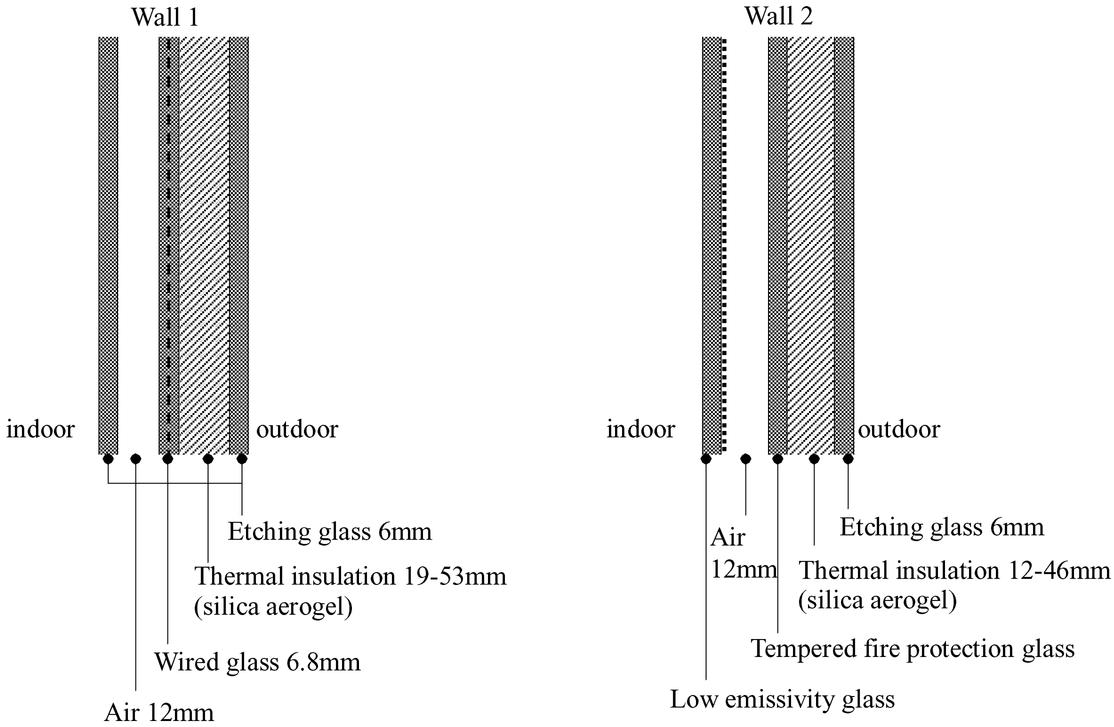


Fig.4 Primary energy for lighting in daytime (Tokyo)



Thickness of thermal insulation was determined for the thermal transmittances to be 0.3,0.4,0.5,0.6,0.7[W/K・m^2].

Fig.5 Translucent thermal insulation walls

4.2 INFLUENCE OF THE ANGLE OF DIRECT SOLAR RADIATION INCIDENCE

Solar radiation transmittance of glass depends on the angle of incidence. Figure 6 shows the total solar energy transmittance considering the angle of incidence of direct solar radiation. The conditions of the simulations were as follows: 1) fine weather, 2) solar radiation not blocked by any objects such as neighboring houses, and 3) translucent insulation walls facing south. As can be seen in Fig. 6, solar energy gain is large in winter and small in summer. It is thought that the angle of incidence has a great effect on heating and cooling energy. Therefore, the angle of incidence of direct solar radiation was considered in the following heating and cooling energy simulations.

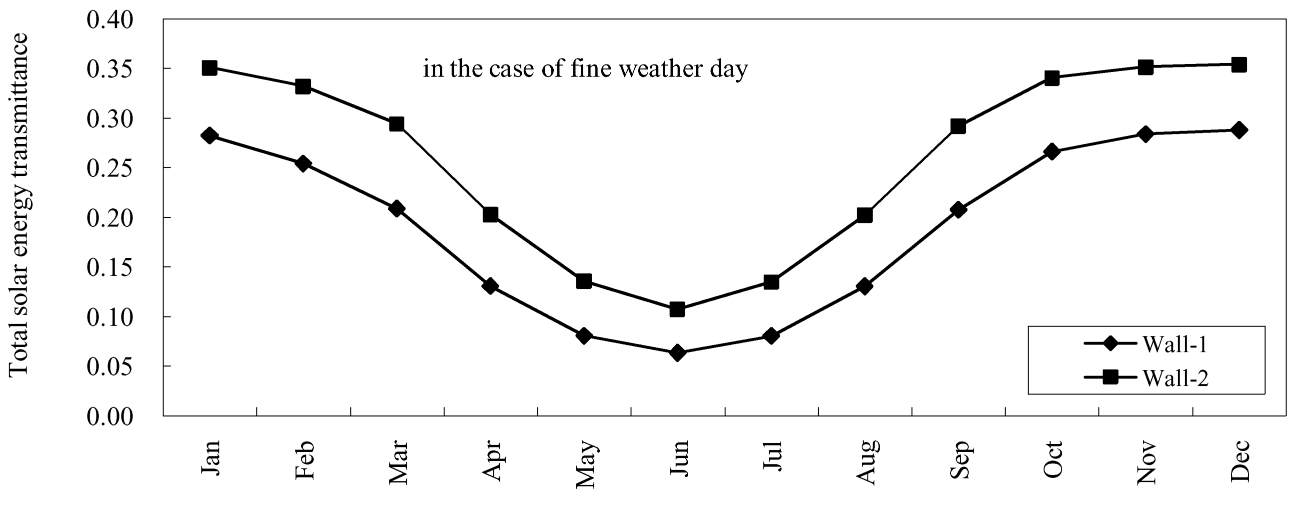


Fig.6 Total solar energy transmittance considering the angle of incidence of direct solar radiation

4.3 CONDITIONS OF SIMULATION OF HEATING AND COOLING ENERGY

Heating (20°C) and cooling (26 °C) by the air conditioner works according to the schedule shown in Table 2. Air change rate is 0.5 [ACH], and ventilation operates all day long. In summer, if room temperature is higher than 25 °C, outdoor temperature is lower than 27 °C, and the air conditioner is off, air change rate is 10 [ACH] as airing. The efficiency of air conditioner is 3.0.

Locations are shown in Fig.7.

4.4 TOTAL ENERGY

Figure 8 shows total energy reduction rate and heating energy reduction rate. The reduction rate values in the Fig. 8 are largest value among 5 walls (0.3, 0.4, 0.5, 0.6, 0.7 thermal transmittance). For all regions, large total solar energy transmittance results in a higher rate of reduction in heating energy. In the cold region of Japan, large total solar energy transmittance, about 0.4, results in high rates of reduction in total energy, because heating energy is very large in houses in this region. In the moderate climate region, heating energy is most large among heating energy, cooling energy and daytime lighting energy.

However, cooling energy is larger than that in the cold region. Therefore, total energy reduction rates become higher in the case of small thermal transmittance (about 0.2) and small total solar energy transmittance (lower than 0.5).

In Tokyo, walls for high total energy reduction require thermal transmittance of about 0.5, total solar energy transmittance of 0.3-0.4, and light transmittance of about 0.4. Walls with such optical and thermal properties can reduce total energy consumption in areas other than Tokyo, e.g., reductions of 26% in Sapporo, 35% in Sendai, 28% in Niigata, 31% in Shizuoka, 19% in Osaka and 24% in Fukuoka, in the case of wall-1 and housing lot type II. Therefore, the optical and thermal properties of translucent thermal insulation walls described above are targets for achieving greater energy conservation in houses in Japan.

Table2 Heating and cooling schedule

	time																
	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
Living room	↔	↔	↔				↔	↔			↔	↔	↔	↔	↔	↔	
Japanese style room																↔	
Main bedroom																↔	↔
Bedroom1 / Bedroom2															↔	↔	↔

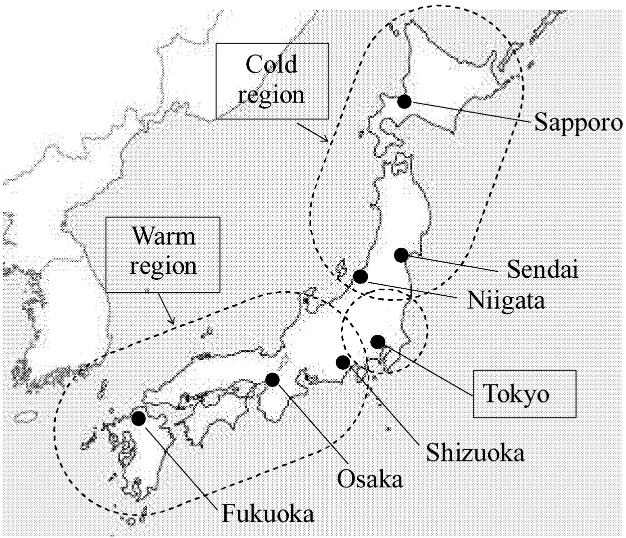


Fig.7 Cities and regions for total energy simulation

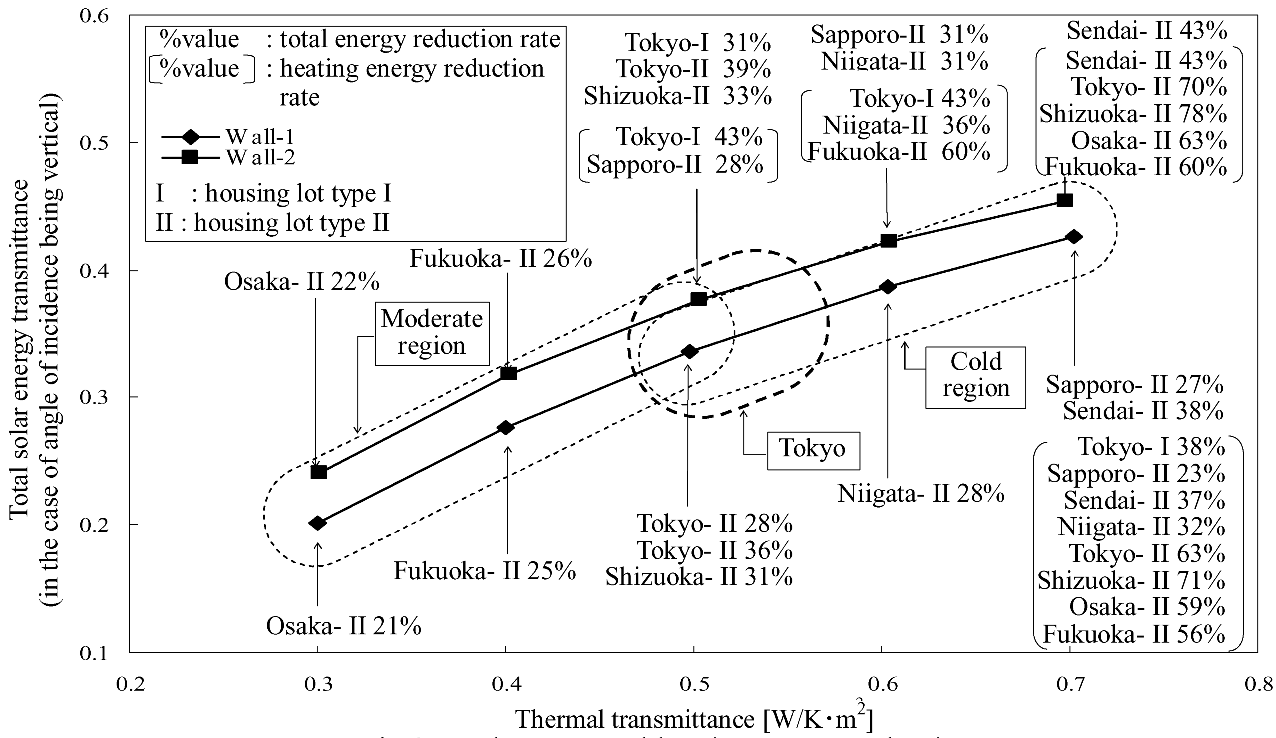


Fig.8 Total energy and heating energy reduction rate

5. CONCLUSIONS

5.1 Optimum transmittance for energy reduction

In cases of wall-1 and wall-2.

-Light transmittance of over 20% is effective for reducing energy for lighting in the daytime. (Fig.4)

-Higher total solar energy transmittance results in large heating energy reduction in almost all areas of Japan. (Fig.8)

-Total solar energy transmittance and thermal transmittance that result in largest total energy reduction depend on the climate. In the cold region of Japan, high total solar energy transmittance, about 0.4, results in large total energy reduction. In the moderate climate region, walls with total solar energy transmittance of about 0.2 and thermal transmittance lower than 0.5 are needed for a large reduction in total energy . (Fig.8)

-Walls with thermal transmittance of about 0.5, total solar energy transmittance of 0.3-0.4, and light transmittance of about 40% are needed to obtain maximal reduction in energy in almost all areas of Japan, particularly in Tokyo. (Fig.8)

5.2 DEVELOPMENT OF TRANSLUCENT THERMAL INSULATION WALLS

Translucent insulation walls should have some benefits other than the benefit of energy conservation. For example, translucent insulation walls could be used to improve the lighting environment. An experimental study (reference) has shown that light transmittance should be in the range of 20% to 40% to prevent discomforting glare and to provide comfortable luminance. Earthquake resistance and fire resistance are also important. Wall components have been developed to increase the strength of walls in order to enhance earthquake resistance. The energy conservation performance of translucent thermal insulation walls with strong earthquake resistance is similar to that of the walls described in this paper. Fire resistance is also taken into account in the specifications of walls described in this paper.

Translucent insulation walls that are currently available in Japan have been improved with consideration given to various factors, including performance, cost, durability, and room temperature in summer.

REFERENCE

Kitadani Y., Suzuki H., Kihara M. (2007). Development of thermal insulation wall utilizing daylight. Summaries of technical papers of annual meeting architectural institute of Japan.D-1-p.419-422.