High Efficiency Small House in Musashino City, Tokyo

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There has been great discussion recently about energy-saving houses. In summer in Japan, the outside temperature is high, and humidity is also high. Japanese houses have been built to be easy to live in, in summer. Traditional Japanese houses are not insulated and are open to the outside. These days, to build a thermal insulated house is recommended by the government. Because of the lack of experience in thermal insulation techniques, sometimes failures occur.

We built a highly airtight and well thermally insulated house in Tokyo. Using new heating and cooling technology, the electricity costs for heating and cooling became lower. The characteristics of this house are as follows. An external thermal insulation compound system with thick wooden fiber board was used. Next, triple glass windows with wooden frames were used. Waterproof and porous sheeting was used for moisture control in the wall. In addition, to prevent solar heat gain in summer, external blinds were installed. Heating and cooling radiator panels were installed on the ground and first floors. Finally, inorganic paint was used for its fire resistance and to keep the room free of VOCs.

Introduction

This house was built for a childless couple in their forties. The construction began in May and ended in the beginning of December 2015.The construction site was in Musashino City, Tokyo. This house was built with a wooden 2x4 construction method because of the narrow front path leading to the driveway.

1. Energy saving method

The outside walls, roof, and floor were insulated by thick, hard wooden fiber board.

They were also insulated by an external thermal compound system. The thick wooden fiber boards were attached directly to the outside wall with 70 mm metal nails. Furring strips were not used for the attachment of insulation board. The surface of the wooden fiber boards was coated with a thin adhesive mortar. To prevent cracks, alkali-resistant glass fiber mesh was inserted into the mortar layer. Finally, the surface of the mortar layer was coated with plaster (stucco). Wooden fiber boards were connected by shiplap. This was so that when it rained at the construction site, rainwater could not enter the walls and roof. The corners of the outside walls were covered by plastic profiles to prevent scuffing from the outside, such as from bicycle handles.

During production, most building materials, such as plastics, steel, aluminum, glass and cement discharge a great amount of CO_2. However wood absorbs CO_2 while growing in a forest.

Wooden materials, such as wooden construction materials, wooden fiber board, and wooden frames for glass windows return to the earth when the house becomes unused. Therefore, the application of wooden material is environmentally friendly. In the future, wooden building materials must become more common in the construction of houses.

The roof was also insulated by wooden fiber board. The thermal conductivity of this wooden fiber board is 0.040W/(m・K) and density is 110kg/m^3. The thermal conductivity of commonly used glass fiber is 0.038W/(m・K) and the density is 24kg/m^3. During summer there is a time lag between indoor air temperature and the maximum sol air temperature. The maximum sol air temperature reaches the room with significant reduction because of the thermal capacity of wooden fiber board.

The overall thermal transmittance of the outside wall is 0.19 W/m^2. The overall thermal transmittance of openings is 0.95 W/m^2.

Because of the thickness of wooden fiber board, water condensation sometimes occurs in the outside wall. To prevent such water condensation, waterproof porous sheeting was installed between the wooden fiber board and the outside wall. This waterproof porous sheeting changes its molecular construction according to the relative environmental humidity. In winter, when the vapor pressure of indoor air becomes higher, the very small holes in this sheeting close according to the change in molecular construction. Thus, vapor is prevented from entering the wall.[1)]

Fig. 1 High density wooden panels attached to the exterior walls

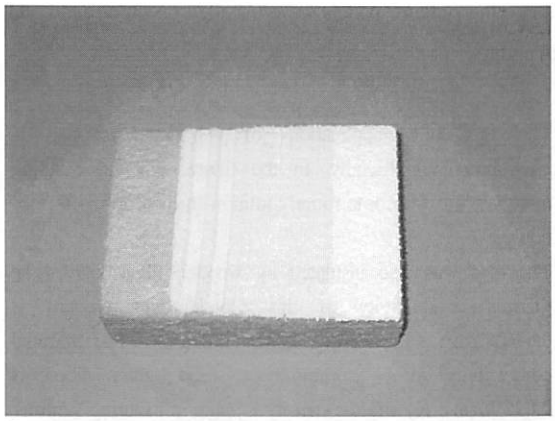

Fig. 2 Structure of the external thermal compound system

Fig. 3 Plaster work with adhesive mortar on the wooden fiber board

In summer, as the vapor pressure of the inside of a wall increases, tiny holes in the sheeting expand, and vapor is carried into the room. To determine if waterproof and porous sheeting is necessary, the software tool " Wärme und Feuchte instationär"(WUFI) is used. WUFI was developed by Fraunhofer Institute for building science. It is sometimes difficult for vapor to escape from inside the wall. This is called "moisture condensation". Using WUFI, it is simple to investigate the hygrothermal behavior of building components.[2] Vapor doesn't remain in the wall because waterproof and porous sheeting has 60 times the variation in vapor transmission, and the absolute humidity in the wall is always in an ideal state.

The outside insulation method is the industry standard for buildings and houses outside Japan. However, the Japanese method for buildings lags behind , so the outside insulation method has not yet become popular in Japan. On the contrary, some books have criticized the outside insulation method. The common criticism concerns overheating in the summer. It is a matter of course that when sunshine enters through the openings, room air temperature increases. In Japan, with its hot and humid summers, outside sunshades are necessary. In Germany, where outside insulation is popular, outside sunshades are commonly installed. Therefore, outside sunshades were installed in this house.

2. Heating & Cooling Technology

Heating and cooling radiator panels were installed on the ground floor and first floor.

In winter rooms are heated by circulating warm water, which is

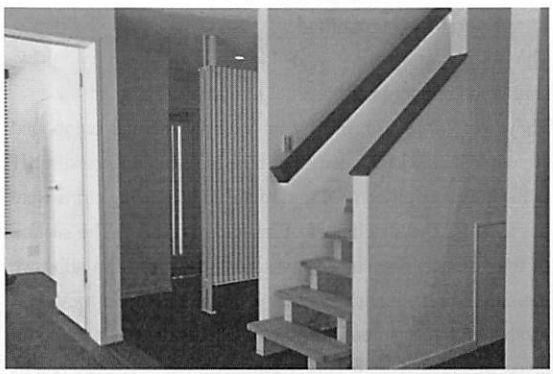

Fig. 4 Attachment of low temperature heating & cooling radiator. Inorganic paint was used for its fire resistance and to keep the room VOC free

provided by a heat pump (rating output 7.5kWh). In summer, rooms are cooled down by circulating chilled water which is provided by the same heat pump. The heating and cooling panel of the ground floor is 177cm high, 126cm wide, and fins width 70mm with double. The 1st floor panel is 158cm high, 134cm wide, and fin width 70mm with double. With the circulating of chilled water in summer, water condensation

occurs on the surface of the panels. This condensed water is discharged to the outside by a drainage pipe. In collaboration with the panel heater manufacturer, the author conducted research into this technique.

In the summer of 1997, with the manufacturer of this panel heater, we explored the possibility of using this apparatus for cooling. Using an infrared thermal camera and wide gauze, the air temperature distribution was determined[3] .The radiant heat from the panel to the designated points was also measured. When the condensed water from the panel drops on the floor, the floor becomes moldy. Research about mold and its countermeasures were also carried out[5] After that, this manufacturer made an effort to improve the panel heater for rust proofing. Consequently, utilization of this heating and cooling radiator panel is increasing now.

This house was not an experiment, and is lived in every day. Therefore measuring used thermal quantity for the panel heater was not done.

Fig. 5 Measuring the distribution of air temperature using a thin sheet. (1997 Ochanomizu Univ.)

The owner moved into this house in the beginning of December 2015. The electricity consumption by this house in February(from 10th Jan. to 10th Feb.) was 495kWh and in March(from 10th Feb. to 10th March) was 368 kWh. The electricity usage in March was lower than it was in February. The author thinks that at the beginning of heating, heat load had been used for heating the housing components. A heat pump was used to regulate the temperature of the water supply. Room air temperature was kept at 23℃ by heating the water supply to 36℃, on the coldest day in January 2016. In February the temperature of the warm water supply was lowered. In the summer of 2016, room air temperature was kept between 25 and 26 ℃ by supplying chilled water at 17℃, using the heating and cooling radiator panel.

Nowadays most houses are heated and cooled by a heat pump air conditioner. In this house, heating and cooling radiator panels were installed. These do not generate airflow in a room, so this heating and cooling method is more comfortable.

In the summer of 2016, this house was also cooled using this heating panel. Triple glass windows with air tight wooden frames were used to keep openings air tight and thermally insulated. Under the windows, throating (water drop) was installed. Throating must have enough width to prevent rain water from entering the wall. Also when it snows, if the width of the throating is insufficient, melted snow water will enter the wall. Table 1 shows the monthly electric power consumption of this house from January to July, 2016. Table-2 shows the estimated monthly cooling and heating power consumption of this house from January to July, 2016 and the average outside air temperature and relative humidity reported by the meteorological agency.

This house has two stories, with the ground floor area of 53.61m^2 and the first floor area of 51.26 m^2.

Table 1 Monthly Electric Power Consumption(JAN.-JUL., 2016)

Month	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.
Days	33	29	30	32	31	31	29
Elec. Power Consumption (kWh)	495	313	368	318	244	326	393

Table 2 Estimated Monthly Cooling & Heating Power Consumption (JAN.-JUL., 2016)

C. & H. Power Consumption (kWh)	251	269	124	74	----------	82	149
Avg. outside temp. (℃)	5.8	5.7	10.3	14.5	21.1	22.1	26.2
Avg.outside rel. Hum. (%)	52	59	57.	71	62	76	80

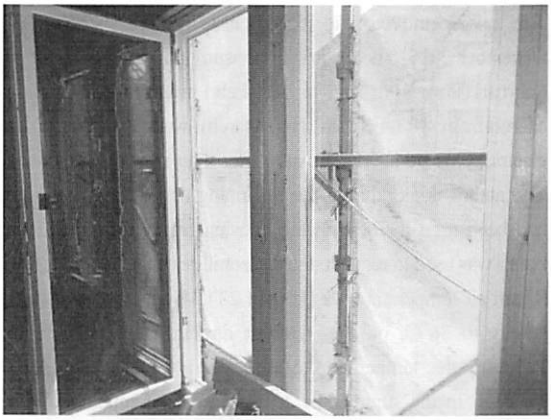

Fig. 6 Triple pane windows with wooden frames

3. Painting

Inorganic paint was used in this house for its fire resistance and to keep the room VOC free. Inorganic paint is not popular in Japan, but it is often used in Germany. Bruno Taut is also known as the painting architect. He observed that, after retirement, some painters sustained brain damage. It was caused by using organic paints. After that he used inorganic paint. Not only Bruno Taut[4) 6)] but also the first director of Bauhaus, Walther Gropius, used inorganic paints for the Bauhaus Building in Dessau and lodging for teachers in Dessau.

4. Conclusion

The author introduces a small high efficiency house, which was built in Musashino City, Tokyo in 2015.

Before moving into this house, the clients lived in a nearby multi-family dwelling. Their electricity consumption actually went down in the new, single-family house.

Using new heating and cooling technology, the electricity cost of heating and cooling became lower.

Afterthoughts

In the title of this paper, I used the words, "Small House". This house is not far from Kichijoji station, and the price of land in this area is high. Living in a small house is environmentally friendly. Kamo no Chomei (1155-1216), high ranking Shinto priest abandoned the material world to live in a small house and enjoy nature.

A big earthquake occurred in eastern Japan on March 11, 2011, and sent a large tsunami to the northeastern coast. An accident occurred at a nuclear power plant in Fukushima due to the large tsunami. It has been found that enormous cost is required for decommissioning the furnace as well. For the last two years Japan has been able to supply electric power without using nuclear power plants. Nevertheless, the government has begun to restart the nuclear power plants stopped. At one time, it was said that the nuclear power plant makes electricity cheaply and does not destroy the environment. But this turned out to be untrue. A world without nuclear power is desirable. We are afraid of nuclear power plants. It is necessary to develop energy efficient buildings. I hope for the spread of such houses, as introduced here.

Acknowledgements

I thank the constructor, Eco House Co. (Director Mr. Hiromasa Matsuoka), for its faithful work.

[Space]

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