# Research Regarding the Effects of Ultra-highly Insulated Homes in Regions with Great External Thermal Load in Summer on Energy Conservation

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***Abstract*** -It is being conducted by Haraguchi et al.1) that study of ultra-high insulation housing that combination of Air circulation type whole building air conditioning system and Passive active heating method. In the studied houses of 6 buildings on 6 regions with different climatic characteristics were verified by simulation has been performed. There is effective in reducing cooling and heating load in each studied houses of each area. However, the model of studied house built in Miyazaki city that is the warmest region of the six regions is the air conditioning load reduction rate is smaller than the model in other areas. This study actually measures and simulates how much energy-saving effect can be demonstrated ultra-high insulation houses in areas with high external heat load during the summer. During the winter, even after the air conditioner has stopped, LDK temperature is less likely to decrease compared to the outside temperature. In the daytime, room temperature rises without air conditioning by heat in double skin and heat acquisition by solar radiation. During the summer, despite the whole air conditioning depends on one air conditioner, very stable room temperature is maintained. Regions where the external thermal load of the summer season is larger than that of Miyazaki City like a Naha city also annual air-conditioning load is reduced as heat insulation performance improves. Keywords— ultra-high insulated houses, Using solar heat, Air conditioning load, Energy Conservation, measurement, simulation

## 1. Introduction

Haraguchi et al. [1)] have been researching ultra-highly insulated homes using a combination of ventilation-based all-room air conditioning and passive active heating. It is aimed at saving energy by using a highly-efficient all-room air conditioning system that combines ventilation and air-conditioning and reducing air-conditioning and water-heating energy consumption, which accounts for 1/2 of household energy consumption. The author conducted simulation for six homes built in six different regions with different climate traits, and reported that there were decreases in air conditioning burdens in each region through improvements in insulation performance and insolation control as well as the use of an air circulation system. However, the drop rate in air conditioning burden in the home model built in Miyazaki-shi, which has the highest temperature among the six areas, was small in comparison to the others. This report aims to clarify how much energy ultra-highly insulated homes can save in regions with great external heat burdens during summertime by conducting actual measurements and simulations.

**Table 1** Outlines the studied homes

| | | |
|---|---|---|
| location | | Miyazaki |
| Area classification of energy saving standard | | 7 region |
| Area classification of solar radiation in the heating season | | 3 |
| total floor space | | 115.5[㎡] |
| total building skin space | | 350.9[㎡] |
| direct gain opening space | | 8.1[㎡] |
| double skin opening space | | 9[㎡] |
| insulating materia | roof | Aishinen200mm |
| | outer wall | Aishinen80mm, Polystyrene foamⅢ 50mm (outside) |
| | floor | Aishinen100mm |
| window glass | sun room (outside) | pair glass |
| | other | Triple Shannon Ⅱ S |
| skin heat transmission coefficient average (UA) | | 0.26[W/㎡・K] |
| air conditioner | | There are a household air-conditioner of heat pump unit in the bed room of second floor (cooling capacity 4.0kW, heating capacity 5.0kW), DC motor, the Central Air Conditioning and Circulation System |
| ventilating equipment | | total enthalpy heat exchanger |

**Figure 1** External appearances and photos of the inside of the double skin

**Figure 2** The floorplans of the first and second floors of the homes

## 2. Overview of the Studied Homes

Table 1 outlines the studied homes while Figure 1 shows their external appearances and photos of the inside of the double skin and Figure 2 shows the floorplans of the first and second floors of the homes. The average heat transmission rate of the outer layer (UA value) of the homes was 0.26, much lower than the standard 0.87 in Miyazaki-shi. This indicates that the homes had high insulation capabilities. A single household air-conditioner heats or cools the entire home and the temperature and humidity of the air are adjusted in air-conditioned rooms on the second floor and the air is sent to each room via air ducts, as shown in Figure 2. When using the heating function, the heat energy gained from the solar heat collector is distributed throughout the building via air circulation and accumulated, to reduce the burden of air conditioning. The heat acquired from the double skin is sent to air-conditioned rooms where it distributes the heat. When using the cooling function, the cooling burden is reduced by opening the window of the outer double skin and using the roof and side wall sections as an external shield to block insolation.

## 3. Measurement Results

*3.1 Overview of Measurements in Winter*

Figure 3 shows the drop in air temperature in an LDK, which is air-conditioned in winter, after the stop of the air conditioning. Heating stopped around 11 a.m. on February 2 and air temperature in the LDK dropped accordingly. However, compared to the fall in outside air temperature, the fall in air temperature in the LDK was gentle, so it is clear that the effects of high insulation worked sufficiently. Around 10 a.m. on February 3, air temperature in the LDK rose by about 2 degrees Celsius and it is evident that heat was distributed from sunlight and the double skin. Figure 4 shows the state of heating use in the air inside of the double skin. From around noon to 6 p.m. ventilation fans in the double skin operated, and the heat accumulated in the double skin was distributed to air-conditioned rooms. Temperature in the air-conditioned rooms rose by around 1 due to the air intake from the double skin, and it in turn caused the room temperature to increase. However, even after the double skin began sending air to the air-conditioned rooms, the temperature inside the double skin remained high, which means further heating use could be expected.

*3.2 Results of Measurements in Summer*

Figure 5 shows the variation in air temperature in the LDK in summer. The home only used a household heat pump air conditioner with 4.0kW cooling capabilities for all-room air conditioning, yet the air temperature in the LDK remained constant, maintaining a comfortable environment. It is considered due to ultrahigh insulation and insolation shielding on the southern side. Figure 6 shows the variation in air temperature for each living room in summer. Normally the rooms on the second floor had higher air temperature than the LDK on the first floor. Moreover, bedrooms were located on the western side of the second floor and children's rooms on

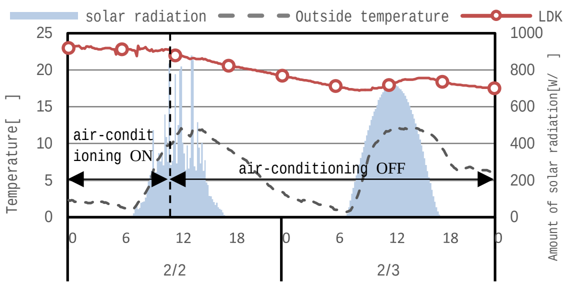



**Figure 3** The drop in air temperature in an LDK

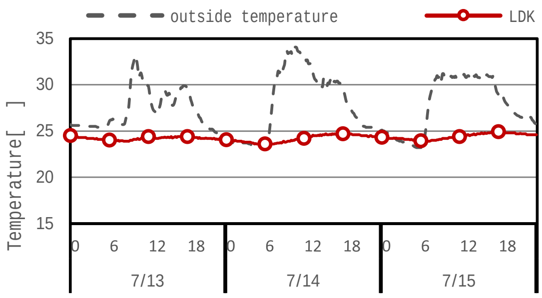



**Figure 5** The variation in air temperature in the LDK in summer

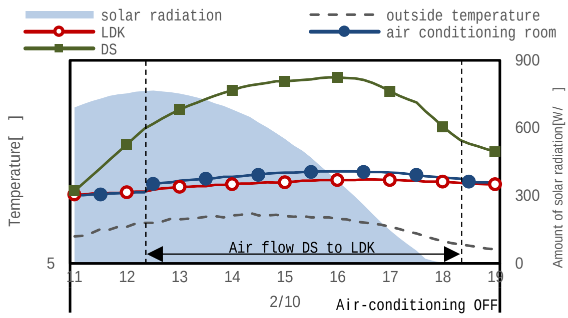



**Figure 4** The state of heating use in the air inside of the double skin

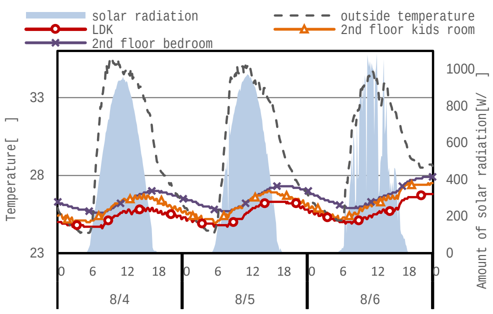



**Figure 6** The variation in air temperature for each living room in summer

**Table 2** The average room temperature in each weather condition during summer

| | | 2 -1 | 2 -1 | 2 -2 |
|---|---|---|---|---|
| 5h | | 0.91 | 0.56 | 0.35 |
| | | 1.23 | 0.47 | 0.76 |
| | | 1.07 | 0.51 | 0.55 |
| 5h | | 0.79 | 0.48 | 0.31 |
| | | 1.06 | 0.42 | 0.64 |
| | | 0.92 | 0.45 | 0.47 |
| | | 1.02 | 0.49 | 0.53 |

7/15 8/15 6 00 18 00 18 00 6 00

the eastern side; it is considered from the difference in temperature from the LDK that these rooms are affected by sunlight in the morning and afternoon. Table 2 shows the average room temperature in each weather condition during summer. Five or more hours of sunlight caused a greater temperature disparity among rooms than when there was less than five hours of sunlight. Especially the air temperature in the bedroom on the second floor was considerably different from that in the LDK on the first floor. It is evident that the afternoon sun had a great impact on the second floor bedroom. Nonetheless, the temperature disparity was approximately within 1 and temperature conditions were stable throughout the home due to the air circulation system and the effects of the ultrahigh insulation.

## 4. Study of the Effect of Reducing Air Conditioning Burden with Simulation

*4.1 Calculation Contents and Conditions*

In this study, the authors used the dynamic heat burden calculation software THERB for HAM, to conduct numerical calculations. Table 3 outlines the numerical calculation model. Table 4 shows the air conditioning schedule of the system. Fourteen types of models were created based on the homes where the actual measurement was conducted, while combining insulation performance, air-conditioning type, and air volume sent from the double skin to air-conditioned rooms. The meteorological data used in this study consisted of standard weather data collected in Miyazaki-shi, Kagoshima-shi, and Naha-shi, and measurement data in 2015.

*4.2 Calculation Results*

*B-1 Verification of Precision of Simulation Software*

Figure 7 shows the results of the verification of the precision of numerical calculations regarding thermal environments. A precision test was conducted for the air temperature in the LDK and since it matched the actual values as a whole, it was confirmed that the simulation software is highly precise.

*B-2 Change in Annual Air Conditioning Burden due to the Difference in Insulation Performance*

Figure 8 shows the change in annual air conditioning burden due to the difference in insulation performance. It is evident that the higher insulation capabilities, the greater the reduction in air conditioning burden for each region.

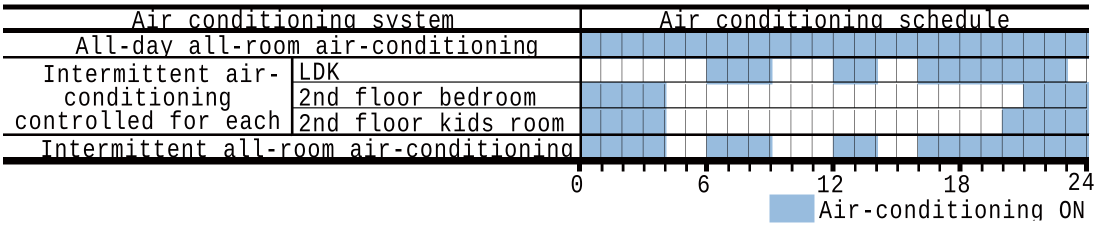
*B-3 Regarding the Cooling Burden of Each Ventilation Type and Room Temperature Control*

Figure 9 shows the variation in the cooling burden per hour according to ventilation types, regions and insulation performance. The burden decreases as insulation performance improves. In particular, Naha-shi had a significant reduction in the burden as insulation performance increased, compared to other areas. It was found that even in areas where the external heat burden is large during summer, ultrahigh insulation can exert sufficient performance. The burden of all-day all-room air-conditioning is smaller than that of intermittent all-room

**Table 3** Outlines the numerical calculation model

| Model | Skin average heat transfer coefficient[W/ ] | Air conditioning | Air volume sent from DS to air-conditioned rooms |
|---|---|---|---|
| | 0.26 Current status | | 0 / |
| | | | 500 / Current status |
| | | | 1000 / |
| | 0.57 | | 500 / |
| | 0.87 Reference value | | |
| | 0.26 | | Opening the window of the outer double skin |
| | | | |
| | | | |
| | 0.57 | | |
| | | | |
| | | | |
| | 0.87 | | |
| | | | |
| | | | |

**Table 4** The air conditioning schedule of the system



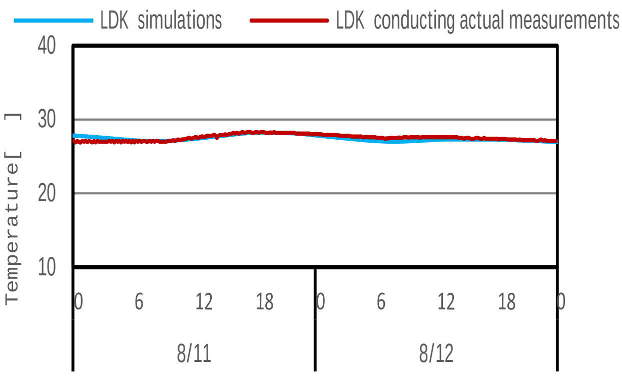




**Figure 7** The results of the verification of the precision of numerical calculations regarding thermal environments

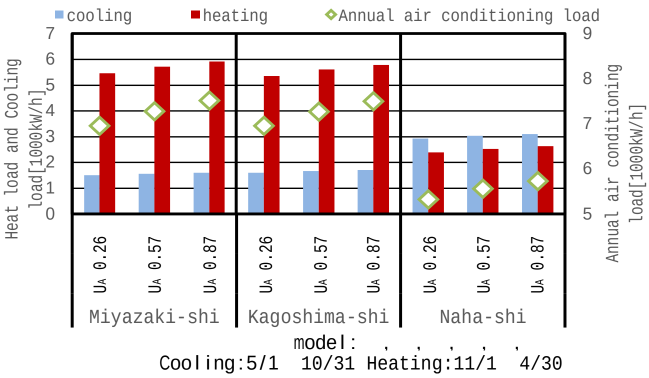



**Figure 8** The change in annual air conditioning burden due to the difference in insulation performance

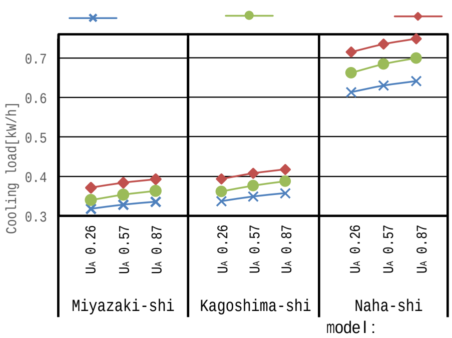



**Figure 9** The variation in the cooling burden per hour according to ventilation types, regions and insulation performance

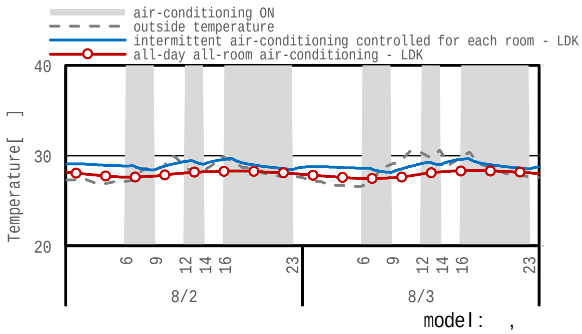



**Figure 10** The situation of the control of air temperature inside rooms with each air-conditioning type

air-conditioning, but larger than that of the intermittent air-conditioning controlled for each room. Nonetheless, it was found, from the situation of the control of air temperature inside rooms with each air-conditioning type shown in Figure 10, that intermittent air-conditioning cannot keep air temperature lower than that of all-day all-room air conditioning and that all-day all-room air-conditioning is effective for controlling the room temperature of the entire building via air-conditioned rooms using a single air conditioner.

*B-4 Using the Heat Accumulated in the Double Skin for Air-conditioning*

Figure 11 shows the heating burden reduction rate (i) according to the increase of air flow from the double skin to the air-conditioned rooms and the variation in air temperature within the double skin (ii), which were calculated with reference to the simulation results of Models I, II, and III. Comparing the heating burdens of Model 1, which had no air flow, and Model 2, which had the currently adopted

air flow volume of 500 m3/h, it was found that reduction rate was approximately 4%. When air flow volume was increased to 1000 m3/h (Model 3), reduction rate was around 5.1%. The temperature in the double skin exceeded 30  when ventilation air volume was 1000 m3/h (Model 3). It is considered because the air flow from the double skin to the air-conditioned rooms exceeds capacity, and thus, heat cannot be distributed to each room, so it returns to the double skin.
Figure 12 shows the change in the temperature of the LDK when the air conditioning was stopped while the heat collected in the double skin was used for air-conditioning from noon to 6 p.m. in Models 1 and 2. Between noon and 6 p.m., air was sent from the double skin to the air-conditioned room, increasing the air temperature of the LDK and exceeding that in the case where there was no air flow. It can be understood that if weather conditions allow the double skin to collect heat, it is possible to heat the inside of a room during the day without using air-conditioners. Moreover, the temperature of the LDK is stable even when there is no air flow from the double skin, and it is considered due to the effect of heat insulation and solar radiation heat collected through direct gain, etc.

## 5. Conclusion

The author conducted actual measurements and simulations for homes built in Miyazaki-shi in order to clarify the effectiveness of ultrahigh insulation in houses in regions where the summer external heat burden is enormous. The findings are as follows:

1) In winter, the air temperature of the LDK does not decrease easily compared to outside air temperature even after stopping an air-conditioner. During the day, the heat from insolation and the double skin causes room temperature to rise without air conditioning.
2) In winter, the air flow from the double skin to an air-conditioned room increases the temperature of the room by about 1  and in turn causes room temperature to rise.
3) Room temperature can be maintained in a fairly stable manner regardless of all-room air-conditioning using an air-conditioner with a cooling capability of 4.0 kW in summer. The difference in temperature among rooms is as small as approximately 1  thanks to air circulation.
4) The annual air-conditioning burden can be reduced when insulation capabilities are increased, even in regions where the external heat burden is larger than that of Miyazaki-shi, such as Naha-shi.
5) Air-conditioning that uses the air heated by double skins is effective for reducing heat burdens. It was also discovered that when double skins send air to an air-conditioned room, room temperature rises even without a heating system. However, it can be said that a new method of effective use is needed because the currently adopted air flow volume cannot use up the collected heat and it is not realistic to increase the volume of air flow. For example, a method of opening a window facing the hollow part inside a double skin, sending air with a circulator to the LDK located at the bottom of the hollow part, and distributing heat from the LDK to each room through air circulation is effective for reducing heating burdens.

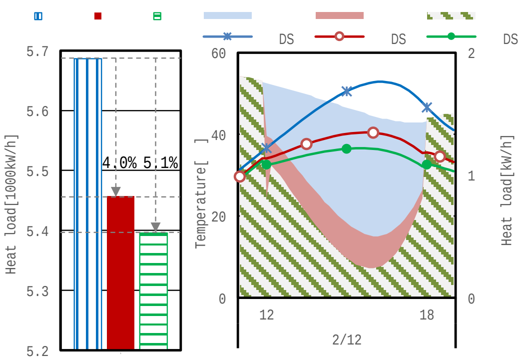



**Figure 11** The heating burden reduction rate

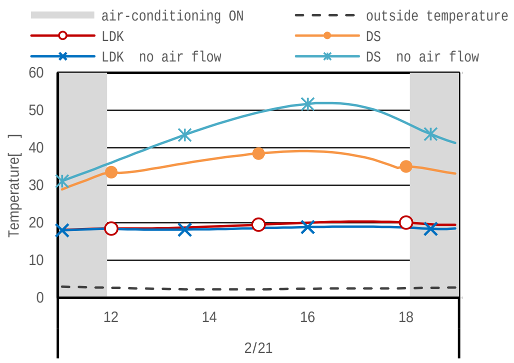



**Figure 12** The change in the temperature of the LDK

## References

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