Research Papers

A Developmental Study on the Utilization of Geothermal Energy for Saving Energy in Houses

KAMADA Kiyoko

(Recieved December 12, 2014)

Abstract: Japan is a long and narrow island country from north to south and in some areas in Hokkaido, the northernmost part of Japan, the temperature difference in a year is more than 70deg.C. Under the harsh climate, the heat of summer and the severe cold of winter, a greater consideration is necessary in choosing architectural technique and a way of life. Rikubetsu-cho, which is well-known as the coldest area in Japan, has studied about the following three points for 26 years: (1) a high insulation and airtight technique of housing design in which the least energy is needed (2) a design of a cooperative house, in which elderly people live with comfort even under severe climate conditions (3) to put into practice a ventilation and heating system by geothermal energy. In Japan the utilization of geothermal energy is far behind that of solar power generation. Especially in areas with many volcanoes or hot springs, to utilize geothermal energy is effective. The author investigates a technique which can be applied to general buildings or houses without excessive investment on equipments.

Introduction

In Japan, since the disaster in Fukushima nuclear power plants caused by the earthquake and tsunami in March, 2011, the development of new or recyclable energy sources and energy saving has been in an urgent need.

This study reports a building in which geothermal energy is utilized in order for people to live with minimum energy on the basis of "the utilization of geothermal energy using a passive system and an improved low-cost equipment design", which has been acknowledged to be effective for more than thirty years. The challenging idea and technique in Rikubetsu-cho, which is in a severe hot and sever cold climate, can also be applied to heating in cold regions or cooling in mild or warm regions. It is effective in saving energy in houses globally and in supporting the lives of patients with chronic diseases such as high blood pressure, heart diseases, and respiratory diseases. This study also reports the good results of the technique and it will contribute toward designing zero-energy houses with high durability or low-cost equipment, and reducing carbon dioxide emission by 6%.

I. Purposes of the Study

1-1 Examination of the design technique of passive ventilation and heating

1-2 Examination of the construction method of geothermal floor basement

1-3 Examination of the cost of installing ventilation equipment or its maintenance, and comparative examination between cost and effect

Dept. of International Language Studies , Hokkaido Bunkyo University

1-4 Confirmation of the effect of reducing the cost of heating and cooling

1-5 Confirmation of protection performance against disasters such as earthquakes or tsunami

1-6 Examination of the evaluation of the building by the residents or users and the effects on their health

II. Methods

The reduction of initial cost and maintenance cost, and high durability are investigated in a low-cost construction method by “a passive system”.

2-1 Analysis of the construction technique and the design fee of the building in Rikubetsu-cho

2-1-1 A passive ventilation system

Fresh air is taken into the space under the floor with a 24 hour ventilation system in winter which is essential in a high insulation and airtight construction method. Next the cool air is taken in the space under the closet floor and heated there by a floor heater with heat storage under the slab of the basement. The heated air, linked with the operation of exhaust air fans (24-hour ventilation), is taken into the rooms from the intake registers on the floor under the windows of a living room and a bedroom.

2-1-2 The designing method of the storage of geothermal energy under the floor, the addition of heat and convection

The ventilation method by the storage of heat under the floor (see 2-1-1) is improved: The air taken into the space under the basement floor is heated and stirred up through a vent on the first floor by “natural convection”, which enables both ventilation and heating in the rooms.

The house is all electrified for residents’ safety in cooking in case they suffer from senile dementia or other diseases.

The followings are the advantages of the house.

①Fire prevention is easy.

②Midnight electricity supplied at cut rates is used to the maximum.

③The cost of heating and ventilation equipment is low.

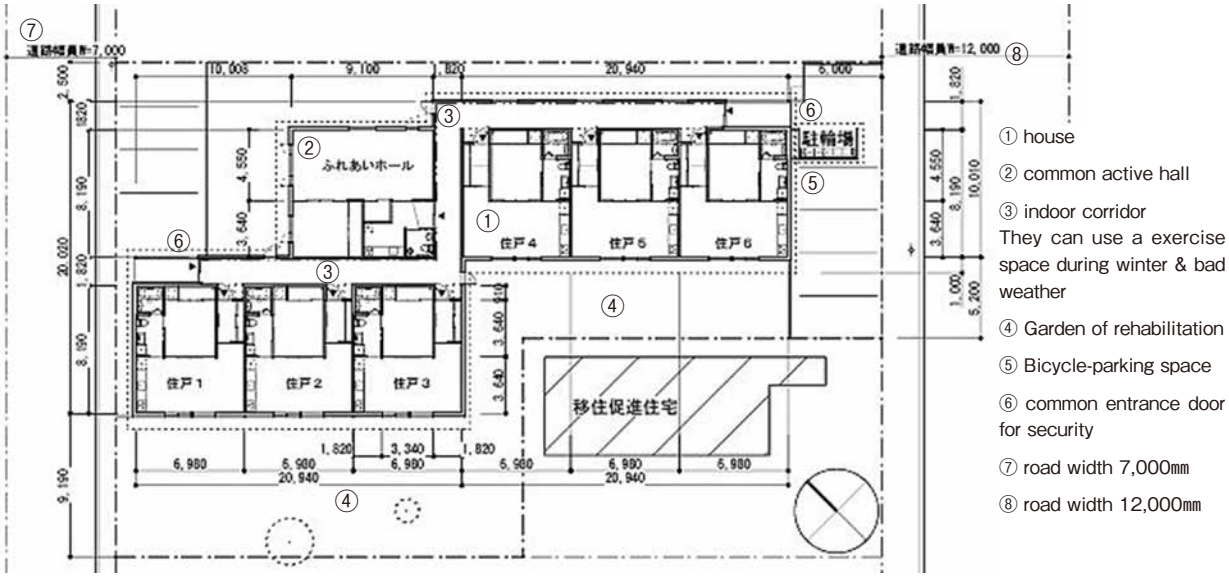
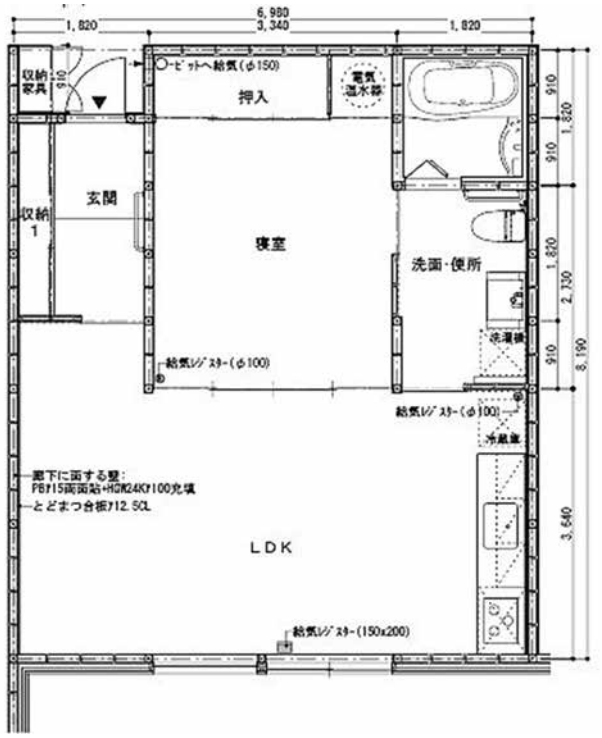


Figure1.The Floor Plan and the Arrangement Plan of the First Floor of Karamatsu House (2)
Designed by Masanobu Komuro of Hokkaido kenchiku Kobo Inc.



(2)

Figure2.The Floor Plan of Private room of Karamatsu House

④The total consumption of electricity can be reduced with an appropriate way of living

⑤The individual electricity rate a month is reduced.

The building design of ‘Rikubetsu Welfare House----Karamatsu House’ is shown in Figure 1 and the floor plan of an individual apartment is shown in Figure 2. It is a one-storied house and consists of six apartments. The area of each apartment is 57.2m2. The area of the premises is 1235.72 m2, that of the building is 511.96 m2 and the total floor area is 497.06 m2. Air conditioners and a hot -water

supply system are equipped. All the floors are heated by an

Electric floor heater with heat storage installed under all the floors using midnight electricity and a hot-water supply system is also operated using midnight electricity.

The house was built in 2011 as a Rikubetsu welfare house and now six aged families are living. For the first year after the construction was finished, because of the large amount of water in the building (lumbers or RC concrete under the floor), heat consumption was large and it will continue until the building becomes dry and stores heat. Table 1 shows the measurement results for a year after construction was finished based on the electric company bills.

The daytime electricity consumption (including lighting, TV or other electric appliances and cooking) was 38%, hot-water supply (including bath, washing and etc.) 23%, and heating 39%. The changes of electricity consumption are caused by the seasonal changes of the outside air. The consumption from November to March, the coldest season, was very large. The largest consumption in December was about 7 times the amount of the least consumption in July and 6 times as large as those in November, January, February, and March. This shows the severe cold of the winter in this region. The electricity consumption at daytime was steady through the year and that at night in winter was 9.5 times as large as that in summer, which shows the consumption by heating is large. The consumption at daytime was the least in summer, from July to October, mainly used for lighting or electric appliances, which suggests the summer lifestyle of enjoying outdoor activities instead of watching TV at home.

The total electricity consumption of the year was 13,817Kwh, and its electricity rate was 132,069 yen. This energy cost is quite reasonable and economical expense compare with average expense in Hokkaido Japan.

They exceed those in urban areas in Hokkaido such as Sapporo, but the residents are fully satisfied with the life there. After some years the building will be dry and its heat storage will increase, so the heating consumption will decrease by some degree.

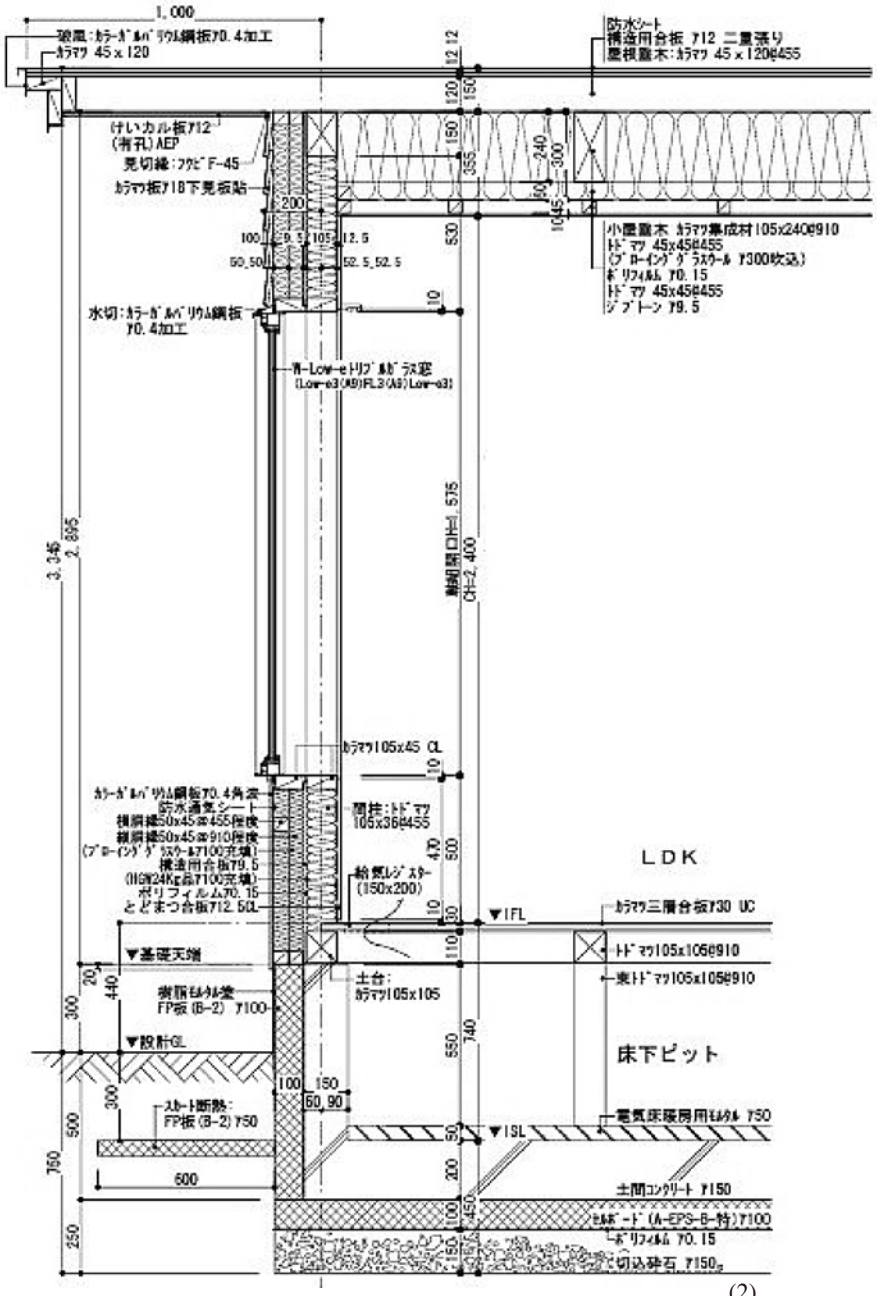


Figure3.A Sectional Detail Drawing of “Karamatsu House” (2)

P.1. A kitchen garden of Karamatsu House
Original photo by K.KAMADA in August 2014

P.2. Main entrance of Karamatsu House
Original photo by K.KAMADA in August 2014

Indoor wide Passage is guaranteed safety & weather resistance Rehabilitation space in winter.

Also this space contribute to prevent the wandering of Dementia patients

Table-1. Electricity bill 2011-2012 Track record. October 2nd 2012 created Contract capacity:6 KVA, Midnight water-heater:4KVA

	Year	2012	2012	2012	2012	2012	2012	2012	2011	2011	2011	2011	2011	yen	yen	yen	yen
	Month	January	february	march	april	may	Jun	july	August	septemb	Octobe	Novemb	Decembe	Total	monthly	summer	winter
electricity KW	daytime	144	144	137	168	116	101	91	99	99	99	103	146	1,447			
	nighttime	1,720	1,720	1,577	1,119	616	446	214	230	518	920	1,257	2,933	12,370			
	the total	1,864	1,864	1,714	1,287	732	547	305	329	617	1,019	1,360	2,179	13,317			
a charge yen	basic charge	1,365	1,365	1,365	1,365	1,365	1,365	1,365	1,365	1,365	1,365	1,365	1,365	16,380			
	daytime-1	1,966	1,966	1,966	1,966	1,966	1,966	1,966	1,966	1,966	1,966	1,966	1,966	23,587			
	daytime-2	1,533	1,533	1,533	1,533	1,533	28	255	255	255	255	369	1,589	10,415			
	daytime-3	—	—	—	—	—	—	-54	-55	—	—	—	—	-109			
	daytime- total	4,863	4,863	4,664	5,544	4,068	3,643	3,305	3,531	3,586	3,596	3,700	4,920	50,273			
	night time	14,396	14,396	13,199	9,366	5,156	3,733	1,791	1,925	4,336	7,700	10,521	17,016	103,537			
	rebate-hotwate	-756	-756	-756	-756	-756	-756	-756	-756	-756	-756	-756	-756	-9,072			
	rebate-heating	-1,029	-1,029	-1,029	-1,029	-1,029	-1,029	-1,029	-1,029	-1,029	-1,029	-1,029	-1,029	-12,348			
	solar-dues	18	18	51	38	21	16	76	3	6	10	13	21	291			
	sum demanded	12,529	12,620	11,465	7,519	3,392	1,964	83	143	2,557	5,925	8,749	15,252	67,555			
	fuel-cost adjus	-336	-336	-137	-39	81	186	146	43	80	51	-68	-233	-511	-51	114	-133
	Total rates	17,157	17,157	15,992	13,126	7,541	5,793	3,534	3,711	6,223	9,562	12,381	19,389	132,369	11,336	5,146	13,936

Table-2.Total construction cost & expenditure ratio comparison table yen

section	practice name	sum of money	ratio
A. construction works		52,601,000	61%
1. Base-construction	temporary works,earthwork,basement works,et	18,087,000	21%
2.Interior finishing work	interior finishing,innner doors,	18,737,000	22%
3.exterior finishing work	water proof works on the roof,windows,out-do	7,538,000	9%
4.exterior doors		4,523,000	5%
5.insulation works		3,716,000	4%
B.haetstorage heating	electorical floor heating	2,986,000	3%
C.machinery works		6,768,000	8%
D.electricity works	electorical appliances,IH cooker,water heater,e	6,791,000	8%
E.overhead expenses		17,529,000	20%
the sum total		86,675,000	100%

P.3. The wide space indoor Hallway
Original photo by K.KAMADA

P.4. An Air-intake
Register near the Entrance Door

P5.Ventialation Pipe to Heat Storage under the Floor

P6.A Ventilation Register on the Floor of the Living Room

III. Results

3-1 The merits of the building design with the storage of geothermal energy under the floor, based on the results of the inquiries for residents

Heavy snowfall sometimes causes blackout accidents in cold regions. After the supply of electricity stops, e room temperature gradually goes down, In this house, however, not until three days passed after a blackout did the residents begin to complain about the coldness of their rooms. It corresponds to the thermal storage performance of this floor heater.

The price of this public house rent is 10000yen per month, and fuel, lighting, TV, etc is 130,000yen per year.The pensioner of the basic pension getting a monthly amount of 66,000yen now. Aged people have to pay the expense about 30% from their basic pension income. This ratio of pension income is quite reasonable burden in cold region.

3-1-1 The protection performance of the building design against disasters

A house with a geothermal floor built by a housing company Universal home which supplies low cost houses of good quality all over Japan has miraculously remained after the attack of Tohoku earthquake and tsunami in March, 2011. Its underground digging method was effective in protecting the house against serious earth-quake disasters.

P7.A House Which Withstood the Attack of 2011 Tohoku Earthquake and Tsunami (3)

3-1-2 The effect on the improvement of the residents' health. The residents reported that chronic diseases such as high blood pressure, asthma, or allergic nasal inflammation are improving but there's no medical evidence at present.

3-2 The building performance of a public house in Rikubetsu-cho called 'Karamatsu House'

3-2-1 The construction method of a skirt insulation and Passive ventilation system with the storage of heat under the floor

In Karamatsu House, the fresh air is taken in from a ventilation register on a hallway for common use to the rooms and is stored under the floor. The air heated by an electric floor heater of which wiring is set on the slab under the floor is sent to the rooms from the register on the wall under the window. Energy saving effect is expected to be greater than a ventilation method of storage of heat under the floor. See phot-3,4,5,6

Contaminated air is automatic-exhausted for a bathroom,

Rest room's ventilation fan which works 24hours.

.In addition, an intensive exhaust gas can be performed from the ventilation fan only for a kitchen when needed. However, it is impossible to open a window or to use the ventilation fan for kitchen in the severe midwinter time

3-2-2 A passive cooling ventilation system

In hot summer, from June to August, the heating system on the slab under the floor is not operated. It enables the cool air under the floor to come

into the rooms, so passive ventilation and cooling becomes possible by natural ventilation. The electric consumption in summer is limited to cooking and hot-water supply, so the electric rate becomes low. The measures against the severe cold of midwinter are thought to be important and a skylight window was fixed on the roof of passage. Natural draft is not drawn here but indoor temperature becomes very high owing to the solar heat from the window. A two-direction ventilation design is required to draw a draft. The solution is possible in replacing a north-side window by an opening-and closing type.

IV. Discussion

4-1 Establishment of the control method of air quality, anti-bacteria, or sanitation

Carbon or anti-oxidizers are used as measures against humidity, bacteria, mold and insects under the floor or basement of houses. In highly insulated and airtight houses, deodorization is also necessary when the houses become old.

4-2 The maintenance of the equipment

It is necessary to repair the materials or replace the parts of the floor heater and to clean the space under the floor.

4-3 Temperature barrier-free measures against sick house syndrome or pollen allergy

Measures to clean air against environmental pollutants in industrial areas and measures against pollens in forest areas have to be taken.

4-4 Tasks to be done

4-4-1 To take measures to reduce the cost of installing the equipment and to develop public aid

Public aid (aid by the government, local governments or equipment makers) is necessary because of the rise of the first investment. Aid by the government or a local government at present covers one-third or a half of the cost of the equipment or an upper limit on the grant-in-aid is set. Measures to promote its diffusion and at the same time the reduction of the cost of installing equipment are essential.

4-4-2 The normalization of construction methods and materials

4-4-3. The simplification of the method of controlling room temperature, humidity, and water supply temperature.

Elderly people and menopausal woman are subject to weather conditions and daily or yearly control of the temperature is necessary. Therefore thermostats should be easy to operate: especially an easy reset method is desirable after a blackout in a large scale caused by a heavy snowfall or a typhoon.

4-4-4.The development of the technique to remove air pollutants

The development of filtering materials (ultra-fine particles such as PM2.5, agricultural chemicals, particles with a stench, bacteria, or radioactive contaminants) in accordance with their characteristics is in an urgent need, and the normalization of exchangeable parts of ventilation registers and an easy exchange and installment method are also necessary.

4-4-5. The change of energy consumption in some years and the effects of the house on chronic diseases

It is necessary to continue to measure scientifically

the amount of heat storage and energy consumption of the building for some years and to investigate its medical effect on the health of people suffering from respiratory diseases, childhood asthma, chronic nasal inflammation or environmental pollutant allergies.

Acknowledgements

The author gives her gratitude to Mr. Mikio Oguri, the former head of construction section of Rikubetsu-cho, Hokkaido, Mr. Keisuke Nagai, the chief of the same section, Mr.Masanobu Komuro, Mr. Mitsuru Kato, the president of Universal Home Ltd., and Mr. Motoyuki Suzuki for their cooperation, expecting a further development of the technique.

References

[1] Mikio Oguri, Naruo Fujimura, and Katsuo Hattori
"A Study on the Basic Construction Method of Houses Using Space under the Floor"
Investigation Reports No.1, 2, 3, 4, and 5 of Hokkaido Prefect. Cold Region Building Res. Inst. 1985-1987

[2] Masanobu Komuro, a president of Hokkaido Kenchiku Kobo Inc.
"Construction Design Measures against the Hot or Cold Weather" Shokokusha Ltd. P68-P69, 2013.

[3] "A Report on the areas struck by 2011 Tohoku Earthquake and Tsunami" Universal Homes Ltd. 2011

[4] Kiyoko Kamada
"A Study on the Effectiveness and Utility of Charcoal and Recycled Charcoal Materials in a Housing and Indoor Environment"
Hokkaido Bunkyo University Journal No.29
P39-P54
2005.3.31

[5] Kiyoko Kamada
"A Study of Effective Usage of Anti-oxidative Material of Industrial Trash"
Hokkaido Bunkyo University Journal No.30
P51-54
2006.3.31

本原稿は2014年11月中国鄭州市にて開催された「住宅の省エネルギー、環境国際学会」ICEERB2014にて採択された論文をもとにさらに測定データ、東北大震災で実証された防災性能、住環境・暮らし方の快適さ等の情報を追加・加筆した論文である。

住宅設計における省エネルギー技術・地熱活用法の開発研究

鎌田　清子

抄録：　日本は東北大震災，東京電力福島原発事故以来，自然再生エネルギー活用技術，民生用住宅のゼロエネルギー化を目指す研究を加速している．本稿は国内で最も過酷な気象条件下で高齢期を過ごす北海道足寄郡陸別町に建設した「要介護高齢者向け町営福祉住宅」の深夜電力活用とパッシブシステムで設計した地熱活用法とその蓄熱性能の実験測定実測データの検証研究である．