DEVELOPMENT OF ROAD SNOW MELTING TECHNOLOGY USING GROUND WATER AS A HEAT SOURCE

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1. Abstract

The weather in winter Japan is distinguished from others, because of much snowfall with not so cold temperature. And more than 20% of Japanese live in such snowy area, which occupies about 60% of the country of Japan. Therefore, snow removal and snow control on roads have been essential since early times in Japan. Road snow melting systems using ground water had been developed and put to a practical use in Japan.

Snow melting system with sprinkling ground water from nozzles to clear snow on roads was developed in 1961 and became popular in the snowy area of Japan. It, however, wasted much ground water without recovery and it sometimes causes troubles such as lack of ground water and land subsidence.

Snow melting system without sprinkling ground water was developed in 1980 in order to prevent land subsidence and to maintain ground water as a precious resource. This system utilizes only heat energy of ground water and recharges used ground water into the aquifer again without sprinkling. It is popular in the snowy area of Japan recently.

It can be said that this system is relatively an energy saving system, because it utilizes unused energy effectively. However, some ideas of energy saving described hereafter, to reduce a load on global environment are developed and tried, reflecting having wasted much energy previously without forecasting such environmental disruption as global warming in these days.

2. Winter weather in Japan

Winter weather in Japan is characterized by much snowfall despite moderate temperatures, especially in Northeastern districts.

Fig.1 shows the relationship between amount of precipitation and average temperature in January and February in certain cities. It shows that the amount of precipitation of Japanese cities is much more than that of many American and European cities.

It is known that the rain changes to the snow at a ground temperature around 2 to 3℃, therefore the precipitation in the month of January and February at such Japanese cities is mostly snowfall.

During winter in Northeastern districts, such as Tohoku and Hokuriku districts, there are many days whose minimum temperatures are below 0℃, but there are a few days whose maximum temperature are also below 0℃.

Snow on roads melts during daytime with plus temperatures and it freezes again during nighttime with minus temperatures. This is repeated daily or in a short intervals and makes the iced surface irregular.

Such road conditions cause traffic difficulties and many efforts have been made to remove and control the snow on the roads in Japan.

3. Snow melting without sprinkling water

This basic system consists of two wells and a heat radiation area. Fig.2 shows an outline of this system. One well (the "pumping well") is for pumping ground water and the other (the "recharge well") is for infiltrating used ground water into aquifer again.

Heat radiation pipes of small diameter are embedded underneath the surface of roads, sidewalks, ramps and parking lots, etc., where snow is to be controlled.

Ground water pumped from the pumping well is let to the radiation pipes and radiates its heat energy to warm the pavements above and melts snow thereon, and it infiltrated into the aquifer again through the recharge well.

It is said that the temperature of ground water at a certain depth is nearly same as the annual average atmospheric temperature there, so ground water at 10 to 15℃ is available in Northeastern districts of Japan.

Such ground water is not so warm that its heat energy can be utilized for any industrial purpose but it is sufficient as a heat source for snow melting system.

So it can be said that this system utilizes unused energy effectively.

Fig.1 Amount of precipitation and average temperature in January and February

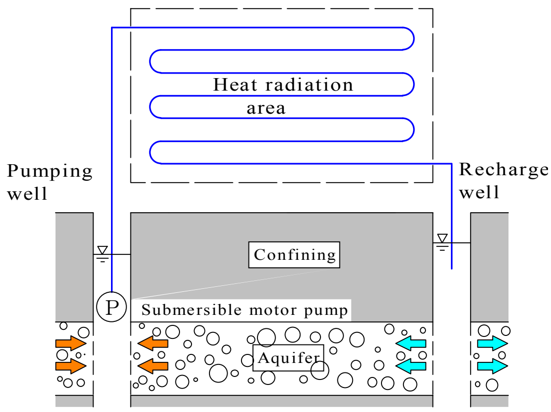

Fig.2 Outline of snow melting without sprinkling water

The followings are advantages of this system:

1) Since no water is sprinkled on the surface, snow can be cleared from sloped and irregular surface.

2) Since there is no water sprinkled nor splashed on the surface, it is more convenient for pedestrians.
3) Since it utilizes the thermal energy of ground water which is unused, it proves to be energy-saving and has low running costs.
   Table 1 prepared by Prof. Zenpachi Watanabe, compares initial costs and running costs for various snow melting systems in Japan.
4) Since it dose not waste ground water, it will not cause troubles such as lack of ground water and land subsidence.

Table 1 Comparison of initial and running costs for various snow melting systems in Japan

Snow Melting System	Heat Source	Heating Device	Initial Cost*	Running Cost*	Remark
Ground Water Without Sprinkling	Earth	Circulation Pipe	50～60	0.5	Preservation of environment
Ground Water With Sprinkling	Earth	Spray Nozzle	15～30	0.45	Risk of land subsidence
Hot Fluid Circulation	Fuel	Circulation Pipe	47	1.0～1.2	Need of facility maintenance
Hot Fluid Circulation	Fuel	Heat Pipe	60	1.2～1.5	Need of facility maintenance
Electric Heating Cable	Electricity	Heating Cable	47	3.5～4.9	Easy to control
Hot Spring Heating	Hot spring	Heat Pipe	30～40	0	Limited to hot spring areas

* cost; 1,000￥/m^2

Actual data obtained from the experiments show the following phenomena for snow melting system without sprinkling ground water.

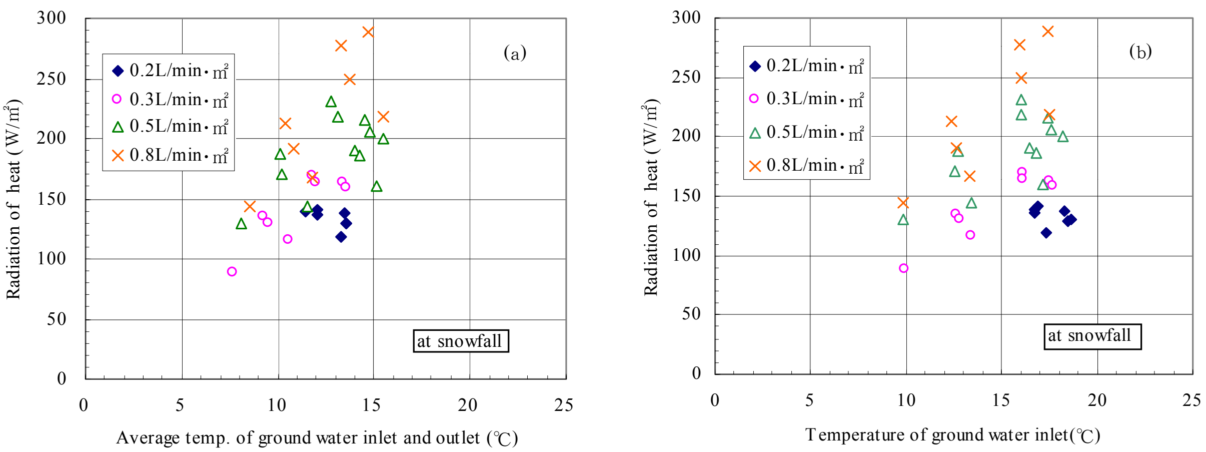

Fig.3 Relation between the radiation of heat and the ground water temperature in Yamagata-city

1. The higher temperature of ground water inlet, the bigger heat radiated from the radiation pipes, with the same quantity of ground water at the same atmospheric temperature and the same snowfall.
2. The bigger quantity of ground water, the bigger heat radiated from the radiation pipes, at the same atmospheric temperature and the same snowfall.

3. The lower atmospheric temperature and the smaller quantity of ground water, the bigger temperature drop of ground water in the radiation pipes.
4. The heat from the radiation pipes is saturated when the surface is covered with snow, and the level of this value depends on quantity and temperature of ground water.

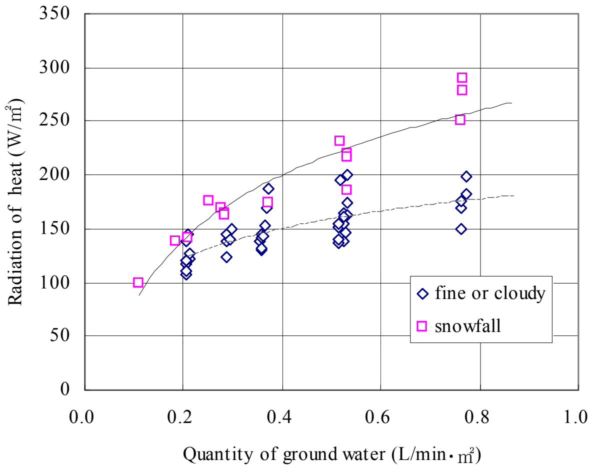

Fig.4 Relation between the radiation of heat and the quantity of ground water in Yamagata-city

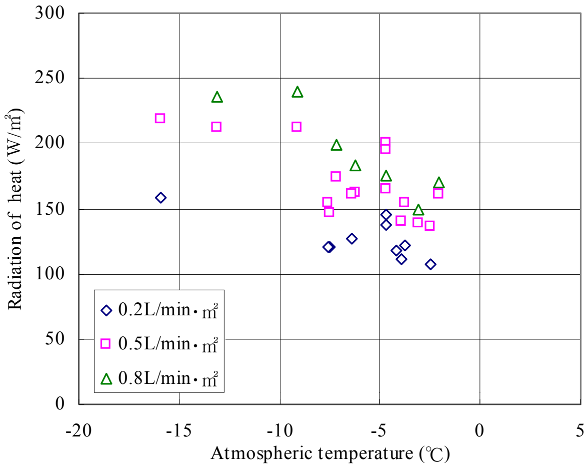

Fig.5 Relation between the radiation of heat and the atmospheric temperature in Yamagata-city

4. Ideas of energy saving recently

It can be said that this basic system is relatively an energy saving system, because it utilizes unused energy effectively. However, some ideas of energy saving described hereafter, to reduce a load on global environment are developed and tried.

(1) Reduce theoretical heat value required for melting snow to a permissible level

(2) Reduce ground water required for the system by effective use

(3) Utilizing recyclable energy

4.1 Reduce theoretical heat value required for melting snow to a permissible level

Snow melting systems with heated-slab shall have enough capacity to melt snow and control icing on roads.

Output required for the system can be calculated by the following equation with individual heat values theoretically calculated from weather data:

$$qo = qs + qm + Ar(qe + qh) \qquad (1)$$

where

qo; output required, W/m^2

qs; sensible heat transferred to snow, W/m^2

qm; heat of fusion, W/m^2

Ar; free area ratio (ratio of snow-free area to total area), dimensionless

qe; heat of evaporation, W/m^2

qh; heat transfer by convection and radiation, W/m^2

We, in Japan, have used 0.5≦Ar≦1.0 for free area ratio generally instead of 0≦Ar≦1.0 and have installed many such systems.

However, it is sometimes reported that systems designed this way have overcapacity especially in the Northeastern districts of Japan.

Thus, we evaluated the theoretical equation again, which supposed that the unit area is partially covered with snow. The area without snow needs the heat of evaporation (qe) and the heat transfer by convection and radiation (qh). The area covered with snow requires the sensible heat (qs) and the heat of fusion (qm).

Considering this, we have derived the theoretical equation below. It is much more applicable to our Northeastern districts.

$$qo = (1 - Ar)(qs + qm) + Ar(qe + qh) \quad (2)$$

It means that when snow falls (it is permissible to cover the surface with the thin snow layer practically, that is Ar=0), only the sensible heat (qs) and the heat of fusion (qm) need be considered.

When there is no snow there (that is Ar=1.0), only the heat of evaporation (qe) and the heat transfer by convection and radiation (qh) need be considered.

Therefore, the output of the system is sized to cover the heat required to melt snow or the heat required to melt snow or the heat required to control icing whichever is lager.

4.2 Reduce ground water required for the system by effective use

4.2.1 Use ground water twice for the system

When the temperature of ground water is high and it has sufficient heat even at the outlet of the system, it can be used for the other system again. It can reduce the quantity of ground water required for the system. Temperature drop of ground water in the radiation pipes at the 1st stage is bigger than that of 2nd stage, or the heat radiated from the radiation pipes at the 1st stage is bigger than that of 2nd stage. The allocation of the 1st stage area and the 2nd stage area is decided considering their priority. The schematic is shown leftward.

Relation between the atmospheric temperature and the road surface temperature at the 1st stage and the 2nd stage is shown in Fig.7 (a)-(d).

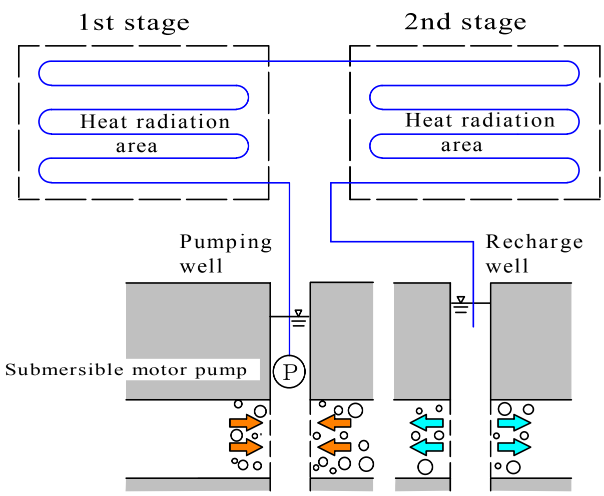

Fig.6 Outline of use ground water twice for the system

This system has the following advantages.

1. Only a half quantity of ground water is required compared with the basic system.
2. A reduction in construction of ground water wells.

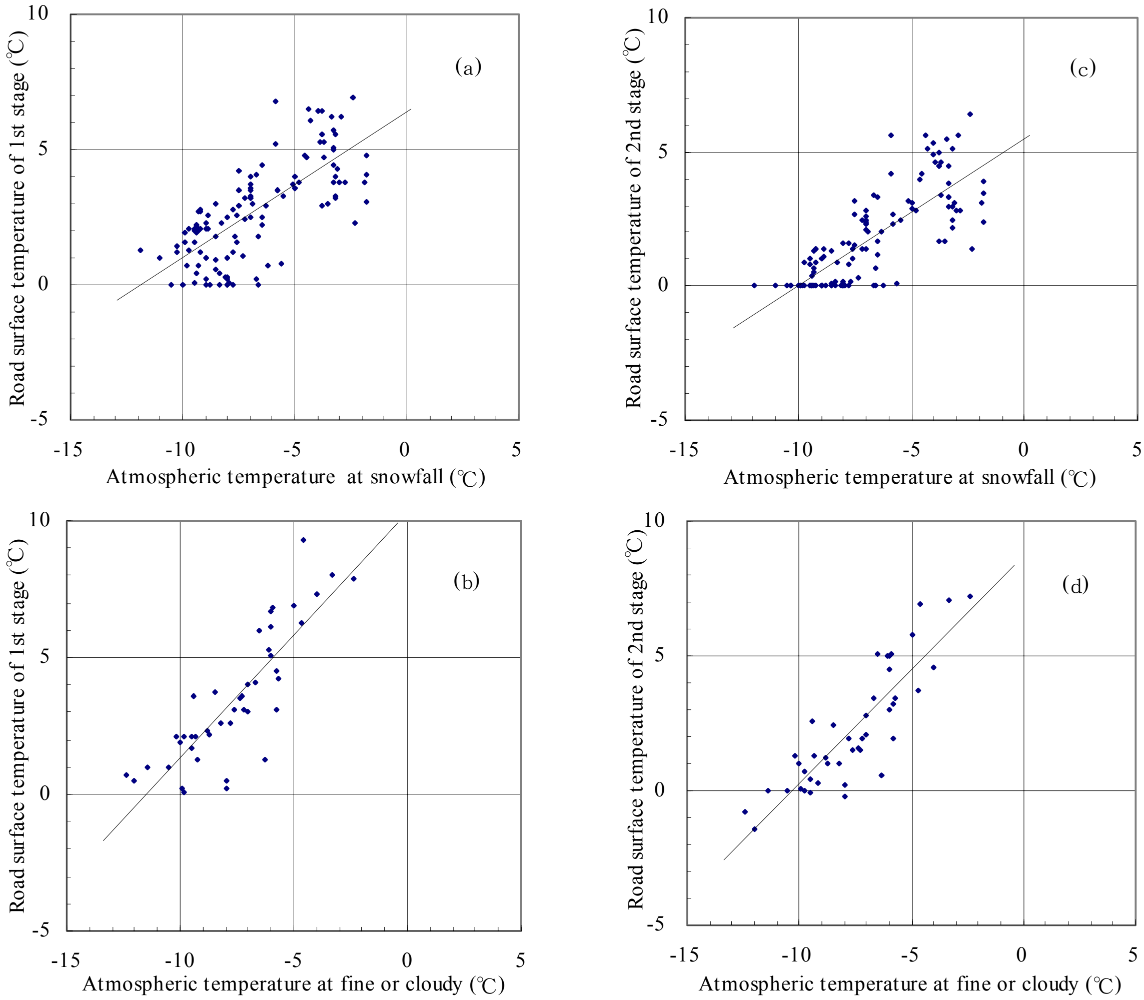

Fig.6 Relation between the atmospheric temperature and the road surface temperature at the 1st stage and the 2nd stage (Quantity of ground water; 0.8L/min/m^2)

4.2.2 Reuse ground water for a heat source of other heat pump system before recharge

It can be applicable even the temperature of ground water is not so high, because heat is recovered by a heat pump from the ground water after the system before recharge. The schematic drawing is shown below.

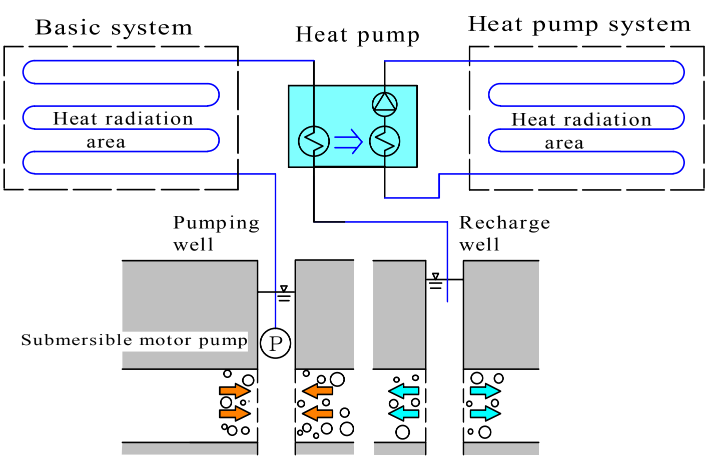

Fig.8 Outline of reuse ground water for a heat source of other heat pump system before recharge

This system has the following advantages.

1. Only a half quantity of ground water is required compared with the basic system.
2. A reduction in construction of ground water wells
3. A reduction in operation hours for heat pump system area, because of circulation system.

Actual operation results of this system installed in Morioka-city, Northeastern district of Japan, are shown hereunder, with the weather in this period there.

Table 2 Actual operation results of this system installed in Morioka-city (2000/2001 in winter)

Total hours of snowfall	Total hours of below 0℃	Operation hours of Submersible motor pump	Operation hours of Heat pump
197.7hr.	1,513.4hr.	1,259.0hr	431.2hr

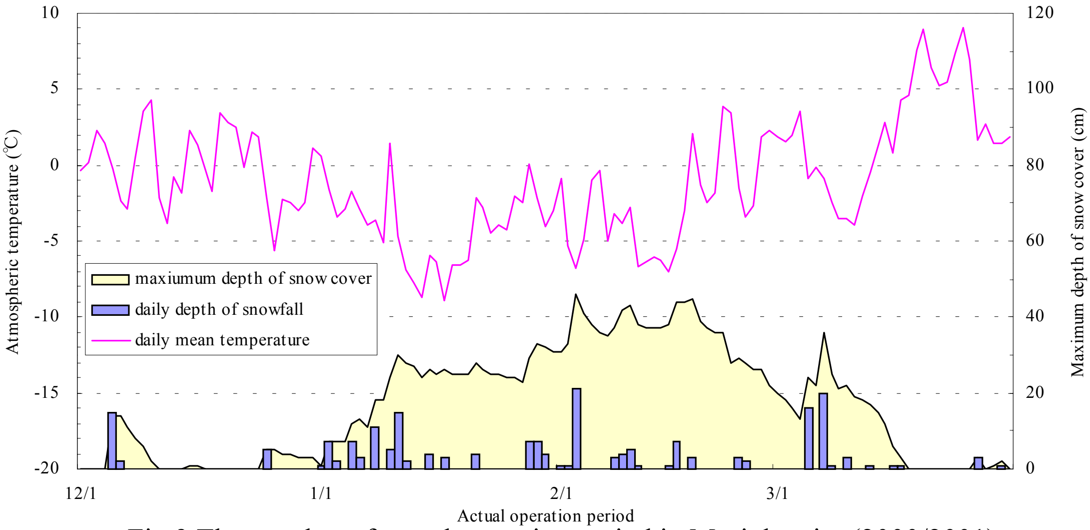

Fig.9 The weather of actual operation period in Morioka-city (2000/2001)

4.2.3 Utilizing recyclable energy

Storage of heat energy (whether hot or cold) in aquifer by ground water infiltration is put in practical use stage recently using a heat pump for not only snow melting systems but also air conditioning systems of buildings. This heat storage and recovery in the aquifer system is operated seasonally, it means ground water is warmed up during flowing though the heat radiation pipes (acting as solar collectors) by solar energy and infiltrated into the aquifer during the

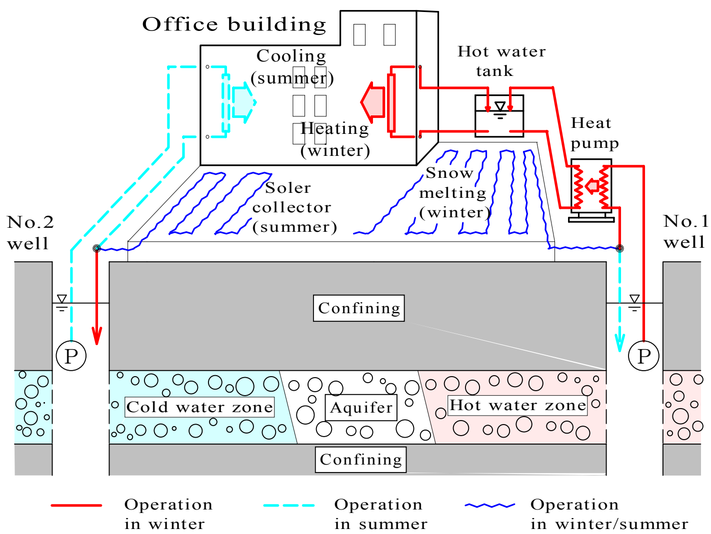

Fig.10 Utilizing recyclable energy

summer, and is pumped up in the next winter with a still higher temperature than normal. The schematic drawing is shown Fig.10.

This system has the following advantages.

1. A reduction in ground water quantity required for snow melting systems because of higher ground water temperature.
2. It can be applied for the air conditioning systems also with the higher coefficient of performance (COP) of a heat pump because of higher (lower) temperature of ground water than normal.

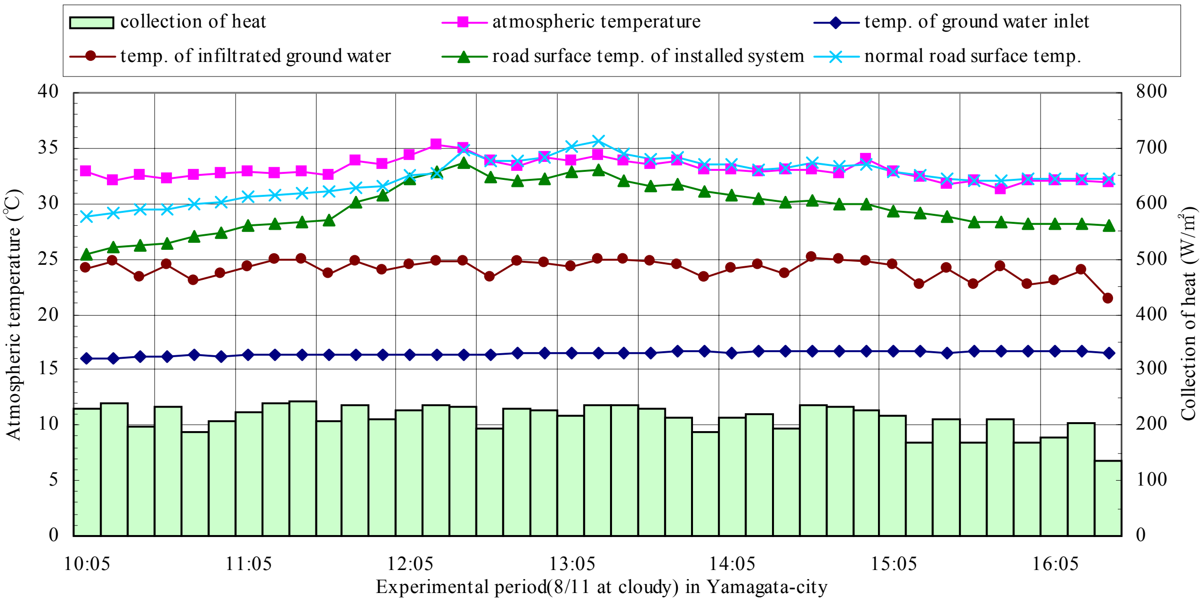

Fig.11 Acting as solar collectors during the summer in Yamagata-city

5. Conclusion

We are confident that the basic snow melting system without sprinkling ground water is still energy saving system nowadays, because it utilizes unused energy effectively.

However, we will continue to improve the snow melting systems in order to save energy and to reduce load on global environment somehow, considering such environmental disruption as global warming in these days.

References

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