ROAD HEATING SYSTEM USING HOT SPRING WATER AS THE RENEWABLE HEAT SOURCE

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ABSTRACT

This paper introduces a case study of a road heating system that uses hot spring water as a renewable heat source.

Road heating systems that use hot spring water as a heat source have been installed on the main street of the Jozankei district in Sapporo, Japan. Jozankei is one of the most famous spa resorts in Japan. The maximum road gradient on this street is about 11%, and the minimum road width is about 6 m. This makes it difficult to conduct conventional winter road management operations. Road heating systems using hot spring water date from 1966. A three-year retrofit project started in 2008 to renovate the system.

The renovation considers environmental preservation as well as more efficient use of hot spring heat. Also, because Jozankei is a major sightseeing district in Hokkaido and has a celebrated history, preservation of the traditional atmosphere has been discussed for three years with an organization of local hotel managers and experts.

The City of Sapporo has been preparing a 10-year plan for new snow countermeasures. Its cornerstone is environmental preservation. Hot spring road heating satisfies the new plan's concept. It promises to serve as an example to the world of an environmental snow countermeasure from Sapporo, a city that takes environmental preservation to heart.

KEYWORDS

ROAD HEATING / HOT SPRING / RENEWABLE HEAT SOURCE

1. INTRODUCTION

Sapporo (pop. 1.9 million) is a large city in a cold, snowy region. The annual snowfall exceeds 6 m. Road snow-melting facilities such as road heating systems using electricity and gas are installed to ensure road safety, particularly on steep slopes.

This report introduces an ongoing road heating system renovation project in the Jozankei hot spring resort district of Sapporo. The project uses locally available spring water heat, which is renewable energy. A third road heating system is being installed at the site. After comparing the two former two systems (a heat pump system and a hot spring water circulating system), the later was chosen for the renovation due to lower long-term cost performance and greater environmental friendliness. In addition, the project features a streetscape design that has been determined through dialogues with local residents.

2. GEOLOGRAPHIC LOCATION, MODERN DEVELOPMENT, CLIMATE AND SNOW REMOVAL OF SAPPORO

Sapporo is at 43º North latitude (Figure 1). Cities at the same latitude include Vladivostok and Changchun in Asia, and Marseille and Rome in Europe. London and Paris are slightly farther north. Boston and Chicago are slightly farther south. Washington D.C and New York are even farther south. In 1972, Sapporo hosted the XI th Winter Olympic Games. The city underwent rapid social infrastructure development in preparation for this event. The construction of a new city hall building and an urban regional heating system were completed. Underground shopping streets and a new concert hall were opened along with the city's first subway system.

Figure 1 - Location of Sapporo

A: Weather conditions

The average annual temperature in Sapporo is 8.5 ºC. Annually there are 130 "winter days" (daily min. temp. <0ºC) and 48 "frost days" (daily max. temp. <0ºC).

B: Snow removal in Sapporo

As a result of infrastructure development for the Olympic Games and thereafter, the total distance for road maintenance in Sapporo has been extended to approximately 5,400 km, of which approximately 5,200 km is subject to snow removal. Snow control measures are absolutely necessary in winter in Sapporo, where the annual snowfall is approximately 630 cm. The city's annual snow removal budget is approximately 14 billion yen ($143 million

or €102 million) ($1 = ¥98, €1 = ¥137). Common methods used to keep snow from accumulating on roads are shoveling or plowing it. De-icing agents are spread to clear icy roads, and road heating is installed on steep slopes (> 6% gradient, in general), at curbs and at underpass approaches/exits.

Road heating systems have been installed in snowy areas to melt snow. Electric heating coils or pipes through which warm water runs are installed beneath paved roads.

Currently, 463 road heating systems have been installed in Sapporo. Of the total, 366 are electric, 75 are gas-fired and 2 others use hot spring and other energy sources (Table 1).

Table1 - Number of road heating systems on roadways

Energy source	Number of systems	Coverage (m^3)
Electric	366	166,411
Gas	75	32,511
Other	2	7,995

(As of April 1, 2009)

3. JOZANKEI DISTRICT

Jozankei is a hot spring district approximately 25 km southwest of the Sapporo city center. The hot springs were discovered in 1866 by Miizumi Jozan, a Buddhist monk who turned it into a therapeutic spa and settled there. Since then, it has become a popular retreat in Sapporo. It is adjoined by two artificial lakes, Hoheikyo Lake and Jozankei Lake, which provide drinking water for Sapporo, and by tourist destinations such as the Kokusai ski area. The Jozankei hot spring district serves as the core of these facilities and has become a popular tourist destination. In 2007, approximately 1.4 million people stayed at the hot spring resort.

Figure 2 - Jozankei District

4. ROAD HEATING SYSTEMS USING HOT SPRING WATER

Jozankei's elevation is approximately 270 meters above sea level, the average temperature is approximately 2.5ºC lower than in downtown Sapporo. The district has more snowfall than downtown. Furthermore, the steepest road gradients are approximately 11% and some roads are narrower than 6 meters, so it would be difficult to maintain roads there by normal snow removal operations. Traffic hindrances arise when the conditions are wintry, so that there was a call for installation of snow melting systems.

Development of the system was inspired by observations of snow melting on paths in the hot spring district. In January 1966, the first road heating system using hot spring water in Japan was completed on the Mikaeri-slope section of Chuosen Street, which is the main street of the Jozankei hot spring resort district. The system is called a hot spring water circulation road heating system, in which hot spring water runs through the piles buried under the street.

The heat source, i.e., the hot spring water, is at 80ºC, and it has a mild salt content, with salts of arsenic, boric acid and hydrogen sulfide.

In addition, in the use of the hot spring water, it is based on "Hot Spring Law" and gets "the digging permission in the purpose to let a hot spring gush out" from Governor of Hokkaido.

In 1984, the existing road heating system was overhauled and replaced by a heat pipe system (Figure 3). After operating for more than 15 years, that system's snow melting performance dropped due to deterioration, and in 1998 the local community requested that city government make a second renovation of the system. In 2004, the city government began to discuss the details of a new road heating system with local residents, and a three-year renovation project was launched in 2008. The construction work is expected to be completed in 2010.

1966:	Road heating is installed on Jozankei Chuosen Street (the first road heating system installed in Sapporo and in Japan).
1984:	The heating system is converted to a heat pipe system (complete overhaul).
1998:	Renovation is requested by the local community.
2004:	Talks with local residents start.
2008:	The improvement work project starts.
2010:	The project is scheduled to be completed in this year.

Figure 3 - Chronology of Jozankei's Road Heating System

5. RENOVATION PROJECT

The former road-heating system, which used heat pipes, was installed in 1984. The system had heat receiving and radiating units, the pipes were filled with chlorofluorocarbon gas (CFC gas) as a heat-conveying medium, and the heat receiving unit was connected to a hot spring water pipe.

The current renovation uses a hot spring water circulation system. The primary reasons for the change are as follows:

1) Use of each system revealed that the hot spring water circulation system had higher economic efficiency than the heat pipe system, in terms of life-cycle cost. In addition, the operating costs of using hot spring water as the heat source were lower than those of using electricity as the heat source (refer to 6. below).

2) The former heat pipe system uses a CFC gas that has a high greenhouse gas coefficient. The system may be environmentally harmful.

Several types of pipes for circulating hot spring water were considered for the project: a polybutylene pipe, a special kind of nylon pipe and a cross-linked polyethylene pipe. After conducting a careful comparative review, the polybutylene pipe was selected, for the following reasons:

1) Polybutylene resists corrosion by hot spring water, which contains chlorine.

2) Polybutylene pipes can be joined using heat fusion, a method that produces durability against water leakage.

As for the paving materials, different materials from the former ones were chosen. Paving materials that have higher heat conductivity than that of the former materials were adopted. Furthermore, the cross-sectional design of the road was altered to reduce the thickness of the road surface material, making the pipe burial depth 160 mm, instead of the 300 mm of the former system. Such shallow installation of pipes enabled the system to melt snow from most of areas of the roadway and sidewalks, achieving at least the same snow melting performance as the existing system.

For hot spring water conservation, the spring water that is pumped up for snow melting is recirculated to the spring source after its heat is used to melt snow. Figure 4 shows project outline and Figure 5 shows cross-section of the subject street section before and after renovation.

Project area: 6,535 m^2
Length of the street: 684 m
Street lamp replacement: 31 units, aesthetically designed
Utility pole replacement: 9 poles, aesthetically designed
Pumping room: extensive renovation
Pump replacement: 2 pumps (620 liter/min. each)

Figure 4 - Project outline

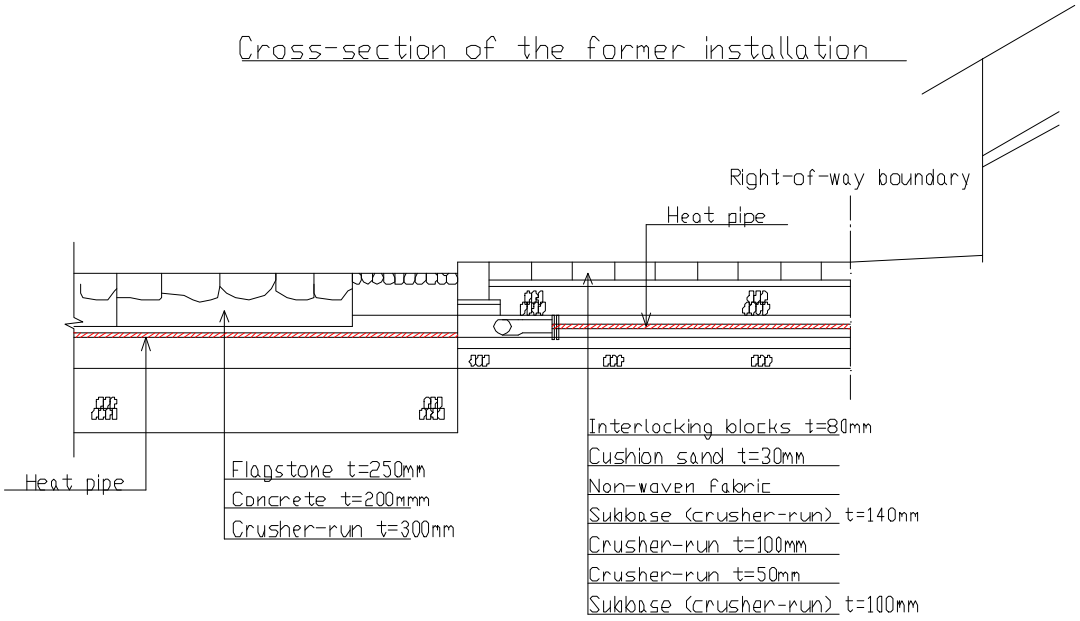

Figure 5 (a) - Cross-section: former system

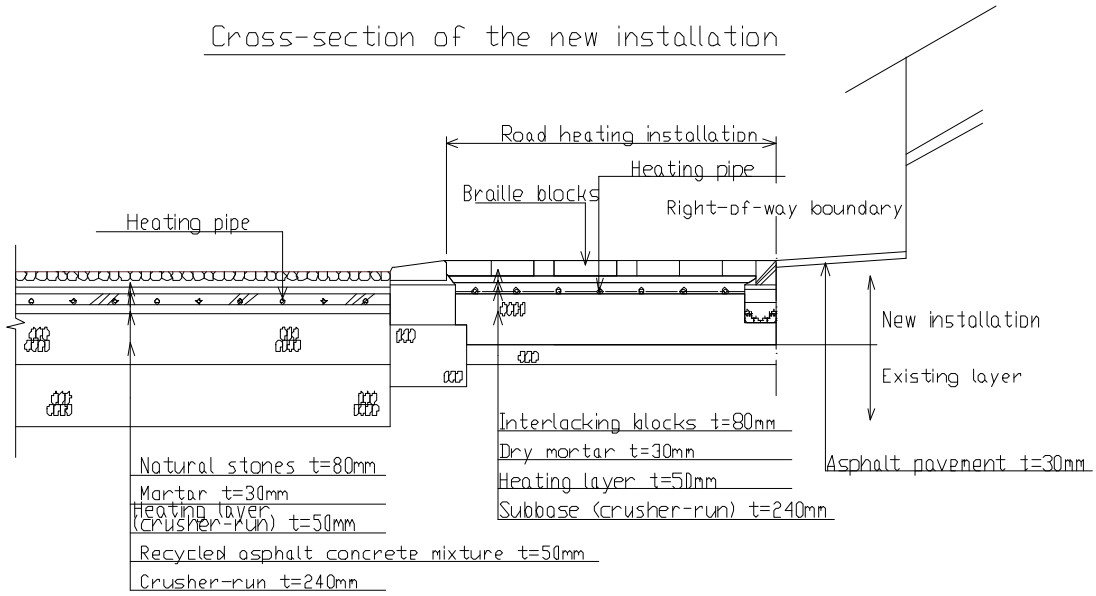

Figure 5 (b) - Cross-section: new system

6. COMPARISON OF OPERATING COSTS

A typical electric road heating system costs 2,880 yen/m^2 per year to operate. On Jozankei Chuosen Street, that would be 18,820,800 yen ($192,000 or €137,000), i.e.,

6,535 m^2 × ¥2,880/m^2 for one winter season (November through April). However, with this new system, electricity is only used to operate pumps and in 2008, it cost approximately 2 million yen ($20,400 or €15,000) to operate. We can expect an approximately 90% cost reduction compared to electric road heating.

7. LNADSCAPE PLANNING

The community development association in Jozankei, which consists of experts and owners of hotels near Jozankei Chuosen Street, discussed the project with the city government for three years, toward achieving an ideal roadscape. The discussions focused the project site's status as a tourist destination in the Jozankei district. The main objective of the discussions was to maintain and enhance the traditional hot spring resort atmosphere. Consequently, the following are adopted: natural stone on the road surface, street lamps with Japanese aesthetics, and street-side planting. Winter conditions of the project site before (left) and after (right) renovation are shown in Figure 6.

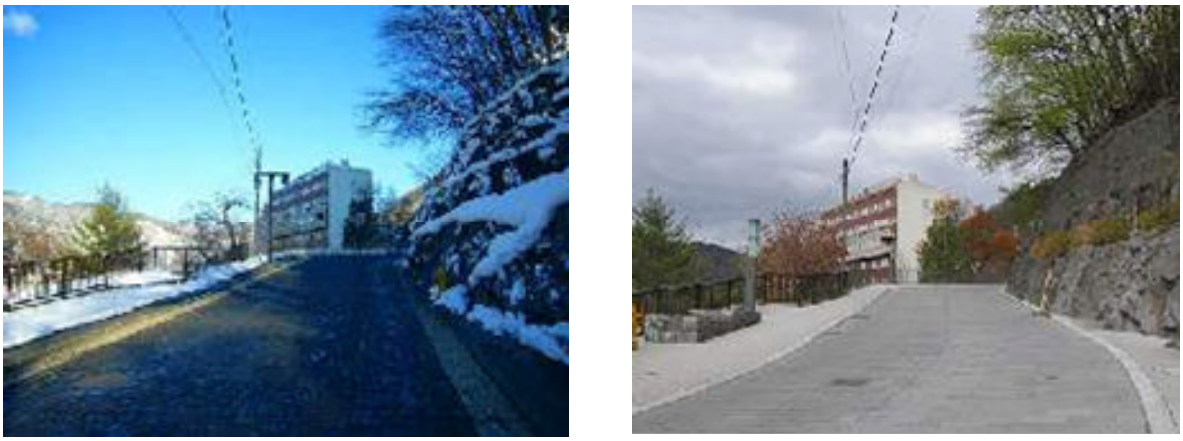

Figure 6 – Winter: before (left) and after (right) renovation

Jozankei Chuosen Street is the main street of a district where hotels line both sides of the street. Some hotel owners were concerned that prolonged construction might adversely affect their business. Therefore, we spent time holding talks with the locals to explain the construction process thoroughly and to receive input about their concerns.

A district planning council in which community residents participate was established, and the first meeting to explain the project was held on January 29, 2004. Since then we have had ten meetings concerning the construction work and five landscape study meetings. Construction began after obtaining acceptance by the local community.

The following topics were discussed and decided upon at the district planning council meeting.

A: Road surface material

1) Rectangular granite flagstones (gray) shall be used for the roadway, in order to create a flagstone atmosphere.

2) Granite-like blocks (gray) shall be used for the sidewalk, with easy reparability in mind.

3) The stone pavement shall blend into the background without becoming too noticeable, and the straight/angular elements of the roadscape will be eliminated through finishing touches to avoid the impression of urbanization.

4) Pavement joints should be designed with consideration for pedestrians wearing high heels.

5) Braille blocks shall be installed for the visually impaired.

B: Greening plan

1)Planting shall be promoted as much as possible, to enhance the verdant ambiance.

2) Planting adjacent to sidewalks will be done concurrently with the road heating installation. Planting involving areas not only by sidewalks but on privately owned lands will be accomplished in cooperation with roadside residents.

3) The chosen species of trees shall be those that epitomize Jozankei. These shall be determined through onsite study involving the local residents. The primary choices for consideration are Usugumo maple (tall tree) and azalea (shrub) (Figure 7).

Figure 7 - Planted trees: Usugumo maple (left) and azalea (right)

C: Street lamps (Figure 8)

1) The luminosity shall be slightly lower than that of the current ones, so as to create more of a Japanese spa atmosphere, but high enough to ensure safety.

2) The design should be simple so to not stand out.

3) The design shall reflect modern Japanese style, so as to harmonize with pavement material.

4) The height shall be as low as possible (roughly 3 meters). They should create a calm and warm sense of space.

Figure 8 - Street lamps: daytime (left) and nighttime (right)

8. CONCLUSION

The first phase of the road heating reconstruction project was completed in 2008. Good snow-melting performance was observed at the renovated road section during the winter season. Also the streetscape received favourable comments from the local residents (Figure 9). In 2010 when the project is to be completed, we expect it to receive high remarks not only from local residents but also from tourists.

Road heating that utilizes the natural energy of hot spring water is an innovative approach for snow control measures. The City of Sapporo, which places a priority on environmental preservation, can be proud of this snow melting facility. We think that this information will be helpful for other parts of the world.

Figure 9 - Project site: before (left) and after (right)