Fundamental Experiments of Pipe Heating by Means of Tunnel Spring Water

Senji NAGAI*, Isamu YOSHITAKE** and Sumio HAMADA**

* Technical Headquarter, Eight Consultants Co., Ltd.
3-1-21 Tsushima, Okayama, Okayama, Japan
Tel: (+81) 86-252-8943, Fax: (+81) 86-252-8919, E-mail: e0005510@8con.co.jp
** Department of Civil Engineering, Yamaguchi University, Ube, Yamaguchi, Japan

1. INTRODUCTION

Most mountain tunnels are planned to enable to cross short over pass, and some tunnel exits are located on the high attitude and steep slope. As a result, bridges and sunshades are possibly located at tunnel exits, and slip accidents often occur at such locations during snowy season in mountain road. On such locations, e.g. bridges near mountain tunnel exit, snow-removing facilities are needed in order to obtain safety traffic.

Pipe heating facility can be noted as an example for snow-removing facility. This facility has considerably economical advantage when warmer tunnel spring water is used, and where sufficient spring water is available. However, the snow melting cannot be expected when the amount of spring water is short of thawing of snow. The other thawing methods, e.g. the heating with boiler and electric heating, are generally used when tunnel spring water is lack of sufficient amount.

The object of this study is to extend the pipe heating system with the natural energy such as tunnel spring water and geothermal heat in the tunnel. The Chugoku Region in western part of Japan especially was targeted in this study, because tunnel spring water in this region is estimated to have relatively high temperature.

Firstly, this study is carried out against the fundamental experiment on pipe heating near the tunnel in order to assure the ability of snow melting. The actual tunnel spring water with 10^{o}C is employed in this experiment. Secondly, water-heating experiment was carried out in order to assume the amount of spring water is short for the snow melting. Additional water was supplied from the other places of tunnel. This report presented mainly these two fundamental experimental results.

2. EXPERIMENTS ON SNOW MELTING BY MEANS OF TUNNEL SPRING WATER

2.1. DETAILS OF USHINOGOU TUNNEL

All the data obtained from experiments in the present study were carried out at Ushinogou tunnel, shown in **Fig.1**. Ushinogou tunnel locates at a central mountain area in the Chugoku Region. The maximum amount of snowfall reaches to 30cm/day, the slip traffic accidents often occur in this area. However, continuous snowfalls over 20cm/day rarely occur in this area, and this is a typical area in west Japan.

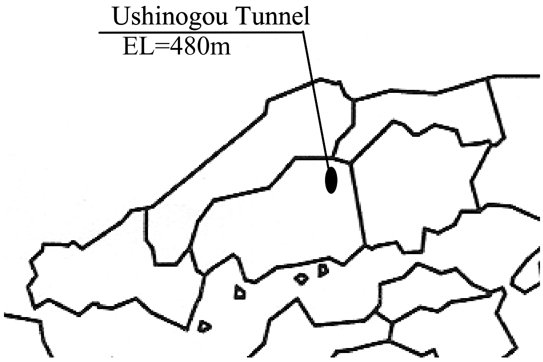


Fig.1 Ushinogou tunnel

2.2. SPECIMEN FOR PIPE HEATING

The specimens for pipe heating were detailed in **Fig.2**. Steel pipes were embedded with 150mm spacing, and thermocouples for temperature measurement were set with 20mm spacing in the specimens. The employed pipe is Φ_i 15mm (internal diameter) and Φ_e 18mm (external diameter). The size of specimens are 1500*1200*80mm or 1500*1200*50mm. The coverings of pipes are 71mm and 41mm in case of 80mm and 50mm thickness by setting at the bottom.

In order to obtain the influence of thermal conductivity on the snow melting, recycled glass and sea sand were employed as fine aggregate in the concrete specimen. The thermal conductivity of recycled glass concrete is 1.16W/mK, and that of sea sand concrete is 2.17W/mK.

2.3. EXPERIMETAL PROGRAM

Table 1 shows experimental parameters in this study **(2)**. Snow melting abilities influenced by the covering of pipe and by the thermal conductivity was compared in the experiments. The specimens were placed on the bridge deck near the Ushinogou tunnel and fixed by mortar concrete with 5mm thickness. The tunnel spring water was transported to a large tank at the test site. Each pipe in the specimen was connected with vinyl hose, and the spring water was provided into the specimen by a small pump. **Fig.3** shows the model in this experiment. The temperature difference between the water in the tank and the drained water was within 1^{o}C, which implies the temperature in the pipe can be assumed as almost the same at every location.

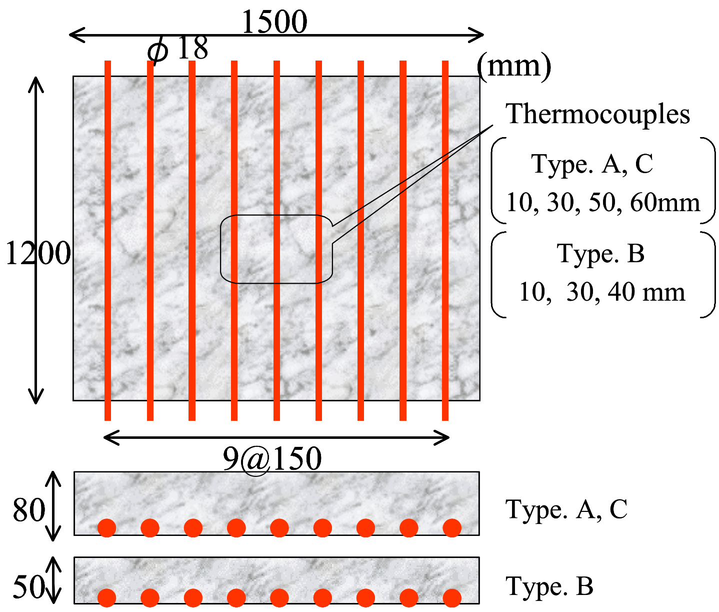


Fig.2 Specimen for pipe heating

A continuous running was executed for 6 hours from the start, and intermittent running was also executed in the specimens exposed to the natural cold condition. The snow of 5cm depth was

Table.1 Experimental parameters for pipe heating

	Running method	Covering	Thermal conductivity W/mK	
A	Continuous or Intermittent	71mm	GS & SF	1.16
B		41mm	Sea sand	2.17
C		71mm		

GS: Recycled Glass Fine Aggregate

SF: Steel Fiber

piled up on the surface of these specimens for intermittent running test. The height of melted snow was obtained by measuring the amount of snowfall and the actual height of snow when it snowed.

In this study temperatures in the concrete specimen were measured every 10 minutes and were recorded in the media of data logger. The height of snow was measured every 30 minutes in order to quantify the amount of melted snow.

2.4. EXPERIMENTAL RESULTS AND DISSUSIONS

A snowfall of 29cm/day was measured on the day of experiment. However, no snow remained on the surface of each specimen during the continuous test, as shown in **Picture.1**. Temperatures at 10mm from the surface were shown in **Fig.4**. These temperatures were at least over 2°C. This implies that this temperature of 2°C is the limit for melting snow.

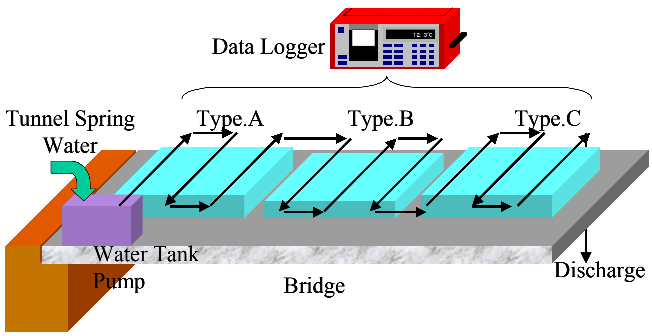
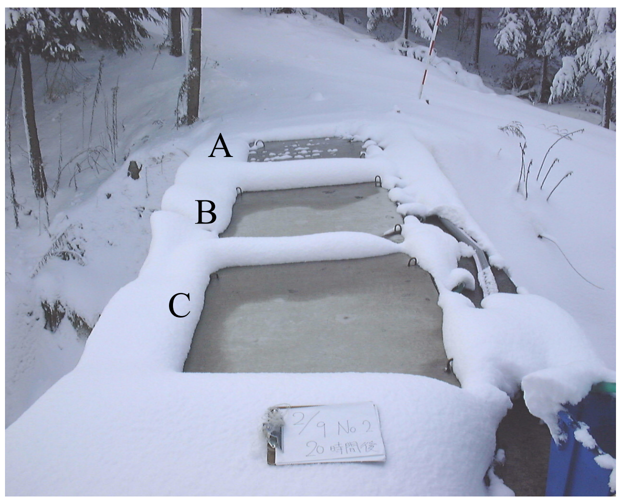


Fig.3 Flow of tunnel spring water

The intermitted test was carried out in order to study the ability of snow melting of each specimen. **Fig.5** shows the amount of melted snow. This figure indicates that the amount of melted snow in Type A was not as much as in Type C after 90 minutes. This phenomenon may be influenced by thermal conductivity. The thinnest specimen, i.e. Type.B, had well melted snow in the 3 specimens. The snow on the Type B was uneven melting at 90minutes, and the snow was almost melted after 120minutes. It can be suggested that the cover of pipe is a most influenced factor to ability of melting snow.



Picture.1. Situation of snow melting during continuous running

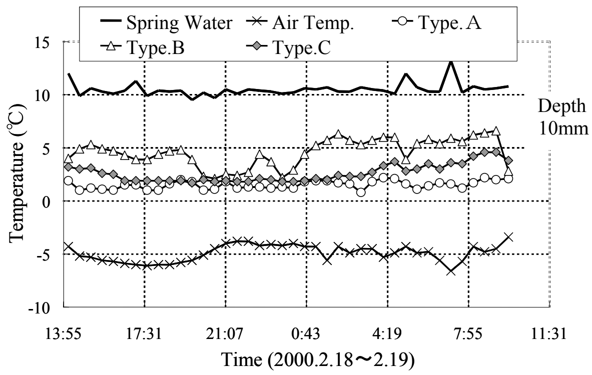


Fig.4 Temperature at 10mm from surface

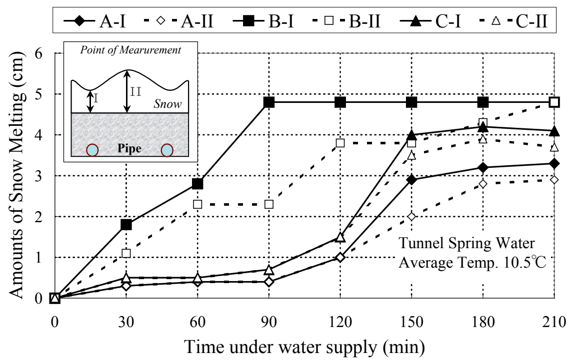


Fig.5 Snow melting under intermitted test

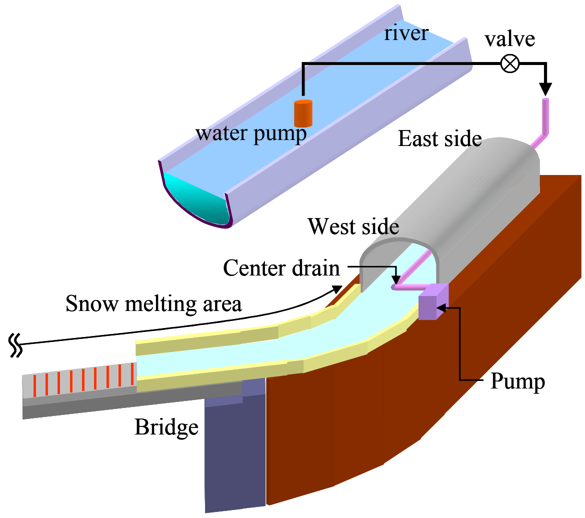


Fig.6 Flow of supplying water

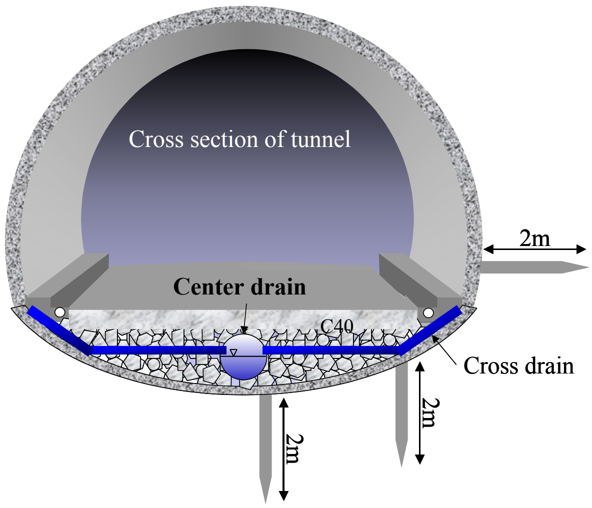


Fig.7 Cross section of tunnel

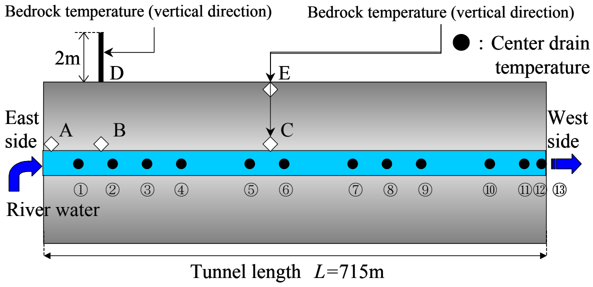
Table.2 Experimental parameters for water heating

Date (test start)	2/6	2/7	2/13	2/14
Additional water (m^3/min)	1.0	0.5	0.25	1.0
Term of supply (hours)	5	5	5	24

3. EXPERIMENTS ON WATER HEATING IN MOUNTAIN TUNNEL

3.1. EXPERIMENTAL PROGRAM

Snow melting cannot be expected when the amount of tunnel spring water is short for snow melting area. In such case, additional warm water must be supplied from the outside of tunnel. This study carried out an experiment of water heating by using thermal energy of bedrock around the tunnel. In this experiments, the water was supplied from a river nearby. The river water employed was an average temperature of 4°C during the test, was poured into the center drain below the tunnel. **Fig.6** and **Fig.7** show the flow of river water, and cross section of tunnel, and water flow from east side to west side of the tunnel.



Distance from East Exit

A: 8m	B: 52m	C:307m
D: 52m	E:307m	⑬:725m 10m from west exit

①: 40m	②: 90m	③: 140m
④: 190m	⑤: 290m	⑥: 340m
⑦: 440m	⑧: 490m	⑨: 540m
⑩: 640m	⑪: 690m	⑫: 714m

Fig.9 Temperature measurement point

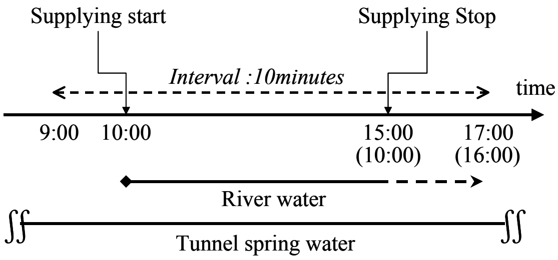


Fig.8 Temperature measurement flow

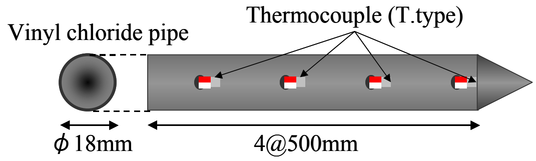


Fig.10 Pipe for measuring temperature

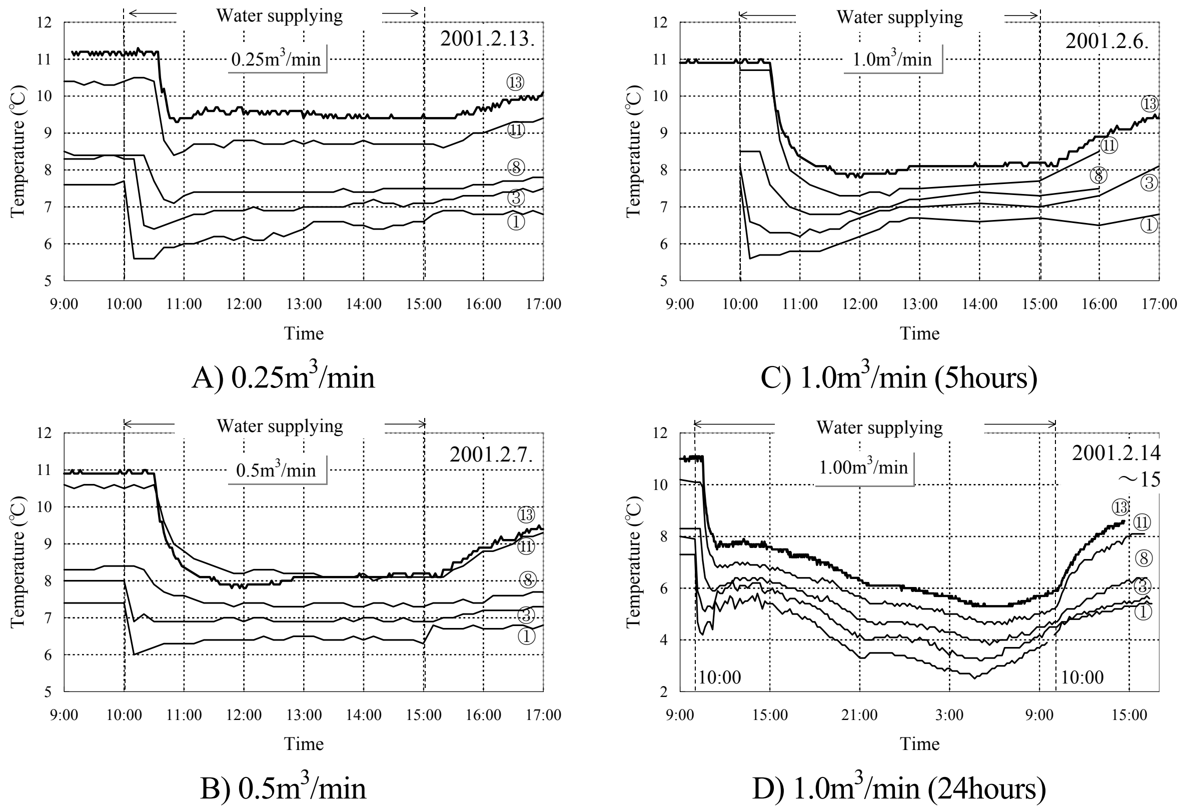


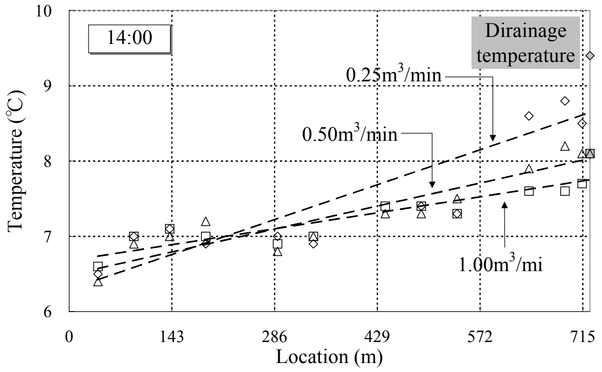
Fig.11 Change of water temperature in center drain

The experimental parameters of this study are mainly the amount of additional water and a term of supplying water, as shown in **Table 2**. Based on the flow shown in **Fig.8**, temperatures of water or bedrock were measured every 10 minutes at the point shown in **Fig.9**. In the present study vinyl pipes shown in **Fig.10** were employed for measuring the temperature of bedrock, and these pipes were set in hole for rock bolts before filling with cement milk.

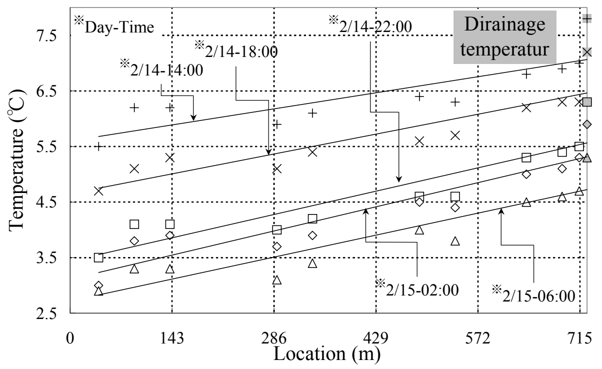
3.2. WATER TEMPERATURE IN A CENTER DRAIN

Fig.11 shows the change of water temperature in the center drain. These results indicate that the water temperature became rapidly lower in turn from east side after the water supplying. These temperatures however became a steady temperature as far as a location of 429m, and gradually increased.

The distribution of water temperatures in the center drain is shown in **Fig.12**. If heat transfer between water and its surrounding is nothing, the temperature in center drain must become the temperature of river water. The water temperatures in the center drain were actually raised up with almost liner relation by heat transfer from the other thermal energy (see **Fig.12**). As shown in **Fig.12**, the temperature rise was at least 1.5°C even in such case of a supply of 1.0m^3/min. From this phenomenon, supplied water to the center drain can be warmed even with enough amounts.



A) 5hours

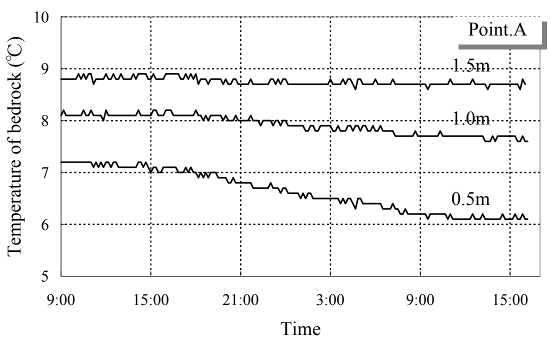


B) 24hours

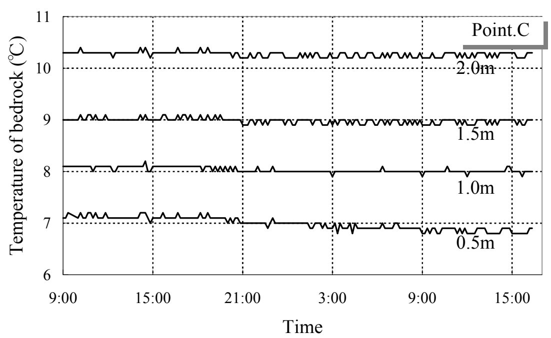
Fig.12 Distribution of water temperature

3.3. TEMPERATURE OF BEDROCK AROUND TUNNEL

Fig.13 shows examples of the relation between time and temperature of bedrock near the center drain after 24 hours of water supply. From this result, it was found that little temperature change except that the temperature of 0.5m at Point.A became gradually lower. It may be due to heat



A) Point. A



B) Point. C

Fig.13 Temperature changes of bedrock around the tunnel capacity of bedrock around this tunnel. The bedrock and drain water cooled by supplying water recovered to the normal temperature by the next day.

4. CONCLUSIONS

The object of this study is to extend utility value of the pipe heating by using natural energy. Especially, this study aimed at the pipe heating by tunnel spring water. As a part of this study, 2 fundamental experiments, i.e. snow-melting test and water-heating test, were carried out in the existing tunnel. The main results from these experiments can be summarized as follows:

1) Snows did not pile up on the surface of each specimen during the continuous test in spite of heavy snowfall of 29cm/day. This result means that it was effective to control the temperature at 10mm depth from the surface.
2) The difference in snow-melting ability of specimens with different thermal conductivity occurred in the intermitted test. The thinnest specimen that was almost finished to melt snow after 120min had the highest ability of snow melting in 3 specimens.
3) The water temperatures in the center drain increased with almost a liner relation by heat transfer. Especially, the temperature rise was at least 1.5^{o}C even in water supply of 1.0m^{3}/min .
4) The temperature change of bedrock was little occurred. This may be resulted from the fact that the heat capacity of bedrock is extremely greater than the heat capacity of water.

REFERENCES

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