

Simple Estimation of the Ground Water Temperature and Snow Melting Process

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1. INTRODUCTION

The half of the Japanese highways is located in the snowy region, where the maximum snow height is 30cm in 10 years. Winter snow and frozen roads on the highways of the main root have been big barrier to the economical activity. Accidents in winter occur due to car slip on the freezing bridges surfaces, sunshade among hills and tunnel exit area. The reason why accidents occur on such places, which is covered with snow, is due to road condition gap from normal road. Especially in case of bridges, the gap between bridge and normal road is produced by the difference of conductivities from geothermal heat. The traffic accident has often happened on the bridge even in comparatively warm region, and this social problem is not limited to the snowy region at all.

There are several methods in order to remove the ice and snow on the bridges, e.g. sprinkle with water and electric road heating etc. This study aims to develop a pipe heating system, which is reasonable cost compared with other method. The purpose of this study is development the pipe heating system by ground water with constant temperature during seasons. This paper presents the simple estimation method of the ground water temperature based on atmospheric temperature model, and the fundamental properties of snow melting through experiments of pipe heating.

2. RELATIONSHIP BETWEEN TEMPERATURE AND GROUND WATER

Ground water temperature is affected by atmospheric temperature where located near the earth surface. Influence of atmospheric temperature to ground temperature become smaller as the depth is deep.

Fig.1 shows the relationship between the ground water temperature and the annual average temperature. The temperature equation given by **Eq.1** is based on the reference (1).

$$T_e = 0.83T_a + 3.7 \quad (\text{Eq.1})$$

T_e : constant temperature of ground water (°C)

T_a : annual average temperature (°C)

Fig.1 shows that the ground water temperature is a little higher than the annual average

temperature under approximately 20°C. Chugoku Region has the average temperature from 10 to 17°C. Therefore, the temperature of ground temperature is in the range from 12 to 18°C in Chugoku Region even in winter.

Fig.2 shows the distribution of the ground temperature in a year as an example. It shows that the ground temperature, i.e. ground water temperature, converges a certain temperature at a deeper location. From this result, the convergent temperature under 600cm is approximately 17~18°C, of which temperature is slightly higher than the annual average temperature at this site. This constant temperature of ground water can roughly be evaluated from the annual average temperature and it may be beneficial for the design of pipe heating.

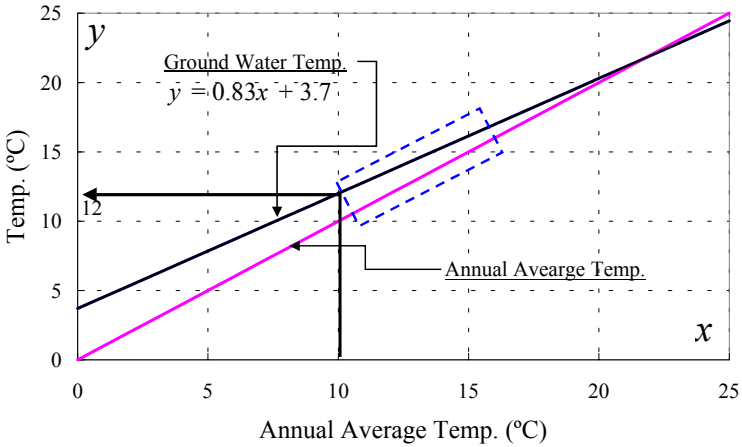


Fig.1 Relationship between ground water temperature and annual average temperature

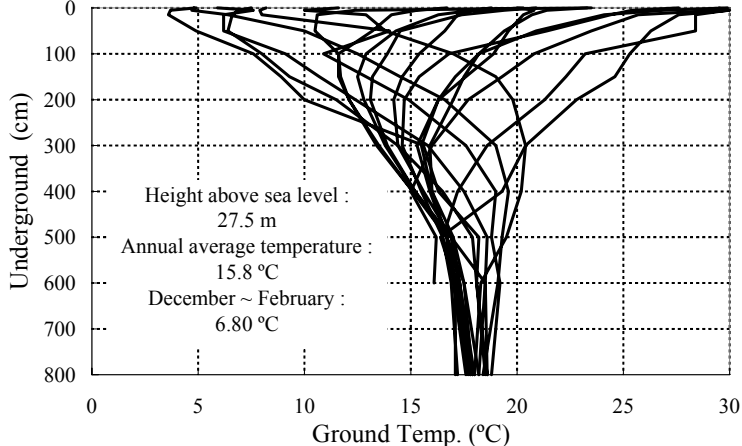


Fig.2 Distribution of ground temperature through a year (Ube)

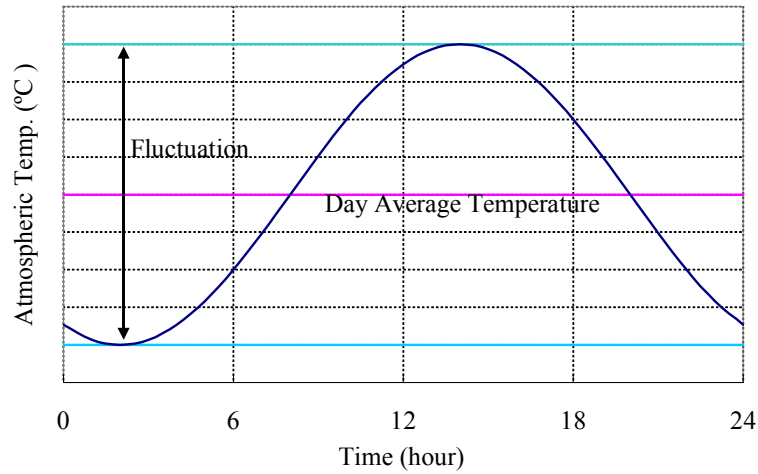


Fig.3. Model concept for atmospheric temperature

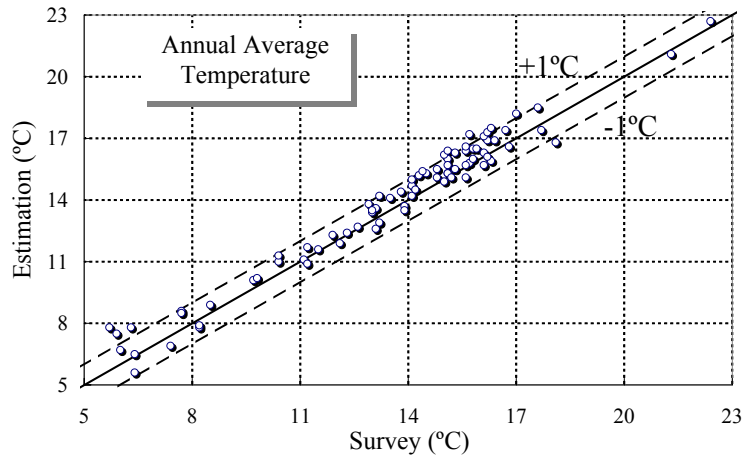


Fig.4. Comparison of survey and estimation

3. SIMPLIFIED MODEL FOR GROUND WATER TEMPERATURE

Nakamura et al proposed the simplified model for atmospheric temperature applying to thermal stress analysis in mass concrete (2). Their model concept for fluctuation in temperature of a day is showed in **Fig.3**. The fluctuation in temperature is assumed as sine curve around the day average temperature. To obtain the day average temperature, the latitude, month and the height above sea level are needed. The equations for the day average temperature are shown from **Eq.2** to **Eq.4**.

$$T_d = a_d(N - 35) + P_d - 0.006H \quad (\text{Eq.2})$$

$$a_d = 0.212k - 1.864 \quad [N \leq 35] \quad (\text{Eq.3})$$

$$= 0.076k - 1.355 \quad [N \geq 35]$$

$$P_d = 4.354k - 6.007 \quad (\text{Eq.4})$$

T_d : day average temperature (°C) N : latitude

k : month (February ~ August) H : height above sea level (m)

The temperature obtained from these equations is an average temperature of a day, and fluctuation in atmospheric temperature varies by the places. The fluctuation of atmospheric temperature is obtained from the contour map provided by the data of 10 years. The day average temperature is determined from the above model expressed by Eq.2~ Eq.4, in order to obtain the ground water temperature at the site, since the temperature of ground water is not affected by the fluctuation of the atmospheric temperature. The comparison of an annual average temperature obtained from the above equations and the surveyed temperatures is shown in Fig.4.

Fig.4 indicate that the evaluation of these equations provides high accuracy, that is, within roughly $\pm 1^{\circ}\text{C}$ to the annual average temperature. These simple equations result in a useful tool for design of pipe heating by using ground water.

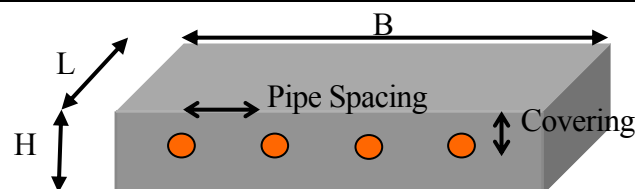
4. EXPERIMENTS OF SNOW MELTING PROCESS

4.1 PURPOSE OF EXPERIMENTS

Laboratory tests for the snow melting process were carried out in order to obtain the fundamental data for the pipe heating by using ground water. In addition to laboratory tests, field tests of snow melting process were carried out as supplementation of laboratory tests. These experiments focused to the pipe location and water temperature, in order to study on the influence of these parameters to the snow melting by the experiments.

Table.1 Detail of specimens and experimental parameters

Specimen	Test Type	Pipe Spacing	Covering	Water Temp.	Specimen Size
Type. 1	Laboratory	100mm	80mm	20, 30, 40°C	B600*L500*H200mm
Type. 2	Laboratory	200mm	80mm	20, 30, 40°C	B600*L500*H200mm
Type. 3	Laboratory	300mm	80mm	20, 30, 40°C	B600*L500*H200mm
Type. 4	Laboratory	100~300mm	30mm	20, 30, 40°C	B600*L600*H200mm
Type. 5	Laboratory	100~300mm	50mm	20, 30, 40°C	B600*L600*H200mm
Type. 6	Field	300mm	80mm	20, 30, 40°C	B1200*L800*H200mm
Type. 7	Field	400mm	80mm	20, 30, 40°C	B1200*L800*H200mm
Type. 8	Field	600mm	80mm	20, 30, 40°C	B1200*L800*H200mm



4.2 DETAILS OF TEST SPECIMENS

Details of the test specimens and experimental parameters in this study are described in Table.1.

Copper pipe was employed as the water pipe for its high thermal conductivity. Copper-Constantan thermocouples embedded in the specimen, and were used as temperature sensors.

The water quantity per unit time in the pipe was determined as to satisfy the condition that the temperature of water is the same everywhere in the pipe. The average water quantity was $327\text{cm}^3/\text{sec}$, and the average water velocity was $138\text{cm}/\text{sec}$. Density of the snow employed in the test was $300\text{kg}/\text{m}^3$, and the depth of snow on the surface of specimen was 50 millimeters. The specimens were set in the freezing chamber controlled 0°C from 3 hours before the laboratory test.

Temperatures were measured every 10 minutes by using a GPIB interface and personal computer. Furthermore, the amount of melting snow was obtained by measuring the height of snow every 30 minutes.

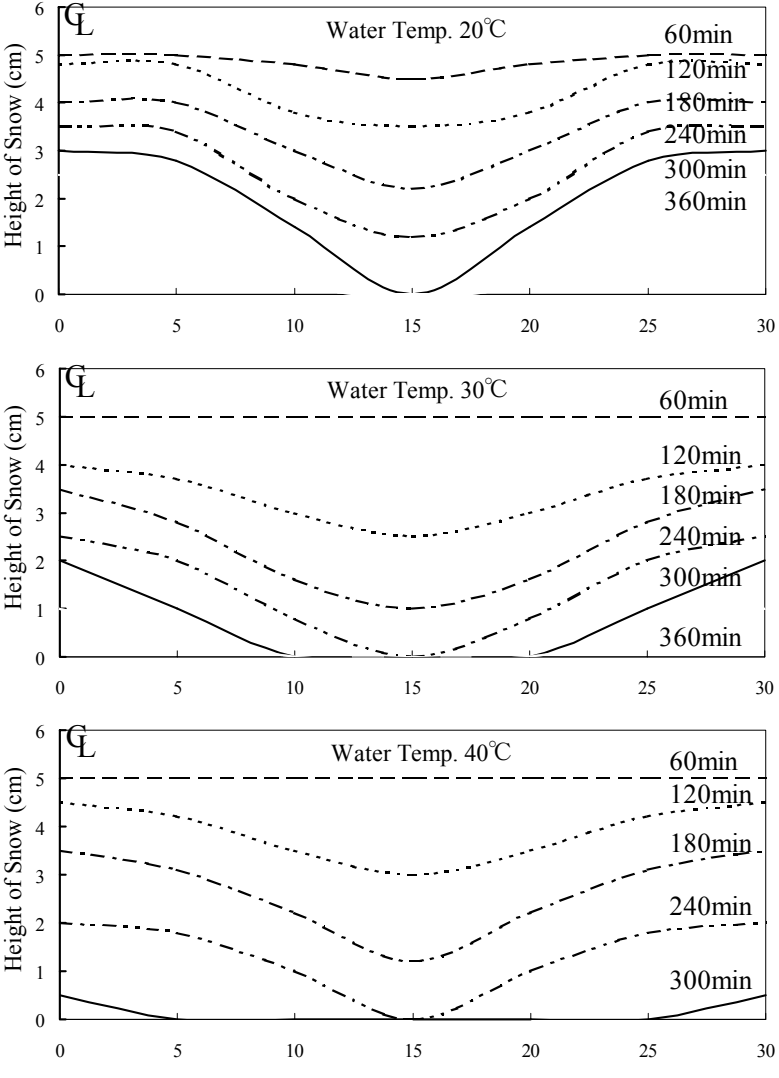


Fig. 5 Influence of water temperature to the snow melting process (Type.3)

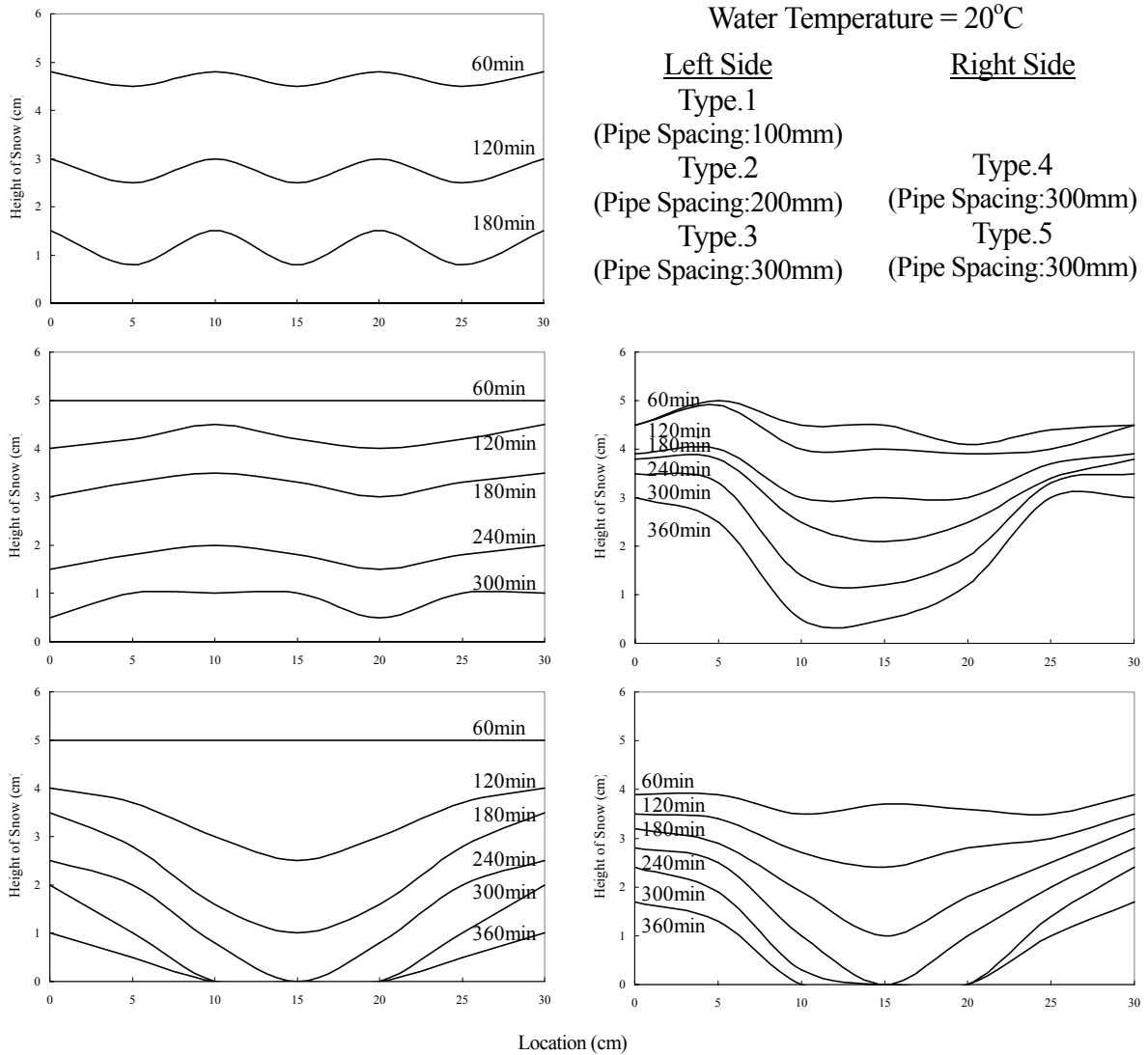


Fig.6 Influence of pipe location to the snow melting process

4.3 EXPERIMENTS OF SNOW MELTING PROCESS (3)

Fig.5 shows the influence of water temperature to the snow melting process of the laboratory test. The figure shows that snow was well melted as higher water temperature. A small amount of snow, however, remained on the surface between the pipes even after 360 minutes. This phenomenon implies that the water temperature is not as effective as the pipe location to state in the next paragraph.

The influence of pipe locations to the snow melting process was presented in **Fig.6**. Type.3~ Type.5 in Fig.6 indicate that the cover thickness does not much influence snow melting after 180 minutes. Snow remains on the surface even after 360 minutes heating, which means that the covering of pipe is not so effective to prevent from traffic accidents.

The effect of pipe spacing is represented from Type.1~ Type.3 in Fig.6. Type.1, which has pipe spacing 100mm, had the most ability of snow melting in the all specimens in this study. This result

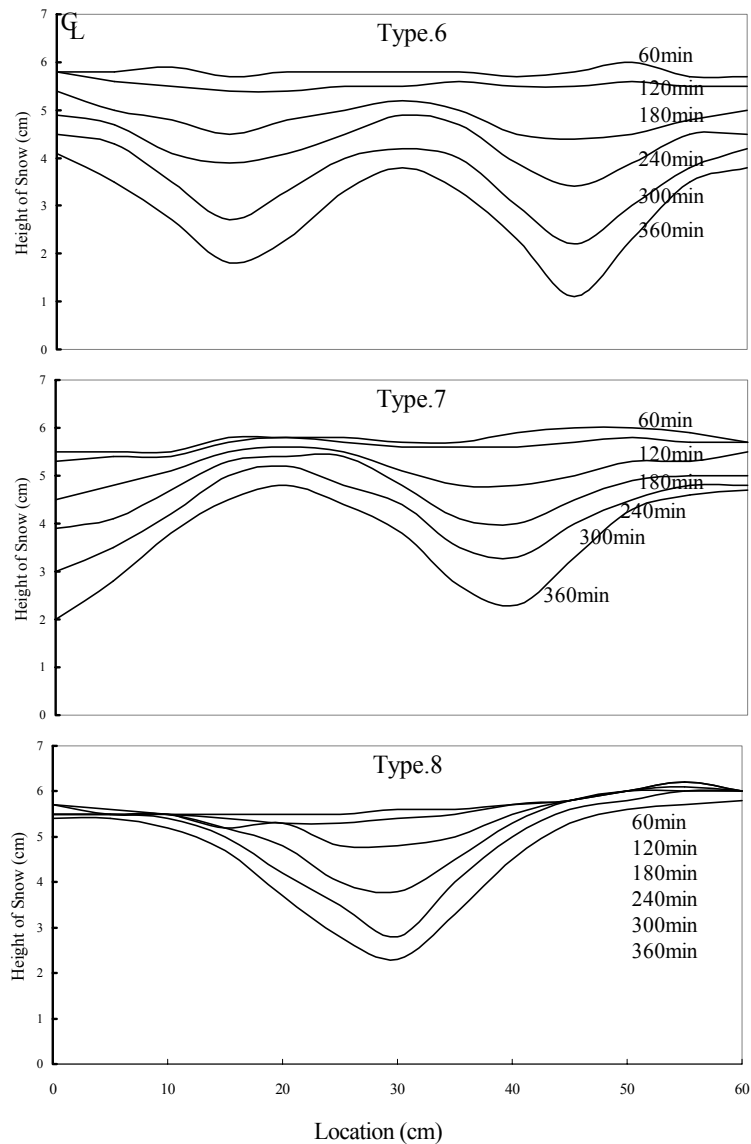


Fig.7 Field test of snow melting process (water temperature : 15°C)

means that the pipe spacing is the most dominant factor for the efficient melting method. Since the water temperature is equal to the temperature of ground water, snow can be sufficiently possible to be melted and the bridge road obtains the safety road condition during winter.

Field test was carried out in order to obtain the practical data in the actual snow melting process. In the present experiment rather wider pipe spacing was employed, since the wider spacing is not easy to test in the laboratory. **Fig.7** shows the snow melting process by using water temperature of 15°C. This water temperature is slightly lower than the ground constant temperature obtained from the **Fig.2**. **Fig.7** indicates that the heating of pipe spacing over 30cm is not able to melt snow sufficiently. However, a little snow remaining on the surface may be thawed or blown off by the passing automobiles. The ultimate aim of this heating is that the snow on the bridge is melted earlier than the snow on the normal road.

5. CONCLUSIONS

The object of this study is to obtain the fundamental data on design of pipe heating by ground water. Firstly, this paper presented the simple estimation method of the ground water temperature based on the atmospheric temperature model. Secondly, experiments of snow melting were carried out in order to obtain the fundamental properties of pipe heating. The conclusions of this study are as follows.

- 1) The temperature of the ground water can be estimated from the annual average temperature by means of a simplified model for the atmospheric temperature. This model may be a useful tool for the design of pipe heating.
- 2) The snow was well melted as higher water temperature. The effect of the water temperature to the snow melting, however, is not as high as the effect of pipe location. The effect of pipe spacing has especially a large influence on the snow melting.
- 3) Temperature equaled to the temperature of ground water is sufficiently possible to melt the snow on the bridge to obtain the safety road condition during winter if pipe is embedded on proper location.

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