# A STUDY ON THE ROAD HEATING SYSTEM OF CONCRETE BLOCK PAVEMENT

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## ABSTRACT

It is important to take some countermeasures for traffic safety against ice and snow on the roads in winter. In using a road heating system, the concrete block pavement has an advantage over the ordinary pavement forms such as asphalt pavements and concrete pavements. Because it has a sand cushion layer which allows the surface layer to move independently and the block thickness is appropriate to lay a heater under the surface layer. In this study, we examined the effect of some factors of the concrete block pavement in the indoor pit. They are heater types, sand cushion thicknesses and block types. And they are examined in winter at the outdoor field.

## 1.INTRODUCTION

Our country extends to north and south long, and the mountains range along the country. About 60% of the region belongs to the snowy and cold areas, as shown in Figure1. And about 1/4 of the population live in the region. Therefore, the countermeasure against ice and snow on the roads in winter is a matter of vital importance for us.

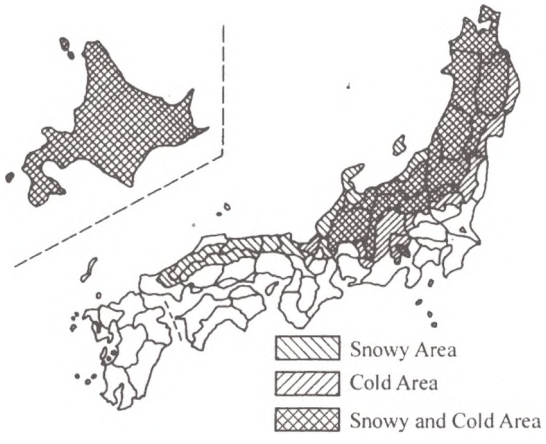



**Figure 1 Snowy Area and Cold Area**

Especially, since the studded tire was entirely forbidden in April 1991, countermeasures for the traffic safety have been worked out not only about the tire but also about the road.

The following means are available.

Clearing snow from a road by machine
Thawing ice and snow by chemical agent
Thawing ice and snow by under ground water or hot water
Pavement which has the function of preventing freezing
Road heating

The former three apply energy directly to the road surface from outside to remove ice and snow, and the latter two give pavements the function of thawing ice and snow for themselves.

This study described the effect of road heating of concrete block pavements by indoor and outdoor experiments. We want to clarify the superiority of the block pavement in road heating, before we show the details of the result. Though the certainty of road heating is greater than the other means, the construction cost and maintenance cost are high. In addition, what seems to be a problem is that the life of pavement does not agree with the life of the heater. There is no problem, if the life of the heater is longer than that of the pavement. However, if the life of the heater is shorter than that of the pavement, the expected thawing function of the pavement will not work after the heater ceases working. That is to say, the pavement must be destroyed, even if the asphalt pavement or the cement concrete pavement are sound, once a problem occurs in the heater. But as regards the concrete block pavement, if the heater breaks down it is possible not only to remove the blocks on the broken heater, but also to use the removed blocks again. It is a great advantage to have the sand cushion layer that exists between the block layer and the base course. The surface layer of the asphalt pavement and the cement concrete pavement is connected with the base course layer, and the repairing area reaches to the base course. On the other hand, it is an advantageous point of the concrete block pavement that the surface layer is removable and so repairing cost is low.

## 2. EXPERIMENTAL METHOD

A pavement model of the cross section of Figure 2 was made in the indoor pit. The pavement structure consists of concrete block layer, sand cushion layer, heater, concrete stabilization base course and subgrade, like usual carriageway pavement. The thermocouples were placed at 5 points, namely, on the concrete block surface, in the middle of the block, on the bottom of the block, on the heater surface and on the bottom of the heater (Figure 2). The experimental conditions were 2 types of heater, 2 types of block and 3 types of sand cushion thickness. Heaters were 2 types (Table1): the voltage of

100V and 200V. The100V heater was covered with the protection layer of a little thick rubber material, and the 200V heater was a very thin sheet type. The thicknesses of sand cushion layers were 10, 20 and 30mm. Concrete blocks were a usual type and a high conductivity type. Their thermal conductivities are shown in Table 2. Table 3 shows the experimental conditions as a list. The measuring time of the temperature was about 6 hours.

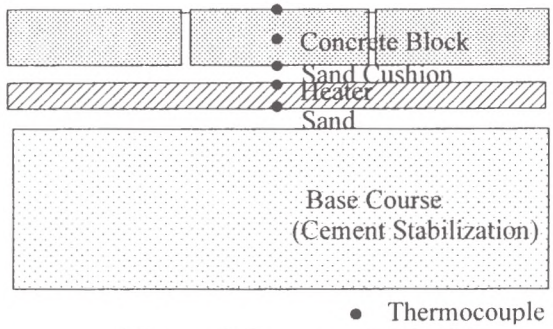



**Figure 2 Pavement Model**

**Table 1 Heater Type**

| | Heater A | Heater B |
|---|---|---|
| Heater Size | 1m×1m | 0.3m×1m |
| Construction Area | 1m×1m | 1m×1m |
| Volt | 100V | 200V |
| Resistance | 48Ω | 420Ω |
| Calorific value | 230W/m$^2$ | 286W/m$^2$ |

**Table 2 Thermal Conductivity of Block**

| | Normal Type | High Heat Conductive Type |
|---|---|---|
| Thermal Conductivity | 1.19(kcal/mh°C) | 2.22(kcal/mh°C) |

**Table 3 Experimental Condition**

| | Heater Type | | Sand Cushion Thickness | | | Block Type | |
|---|---|---|---|---|---|---|---|
| | A | B | 10mm | 20mm | 30mm | Normal | High |
| Heater Type | ○ | ○ | | ○ | | ○ | |
| Sand Cushion Thickness | ○ | | ○ | ○ | ○ | ○ | |
| Block Type | ○ | | | ○ | | ○ | ○ |

## 2.EXPERIMENTAL RESULT

This experiment was mainly carried out in autumn. So, we set the initial temperature at 0 degrees in order to compare these results.

Types of heater: In this experiment, the sand cushion thickness was 20mm, and normal concrete blocks were used. The result of the temperature change on the heater surface is shown in Figure 4. Both of the temperatures of A and B rose rapidly to 7℃, and the shapes were almost the same, but over 7℃, the shapes showed a great difference. The early effects of the initial temperature rise, which is important for thawing, do not seem much different. However, as the curve shapes had a great difference, they should be used properly according to the thawing environment.

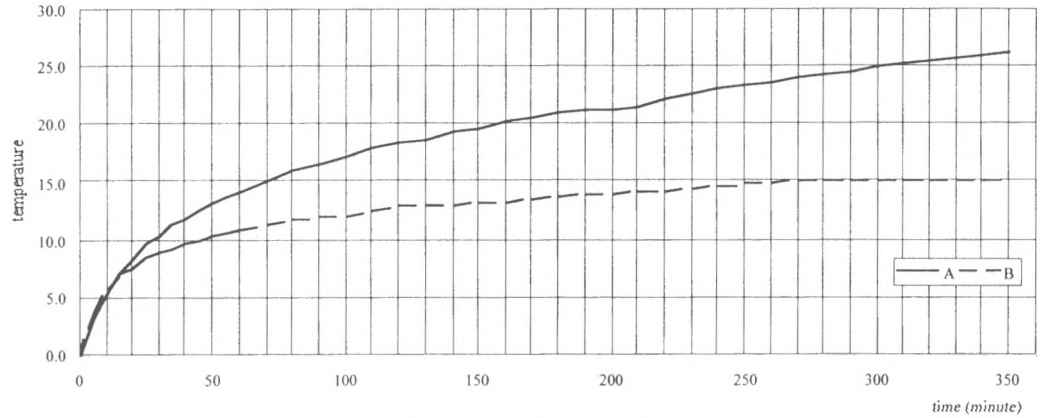



**Figure 4 Heater Type**

Sand cushion thicknesses: In this experiment, the normal block and A heater were used. It is reasonable that the heat transmission becomes more difficult if the sand cushion becomes thicker. Figure 5 shows the result of this experiment. The surface temperature of 10mm cushion thickness rose fastest. The temperature rise slowed down, as the cushion became thicker, from 20mm to 30mm. The behavior of the temperature rise of 20mm thickness did not show the linear relation: the behavior of 20mm was like that of 30mm at the beginning. The clear temperature difference of these layer thicknesses came out after it passed over 150 minutes. By these results, it seems that if the sand cushion can be made thinner than 10mm the heating effect will appear faster.

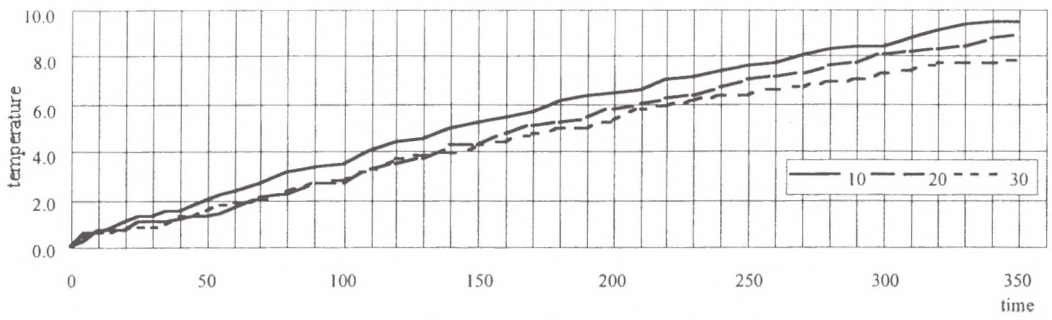



**Figure 5 Sand Cushion Thickness**

Block types: Here, We compared two blocks, in terms of thermal conductivity. In this experiment, 2 kinds of blocks of Table 1 were used with A heater and the identical cushion thickness (20mm). This result is shown in Figure 6. The surface temperature of high conductive type rose faster. But over 200 minutes, the temperature rise slowed down and the surface temperature of normal block went up higher.

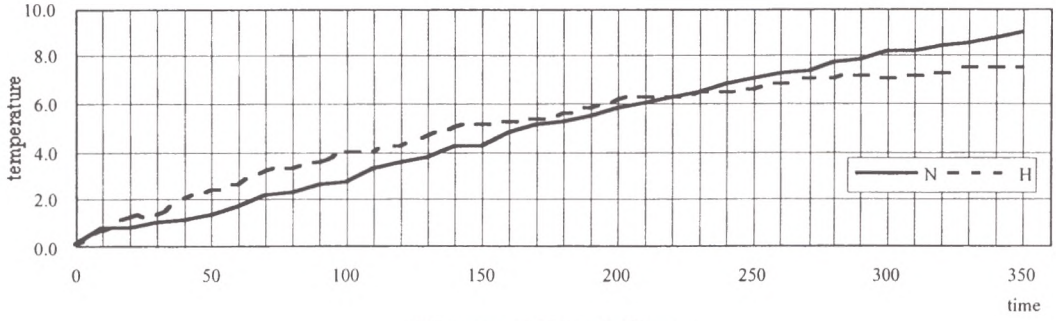
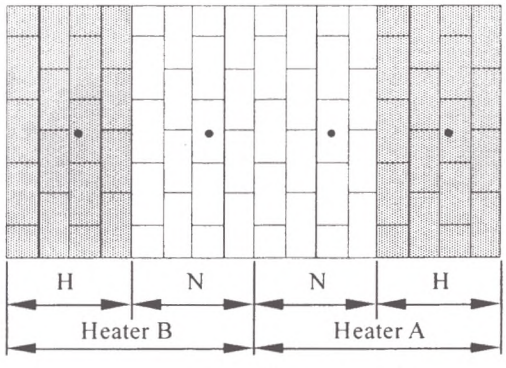



**Figure 6 Block Type**

## 4. THE OUTDOORS THAWING EXPERIMENT

As the indoor experiment was carried out without ice and snow condition, the outdoor experiment was carried out from December 1999 to February 2000. The experiment field was in the campus of Tohoku Institute of Technology in Sendai City, where we do not have much snow in winter. The available areas in the campus were restricted because we must make a comparison under the same condition and the size of a heater was 1m×1m maximum.

The plan of the experimental pavement model is shown in Figure 7, and the section of block pavement is shown in Figure 8. 20mm sand cushion was laid on the heater like in the indoor experiment, and the thermocouples were put on the block surface, on the block bottom, on the heater surface, and the air temperature were measured.




• Thermocouple
N: Normal Type
H: High Conductive Type

**Figure 7 Layout of Blocks**

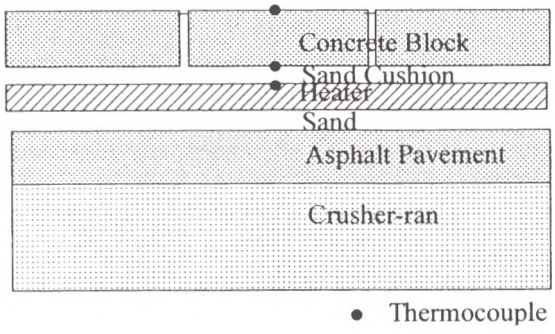



**Figure 8 Pavement Model**

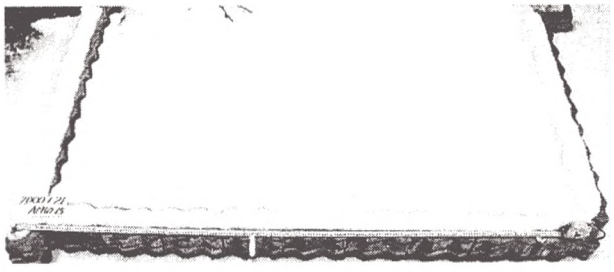


**Photo 1 Start**

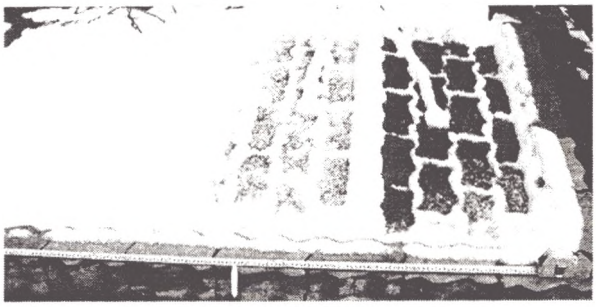


**Photo 2 2hours After**

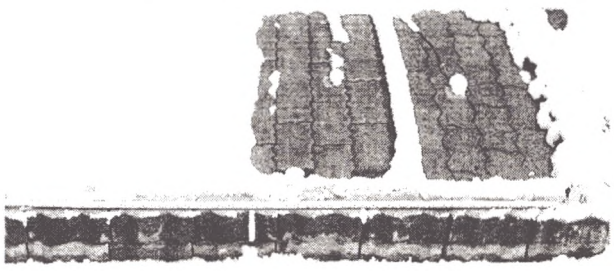
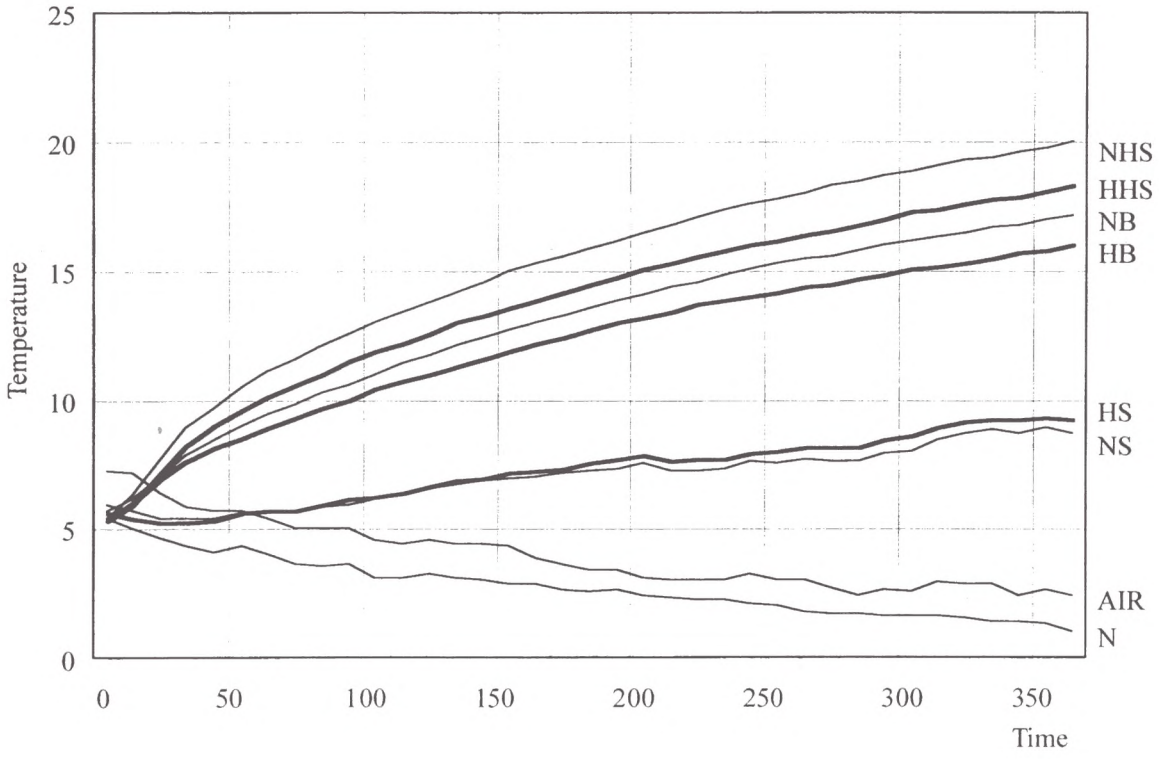


**Photo 3 4hours After**

One type of block had 4 rows and we compared 2 kinds of blocks on the identical heater. On this scale of experiment, the heat would transfer to the lateral direction, but we thought

the same condition to be more important than the size. Photo 1～3 shows the block surface conditions at the energized time, 2 hours and 4 hours after the energized time. This result shows the road heating effect well.

Figure 9 shows one of the measured processes of the temperature rise. The temperature of the heater surface of normal block was highest and the temperature of the heater surface of high conductive type was a little lower. On the other hand, the temperature of the surface of high conductive block was higher than that of the normal block. It shows that the high conductive block transmits heat faster to the surface than normal blocks. The temperature of the air and the block surface without a heater went down, while the temperature of heated block surfaces went up. It can be seen that the heater works well. Though the block of high conductive type was most effective, the normal type of block showed a similar thawing effect.




NHS: Normal Block, Heater Surface HHS: High Conductive Block, Heater Surface
NB: Normal Block, Bottom HB: High Conductive Block, Bottom
NS: Normal Block, Surface HS: High Conductive Block, Surface
N: Normal Block, Surface, Without Heater
AIR: Air Temperature

**Figure 9 Temperature Change in Outdoor Experiment**

## 5. CONCLUSION

As mentioned before, the block pavement is the most suitable paving form for road heating. It is shown that we can expect more effective thawing when we use high conductivity blocks than normal blocks. The actual workability was not discussed here, because this study is a basic experiment. It is clear that the existence of the sand cushion layer is an advantage in lying a heater in the ground. And, it is also clear that the pavement of this structure can be repaired most efficiently, when the heater is damaged by some causes. It is natural that the effect of the heater is greater, if the sand cushion thickness becomes thinner, but it depends on the durability of the heater. Though there are many problems that must be solved in practical use, the concrete block pavement seems to be superior in theory. It will be important to confirm its durability and workability in repairing for its future application to actual road pavements.

## REFERENCES


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