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In December, 1986, a road heating system - heat pipe system using heated water - was const in Sapporo, Japan. Permeable concrete block paving, permeable cement concrete paving, pe asphalt concrete paving, and standard asphalt concrete paving were executed as surface layers system. This report summarizes the execution work and the results of the drainage and snow-m effects at the surface.

1. Introduction

Sapporo is a city with an area of 1,118 km^2 and a population of 1,560,000. Its annual precipitation is 1061 mm, 40% contributed by a total of 532 cm of snowfall in 132 days, namely, the average number of snowfall days in winter; snowfall exerts a variety of influences on urban functions.

This underlies the reason that road heating system has been attracting attention in recent years. Embedded electric resistance cables system has been applied so far; however, its high operating cost has been limiting the number of applications recently. Embedded pipes carrying a heated fluid system or heat pipe system are attracting much attention because of their low operating cost.

The authors applied this heat pipe system as a heating system; permeable concrete block paving was executed for the surface to drain the snowmelt from the surface of the road. For comparison, permeable cement concrete paving, permeable asphalt concrete paving and standard asphalt concrete paving were also executed.

In snowy and cold areas, the effectiveness of permeable paving had been considered doubtful because of the problem of freezing. There had been no cases, however, of executing permeable paving in combination with the construction of a road heating system. Therefore a test paving was executed to observe the effectiveness of permeable paving.

2. Outline of Execution

2-1 Snow-melting System

Stainless heat pipes (ϕ 26.5 mm) using freon as the working fluid were laid normal to the flow of traffic at a pitch of 20 cm. Warm water (about 40°C - heated by a kerosine boiler) is supplied to the pipes to melt snow.

The design surface heat flux was set at 250 W/m^2: this corresponds to an outside air temperature of - 10°C, a wind speed of 3 m/sec and a snowfall of 3 cm/h. In addition, the boiler was equipped with a control system having a snowfall detector and a surface temperature detector. The detectors allow automatic operation of the boiler. The structure of the heat pipes is shown in Fig. 1. Overall and detailed diagrams of the heat pipe layout are shown in Figs. 2, 3 and 4.

Fig.1 Structure of heat pipe

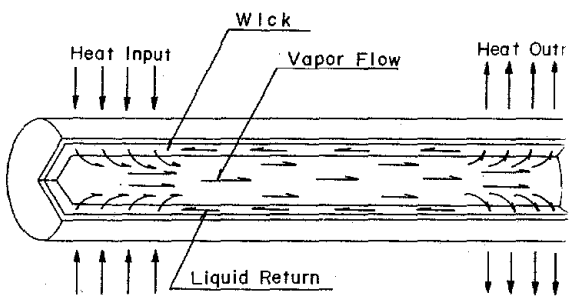


Fig.2 Detail of heat pipe layout

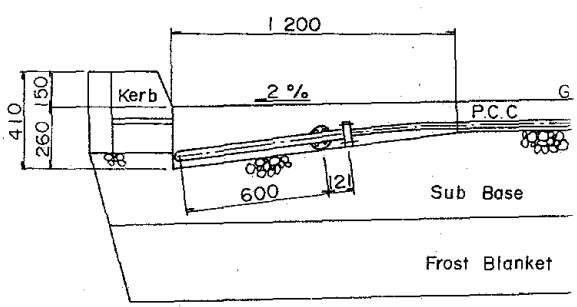
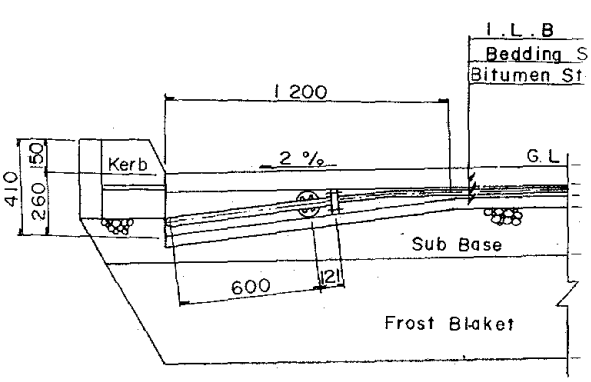


Fig.3 Detail of heat pipe layout



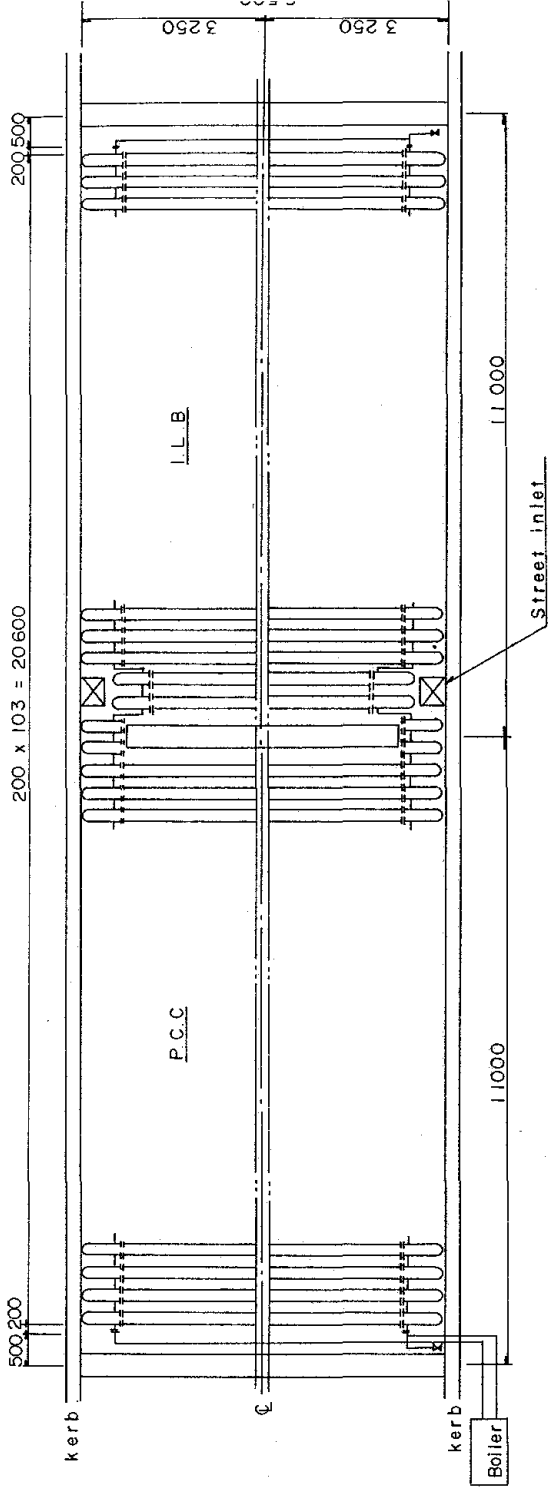


Fig. 5 Structure of permiable concrete block pavement

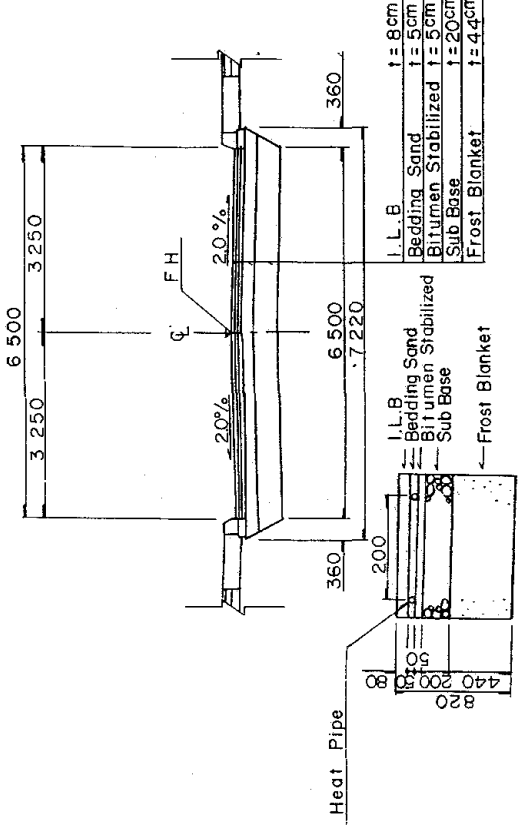
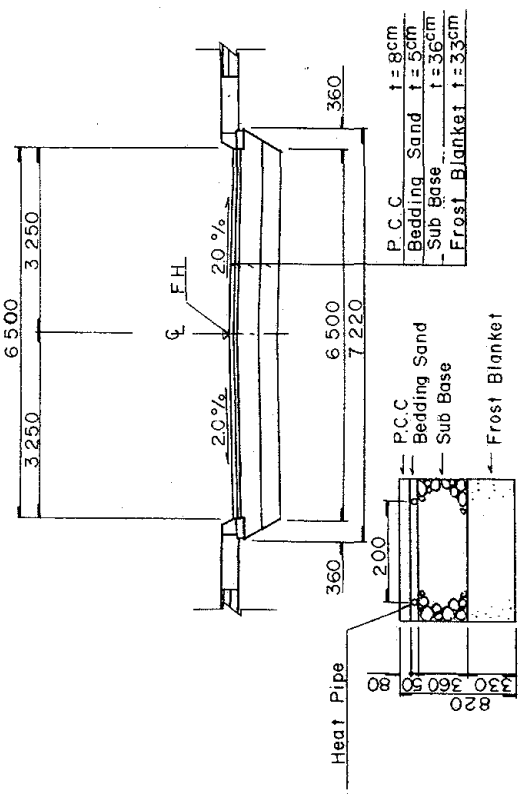


Fig.6 Structure of permiable cement concrete pavement



Test Pavement

A test pavement was constructed on a two- road: 6.5 m wide with 5 - 15 large vehicles ing daily.

Four kinds of pavement were applied: per- le interlocking block pavement (PILB), per- le cement concrete pavement (PCC), permeable alt concrete pavement (PAC), and standard alt concrete pavement (AC). The total length ne pavement was 11 m × 4 = 44 m. The struc- of each pavement is shown in Figs. 5, 6, 7 3, respectively.

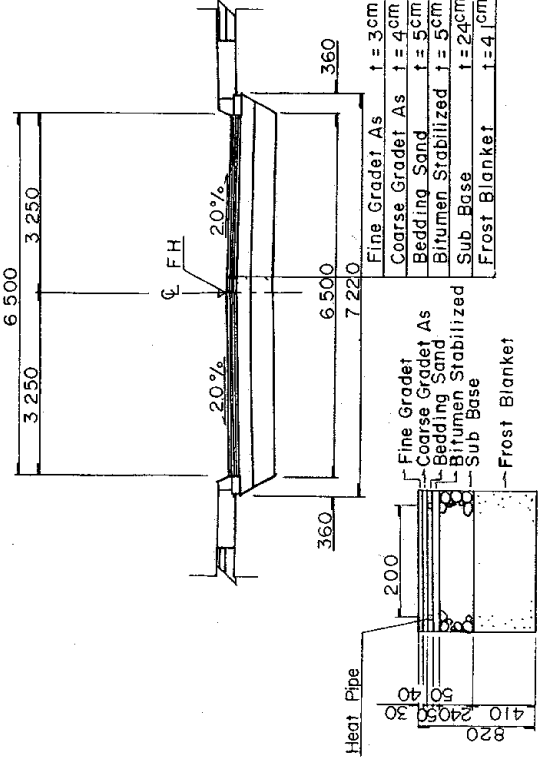


Fig.7 Structure of permiable asphalt concrete pavement

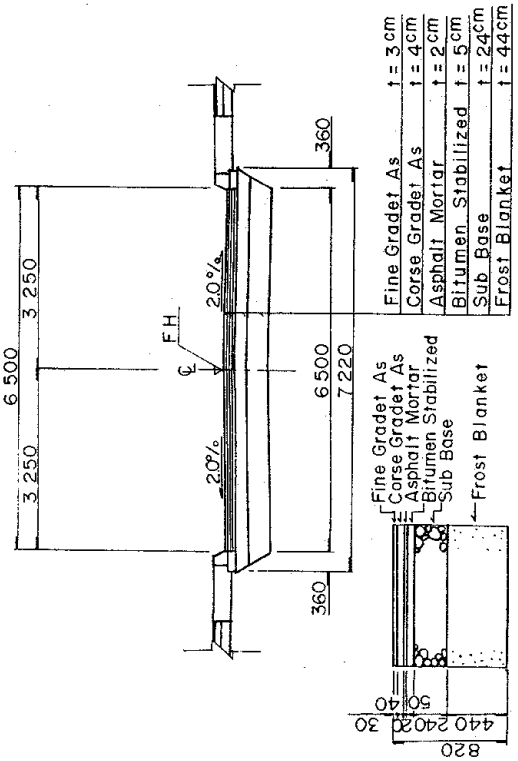
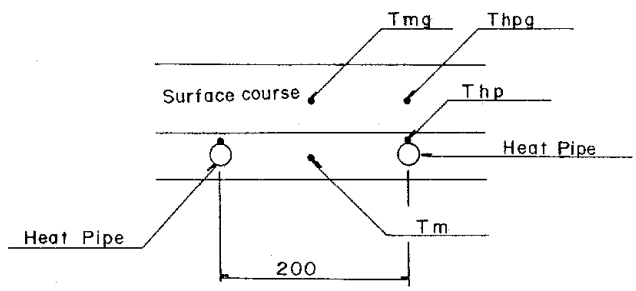


Fig.8 Structure of asphalt concrete pavement

Thermometry

1 Measurement Items

The surface temperatures of the heat pipes (Thp), the temperature of the roadbed between the pipes (Tm), the temperature of the pavement just above the heat pipes (Thpg), the temperature of the pavement between the pipes and the temperature at the inlet of the warm water were measured using thermocouples attached at the positions shown in Fig. 9.



3-2 Results of Measurement

Results of the measurements are shown Table 1.

Table.1 Results of the measurement

Date Time			2/1 20:00			2/9 0:00			2/12 20:00			2/15 0:00		
Fluid Temperature (°C)			T in	48.0	T out	29.5	31.0		20.4	34.3		20.8	42.0		26.2	
Lane (L)	PCC		T hp	37.3	T hpg	17.1	24.2		12.8	28.7		11.3	34.2		17.4	
			T m	12.5	T mg	11.6	10.1		9.4	7.5		6.6	13.6		12.3	
	ILB		T hp	33.4	T hpg	24.6	21.9		16.7	22.4		16.4	29.0		22.5	
			T hp	28.3	T hpg	16.8	20.1		14.6	20.1		12.7	24.6		18.3	
			T m		T mg	12.5			12.2			9.3			15.1	
Lane (R)	PCC		T hp	26.6	T hpg	11.1	18.5		9.6	18.6		8.3	23.9		11.5	
Fluid Temperature (°C)			T in	43.5	T out	25.9	33.0		21.8	36.4		21.8	47.7		29.3	
Lane (L)	PAC		T hp	32.5	T hpg	17.1	24.4		14.4	25.0		13.2	36.2		21.0	
			T m	12.6	T mg	10.8	12.1		10.8	8.8		7.1	16.3		14.4	
	ACC		T hp	30.2	T hpg	14.1	23.1		12.6	24.6		10.0	33.9		16.3	
			T hp	26.2	T hpg	9.0	20.8		7.1	21.8		20.6	29.6		12.0	
Lane (R)	PAC		T m	8.6	T mg	8.6	5.6		5.2	5.8		5.6	11.2		11.5	
Temperature (°C)			T hp	22.0	T hpg	9.4	19.5		11.4	18.5		7.8	26.3		15.1	
			- 8.2				- 5.6			- 7.0					- 8.2	

4. Snow-melting Efficiency

4-1 Snow-melting Efficiency of PILB

The snow-melting efficiency of PILB shown in Photo 1. With the PILB pavement, heat pipes were buried in sand. The autho estimated that PILB would be at a disadvanta in melting snow because sand has a lower he conductivity than concrete and because it subject to the influence of snowmelt. Contra to their assumption, however, there were problems associated with PILB during the test

4-2 Snow-melting Efficiency of PCC

The snow-melting efficiency of PCC is sh in Photo 2. The authors assumed that PCC wo be superior in melting snow because the h pipes were buried in concrete. However, snow-melting efficiency of PCC showed lit

difference from other pavements - probably because of the influence of snowmelt.

4-3 Snow-melting Efficiency of PAC

The snow-melting efficiency of PAC is shown in Photo 3. The authors assumed that PAC would be inefficient in melting snow because it has low heat conductivity and because it is influenced by snowmelt. However, PAC caused no problems and its snow-melting efficiency was satisfactory.

4-4 Snow-melting Efficiency of AC

The snow-melting efficiency of AC is shown in Photo 4. Asphalt has a lower heat conductivity than concrete; therefore the surface temperature of the heat pipes should be increased to bring the surface temperature of the road to that produced with the concrete pavement. In the test paving, however, satisfactory results were obtained because AC is not influenced by snowmelt. It should be noted that freezing may possibly be caused because a small amount of snowmelt remains on the surface of the road.

Photo 1. Snow-melting situation of PILB

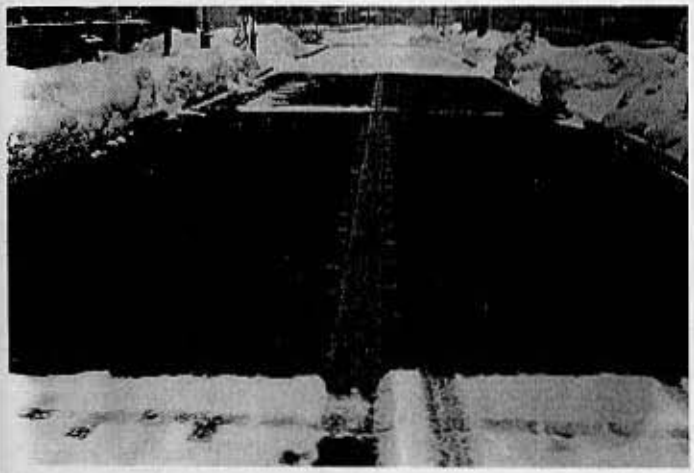


Photo 2. Snow-melting situation of PCC



Photo 3. Snow-melting situation of PAC



Photo 4. Snow-melting situation of ACC



5. Conclusion

The following are the results of a road heating test conducted in Sapporo during the period of January to March, 1987.

(1) The road heating systems - PCC, PILB, PAC and AC - all satisfactorily performed the prescribed capacity.
(2) The structure of the PILB pavement, in which heat pipes are buried in sand, should be altered to more efficiently melt snow and to more equally distribute physical loads.
(3) In applying a road heating system to permeable pavements, due consideration should be paid to the quantity of heat removed by the snowmelt as well as to the quantity of heat required to melt the surface snow.
(4) Permeable pavements are effective in draining snowmelt because the material is little effected by pore clogging.
(5) There is a difference in heat conductivity among the different kinds of pavements, however, there is little difference in their snow-melting efficiency.