PAVEMENT DESIGN IN COLD AREAS

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(Received June 17 1978)

Synopsis

The structure of flexible pavements is designed with the traffic, the design CBR of subgrade and especially the effects of frost action on roads in cold areas of Japan.

The detrimental features resulting from frost action on roads are the differential distortion of the road surface caused by frost heaving and the decrease of shearing strength in subgrade during the thawing period. Especially the loss of the subgrade support results in the destruction of pavements. Then the field elements concerned with frost action should be considered when the pavement structures are designed in cold areas.

The bearing capacity on subgrade has been measured with the field CBR method during the thawing period in Hokkaido and the design CBR is tentatively determined according to the soil classification.

The thicker pavements are repuired in comparison with the pavement thickness designed only with the design CBR.

This paper describes the outline of problems caused by frost action and the methods of frost protection on roads and shows the idea of the replacement method based on the CBR design method, the examples of the design and the use of insulation on a road structure in Hokkaido.

1. Introduction

The thickness and structure of pavements are determined by traffic conditions, subgrade soil, weather and economics. In general, the design of flexible pavement structures has been based on traffic loads and design CBR of subgrade soils in Japan. The effects of frost heave should also be considered together with them in cold areas.

A frost heave is defined as the freezing phenomena by which subgrade soils are heaved by a growth of ice lens in soils. Ice lenses are formed when conditions of a water and temperature gradient in soils may be suited to their forming in the process which ground surfaces are cooled down and the frost line gradually penetrate into the ground.

Types of frost damages can be grouped into two categories; (1) damages of frost heave itself and (2) damages based on considerable loss of shearing strength of soils. Damages of frost heave itself may be resulted from an unevenness of a frost heave in horizontal. In flexible

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pavements, a nonuniform heaving on road causes an uncomfortable driving and in the extreme case causes large longitudinal cracks along the center line on roads. In concrete pavements, it may causes an uneven frost heave on roads, followed by crack developments and the repeated damages in every year result in their destruction.

As ice lenses grow in soils, a large amount of free water may be sucked and accumulated into the zone where ice lenses prevail over. During the thawing period, they begin to thaw both from the ground surface and the lower part of frost grounds. Thawing speeds are much considerably higher in a ground surface than in the lower part of frost grounds.

As a consequence, a flow of thawed water from a ground surface is arrested by frost layers in around the lower part of icy grounds and thus can not percolate into the underground. Therefore, a considerable amount of thawed water may be trapped in such parts of grounds, resulted in that a saturation of water in soils may be produced in such parts. Besides, since the density of soils in such parts may become small because of the presence of icy layers in grounds, a shearing strength of soils therefore is considerably low, and to cite the extreme case, it may result in a flow condition. When heavy wheels pass on roads in such conditions, pavements are damaged destructively so that they are destroyed and wheels are sucked into pavements.

Thus, since frost damages, especially ones caused by a loss of bearing capacity of subgrade, become sometimes severe for pavements, where one carries out a design of pavements in cold areas, one should investigate closely factors involved in frost heave in fields and the presence and degree of it, and one should, if necessary, take effective and proper measures for them.

2. Frost Heave Prevention Methods and Their Selection[2)]

It may be the prevention of frost damages necessary to know the causes of frost heaving for Frost heave may occure if the following three requirements would be satisfied concurrently with each other :

(1) Subgrade soil is frost-susceptible.

(2) There is much supply of water from the undergrounds.

(3) Low temperature and its gradient are convenient so that ice crystals are formed.

A lack of any one of these conditions may not make a frost action in soils. Therefore, a frost heave principally can be prevented by a removal of one or more of these conditions.

The preventive measure for the problem of (1) is to replace frost-susceptible soils with nonfrost-susceptible materials, or to change soils in nonfrost-susceptible conditions by treatments with chemicals.

For the problem of (2), the installation of impermeable layers in a zone where a frost action may prevail, may effectively intercept seepage flows of rainfall or underground water.

For the problem of (3), there are several preventive ones by which a frost action may be prevented by minimizing a temperature lowering of a soil by the installation of insulating layers or by lowereing a freezing temperature with the addition of chemicals in soils.

Selection of some suitable measure is carried out with the consideration of the required conditions to pavements and economical features. Pavements must have the following requirements ; They must show so much surface smoothness as to make a comfortable ride on roads and have sufficient durabilities against repeating loads with which heavy wheels provide on roads.

Also, since pavement roads are very long, small increases of construction cost per unit of area will result in huge amounts of money for the whole areas. For flexible pavements, selection of such a measure as not to permit the formation of slight frost heave is uneconomical and not required.

Thus, where the depth of frost penetration is found to be considerably deep from experiences, frost prevention works shall be done over the necessary minimum depth, and for the shallow one, they shall be done over the entire depth or sometimes the deeper with the consideration of a loss of bearing capacity resulted from the percolation of thaw waters into subgrade.

For rigid pavements, since only a little uneven formation of frost heave causes cracks, selection of such a measure as not to permit a formation of only slight frost heave should be done in general. However, where the depth of frost penetration is found to be considerably large, the above limitation can be lightened from the point of economical view and besides a modification of pavement types, for example a change of a surface layer into its flexible type, should be considered.

For the runway in a airport, comparing with roads, its load conditions are clearer, areas are relatively small and its surface smoothness is much more requiread, and selection of such a measure as not to permit a frost action is done in general. However, where the depth of frost penetration is found to be large, from the point of economical view, selection of such a measure as to permit a formation of some slight frost heave can be done.

There are a replacement method, heat insulation method, chemical treatments method and water interception method for frost prevention methods, but the reliabilities and economical features of a replacement method have put itself into the present wide uses.

Some heat insulation method which keeps warm frostsusceptible subgrade soils with insulating layers have been experimentally used in various places recently, and the plan of its application is going on. A chemical treatment method may prevent a frost action in a way that a freezing temperature may be lowered by adding and mixing of chemicals such as salts in frost-susceptible soils.

However, such a method is not intented for practical use, because the lowering of its preventive effect will result from the gradual infiltration of salts into the undergrounds with the time, since salts dissolve in water in general.

A water interception method has a lot of problems to be solved such as controlling of a ratio of water contents in frost-susceptible soils, protecting against percolated waters from surfaces and sides on roads, and covering for a rainfall during construction works, hence it is very questionable whether some effective construction works can be practically performed or not by this method.

3. A Replacement Method

The replacement method is principally some measures to replace all frost-susceptible soils within the depth of frost penetration with suitable nonfrost-susceptible materials.

For roads, the measures in which nonfrost-susceptible materials are filled up on a native ground by the required depth, are involved in this categoty.

There are the following two basic considerations in derterming certain depth to be replaced;

(1) Not to permit only slight frost action.

(2) To permit slight frost action and a little loss of bearing capacity of subgrade during the thawing period, if some bad effects would not be provided on pavements.

For roads, the consideration of (2) is taken from the economical point of view and certain depth to be replaced is determined based on it, while for roads of shallow depth of frost penetration, the consideration of (1) can be based on. It is difficult to determine quantitatively how much degree of nonuniform heaving on roads caused by nonuniform frost action is to be harmful for traffic of vehicles.

In Hokkaido, the treatments in which a depth of 80 percent of the full depth of frost penetration is replaced with nonfrostsusceptible materials, are sufficient to solve such a problem.

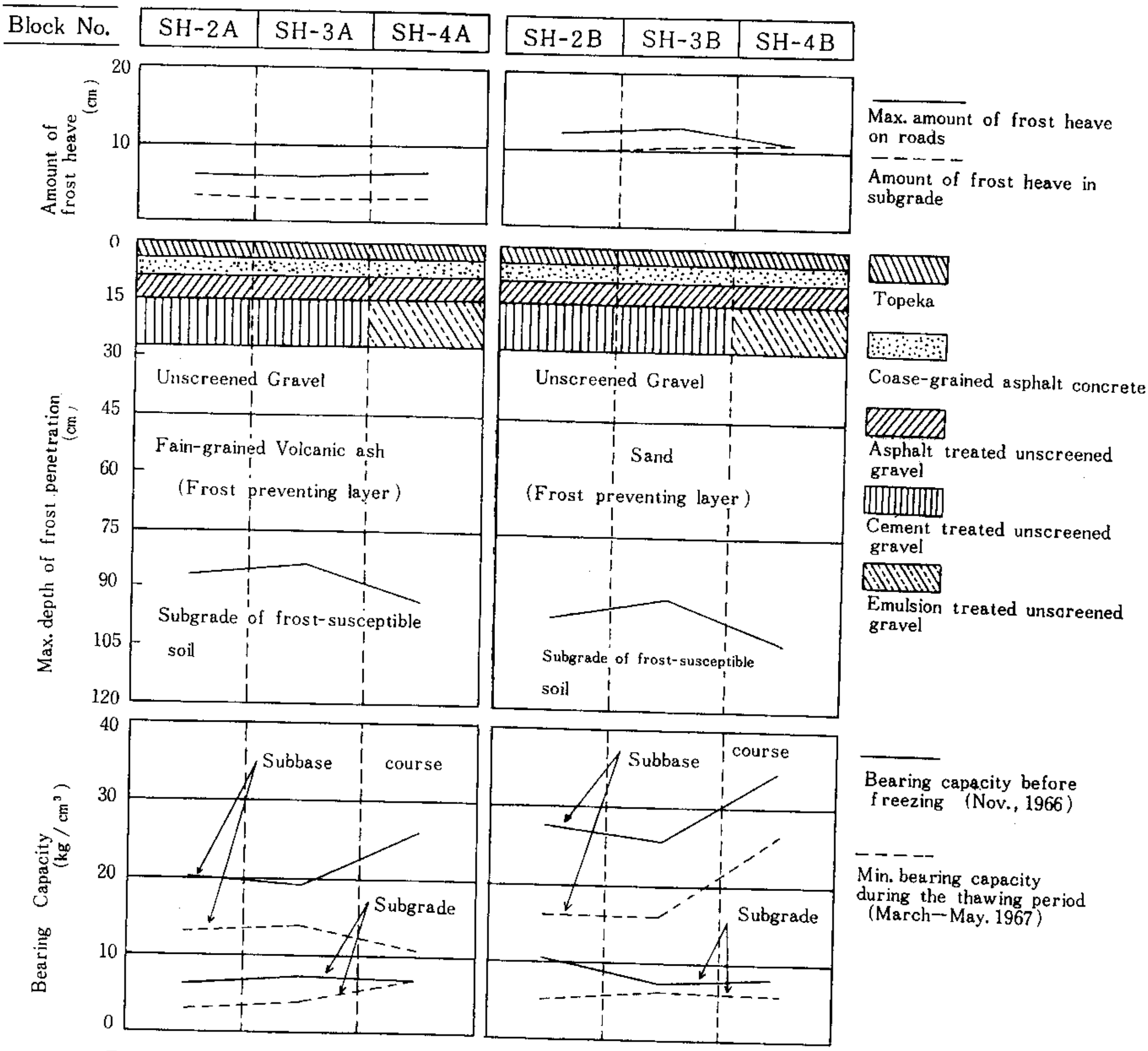


Fig. 1. Max. depth of frost penetration, amount of frost heave and bearing capacity on subgrades and subbase courses on Bibi test roads.

This solution is based on the following results from many investigations in which gravel roads were excavated at the time of the deepest frost penetration ; Most of ice crystals were distributed between 60 percent and 70 percent of the depth of frost penetration from a ground surface and no ice crystals or a little ice crystals were present between 80 percent and 100 percent of the depth of frost penetration.

Fig. 1 shows the results of field studies which were conducted on some section of Bibi test roads between Chitose and Tomakomai along the national road route No. 36. Test roads were constructed in a way that the replaced depth might correspond to about 80 percent of the full depth of frost penetration. Where nonfrost materials are fine-grained volcanic ash, its height of frost heave on roads is about 7cm and it is about 12cm for sands, while both A and B block groups show uniform frost action. Thus, if same pavement structures and replacement materials will be applied on roads, it may be expected that no harmful ununiform heaves are formed with such a replacement depth as described above.

However, when the magnitude of frost heaving on road shoulders is considerably less in comparison with the heaving on road center, longitudinal cracks may occur along the center line on pavements.

Since a snow-removing on this test roads is conducted perfectly, any vertical cracks resulting from a frost action on them have not been found yet. Frost heaves of more than 3—4cm in height are considered to be harmful in Switzerland. Also, some recent investigations show that the magnitude of frost heaves on pavements on which cracks were resulted from a frost action was more than 4cm in height.

Some magnitude of the harmful frost heaves is required to be studied closely from the economical point of view and it is one of the future research programs.

The bearing capacity of subgrades during the thawing period do not reduce so much, whereas the bearing capacity of subbase courses decrease considerably, as shown in Fig. 1. The latter may be expected to base on the effects by which since loads were not applied on subbase courses to be measured for K_{30} values except during measuring works, upper part of subbase courses may have come loose.

4. Replacement Methods for the National Roads in Hokkaido

In Hokkaido, the populaization of snow-removal has resulted in the remarkable increases of frost damages on roads after World War II, hence one of its preventive measures was regulated at the Hokkaido Development Bureau (HDB) in 1952, in which the original thichness of pavements, 40—50cm, was changed to 50—60cm.

However, as this measure could not sufficiently prevent frost damages, the standard of a replaced depth was determined as a depth of 80 percent of the full depth of frost penetration from a surface on the original grounds in 1953, based on the investigations of roads which were conducted during the deepest frost penetration in both 1951 and 1952, and the actual depth to be replaced was found to be in a range of 70—100cm.

The regulations of “Design Standards in Road Construction” HDB, was made in 1958 and the general depth to be replaced was standardized as 80cm except 50cm in Hakodate area and 90—100cm in Obihiro and Asahikawa areas.[9]

Hereafter, the several amendments for a depth to be replaced were based on the actual circumstances of frost damages.

The asphalt pavement criterions were put into a revision in 1961 and then a pavement design be came to be based on the CBR design method. However, it had been considered that the determination of pavement structures by the CBR design method would not have been required in Hokkaido.

The reason is that on such a assumption in which the required bearing capacity on roads during the thawing period would be considerably small because of relatively small traffic loads at that time, the obtained depth to be replaced was turned out to be larger than the found pavement depth from the CBR design curve.

Since the asphalt pavement criterions were revised again in 1961, some areas have shown the phenomenon in which the found pavement depths from the CBR design method exceeded their replacement depths.

However, sufficient amounts of data about a lowering of a bearing capacity on subgrade during the thawing period were not obtained here, hence the data from the past investgations on Bibi test roads were utilized in order to determine a design CBR value on the surface of frost preventing layers and 3 percent was set up temporarily for it since 1969.

Hereafter, the pavement structures were designed with such a limitation. Further, the minimum thickness of frost preventing layers was 30cm. In addition to the above works, the bearing capacity on subgrade during the thawing period in eary spring was investigated in all Hokkaido in both 1970 and 1971 and now each design CBR value has been set up for each group of soil characters, based on their results.

Further, both the obtained pavement depths based on the above and replacement depths in some areas were compared with each together and the larger may be taken for the determination of pavement structures.

(1) A Field CBR during the Thawing Period and Design CBR[3),4)]

The field CBR test on subgrade, frost preventing layers and 30cm thick layer of frost prevention layers above the subgrade was conducted at the following 73 test points during the thawing period in both April and March, 1970.

The field investigations were carried out on the roads in each jurisdiction area of the Construction Departments of Muroran, Otaru and Obihiro. The same investigations were conducted on the following 35 test points in each jurisdiction area of Sapporo and Asahikawa Construction Department in March, 1971.

They were selected objectively on the sections where overlay works and reconstruction works of pavements would be scheduled in 1971 because of pavement damages from the construction more than 10 years ago. Their field CBR values generally were larger than the estimated ones, because some tests were conducted not on a completion of the theawing, but actually on a time when the thawing of sutbgrades or frost preventing layers was not complete, or the thawing time has already gone in some areas, while their corrections shall be carried out in the future studies.

Each CBR value of subgrades and frost prevention materials was set down temporarily for 1972 as follows :

a) A CBR Value of Subgrade Soil

Test subgrade soils are called to be common soils in fields and correspond to each category of SM, SC, ML, CL, OL in "Unified soil Classification System".

Fig. 2 shows the results of field CBR tests.

The design CBR value can be expressed as the following equation, according to the Asphalt Pavement Criterion :

$$\text{Design CBR} = (\text{Average CBR at each test point}) - \frac{(\text{Maximum CBR} - \text{Minimum CBR})}{d_2}$$

Accordingly, the calculated value of the design CBR of subgrade soil from Fig. 3 is

$$\text{Design CBR} = 6.2 - \frac{12-2}{3.18} = 3.1;$$ that is, it was set up to 3.

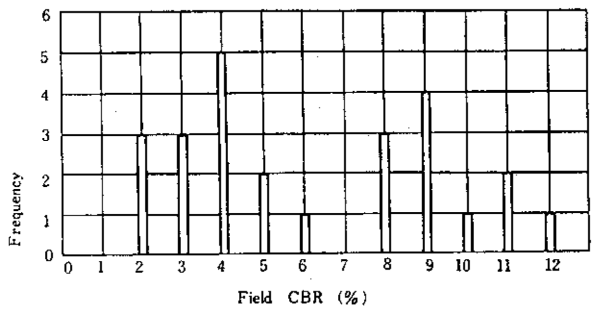


Fig. 2 Field CBR Values of ubgrade Soil during the Thawing Period

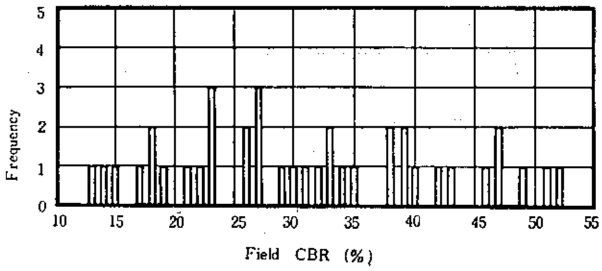


Fig. 3 Field CBR Values of Frost Preventing Layer (Volcanci Ash)

b) A CBR Value of Frost Preventing Layers consisting of Volcanic Ash

Their field CBR values are seen in Fig. 3, where frost preventing layer materials are volcanic ash.

Volcanic ash in Hokkaido are relatively new volcanic eject which were distributed widely in Hokkaido during about the end of the Quaternary era of which maximum diameter is around 20mm, and generally correspond to categories of GM and SM in "Unified Soil Classification System".

The design CBR value is calculated from the above equation, hence

$$\text{Design CBR} = 31.24 - \frac{52-13}{3.18} = 19$$; That is, it comes out to be considerably large.

As volcanic ash may be subjected to the repetitions of freezing and thawing action, weathering actions may grow on them and their bearing capacities are likely to be remarkably low. Since 34 places out of all the present test roads were constructed in 1969, they may be subjected to only one time of freezing and thawing action. Accordingly, it is dangerous to take this value itself as the design CBR and hence some reduction of CBR value should be taken into account.

Fig. 4 shows the relationship between frost heave rates of volcanic ash obtained from laboratory experiments and CBR preservation rates.[7)]

CBR preservation rates are expressed as percentages of CBR values after several cycles of a freeze and thaw divided by CBR values after the submergence of 4 days. It is shown in Fig. 4 that the CBR preservation rates are distributed between 20 percent and 70 percent, and the tendecy can be seen that the rates may become smaller as the cycles of freeze and thaw become larger.

Thus, the present CBR preservation rate took 20 percent which was the almost minimum value in all experiments.

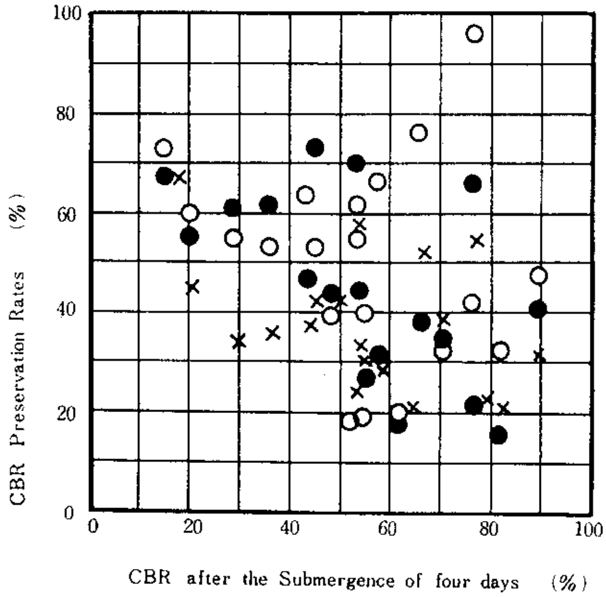


Fig. 4 Relationship between CBR Values after the Submergence of Four Days of Volcanic Ash and CBR Rreservation Rates

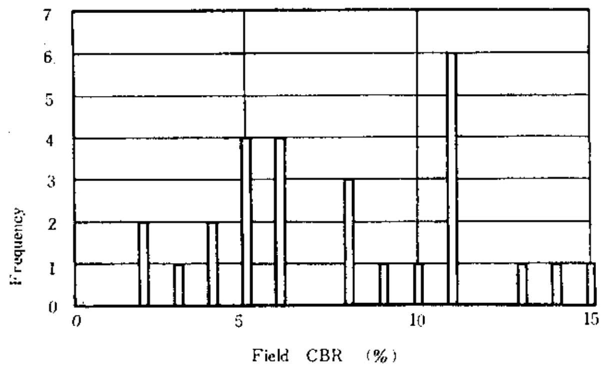


Fig. 5 Field CBR Values of Frost Preventing Layer (Sand)

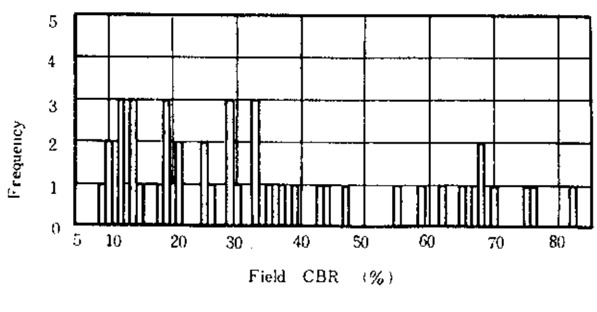


Fig. 6 Field CBR Values of Frost Preventing Layer (Unscreened Gravel and Crusher-run)

Accordingly, the actual Design CBR becomes as follows ;

Design CBR=19×0.2≒4

Hence, the Design CBR of volcanic ash was set down to 4.

c) A CBR Value of Frost Preventing Layers consisting of Sand

The results of the field CBR test are shown in Fig. 5, where frost preventing layer materials are sand.

In this case, the Design CBR values are calculated as follows ;

$$\text{Design CBR}=8.46-\frac{15-4}{3.18}=5$$

Some results of this test showed that the field CBR values of those which were constructed more than about 10 years ago were generally larger than those value when one winter season passed after constructions. Accordingly, the Design CBR value was set down to 5 with no considerations of the loss of bearing capacities caused by repetitions of freeze and thaw.

d) A CBR Value of Frost Preventing Layers consisting of Coarse Materials such as Unscreened Gravel

The field CBR values are shown together in Fig. 6, where frost preventing layer materials are unscreened gravel and crusher-run.

The Design CBR values were calculated from the equation in the Asphalt Pavement Criterion as follows ;

$$\text{Design CBR}=37.14-\frac{82-9}{3.18}=14.2$$

For unscreened gravel, laboratory works on the CBR values subjected to the cycles of freeze and thaw were carried out in the same way as volcanic ash. The CBR preservation rate was assumed 70 percent, based on the above results. Hence, the Design CBR values of frost preventing layers consisting of unscreened gravels and crusher-run, were set down to 10.

e) A Design CBR

The required Design CBR values for designs of pavement were calculated by the equations for

Table 1. A Design CBR

Subgrade Material \ Frost Preventing Layer	Volcanic Ash		Sand		Unscreened Gravel and Crusher-run	
	Thickness (cm)	Design CBR (%)	Thickness (cm)	Design CBR (%)	Thickness (cm)	Design CBR (%)
Fine-Grained Soil	52– 53+	3 3.5	28– 29–54 55+	3 3.5 4	10– 11–20 21–37 38–52 53–78 79+	8 3.5 4 5 6 8
Volcanic Ash		4		4	21– 22–40 41–72 73+	4 5 6 8
Sand		4		5	24– 25–65 66+	5 6 8
Unscreened Gravel and Crusher-run		4		5		10

CBR values of multiplelayer subgrades in the Asphalt Pavement Criterion, based on the values of a)–d) as described above.

However, where the CBR values of frost preventing layers are smaller than ones of subgrades below the frost preventing layers, the former ones should be taken to Design CBR values as safe values (Table. 1).

(2) A Replacement Depth

It is regulated that since roads in Hokkaido show generally large freezing depth, a replacement depth of roads should be 80 percent of the deepest frost penetration in existing gravel roads as a rule. This figure corresponds to about 70 percent of the frost penetration in the roads which are replaced to full depth with nonfrost grained materials.

Frost penetration depth is changeable every year, and it is required that the standards of frost penetration depth should be set for the determination of the actual replacement depth for the design of pavements. The standard depth is the maximum in the past 10 years or the average of three large ones in the past 30 years in the Corps of Engineers of the United States, the average in the past 10 years at the Ministry of Transportation in Canada, and the average in three coldest winters in the past 30 years in Switzerland.[11)]

In Hokkaido, it is the maximum in the last 10 years as a rule. However, the past many works by a replacement method were held in a high estimation and the standard depth was determined in each construction Department as follows[3)]; Replacement depth is 80—90cm in Sapporo, 70—80cm in Otaru, 50—70cm in Hakodate, 70—90cm in Muroran, 90—100cm in Asahikawa, 80—90cm in Rumoi, 80—90cm in Wakkanai, 80—100cm in Abashiri, 100—110cm in Obihiro, and 80—100cm in Kushiro.

They are standard values, and if roads may have frost damages, the following is one of

Table 2. Maximum Freezing Index at Each Location in Hokkaido in the Last 10 Years

Location	Frost Index (℃・days)	Above Sea Level (m)	Location	Frost Index (℃・days)	Above Sea Level (m)
Wakkanai	690	3	Nemuro	598	28
Asahikawa	867	112	Kushiro	676	32
Rumoi	544	22	Lake Akan	1,381	430
Sapporo	493	17	Obihiro	952	39
Iwamizawa	668	33	Muroran	353	43
Otaru	431	24	Urakawa	376	34
Abashiri	774	38	Hakodate	409	33
Kitami	1,114	84			

Calculated Values with the Table of Average Temperature per Day in 1961—1970 in "Weather in Hokkaido" Hokkaido Branch of Japan Weather Association

correcting measures : A standard replacement depth can be corrected with the assumed maximum frost penetration depth which can be obtained from some formulas based on heat conduction theories, determing freezing index from weather obse vation data.

Table 2 shows the maximum freezing index at each place in Hokkaido in the last 10 years.

(3) A Pavement Thickness and Frost Preventing Layer

A total pavement thickness and pavement structures are determined from the Design CBR values as described in (1) e) and traffic volume, depending on the Asphalt Pavement Criterion.

Where the obtained pavement depth above is smaller than the standard replacement depth, frost-susceptible materials shall be filled below the subbase course for such a depth difference. However, a Design CBR of frost preventing layer and subgrade soil for the determination of a pavement depth is changeable with the thickness of frost preventing layer, while the thickness of frost preventing layer can be obtained from the replacement thickness of pavements.

Therefore, in order to determine both depth of pavements and frost preventing layers, a calculation must be done repeatedly so that the total depth of both corresponds to the replacement depth. Table 1 can be utilized in such measures. In a determination of pavement depth, an unit of a depth of subbase course shall be 5cm, raising to unit all fractions and for frost preventing layers, it shall be 5cm, counting one fraction of more than 3 inclusively and cutting away the rest. And the minimum depth of frost preventing layer shall be 15cm.

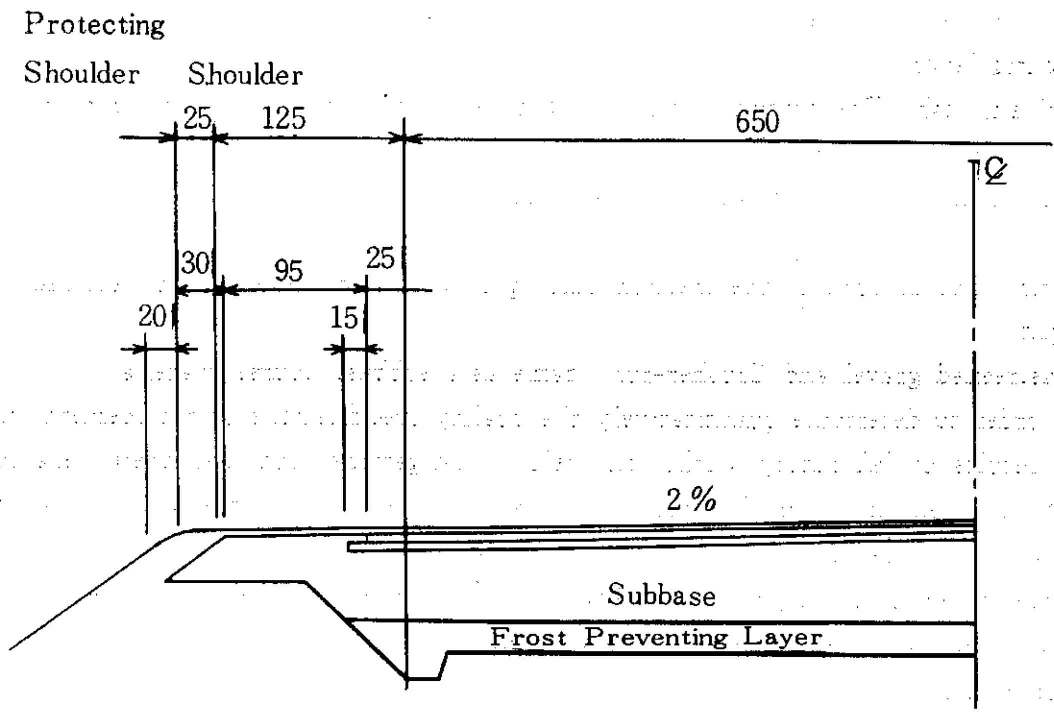
Fig. 7 shows one of the examples in which the pavement structure was built up by a replacement method in Hokkaido Development Bureau.

Since there are the ideas in which a part of shoulder may be protected from a frost action by a pile of snow, this part is not taken into account of a frost heave, and in the eastern areas of Hokkaido where the cold is severe with a little snow, relatively large amount of frost heave can be seen in the part of shoulder.

(4) A Quality Specification of Replacement Materials

The qualities which are required for replacement materials are as follows ;

1) To be non-frost susceptible.
2) To have the required bearing capacity for traffic loads, depending on the depth of its layer.
3) Not to change in quality for a long time.



Layer	Pavement Structures	Thickness (cm)
1	Dense Graded Asphalt Concrete (Surface Course)	4
2	Coase Graded Asphalt Concrete (Binder Course)	5
3	Asphalt Stabilization (Base Course)	6
4	Unscreened Gravel (Max. Size 40mm) (Subbase Course)	55
5	Sand (Frost Preventing Layer)	20
Total		90

Fig. 7 Standard Cross Section of Pavements (B Traffic Volume : Replacement Depth 90cm)

The conditions of 2) and 3) have no relationship with a frost action and are generally required for road construction materials. Thus, here is described about 1).[5]

a) A Subbase Course Material

Unscreened gravel ; The amount of the fraction passing a 74 micron sieve in the sand fraction passing a 4760 micron sieve shall be less than 9 percent by weight.

Crusher-run ; The amount of the fraction passing a 74 micron sieve in the crusher-run passing a 4760 micron sieve shall be less than 15 percent by weight.

Filling materials for subbase course ; The amount of the fraction passing a 74 micron sieve in materials passing a 4760 micron sieve shall be less than 15 percent by weight.

b) Materials for Frost Preventing Layer

Coarse-grained volcanic ash, sand and unscreend gravel passing a 80㎜ sieve are used for frost preventig layer.

Volcanic ash : The amount passing a 74 micron sieve and its ignition loss shall be less than 20 percent and 4 percent by weight, respectively. And even those materials out of the specifications can be used when they are found to be nonfrost-susceptible by a frost heaveing test.

Sand : The amount of the fraction passing a 74 micron sieve shall be less than 6 percent by weight.

Unscreened gravel and Crusher-run ; Same as a subbase course material.

In order to determine quantitatively the quality specifications of replacement materials, not only results of laboratory works and field investigations, but also their behaviors in fields must be taken into consideration. For instance, where the time goes by fairly long after constructions, the amount of fraction passing a 74 micron sieve in replacement materials becomes often fairly larger, compared with the time when materials are carried into construction fields. This is caused by fine particles which are carried or entered there under constructions or after them.

Therefore, it is desirable for extra safety from a frost preventing point of view to use as small materials passing a 74 micron sieve as possible. But, when the contents of fine particles are too small, compaction works may become difficult and a high density of soils is not likely to be obtained. Quality specifications of replacement materials are determined by taking into considerations from both factors.

5. A Heat Insulation Method

It is the method by which a frost action on roads is prevented by keeping warm frost-susceptible soils, installing insulating materials on the frost preventing layer or subgrade.

Although there are different types of heat insulating materials, a extruded polystyrene board is recently used in Japan. While heat insulating materials should be excellent in an insulating efficiency, they should have a long durability, less water absorption and no change in quality and volume under traffic loads applied on roads for a long time. The materials which have a high strength are much better, but in general, materials which have a high insulating efficiency are inclined to show a low strength. And there are some materials which show low insulating efficiencies and low strength after water absorption. Hence, sufficient care should be taken of the choice of insulating materials.

The full-scale field test for a frost preventing method with heat insulating materials was carried out on municipal roads in Obihiro in 1962 and this was the first of this method to be applied on roads in Hokkaido.[2)]

The few test sections of roads were installed with extruded polystyrene board on subgrade soil in 1965, but after that such a type of test sections of roads was carried out in many places every year and the total area of this type of roads in Hokkaido is about 445,000㎡ up to October, 1971.

The thicknesses of 25㎜, 30㎜, 38㎜ and 50㎜ are used for the insulating method.

Some test works were done sporadically and systematic studies, however, were not done and

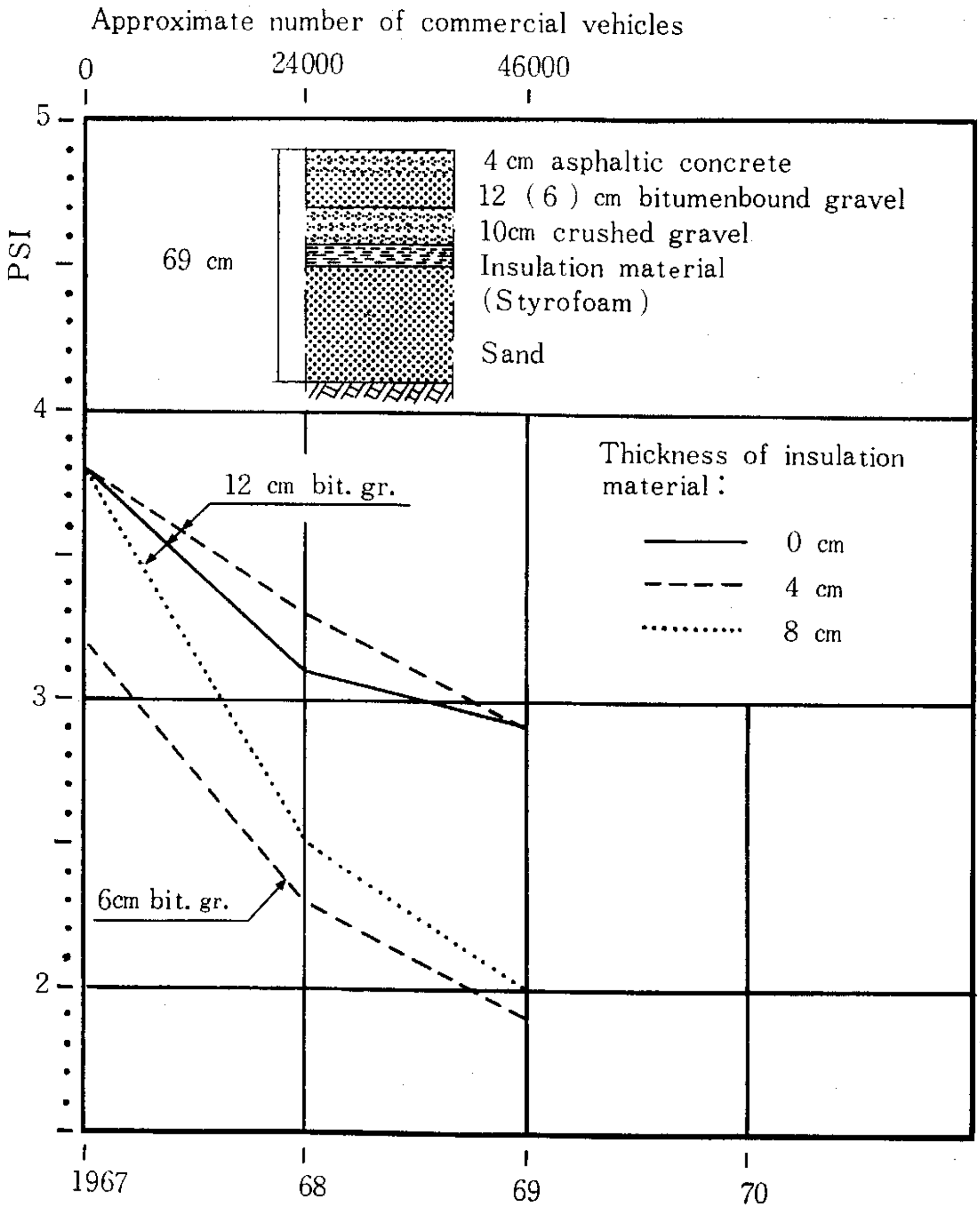


Fig. 8 Effect of foam plastics layers on road serviceability (PSI). Bitumen bound and unbound gravel base

follow-up works were not sufficient after constructions and it is difficult at this time to estimate quantitatively its actual effects against a frost action in fields. Accordingly, it does not come to prepare a design standard on the reasonable depth of heat insulating materials and reasonable thickness. A shallow depth of their materials is better in the aspect of an insulating effect, but they may be changed in thickness when it is too shallow and be worse in its effects and moreover may make unevenness of road surface. In the worst case it may be possible that pavements can be destoried soon.

Fig. 8 shows a certain result of investigations in which the effectiveness of a heat insulating method was studied on test roads which were built near Karlstad in the west part of Sweden.[10]

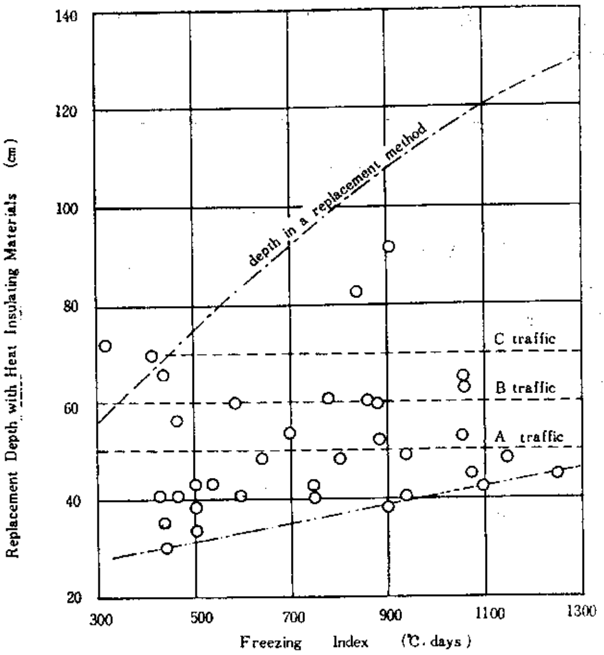


Fig. 9 Replacement Depth with Heat Insulating Materials in Hokkaido

In this example, since the depths of heat insulating board are too shallow, 26cm and 20 cm, the sharp reduction of Present Serviceability Indexes can be observed.

And even though its depth is same, it is shown that the thicker the heat insulating board is, the larger the reduction of Present Serviceability Index is. The Present Serviceability Index which came from the AASHO Test Roads is defined as a measure to evaluate a degree of comfortableness for traffic.

Such an evaluation for asphalt concrete can be expressed as the following formula ;

$$p = 5.03 - 1.91 \log(1+\overline{SV}) - 0.01\sqrt{C+P} + 0.21\overline{RD}^2$$

Where p is a Serviceability Index, SV is a slope variance in the two wheel paths, C is cracked area of pavements ($m/1000m^2$), P is patching area of pavements ($m^2/1000m^2$), and RD is a rutting of surfaces (cm). It has been regarded that an overlay on pavements is required for p of less than 2.5 and a reconstruction of pavements is required for p of less than 1.5.

Fig. 9 shows the relationship between depths of heat insulating materials which were selected on trial in Hokkaido and freezing index in such depths. Such depths are distributed in 30—90cm and depths of 40—50cm are most distributed, accounting for 45 percent of total numbers.

Further, water contents of subgrade soils right under heat insulating boards are inclined to increase in general and where heat insulating materials are used, it is desirable to built right under a heat insulating board such materials as sand which do not show any remerkable reduction of shearing strength with a increase of water contents.

6. Conclusions

Studies on a countermeasure method for frost action in roads and airports have been undertaken in many countries where are located in cold areas. Those countries now apply mainly a replacement method for it and it seems to be the common ideas for many countries that slight amounts of frost heave and slight loss of bearing capacity of subgrade soils at the thawing period shall be permitted. And there is the increasing tendency to prepare the design standard, based on that a bearing capacity of subgrade soils should be determined for each soil.

In Hokkaido, pavement structure have been determined by the underestimation of a bearing capacity of subgrade soils at the thawing period. However, it is temporarily adopted since 1972 that a bearing capacity of a subgrade soil shall be determined for each soil and the reasons were already mentioned in this paper.

However, since data are not sufficient, it is recognized that amendments and modifications should be done in future, adding the measured data in fields and conducting their followup experiments in laboratories.

The investigations of the field CBR in this paper were carried out by the Pavement Laboratory at Civil Engineering Research Institute, and the data on the Design CBR for each soil and the determination of pavement depths were prepared by both sections of Road Planning and Road Construction at the Hokkaido Development Bureau and the above Laboratory.

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寒冷地における舗装設計

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要　　旨

わが国のたわみ性舗装の構造は一般に交通荷重と路床土の設計ＣＢＲなどをもとにして設計されている。しかし寒冷地においては，このほかに凍上の影響を考慮する必要がある。

凍上による舗装の被害には，凍上そのものによるものと融解期における土のせん断強度の低下に基づくものとがある。凍上による被害，とくに路床土の支持力低下に基づくものは，時としては舗装に致命的な影響を与えるものであるから，寒冷地の舗装設計にあたっては，現地の凍上に関与する要素を十分吟味し，有効適切な措置を講じなければならない。

現在，北海道では春先の融解期に実測調査した路床の支持力に基づいて，路床土の土質区分ごとに設計ＣＢＲを定め，これに基づいて求めた舗装厚さとその地域の置換厚の双方を比較し，大きな方をもとにして舗装構成を決定することにしている。

本文では，寒冷地における道路の凍上に関する問題点とその対策について概述し，ＣＢＲ設計法に基づく凍上対策置換工法の考え方と北海道における実施例を述べ，あわせて断熱工法の現状について紹介する。

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