Invention for paved roads with freeze-controlling function and method for construction*1

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Abstract

This invention relates to a paved road structure having a freeze-controlling function and a method for construction the same, for road surfaces of existing paved roads or newly constructed paved roads, in order to control packed snow or attachment of ice on the paved road surface on which vehicles move in the low temperature time of winter season, in a snowy and cold area, mountain district etc.

1. Introduction

1.1 Background

The research and study of asphalt pavement in Japan has come to be active since the publication of ASPHALT PAVEMENT MANUAL by the Japan Road Association. The field confirmation of Marshall stability test made by the US Army a Corps of Engineers in 1948 led to the introduction, in many States, of proportioning design method by Marshall stability test. Up to today this method has been the main stream in Japan. The Marshall stability test measures the static stability, while Wheel tracking test measures the dynamic one. In the Wheel tracking test, which was developed in England, rutting and kneading action is simulated by the travel of heavyweight vehicle under high temperature on actual road to evaluate the fluidity of asphalt mixture. For the pavement in such cold districts as Hokkaido, study on proportioning method of asphalt mixture was initiated at the Civil Engineering Research Institute Hokkaido Development Bureau within the framework of anti-wearing measures against the studded tires. In1957 the laboratory developed Ravelling test, which is a sort of wearing test. In this test intended to evaluate the abrasion resistance of asphalt mortar by tire chain, the wheel provided with a chain comes down rotating and touches the test piece installed on the

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testing equipment. The surface of the test piece is thus stripped into abrasion by the chain. From the experimental research using this tester, it has turned out that the high temperature stability and abrasion resistance of the asphalt mortar is largely influenced by the physical property of filler bitumen method in the asphalt mixture. The present study does succeed and develop this method, That is, we have so far carried out many mix proportion tests through the Marshall stability test(one of the indoor tests)varying the asphalt contents and assuming constant the Asphalt(A), Filler(F), Sand(S), Gravel(G) contents and F/A ratio. One of these experimental studies implies that the asphalt mortar is one of the binders for asphalt concrete because although the G/S ratio varies despite the constant F/A ratio if asphalt content varies, the asphalt content in the asphalt mortar remains constant.

The abrasion resistance of the mixture is likely to be influenced by F to A ratio rather than by the asphalt volume in the mixture. The higher the penetration of asphalt, the lesser the abrasion is. The filler bitumen volume has certain influence on the anti-fluidity, the volume of G, 2.5 to 13 mm in diameter does on the skid and strength, and the volume of S of intermediate diameter on the durability and workability. The G contents of the order of G/S=40/60 has anti-skid effect and F/A=1.75, which is just the median of F/A=1.5 to 2.0, becomes the most efficient. Making up a representative mix proportion example by this ratio gives the mix proportion of the order of A:F:S:G=6.0:10.5:50.1:33.4. Fine and gap-graded asphalt concrete (Standard Proportion of Mixture) has widely been used as the pavement in the snowy and cold districts as Hokkaido.

1.2 Paved roads in the prior art

Paved roads constructed in the prior art having a freeze-controlling function, are generally as described below.

(A) The road surface is formed by using a road -paving material having a chloride-type anti-freezing agent blended with a pavement material mainly composed of a bituminous material. This type of pavement is generally called a freeze-retarding pavement. This pavement is usually constructed by incorporating from 4 to 8% of an anti-freezing agent into an asphalt compound for the surface and effecting a rolling compaction so that the finished thickness would be from 3 to 5cm. This anti-freezing agent gradually exposes its surface on the road surface and ooze therefrom to prevent freezing and calcium chloride, sodium chloride or the like is used from the viewpoint of economical efficiency. Further, as the anti-freezing agent, ones having the surface covered with a rubber film are devised to retain the effects for a long period of time.

(B) The road surface is formed by using a road-paving material having from 3 to 4% of rubber chips blended in a paving material mainly composed of a bituminous material. This type of pavement prevents the freezing by utilizing the elasticity of rubber chips, and is called an elastic pavement.Further, there is also a method wherein, immediately after the laying of a paving material mainly composed of a heated bituminous material containing a relatively large amount of fine particles, rubber chips having a relatively large particle size are forced to penetrate into the road followed by rolling compaction.

(C) As a convenient method generally widely employed, there is a method wherein the above-mentioned chloride-type anti-freezing agent or an anti-slip agent is directly sprayed on the road surface. As the anti-slip agent, sand having a particle size of at most 2mm or fine gravel having a particle size of about 3 to 5mm is used. In this spraying method, it is required to repeat the spraying to maintain the effects.

(D) There is a method wherein an asphalt-mortar mixture is laid on the road surface, and immediately after it, single grading crushed stone preliminarily coated with asphalt is sprayed over the entire surface, followed by rolling compaction for fixing. This pavement is called a rolled asphalt pavement.

(E) As a method for increasing the slip resistance to the road surface, there is a water-draining pavement or a grooving technique, by which anti-slip effect can be obtained by the drainage of water from the paved surface or the roughness of the road. In the grooving technique, shallow grooves are formed at regular intervals on the paved surface by a special machine.

(F) There is a method wherein a hot water pipe or an electrically heating material is laid under the paved road surface to heat the road surface, thereby melting snow ice. This method is called road heating.

The above-mentioned pavements having a freeze-controlling function constructed in the prior art, have the following drawbacks.

With respect to (A):With this method, the cost of construction is high and it is difficult to maintain the effect of the chloride as the anti-freezing agent for a long period of time. Further, the amount of the freeze-controlling agent to be blended is limited, and the anti-freezing agent is gradually lost from the road surface and the effect is thereby no longer obtained, whereby no substantial difference will be seen between such a pavement and normal road. Since the use of studded tires has heretofore been permitted, the road surface was scraped by the studded tires, and the anti-freezing agent was thereby exposed, whereby the effect was retained. However, by the prohibition of the studded tires, sufficient effect thereof can not be expected.

With respect to (B):In this method, rubber chips are incorporated into the paving material and the road is entirely paved. Accordingly, it is not easy to conduct this method, although advantageous from the economical viewpoint. If the mixed amount of the rubber chips is decreased, the effect will be small, and if the mixed amount is increased, problems in the durability and laying properties will be caused.

With respect to (C):In this method, the anti-freezing agent or anti-slip agent is sprayed on the road on occasion as the case requires, whereby the management is cumbersom and the sprayed amount is large.

With respect to (D):By this method, some effect can be expected on a slope or the like. However, coarse aggregates are scraped by snow-removing machines and the road surface is susceptible to peeling off, whereby substantial problem is seen in the durability.

With respect to (E):In the grooving method, when grooves are formed so that they run at right-angle with the direction of traffic of vehicles, some anti-slip effect can be obtained. How-

ever, when the grooves are formed in parallel to the direction of traffic, the road surface is contrarily slippery.

With respect to (F):For the construction of the road heating on the road, a huge cost is needed, and for the management, the cost is high.

1.3 Summary of the invention

The present invention has been made taking into consideration the above problems of the prior art. It is an object of the present invention to provide a paved road, by which the following effects can be obtained. Namely, in order to control the formation of frozen road surface, it is required to remove the snow on the road by snow-removing machines, and construct a pavement having a freeze-controlling function on the road, to maintain the road in an exposed state.As the conventional approach to paved roads to control the freezing on the road, heating on the entire road surface, wetting of chlorides, penetration or drainage of water, or the like may be mentioned as above, and such methods are made by the road heating, elastic pavement, freeze-retarding pavement, water-draining pavement, grooving pavement, or the like.However, it is not economical to conduct controlling measurements on the entire surface of the paved road in order to control the freezing of the road surface as conducted in the prior art. Accordingly, in the present invention the controlling measurements are given only at necessary portions of the road. Namely, attention has been given to the contact portions of vehicle tires with a paved road along the direction of traffic of vehicles.The present invention provides a paved road obtained by forming a pair of rail-like grooves at an interval substantially correspond to a tread width of tires of both wheels of a vehicle on a paved road along the direction of traffic of vehicles, and disposing acting members for freeze controlling into the grooves.**(Figure.I).**

The types of vehicles are classified into small-sized cars, medium-sized cars and large-sized cars, and the tread width of front tires of each type is generally 120cm, 140cm or 180cm,

Fig.1 Paved road by the present invention

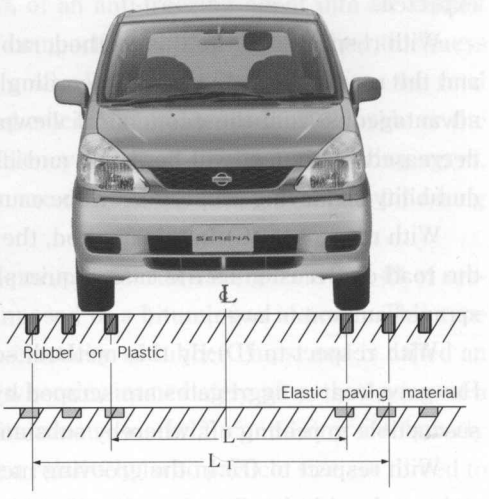

Fig.2 Schematic cross-sectional by the present invention

and the ground contact width of the tires is generally from 12 to 20cm. With the ones as shown in **Figure.2,** the size of **L** is 120cm and the size of L_1 is 180cm.**(Figure.2).**

1.4 Action fo the invention

As the acting member for freeze controlling, an elastic paving material, a rubber material such as natural rubber or a synthetic rubber, or a plastic material having a low thermal conductivity to which snow ice is hardly attached, may be used. If the elastic paving material or rubber material is disposed at the road surface to which the vehicle tires contact, the material is compressed and deformed by the weight when the vehicles run thereon, whereby the snow ice will be crushed. Further, if the plastic material is disposed, when the vehicles run thereon, snow ice will slip on the surface of the plastic material having a low friction and be put sidewards. It has been found that the attachment of snow ice on the surface of the acting member can be prevented, thereby presenting a function of controlling the freezing. Namely, utilizing the difference in the elasticity or friction between a road material and the acting member for freeze controlling disposed at an interval corresponding to the tread width of vehicle tires, and further utilizing the traffic of vehicles, snow ice is removed. The snow ice on the road surface surrounding the acting member is melted by the frictional heat by the traffic of vehicles, and the snow ice is stayed at the side portions of the acting member by the high friction of the road so that the vehicle tires will not slip out off the acting member and rush sidewards.

2. Methods

2.1 Materials of the invention

As the acting members for freeze-controlling, an elastic paving material, a rubber material such as natural rubber or a synthetic rubber, and a plastic material having a low thermal conductivity to whitch snow ice is hardly attached, are used as described above. The elastic paving materials may specifically be, for example, ones obtained by bonding rubber particles or rubber chips by an adhesive such as a synthetic rubber or a urethane resin, having an elasticity and slip properties as the paving material. With the rubber particles or rubber chips, inorganic fillers such as clay,kaolin or bentonite, auxiliaries for preventing deterioration, or additives for obtaining extending effect or matte effect, may appropriately be used. As examples for blending the elastic paving material, a single body of styrene/butadiene rubber having a non-volatile content to 50%, ones having a thermoplastic elastomer added in an amount of 50 parts, or ones having 100 parts of vulcanized rubber powder of black color, 25 parts of clay, 20 parts of chromium oxide powder or the like blended. Further, as the rubber materials, natural rubber and a synthetic rubber may be mentioned. The natural rubber is a vulcanized rubber obtained by blending sulfur for giving an appropriate elasticity to the rubber, followed by heating. Corbon black used for the production of tires is one for increasing the strength of the rubber, and as the blended amount, carbon black is used in an amount of at least 40 parts based on 100 parts of the rubber. As the plastic materials having a low thermal conductivity to which snow ice is hardly attached, a thermoplastic resin and a thermosetting resin may be mentioned. These are used in a solid state on a paved road, and change their

mechanical properties remarkably depending upon the temperature. The thermosetting resin shows an elasticity at a remarkably high level at a low temperature, and with the increase of the temperature, the elasticity tends to decrease, and afterwards, the elasticity is substantially conslant.The thermoplastic resin likewise shows an elasticity at a remarkably high level at a low temperature, and with the increase of the temperture the elasticity tends to rapidly decrease, and afterwards, it be comes to a fluid state through a rubber state.

2.2 Methods for the cases where grooves are formed

In the cases where grooves are formed on the existent paved road, the grooves are formed by using a machinery such as an asphalt cutter, a sealing machine, a burner heating-type scraping machine on a rotary-type gear scraping-type machine. In the cases of a newly constructed paved road, a shaped frame for groove is disposed, and a paving material is laid around it to form a road surface, and then the shaped frame is detached to form a groove. This groove is formed in an appropriate depth and width, and it is preferred to form the groove so that it would have a width taking the freeze-controlling effect and the width of tires into consideration, for example, the groove has a depth of about 3cm and a width of about 7cm. Further, when a plastic material is used as the acting member, the width of the groove is preferably narrower than that of the elastic material or the rubber material,for example, about 5cm. The distance between the acting members for freeze controlling, formed in a rail-like shape, is preferably made to correspond to the tread of vehicle tires,and usually formed taking into consideration the standard such that small-sized cars are from about 120 to 130cm, medium-sized cars are from about 140 to 150cm, and large-sized cars are from about 180 to 190cm.

2.3 Plan of operations

The surface treatment against the skid on ordinary roads may roughly be classified into four:(1)mixing, (2)spreading, (3)slurry seal, (4)fog seal. In the mixing method, the way of thinking may follow the item of standard proportioning in the ASPHALT PAVEMENT MANUAL, while in the spreading method, any aggregates great in anti-skid effect should be sprayed. Further, in this method, it is necessary to select a binder that is great in adhesion in order to control the exfoliation. In a conceivable method, a resin such as epoxy may be used to stick an emery or silica sand of 0.5 to 2.0mm. To prevent the frosting, we have been performing a tentative pavement, in which the ceramics, used with earthen ware at Abashiri Development Construction Division, are adhered to the road surface alternately with the usual surface into zebra form near an intersection perpendicularly ahead of the vehicle travel. Making use of extreme infrared radiation effect, the balance with road heating is taken into consideration from the viewpoint of the coefficient of thermal conductivity. Since the prohibition of studded tire, our college has developed a construction process of rubber mat to assure the safety against slippery road in winter. As for the study on a working example of this invention, we had first to find and test some equivalent materials required to this idea. To discuss the suitability of the materials, we made selection out of pressure proof rubber hose, dry

pole, drainage pipe, drainage trough, synthetic rubber, urethane resin and so on. The rubber hose was doubled to raise its strength with the vinyl chloride pipe as a core. They were set into asphalt pavement, cement mixtures and gravel on a private road. The results indicated that pouring rubber solution, etc. into stripped pavement surface is an effective working method without making any rutting on the road surface. Pasting up a sheet composed of thin resin layers has a similar effect, but it is problematical from the durability point of view. It is clear that when conducting varied tests, sealing anti-freezing agent up into the cavities of hose or pipe provided with certain measures, some chloride, for instance, flows over the road surface as a solution, thereby controlling the freezing control effect. Passing warm water into hose or pipe will have a similar effect.

3. Considerations

3.1 Considerations of these materials

In our study that employs elastic materials, rubbers, and plastics, we consider the physicochemical properties of these materials. Though the rubber itself is elastie at lower temperature in winter, it becomes harder and then vitreous at extremely low temperature. Although the glass transition point of natural rubber and synthetic one is -62℃ and -104℃ respectively, these rubbers may be thought to be elastic at such low temperature as usual frozen road surface. The plastic, though it is not elastic under normal conditions, is by far lower in thermal conductivity than metals, porcelain,marble, glass, etc. as is the case with the rubbers. Because of this, polyethylene is used for the bottom of ski. This makes use of the fact that the friction with the snow surface does not vary much depending on the temperature, which is the origin of our idea of using plastic in our invention. Mixed in the rubber to a certain proportion are the vulcanizing agent, vulcanization accelerator, antioxidant, softener and other additives to soften the rubber at lower temperature. Lower thermal conductivity is advantageous for heat insulation and disadvantegeous for heat radiation. As for the specific gravity, the metals are highest, and plastic is a little higher than wood. Any industrial use of largs volume requires that the material is cheap. Though its cost per weight might sometimes be expensive, the cost of plastic per volume may become less expensive in many cases because the specific gravity of plastic is low enough. **Spacific Gravity(Gs)** and **Thermal Conductivity(Ct)** of there materials, are shown in the **Table.1.**

3.2 Considerations for the skid resistance

A lot of researches and studies have thus far been made also in Japan on the skid resistance of road surface and tires, and the interrelationship there between is intricate. There are three sorts of friction between the road surface and tires:(1)agglutination friction where the molecules constituting the road surface and those of tread rubber of tires pull against each other, (2)deformation loss friction where the rubber deforms due to the irregularities of the road surface and the rubber thus deformed resists to recover the original shape, and finallly(3)puncture friction where the tires wears out and torn up by the contact with the road surface. The frictional resistance of the road surface is influenced by the smoothness of the

surface, existence of small grain size of gravel, and existence of wetting. **Figure.3** represents the relationship between the traveling speed and the coefficient of skid friction where a vehicle travels at each traveling speed on the road surface with compacted snow and granular snow, with ice plate and ice diaphragm,on the one hand, and on the normal dry and wet pavements, on the other. **(Figure.3).**

Table.1 Gs and Ct of there materials

Materials	Gs	Ct Kcal/m·hr·℃
Copper	8.93	338.4
Iron	7.86	64.8
Porcelain	2.1~5.3	18~25.2
Marble	1.5~3.0	2.5
Crystal	2.1~3.0	0.6~0.8
Wood	0.2~0.8	0.1~0.3
Cork·Charcoal	0.1~0.2	0.04~0.05
Concrete	2.3~2.4	0.6~1.2
Asphalt	1.01~1.05	0.14~0.64
Sand(Dry)	2.2~2.4	0.3
Sand(Wet)		1~1.2
Rubber	0.9~1.8	0.11~0.20
Plastic		
Polyvinyl	1.35~1.45	0.108~0.252
Polystyrene	1.05~1.07	0.036~0.108
Acrylic Resin	1.17~1.20	0.144~0.216
Polyethlene	0.83~0.96	0.288~0.446
Ice (0℃)	0.917	0.98
Water (4℃)	1.000	0.52

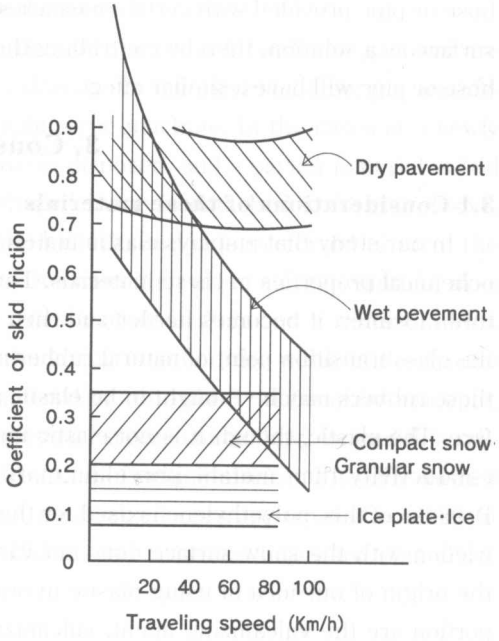

Fig.3 Traveling speed and coefficient of skid friction

4. Conclusions

We found the fact that using 3 pieces of rubbers or plastics for over 20 cm of interal with about 5 cm of width of one piece of rubber or plastic is efective if the intervals one executed in such a manner as to prevent the slippage. Since the present invention is constituted as above, the following effects can be obtained.

1. By forming a paved road having acting members for freeze controlling arranged at an interval corresponding to the tread width of tires of form small-sized cars to large-sized cars such as trucks or basses, it is possible to effectively destroy black ice road formed by freezing at a low temperature time in winter season by virtue of the elasticity and slip properties.

2. Many traffic accidents have happened in winter season, and almost were caused by running out opposite lane by slip. Such over running on the opposite lane can be prevented by vibration effect of vehicles by the elastic paving material of the road surface.

3. Small-sized cars and midium-sized cars can run on the area on which ice is destroyed by large-sized cars and paved road surface is exposed, such being highly safe and psychologi-

cally suitable for drivers.

4. By disposing acting members for freeze controlling, rail-like traffic lanes to which snow ice is hardly attached can be formed, such being extremely economical. Further, its repair can be made economically.

5. Even if a plastic type material having a low thermal conductivity to which snow ice is hardly attached, is used, similar effects as the rubber material or the like can be obtained.

6. The acting members for freeze controlling are disposed along the direction of the traffic of vehicles, and the surface conditions on the rail is good, whereby the vehicles can be driven stably,such being effective to increase the driving force and prevent the noise.

7. The present invention is particularly effective in cold areas where pressed snow is small, the temperature is low, the air is dry, and freezing is easily formed.

Acknowledgement

The present invention was filed March 30, 1998 as anti-smoothness pavement against iced road surface(Japanese Patent Application 104163-1998), and is patent number 3194038 assigned June the 1st, 2001. We owe much to Mr.Yasuo KAWANARI, the patent attorney, who comprehended the technological content of our researches and studies in such a fashion that the contents should be written up systematically and patented.We would like to express our deepest thanks to Professors SUZUKI and AYUTA who watched warmly the development of our researches and studies.

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