

(19)



(11)

EP 2 221 415 A1

(12)

EUROPEAN PATENT APPLICATION
published in accordance with Art. 153(4) EPC

(43) Date of publication:
25.08.2010 Bulletin 2010/34

(51) Int Cl.:
E01C 23/00 (2006.01)

(21) Application number: **08849780.5**

(86) International application number:
PCT/JP2008/003292

(22) Date of filing: **12.11.2008**

(87) International publication number:
WO 2009/063632 (22.05.2009 Gazette 2009/21)

(84) Designated Contracting States:
AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MT NL NO PL PT RO SE SI SK TR
Designated Extension States:
AL BA MK RS

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(30) Priority: **12.11.2007 JP 2007292914**

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(54) **METHOD OF CONTINUOUSLY REPAVING ASPHALT MIXTURE LAYER OF PAVED ROAD IN-SITU AND SELF-PROPELLED VEHICLE SYSTEM THEREFOR**

(57) Problem to be solved

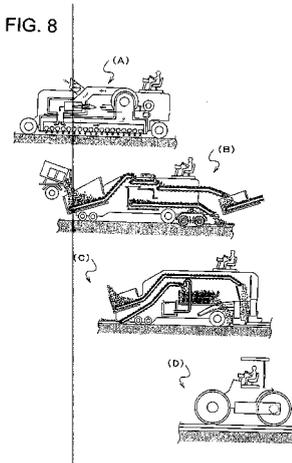
The present invention provides a method for continuous on-site repaving of an asphalt mixture layer of a road pavement and a motor-driven vehicle system therefor, while moving the motor-driven vehicle system.

Solution to solve the problem

A method for continuous on-site repaving of an asphalt mixture layer of a road pavement, which comprises a step of applying heat to a surface of an asphalt mixture layer so as to allow the heat to reach to a predetermined depth and soften the asphalt mixture layer, a step of scarifying the asphalt mixture layer to the predetermined depth to obtain an old asphalt mixture, a step of adding a coarse graded aggregate being stored to the old asphalt mixture, a step of obtaining a reinforcing asphalt mixture which the coarse graded aggregate being added therein, a step of spreading the reinforcing asphalt mixture onto a remaining layer of the asphalt mixture layer to form a reinforcing layer having an elastic modulus greater than that of the remaining layer, a step of adding an asphalt

mixture for a new surface layer being stored onto the reinforcing layer, a step of spreading the asphalt mixture for a new surface layer to form a new surface layer, and a step of compacting the reinforcing layer and the new surface layer together while heat still being stored.

FIG. 8



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Description

FIELD OF THE INVENTION

5 **[0001]** The present invention relates generally to a method for continuous on-site repaving of an asphalt mixture layer of road pavement and a motor-driven vehicle system therefor, and, more particularly, to a method comprising steps of: applying heat to a surface of an asphalt mixture layer so as to allow the heat to reach to a depth exceeding the boundary surface between the base layer and the surface layer of the asphalt mixture layer or to a depth within the asphalt mixture layer equivalent to that depth exceeding the boundary, whereby obtaining an asphalt mixture derived from existing road pavement (old asphalt mixture); adding and mixing either one of new materials of a coarse aggregate or an aggregate covered with an asphalt or an asphalt mixture having a particle size distribution including coarse aggregates mixed therein, to produce a reinforcing asphalt mixture spreading the reinforcing asphalt mixture onto the remaining layer of the existing asphalt mixture layer to form a coarse graded reinforcing layer as a middle layer having an elastic modulus greater than the remaining layer of the existing asphalt mixture; adding an asphalt mixture onto the coarse graded reinforcing layer to form a new layer; compacting the coarse graded reinforcing layer and the new layer together while heat still being stored, for continuous on-site repaving of an asphalt mixture layer of road pavement, and a motor-driven vehicle system used with the method.

BACKGROUND OF THE ART

20 **[0002]** Road pavement is prone to often experiencing cracking such as rutting and subsidence due to compressive and tensile strain in both vertical and horizontal direction caused by heavy traffic volume. To address this, the road pavement is formed with three layers including a roadbed, a sub-base and an asphalt mixture layer, as shown in FIG. 1. More in detail, as shown in FIG. 2, the sub-base is provided on a compacted roadbed and comprises aggregates such as sand and crushed rocks added with a cement or a stabilizing agent such as petroleum asphalt emulsion, the sub-base being compacted after the stabilizing agent is added to the aggregates and being comprised of a lower layer and an upper layer. To provide a required strength, the sub-base has a total thickness of 200 to 700 mm whereas each of the upper layer and the lower layer has a thickness of about 100 to 350 mm. The asphalt mixture comprising a base layer and a surface layer is generally provided over the sub-base and compacted via a layer binder to form an asphalt mixture layer.

25 **[0003]** In general, the term pavement is used to designate the four layers in "a sub-base and an asphalt mixture layer," and the asphalt mixture layer includes a base layer and a surface layer, each having a thickness of about 40 to 50 mm to provide a required strength for a traffic volume. This is because that the thickness of a pavement is determined by the strength of the roadbed (California Bearing Ratio (CBR.) value) and the traffic volume (N value) from the durability point of view, but, the thickness of each layer of a sub-base and an asphalt mixture layer is usually designed to be about two to three times in length of the maximum diameter of aggregates mixed therein. The maximum diameter of aggregates mixed into an asphalt mixture layer is usually around 20 mm, thus each thickness of the base layer and the surface layer comprising the asphalt mixture layer is designed to be around 40 to 50 mm, consequently the total thickness of the asphalt mixture layer may be around 80 to 100 mm.

30 **[0004]** However, depending on a required property, there are cases where an aggregate having the maximum particle size in a particle size distribution included in the surface layer with a thickness of about 40 to 50 mm is used in a dense graded layer having a thickness of about 13mm and an aggregate having the maximum particle size in a particle size distribution included in the base layer with the same thickness of about 40 to 50 mm is used in a coarse graded layer of about 20 mm. The thickness of the base layer is flexibly determined depending on a traffic volume. Thus, there are cases where a thickness of a base layer is determined to be about 40 to 350 mm. Figure 15 illustrates a section of atypical example of such pavement, though its detail will be described later, which is a standard pavement model applied to trunk roads in Japan (national highways and main local roads) and is used for the General Analysis of *Multi-layered* Elastic Systems (GAMES, Japan Society of Civil Engineers). The pavement includes a sub-base comprising a lower layer with a thickness of 350 mm and an upper layer with a thickness of 250 mm over a roadbed and an asphalt mixture layer comprising a base layer with a thickness of 120 mm and a surface layer with a thickness of 50 mm over the sub-base. This example of pavement is for roads having C-class traffic volume (1,000 to 3,000 vehicles/day-direction). An elastic modulus representing a deformation resistance of each layer in the sub-base and the asphalt mixture layer, i.e. a restoring force (E) is as shown in the Table of FIG. 15.

35 **[0005]** Repaving of an asphalt mixture layer is explained as follows. Each of a base layer and a surface layer of an asphalt mixture layer includes an asphalt which serves as a binder, particles of aggregate such as sand and crushed rocks and stone powder (filler) comprised of limestone powder adapted to fill spaces among the particles of the aggregate. In the composition ratio, in general, aggregate accounts for about 90%, asphalt (binder) for about 5 to 8%, and filler accounts for the rest.

[0006] The size of aggregate is referred as a particle size, and the mixture condition of these particles of aggregate which can be classified using screening device having a variety of screen meshes is referred as a particle size distribution. FIG. 3 shows an example of a particle size distribution, wherein the horizontal axis indicates the screen meshes, and the vertical axis indicates the weight percent of the particles of aggregate which have passed through each screen mesh (percentage passing by weight).

[0007] There are two kinds of asphalt (binder) used as an aggregates binder, one is crude asphalt called as strait asphalt which is unmodified, the other is modified asphalt which modifying agent such as rubber or resin has been added to improve viscosity. As seen in the relation between temperature and viscosity shown in FIG. 4, an asphalt mixture comprised of asphalt and aggregates will be divided into aggregates without damages and liquid asphalt when the viscosity of any kinds of asphalt diminishes around 180 degrees centigrade. That is, aggregates covered by asphalt may disaggregate to be particles. Meanwhile, the viscosity of asphalt increases under a temperature less than 100 degrees centigrade, whereby aggregates covered by asphalt will begin to re-aggregate, and then the asphalt mixture comprised of aggregates and asphalt will completely solidify at normal ambient temperatures.

[0008] It has been known that paved roads which are subjected to heavy traffic due to busy vehicle transportation have problems such as road surface deformation due to compressive and tensile strain in both vertical and horizontal direction and/or "rutting" as well as cracking due to softening and fluidizing of asphalt (binder) caused by being subjected to serious weather conditions for a prolonged time. These problems make a road surface uneven and cause further deterioration, as shown in FIG. 1, An on-site recycling pavement construction method called Hot In-place Recycling (HIR) using heat is generally performed targeting only a surface layer having a thickness of about 40 to 50 mm of the two-layered asphalt mixture layer composed from a base layer and a surface layer.

[0009] Specifically, there are two construction methods used for the purpose. One of the methods is a remixing method shown in FIG. 5(1) wherein a surface layer of an asphalt mixture layer may be heated, softened, and scarified to obtain a asphalt mixture, then a rejuvenating agent and fresh asphalt mixture (new materials) and/or fresh asphalt may be added and mixed to obtain a recycled asphalt mixture, and the recycled asphalt mixture may be spread and compacted to construct a surface layer of the recycled asphalt mixture.

[0010] The other method is a repaving method shown in FIG. 5 (2) wherein a surface layer of an asphalt mixture layer may be heated, softened, and scarified to obtain a asphalt mixture, then only a rejuvenating agent may be added and mixed together to be spread and compacted for regenerating the surface layer of the asphalt mixture layer, and, after this, fresh asphalt mixture may be added, spread and compacted to produce a two-layer construction of a surface layer of an asphalt mixture layer. Obviously, a thickness of recycled asphalt mixture layer may be thicker than before regenerating. One of the benefits of on-site recycling pavement construction using heat is that, in both methods, an asphalt mixture layer is recycled and reinforcing without damaging aggregates in asphalt mixture layer.

[0011] However, as describe above, there are many cases where cracks and deformation occurred on road pavement reach to a depth exceeding a boundary between a surface layer and a base layer which is generally at about 60 to 100 mm from a road surface or to a depth within an asphalt mixture layer equivalent to that depth exceeding the boundary. In road surface heating methods conventionally used for known on-site recycling pavement construction, such as the above described remixing method and repaving method, there was a limit to a depth from road surface to which heat can reach in a short period of time without causing asphalt to catch fire. Thus, the methods were applied to only a surface layer or a part of a surface layer. Therefore, when such on-site recycling pavement construction is performed for regenerating a surface layer of an asphalt mixture, some of cacks or deformations at the depth of 60 to 100 mm from the road surface, i.e. the depth equivalent to the base layer of an asphalt mixture layer or the equivalent depth in the asphalt mixture layer, had to be left behind.

[0012] US Patent 4534674 describes a method in which a remixing method is applied to a repaving method and repairing cracks and deformations in road pavement are also considered, more specifically, a method wherein a new surface layer is formed on a layer generated by adding a rejuvenating agent and heated fresh asphalt mixture to a scarified asphalt mixture, mixing them together, spreading and compacting. However, this method also has a limit to a depth of existing asphalt mixture layer being repaired as to 50 to 60 mm from road surface. In the above described cases, a life span of the recycled road pavement was short, because it was difficult to continuously recycle pavement on site to a depth exceeding a boundary surface between a base layer and a surface layer of an asphalt mixture layer Or to a depth within the asphalt mixture layer equivalent to that depth, i.e. 60 to 100 mm from road surface, to fundamentally improve a life span of the recycled road pavement. Road pavement damaged to such depth had to be, for example, reconstructed.

[0013] The applicant has, in a patent literature of Japanese Patent NO. 4024293, already developed a heating method and device for on-site continuous recycling of an asphalt mixture layer, which enables materials in a depth exceeding a boundary surface between a base layer and a surface layer of an asphalt mixture layer or to a depth within the asphalt mixture layer equivalent to that depth to be heated in a short period of time without causing asphalt to catch fire while keeping the surface temperature of the existing asphalt mixture layer at around 250 degrees Centigrade, by using a heating means for spraying and circulating a blast of hot air at around 600 to 700 degrees Centigrade to a road surface

of an asphalt mixture layer. The applicant has been committed to developing a repaving method that enables repairing damages and deterioration in road pavement to a depth exceeding a boundary surface between a base layer and a surface layer of an asphalt mixture layer or to a depth within the asphalt mixture layer equivalent to that depth and that enables significantly improving the life span of the road pavement by using the above mentioned heating method and device.

[0014]

(Nonpatent literature 1): "Pavement Recycling Handbook" (Japan Road Association)

(Patent literature 1): Japanese Patent NO. 4024293

(Patent literature 2): US Patent NO. 4534674

SUMMARY OF THE INVENTION

[0015] Asphalt is comprised of particulate ingredient called as asphaltene, and oil ingredient called as maltene, and the content of methane tends to be decreases as the pavement is aged with the result that the asphalt is made harder and less viscous due to an increase in relative amount of asphaltene to maltene. This could occur to both a surface layer and a base layer more or less to a same degree. Furthermore, aggregates mixed in the asphalt mixture layer may be subjected to abrasion and breakage. Therefore, when an asphalt mixture derived from existing road pavement is reused as old asphalt mixture, it may be preferably used for a whole asphalt mixture layer including a surface layer and a base layer.

[0016] The present invention proposes a method for repaving of an asphalt mixture layer of road pavement and a motor-driven vehicle system therefor, wherein the method comprising steps of; by using the above described heating method and device which enables heat to reach in a short period of time to a depth exceeding a boundary surface between a base layer and a surface layer of an asphalt mixture layer or to a depth within the asphalt mixture layer equivalent to that depth to be heated without causing asphalt to catch fire, applying heat so as to reach to a depth exceeding a boundary surface between a base layer and a surface layer of an asphalt mixture layer or to about 60 to 100 mm within the asphalt mixture layer which is equivalent to that depth and thereby softening materials within the depth; adding and mixing not only a rejuvenating agent but either one of new materials of a coarse aggregate or an aggregate covered with an asphalt or an asphalt mixture having a particle size distribution including coarse aggregates mixed therein, with the asphalt mixture scarified to a depth exceeding a boundary surface between a base layer and a surface layer of an asphalt mixture layer or to a depth within the asphalt mixture layer equivalent to that depth, to produce a reinforcing asphalt mixture, as shown in FIG. 6; spreading the reinforcing asphalt mixture on the remaining layer of the existing asphalt mixture layer to form a middle layer (referred as a arse graded reinforcing layer) containing coarse aggregates and having an elastic modulus greater than the remaining layer of the existing asphalt mixture; and spreading an asphalt mixture for new surface layer onto the coarse graded reinforcing layer and compacting them together while heat still being stored to form a new surface layer.

[0017] A solution of the above described problem will be accomplished by the present invention based on a knowledge that an asphalt mixture layer of road pavement can be continuously repaved on site by performing steps of applying heat to a surface of an asphalt mixture layer so as to allow the heat to reach to a depth exceeding a boundary surface between a base layer and a surface layer of an asphalt mixture layer or to a depth within the asphalt mixture layer equivalent to that depth using a motor-driven vehicle system, whereby the materials in a depth exceeding a boundary surface between a base layer and a surface layer of an asphalt mixture layer or to a depth within the asphalt mixture layer equivalent to that depth are softened and scarified to obtain an old asphalt mixture; adding and mixing a first new material, being heated to a temperature preventing re-aggregation, either one of a coarse aggregate or an aggregate covered with an asphalt or an asphalt mixture having a particle size distribution including coarse aggregate mixed therein, to produce a reinforcing asphalt mixture; spreading the reinforcing asphalt mixture on the remaining layer of the existing asphalt mixture layer to form a coarse graded reinforcing layer having an elastic modulus greater than the remaining layer of the remaining asphalt mixture; and adding and spreading a second new material for a new layer, being stored at a temperature preventing re-aggregation, onto the coarse graded reinforcing layer and compacting them together while heat still being stored to form a new surface layer. The present invention has the following characteristics.

[0018] The invention define in claim 1 is a method for continuous on-site repaving of an asphalt mixture layer of a road pavement with a motor-driven vehicle system, comprising the steps of;
 (a) applying heat to a surface of the asphalt mixture layer so as to allow the heat to reach to a depth exceeding a boundary surface between a base layer and a surface layer of the asphalt mixture layer or to a depth within the asphalt mixture layer equivalent to the depth exceeding the boundary surface and softening the asphalt mixture layer, (b) scarifying the heated and softened asphalt mixture layer to the depth exceeding the boundary surface between the base layer and the surface layer of the asphalt mixture layer or to the depth within the asphalt mixture layer equivalent to that depth exceeding the boundary surface to obtain an old asphalt mixture, (c) adding a first new material to the old asphalt mixture,

the first new material being stored in a storage apparatus at a temperature preventing re-aggregation, the first new material being any one of a coarse aggregate, a coarse aggregate covered with asphalt or an asphalt mixture having a particle size distribution including coarse aggregate mixed therein, (d) mixing the first new material with the old asphalt mixture to form a reinforcing asphalt mixture, (e) spreading the reinforcing asphalt mixture over the remaining layer of the asphalt mixture layer left un-scarified in the step (b) to form a coarse graded reinforcing layer having an elastic modulus greater than that of the remaining layer, (f) adding a second new material onto the formed coarse graded reinforcing layer, the second new material being stored in a storage apparatus at a temperature preventing re-aggregation, the second new material being a fresh asphalt mixture for a new surface layer, (g) spreading the second new material to form the new surface layer, wherein the step of spreading the second new material being linked with the step (e), and (h) compacting the coarse graded reinforcing layer formed over the remaining layer and the new surface layer together while heat still being stored.

[0019] The invention defined in claim 2 is a method, in addition to the characteristics of the invention defined in claim 1, further comprising a step of carrying in, prior to said step (b), the first new material and the second new material at different timings conveyed from outside the motor-driven vehicle system to respective one of the storing apparatus coincidentally with the different timings.

[0020] The invention defined in claim 3 is a method, in addition to the characteristics of the invention defined in any of claim 1 or 2, wherein the first new material is any one of an aggregate or aggregate covered with asphalt having a greater diameter than the greatest diameter of an aggregate included in the asphalt mixture layer or an asphalt mixture having a particle size distribution including coarse aggregate mixed therein having a greater diameter than the greatest diameter of an aggregate included in the asphalt mixture layer.

[0021] The invention defined in claim 4 is a method, in addition to the characteristics of the invention defined in any of claims 1 to 3, wherein the reinforcing asphalt mixture includes an aggregate having a greater diameter than the greatest diameter of an aggregate included in the asphalt mixture layer for about 5 to 35 weight % to the total weight.

[0022] The invention define in claim 5 is a method, in addition to the characteristics of the invention defined in any of claims 1 to 4, wherein said step (d) further comprises a step of adding an asphalt rejuvenating agent when mixing the old asphalt mixture with the first new material added therein.

[0023] The invention defined in claim 6 is a method, in addition to the characteristics of the invention defined in any of claims 1 to 5, wherein the second new material is an asphalt mixture including an aggregate having a substantially same particle size distribution as that of an aggregate included in the asphalt mixture layer.

[0024] The invention defined in claim 7 is a method, in addition to the characteristics of the invention defined in any of claims 1 to 6, wherein said step (e) further comprises a step of spreading an asphalt emulsion 17 a material for enhancing water proof property and bonding property over the remaining layer to bond the remaining layer and the coarse graded reinforcing layer.

[0025] The invention define in claim 8 is a motor-driven vehicle system for continuous on-site repaving of an asphalt mixture layer of road pavement comprising a pre-heater vehicle (A) for applying heat to a surface of the asphalt mixture layer of road pavement so as to allow the heat to reach to a depth exceeding a boundary surface between a base layer and a surface layer of the asphalt mixture layer or to a depth within the asphalt mixture layer equivalent to the depth exceeding the boundary surface and thereby to soften the asphalt mixture layer; a miller vehicle (B) including a first tank for storing a first new material at a temperature preventing re-aggregation, the first new material being any one of a coarse aggregate, a coarse aggregate covered with asphalt or an asphalt mixture having a particle distribution including a coarse aggregate, a scarifying means for scarifying the heated and softened asphalt mixture layer to the depth exceeding the boundary surface or to the depth within the asphalt mixture layer equivalent to that depth exceeding the boundary surface to obtain an old asphalt mixture, and a first adding means for adding the first new material stored at a temperature preventing re-aggregation and discharged out of the first tank to the old asphalt mixture; and a mixer vehicle (C) including a second tank for storing a second new material at a temperature preventing re-aggregation, , the second new material being a fresh asphalt mixture for a new surface layer, a mixing means for receiving the old asphalt mixture which the first new material is added therein and mixing the first new material with the old asphalt mixture to obtain a reinforcing asphalt mixture, a first screed for spreading the reinforcing asphalt mixture over a remaining layer of the asphalt mixture layer left un-scarified by the scarifying means to form a coarse graded reinforcing layer having an elastic modulus greater than that of the remaining layer, a second adding means for adding the second new material stored at a temperature preventing re-aggregation and discharged out of the second tank over the coarse graded reinforcing layer, and a second screed for spreading the added second new material to form a new surface layer, an operation of the second screed being linked with an operation of the first screed.

[0026] The invention defined in claim 9 is a motor-driven vehicle system, in addition to the characteristics of the invention defined in claim 8, further comprising a compacting means for compacting the coarse graded reinforcing layer formed over the remaining layer and the new surface layer formed over the coarse graded reinforcing layer together while heat still being stored.

[0027] The invention defined in claim 10 is a motor-driven vehicle system, in addition to the characteristics of the

invention defined in any of claims 8 or 9, wherein the miller vehicle (B) further comprises a relaying receiving-discharging apparatus for receiving and discharging the first and the second new material carried in at different timings from outside the motor-driven vehicle system, and a new material conveying apparatus including at least 2 continuous conveying paths and having a switching apparatus for carrying the first and the second new material discharged from the relaying receiving-discharging apparatus respectively into the first and the second tank coincidentally with the different timings, wherein, when the first new material is carried from the relaying receiving-discharging apparatus to the first tank, the switching apparatus therein disconnects the at least 2 continuous conveying paths of the new material conveying apparatus to form a carry-in opening, and the first new material is carried into the first tank via the carry-in opening, wherein, when the second new material is carried from the relaying receiving-discharging apparatus into the second tank, the switching apparatus closes the carry-in opening formed in the new material conveying apparatus to form 1 conveying path by connecting the at least 2 conveying paths and the second new material is carried from the relaying receiving-discharging apparatus into the second tank via the 1 conveying path.

[0028] The invention defined in claim 11 is a motor-driven vehicle system, in addition to the characteristics of the invention defined in any of claims 8 to 10, wherein the first new material is any one of an aggregate or aggregate covered with asphalt having a greater diameter than the greatest diameter of an aggregate included in the asphalt mixture layer or an asphalt mixture having a particle size distribution including coarse aggregate mixed therein having a greater diameter than the greatest diameter of an aggregate included in the asphalt mixture layer.

[0029] The invention defined in claim 12 is a motor-driven vehicle system, in addition to the characteristics of the invention defined in any of claims 8 to 11, wherein the reinforcing asphalt mixture includes an aggregate having a greater diameter than the greatest diameter of an aggregate included in the asphalt mixture layer for about 5 to 35 weight % to the total weight.

[0030] The invention defined in claim 13 is a motor-driven vehicle system, in addition to the characteristics of the invention defined in any of claims 8 to 12, wherein the second new material is an asphalt mixture including an aggregate having a substantially same particle size distribution as that of an aggregate included in the asphalt mixture layer.

[0031] The invention defined in claim 14 is a motor-driven vehicle system, in addition to the characteristics of the invention defined in any of claims 8 to 13, wherein the mixer vehicle (C) further comprises a rejuvenating agent adding means for adding an asphalt rejuvenating agent when mixing the old asphalt mixture with the first new material added therein.

[0032] The invention defined in claim 15 is a motor-driven vehicle system, in addition to the characteristics of the invention defined in any of claims 8 to 14, wherein the mixer vehicle (C) further comprises a third tank for storing an asphalt emulsion for bonding the remaining layer and the coarse graded reinforcing layer or a material for enhancing water proof property and bonding property.

[0033] The invention defined in claim 16 is a motor-driven vehicle system, in addition to the characteristics of the invention defined in any of claims 8 to 15, wherein the mixer vehicle (C) further comprises a storing space, arranged between the mixing means and the first screed, for adjusting a supply volume of the reinforcing asphalt mixture onto the remaining layer.

[0034] The invention defined in claim 17 is a motor-driven vehicle system, in addition to the characteristics of the invention defined in any of claims 8 to 16, wherein the mixer vehicle (C) further comprises a storing space, arranged between the first screed and the second screed, for adjusting a supply volume of the second material onto the coarse graded reinforcing layer.

BEST MODE OF CARRYING OUT THE INVENTION

[0035] With reference to Figs. 7 to 21, a method and a motor-driven vehicle system for continuous on-site repaving of an asphalt mixture layer of road pavement will now be described in detail with a best mode of carrying out the invention.

[0036] FIG. 7 shows a whole, step of a method for continuous on-site repaving of an asphalt mixture layer of a road pavement according to embodiments of the present invention. The method comprises, a step for applying heat to a surface of an asphalt mixture layer so as to allow the heat to reach to a depth exceeding a boundary surface between a base layer and a surface layer of an asphalt mixture layer or to a depth within the asphalt mixture layer equivalent to that depth and to soften the asphalt mixture layer (referred as a heating and softening step), a step for scarifying the heated and softened asphalt mixture layer to the depth exceeding a boundary surface between a base layer and a surface layer of an asphalt mixture layer or to a depth within the asphalt mixture layer equivalent to that depth, whereby obtaining an old asphalt mixture (referred as a scarifying step), a step for adding a first new material, being heated to a temperature preventing re-aggregation, either one of a coarse aggregate or an aggregate covered with an asphalt or an asphalt mixture having a particle size distribution including coarse aggregate mixed therein, to the old asphalt mixture (referred as a first adding step), a step for mixing the first new material with the old asphalt mixture to form a reinforcing asphalt mixture (referred as a mixing step), a step for forming a coarse graded reinforcing layer by spreading the reinforcing asphalt mixture onto the remaining layer of the asphalt mixture layer left un-scarified in the scarifying step to

form a coarse graded reinforcing layer having an elastic modulus greater than that of the remaining layer (referred as a coarse graded reinforcing layer forming step), a step for adding a second new material of a fresh asphalt mixture for a new surface layer, being stored in a storage apparatus at a temperature preventing re-aggregation, onto the formed coarse graded reinforcing layer (referred as a second adding step), a step for forming a new surface layer by spreading the second new material to form a new surface layer, which is a step linked with the coarse graded reinforcing layer forming step (referred as a new surface layer forming step), and a step for compacting the coarse graded reinforcing layer formed on the remaining layer and the new surface layer together while heat still being stored (referred as a compacting step).

[0037] The method can further comprise a step, prior to the scarifying step, for conveying the first new material and the second new material carried in at different timings from outside the motor-driven vehicle system to respective one of the storing apparatus coincidentally with the different timings (referred a new material carry-in step), a step for adding for adding an asphalt rejuvenating agent when mixing the old asphalt mixture with the first new material added therein (referred as a rejuvenating agent adding step), and a step for spreading an asphalt emulsion or a material for enhancing water proof property and bonding property onto the remaining layer to bond the remaining layer and the coarse graded reinforcing layer (referred as an inter-layer bonding step).

[0038] FIG. 8 illustrates an embodiment of the motor-driven vehicle system that performs each of the above described steps of the present invention. The motor-driven vehicle system is configured with a pre-heater vehicle (A) a miller vehicle (B) and a mixer vehicle (C), and includes a compacting roller (D) when necessary. The motor-driven vehicle system for continuous on-site repaving of an asphalt mixture layer of road pavement according to the embodiment, along with each element and feature of the vehicles, will be described in the following.

[0039] The pre-heater vehicle (A) is an apparatus operated by a driver controlling the vehicle, and its heating means is located between front wheels and rear wheels of the vehicle and faced against a road surface. FIG. 9 illustrates the heating apparatus 100 viewed from a side with respect to a vehicle moving direction. Although the detailed description is abbreviated, an air-fuel mixture is sent to a high-temperature combustion gas generating part 110, ignited by a burner 140, heated up to about 550 to 750 degrees Celsius, preferably to about 650 degrees Celsius, evenly distributed via a center duct 160 being a portion of a storing part 150 to each of circular-section ducts 120 being a portion of the storing part 150 and arranged like a drain board by locating a plurality of the ducts with a certain interval in a lengthwise direction with respect to the vehicle moving direction, and projected as a high-temperature combustion gas (shown by arrows with solid line) from a plurality of nozzles 130 of the ducts 120 for forming a high-temperature combustion gas layer in a heated region between an open surface of a hood 170 and a surface of an asphalt pavement. The high-temperature combustion gas becomes a collected combustion gas after transferring heat (shown by arrows with dotted line), and is sucked by a sucking means 190 through a space formed by etch of circumference of the ducts 120 and inside of the hood 170 into a combustion gas circulating duct 200, and then sent to the high-temperature combustion gas generating part 110 to start the above cycle again.

[0040] Thus, the pre-heater vehicle (A) can form a high-temperature combustion gas layer of about 550 to 750 degrees Celsius on a surface of road pavement as moving at a speed of about 2 to 5 m/min, keep a temperature the surface of the pavement at about 230 to 260 degrees Celsius, allow heat to reach to a depth exceeding a boundary surface between a base layer and a surface layer of an asphalt mixture layer or to a depth of about 60 to 100 mm within the asphalt mixture layer which is equivalent to that depth and heat up the deepest portion to about 50 to 60 degrees Celsius without causing asphalt to catch fire. The heating and softening step of the present invention is thereby achieved to allow a scarifying means 340 of the later-described miller vehicle (B) scarify without damaging aggregates of the asphalt mixture layer and obtain an old asphalt mixture and achieve the scarifying step. The heating means is not limited to the one described above but can be any one having a similar feature.

[0041] The miller vehicle (B) is also an apparatus operated by a driver controlling the vehicle as shown in FIG. 8. FIG. 10 illustrates the milling apparatus 300 viewed from a side with respect to a vehicle moving direction. The miller vehicle (B) comprises; a first tank 320 for storing a first new material 310 carried in from outside the motor-driven vehicle system by a heavy truck 400A and being any one of a coarse aggregate, a coarse aggregate covered with asphalt or an asphalt mixture having a particle size distribution including coarse aggregate mixed therein at a temperature of about 120 to 150 degrees Celsius for preventing re-aggregation, a scarifying means 340 for scarifying to a depth exceeding a boundary surface between a base layer and a surface layer of the asphalt mixture layer 330 or to a depth within the asphalt mixture layer 330 equivalent to that depth, which is heated and softened by the above described heating apparatus 100 to obtain an old asphalt mixture, and, a first adding means 350 for adding the first new material 310, being stored at a temperature of about 120 to 150 degrees Celsius for preventing re-aggregation and discharged from the first tank 320, to an asphalt mixture 331.

[0042] Specific elements of miller vehicle (B) will now be described with referring to FIG. 10. The first new material 310 carried in by the heavy truck 400A is created at a plant not shown, and an amount of the first new material 310 necessary for repaving is kept at a temperature of about 120 to 150 degrees Celsius for preventing re-aggregation and received by a relaying receiving-discharging apparatus 400. The first new material 310 received is conveyed by a first

conveying apparatus 410 to the first tank 320. Then, a carry-in opening 420 is formed above the first tank 320 for carrying in the first new material through this carry-in opening 420 and an input opening 321 of the first tank 320. The carry-in opening 420 is then closed with a first conveying apparatus 410 and a slidable second conveying apparatus 430. The second conveying apparatus 430 is also located so as to interlock with a third conveying apparatus 440. Thus, when the carry-in opening 420 is closed, the first conveying apparatus 410 and the third conveying apparatus 440 forms one conveying apparatus 450 via the second conveying apparatus 430 slidable by such as an actuator, as described later.

[0043] The scarifying means 340 comprises a set of rotary scarifier (claw for scarifying pavement) including 2 grinding apparatuses 341 and 342 wherein at least 2 rotating axes rotates inwardly to each other driven by generally a hydraulic power and claws thereon are arranged spirally in a direction from the edges to the center with respect to the transverse direction of a paved road. The scarifying means 340 scarifies the heated and softened asphalt mixture layer 330 to a depth exceeding a boundary surface between a base layer and a surface layer or to a depth within the asphalt mixture layer 330 equivalent to that depth for obtaining the old asphalt mixture 331 formed like a ridge along a central part of the apparatus in the transverse direction with respect to the moving direction. The scarifying means 340 comprising 2 grinding apparatuses 341 and 342 may also be arranged in a vehicle in front (B1) of a combination of 2 vehicles (B1+B2) as illustrated in FIG. 12 showing another embodiment of the miller vehicle (B).

[0044] Preferably, a heat insulating apparatus is provided with the first tank 320 for storing the first new material 310. The stored and pre-heated first new material 310 is conveyed from a discharging opening 322 of the first tank 320 by a fourth conveying apparatus 351 of the first adding means 350 which end is placed inside the first tank 320, and added to the old asphalt mixture 331.

[0045] Each of elements of the miller vehicle (B) when a later-described second new material 510 is carried in by another heavy truck 400B will now be described with referring to FIG. 11, prior to describing the mixer vehicle (C). The second new material 510 is created at a plant not shown, and an amount necessary for repaving is kept at a temperature of about 120 to 150 degrees Celsius for preventing re-aggregation and received by a relaying receiving-discharging apparatus 400. Then, the second conveying apparatus 430 is slid to close the carry-in opening 420. Simultaneously, one conveying apparatus 450 is formed by connecting the first conveying apparatus 410 and the third conveying apparatus 440 via the second conveying apparatus 430. More specifically, for conveying the second new material 510, carried in by the heavy truck 400B to the relaying receiving-discharging apparatus 400, to a second tank 520, a driver of the miller vehicle (B) operates a switching apparatus 460 of the slidable second conveying apparatus 430 to close the carry-in opening 420 and thereby forming one conveying apparatus 450 by connecting the first conveying apparatus 410 and the third conveying apparatus 440 via the second conveying apparatus 430. Preferably, a heat insulating apparatus as that of the first tank 320 is also provided with the second tank 520.

[0046] The second new material 510 is thus carried through the conveying apparatus 450 into the second tank 520 provided on the mixer vehicle (C). As will be understood from FIG. 10 and FIG. 11, the first new material 310 and the second new material 510 are carried into the relaying receiving-discharging apparatus of the miller vehicle (B) at different timings from outside the motor-driven vehicle system and each of the new materials is conveyed into respective one of the first tanks and the second tank at the different timings.

[0047] The mixer vehicle (C) is also an apparatus operated by a driver controlling the vehicle as shown in FIG. 8. FIG. 13 illustrates the mixing apparatus 500 viewed from a side with respect to a vehicle moving direction. As described above, the mixer vehicle (C) comprises; the second tank 520 for storing the second new material 510 at a temperature of about 120 to 150 degrees Celsius which prevents re-aggregation wherein the second new material being an asphalt mixture for a new surface layer is carried into the relaying receiving-discharging apparatus 400 by the heavy truck 400B from outside the motor-driven vehicle system, a fifth conveying apparatus 530 for scooping and conveying the old asphalt mixture 331 which the first new material is mixed therein, a mixing means 550 for receiving the old asphalt mixture 331 which the scooped and conveyed first new material 310 is mixed therein and mixing the first new material 310 with the old asphalt mixture 331 to obtain a reinforcing asphalt mixture 540, a first screed 580 for spreading the reinforcing asphalt mixture 540 over a remaining layer 560 of the asphalt mixture 330 left unscarified by the scarifying means 340 to form a coarse graded reinforcing layer 570 having an elastic modulus greater than that of the remaining layer 560, a second adding means 590 for adding the second new material 510 discharged from the second tank 520 over the formed coarse graded reinforcing layer 570, and a second screed 610 which operation is linked with an operation of the first screed 580 for spreading the added second new material 510 onto the coarse graded reinforcing layer 570 to form a new surface layer 600.

[0048] The mixer vehicle (C) further comprises; a rejuvenating agent adding means 620 for adding an asphalt rejuvenating agent when mixing the old asphalt mixture 331 with the first new material 310 added therein, a third tank 630 for storing an asphalt emulsion for bonding the remaining layer 560 and the coarse graded reinforcing layer 570 or a material for enhancing water proof property and bonding property, a storing space 640 for adjusting a supply volume of the reinforcing asphalt mixture 540 onto the remaining layer 560, formed by walls provided on both sides between the mixing means 550 and the first screed 580, and a storing space 650 for adjusting a supply volume of the second new material 510 onto the coarse graded reinforcing layer 570, formed by walls provided on both sides between the first

screed 580 and the second screed 610.

[0049] The first screed 580 and the second screed 610 of the mixer vehicle (C) generally not only spread respective one of the reinforcing asphalt mixture 540 and the second new material 510 as well as compact the materials. Thus, the compacting roller (D) may be used when necessary to compact more rigidly.

[0050] By linking the miller vehicle (B) and the mixer vehicle (C) each storing respective one of the first new material 310 and the second new material 510 with the pre-heater vehicle (A) and moving them together at a speed of about 2 to 5 m/min, heat is reached to a depth of about 60 to 100mm within the asphalt mixture layer 330 and the deepest portion of the asphalt mixture layer 330 is heated up to about 50 to 60 degrees Celsius for accomplishing the heating and softening step of the present invention. And, by scarifying the asphalt mixture layer 330 by the scarifying means 340 without damaging or breaking aggregates mixed in the asphalt mixture layer 330 to obtain the old asphalt mixture 331, the scarifying step of the present invention is accomplished. The steps following the above steps of the present invention will be described below.

[0051] In the first adding step, the first new material 310 is added to the scarified old asphalt mixture. The first new material 310 needs to be any one of an aggregate or aggregate covered with asphalt having a greater diameter than the greatest diameter of an aggregate included in the asphalt mixture layer 330, or an asphalt mixture having a particle size distribution including coarse aggregate mixed therein having a greater diameter than the greatest diameter of an aggregate included in the asphalt mixture layer 330. The reinforcing asphalt mixture 540 created in the next mixing step needs to contain about 5 to 35 weight % of an aggregate having a greater diameter than the greatest diameter of an aggregate included in the asphalt mixture layer 330 to the total weight. Where a content of a coarse graded aggregate is less than 5 weight %, a load bearing capacity of a pavement greater than that obtainable by increasing a thickness of a pavement cannot be achieved. On the other hand, where a content of a coarse graded aggregate is more than 35 weight %, a particle size distribution of an asphalt mixture is deteriorated which makes forming a dense asphalt mixture layer difficult. Therefore, in the coarse graded reinforcing layer forming step which follows, spreading and compacting a reinforcing asphalt mixture over the remaining layer 560 of the asphalt mixture layer 330 allows forming a coarse graded reinforcing layer having an elastic modulus greater than that of the remaining layer 560 as described later, though the thickness of the layer is increased as the asphalt mixture layer 330 is reused. A repaved structure which a new surface layer is formed thereon is intended at Hot In-place Strengthening of pavement structure by forming a coarse graded reinforcing layer.

[0052] FIG. 14 shows a result of repaving provided by a coarse graded reinforcing layer formed by adding a new material to an old asphalt mixture intended at strengthening of a pavement structure, though the detailed description is abbreviated. Each of FIG.18 to FIG. 21 shows data for a strengthened pavement structure based on test results. The result in FIG. 14 shows a measurement result of a thickness of an asphalt pavement in a case where a total thickness of 6cm of the old asphalt mixture, composed by 4cm of a surface layer having the maximum diameter of an aggregate mixed therein being 13mm and 2cm of a base layer having a thickness of X cm and the maximum diameter of an aggregate mixed therein being 20mm, was scarified and mixed with "class #4 ballast" composed by aggregates of a particle size of 20 to 30 mm as a new material at a ratio of 7:3. The total thickness of such layer after adding the new material was 8.6cm i.e. showed 2.6cm increase from the thickness of 6cm of the scarified asphalt mixture layer.

[0053] FIG. 15 shows a result of a test performed in 2003 using the General Analysis of Multi-layered Elastic Systems (GAMES, Japan Society of Civil Engineers) on a standard pavement model for trunk roads (national highways and major local roads) in Japan, which was applied to the pavement constructed in 1999 in Chikushino-Koga Line in Kyushu, Japan. The evaluated pavement structure composed a sub-base having a lower layer of 35cm in thickness and an upper layer of 25cm in thickness over a roadbed, and an asphalt mixture layer having a base layer of 12cm in thickness and a surface layer of 5cm in thickness, and the pavement had been subjected to C-class traffic volume (1,000 to 3,000 vehicles/day-direction). Based on an elastic modulus representing a deformation resistance of each layer in the sub-base and the asphalt mixture layer, i.e. a restoring force (E), as shown in the table of FIG.15, it shows that the expected life span of surface layer was 1 year, and that of the whole pavement was 5 years.

[0054] The above expected life span of the surface layer is a value obtained by dividing a number of wheel loads to fatigue failure (N_f) of the asphalt mixture by the yearly traffic volume, calculated as 3,000 vehicles/ day-direction \times 365 days in this case of C-class traffic volume. A number of wheel loads to fatigue failure (N_f) can be calculated using a standard equation for calculating number of wheel loads to fatigue failure (Manual for Asphalt Pavement, Japan Road Association, December, 1992) as follows.

$$N_f = 8.108 \times 10^{(M-3)} / \left(\frac{\epsilon_f}{\epsilon_c} \right)^{3.291} \times E^{0.854} \quad (\text{Equation 1})$$

where, ϵ_c : tensile strain at the lower surface of an asphalt mixture layer, E: elastic modulus of an asphalt mixture (kgf/cm²), M: a function of porosity (V_v) and an amount of asphalt (V_b) of an asphalt mixture calculated as $M = 4.84 \times \{ [V_b / (V_v - V_b)] \}$

- 0.69}.

[0055] FIG. 16 shows a result of another test performed using the GAMES on the pavement subjected to the same C-class traffic volume as in the case of FIG. 15, wherein a thickness of 50mm from an upper surface of a surface layer of a standard pavement model was regenerated by the remixing method. The result shows that the elastic modulus of the surface layer improved to 35,000 kgf/cm² after regenerating from 24,000 kgf/cm², but, the expected life span of the surface layer is only 2 years i.e. only 1 year longer than that in the case shown in FIG.15. This indicates that the pavement of the standard pavement model has been so deteriorated as both the base layer and the surface layer need to be reconstructed.

[0056] FIG. 17 shows, on the other hand, a yet another test performed using the GAMES on the pavement subjected to the same C-class traffic volume as in the case of FIG. 15, wherein the pavement to a depth of 100mm from the road surface, exceeding the depth of the boundary surface between the surface layer and the base layer, was scarified and mixed with "class #4 ballast" composed by aggregates of a particle size of 20 to 30 mm at a ratio of 7:3 as in the FIG. 14 to obtain a reinforcing asphalt mixture, then the reinforcing asphalt mixture was spread over the unscarified remaining layer of 70mm in thickness to form a coarse graded reinforcing layer of 140mm in thickness (50mm of the surface layer, 50mm out of the base layer of 120mm in thickness and 40mm of the "class #4 ballast"), a second new material as added on the coarse graded reinforcing layer to form a new surface layer, and then the coarse graded reinforcing layer and the new surface layer were compacted together while heat still being stored.

[0057] Comparing the case in FIG. 17 with the cases in FIG. 15 and FIG. 16, an asphalt mixture layer having 170mm thickness in 2 layers was repaved to an asphalt mixture layer having 240mm thickness in 3 layers wherein the 70mm thickness increase owed to 40mm of the first new material and 30mm of the second new material. The elastic modulus to a vertical strain and a horizontal strain of the coarse graded reinforcing layer under the C-class traffic volume was 50,000 kgf/cm², more than 2 times of 24,000 kgf/cm² of the old coarse graded base layer. This is supported by the measured value shown in FIG. 21. The life span of the surface layer can thereby be extended to 11 years from that of 5 or 6 years before repaving. Therefore, the method of the present invention can advantageously extend the life span of pavement by 5 to 6 years compared to a conventional surface layer heating and regenerating method.

[0058] The data obtained in experiments shown in FIG. 21 support the test result. The bending capacity test was performed by 2-point concentrated loading, according to "JIS A 1106 Method of test for flexural strength of concrete." Bending capacity is defined as the maximum bending stress (tensile stress) in a specimen when a bending stress is applied to the specimen. A bending capacity is calculated by the following equation when a specimen is assumed elastic.

$$\sigma_b = M/Z = (Pl/6)/(bd^2/6) = Pl/bd^2 [N/mm^2] \quad (\text{Equation 2})$$

where; M: the maximum bending moment in a specimen, Z: a section modulus [mm³], p: the maximum load [N], l: a distance between lower supporting points [mm] (300mm in the test), b: a section width of a specimen [mm] (100mm in the test), d: a section height a specimen [mm] 100mm in the test)

[0059] The test result confirmed that the elastic modulus used for the numerical analysis of the material characteristics and that obtained from the bending capacity test were similar. The "combined elastic modulus" was 3.395 N/mm² for the conventional 2-layer model, whereas that for the 3-layer model including the coarse graded reinforcing layer was improved by 1.41 times to 4.796 N/mm². The bending capacity of 2-layer model was 6.41 N/mm² whereas that of 3-layer model was improved to 8.1 N/mm² showing about 1.3 times reinforcing effect. Even when considering a reinforcing effect provided by a thickness increase, the test result still clearly shows the reinforcing effect of the method of the present invention.

[0060] The test was performed with the following protocol. The purpose is to confirm a reinforcing effect of a pavement structure constructed with the method of the present invention through laboratory experiments. A compressive strain and a tensile strain at a lower surface of an asphalt pavement under load before and after reinforcing were measured. FIG. 18 shows pavement structures to be compared.

A mixture used for a test is a general mixture satisfying the standard values determined in "Handbook for road pavement construction" and "Marshall procedures for optimum asphalt content of dense graded paving mixtures," a technical material of National Asphalt Pavement Association (NAPA). The table 1 shows the references.

[0061]

Table 1

Mixture	Reference
Dense graded asphalt mixture (13)	Handbook for road pavement construction
Coarse graded asphalt mixture (20)	Handbook for road pavement construction

(continued)

Mixture	Reference
Coarse graded reinforcing asphalt mixture (30)	NAPA technical material

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[0062] FIG. 19 shows a constructing method of a pavement specimen.

In a test, load was applied with 3-point uniform loading by a test machine stipulated in the "JIS A 1106 Method of test for flexural strength of concrete," and a compressive strain and a tensile strain were measured refer to FIG. 20). The strain was measured by a plurality of strain gauges located on an upper and a lower surface of the specimen. The test was performed for 3 specimens for each of the pavement models.

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[0063] A conventional pavement construction method and the method of the present invention were compared by comparing the maximum load at the moment of bending failure of asphalt pavements.

Elastic modulus of each layer was calculated by a reverse analysis of the GAMES using strain occurred at an upper surface and a lower surface of an asphalt pavement to confirm a difference in reinforcing effect of the conventional method and the method of the present invention.

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FIG. 21 shows the test result.

[0064] Since the method of the present invention further includes a rejuvenating agent adding step wherein an asphalt rejuvenating agent is added when mixing the old asphalt mixture with the first new material added therein, and an inter-layer bonding step wherein the remaining layer and the coarse graded reinforcing layer are bonded using an asphalt emulsion or a material for enhancing water-proof property or a bonding property spread over the remaining layer in the coarse graded reinforcing layer forming step, the method can efficiently regenerate a deteriorated asphalt mixture and can minimize influence of damages or deterioration such as cracks in a depth exceeding the boundary surface between the base layer and the surface layer or in the remaining layer by applying the bonding agent between the remaining layer and the coarse graded reinforcing layer.

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Also, since the coarse graded reinforcing layer and the new surface layer were compacted together while heat still being stored, the method can also engage the lower surface of the new surface layer and the upper surface of the coarse graded reinforcing layer together including the aggregates mixed in those layers without applying any bonding agent between the new surface layer and the coarse graded reinforcing layer, and can prevent an inter-layer displacement often caused by layer slippage due to a vertical strain.

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[0065] FIG. 22 to 29 show the outline and result of tests using full-size specimen of each pavement model, performed to quantitatively evaluate a pavement reinforcing effect, i.e. a durability improving effect provided by the coarse graded reinforcing layer. FIG. 22 shows structures of each of pavement specimen used to quantitatively evaluate a pavement reinforcing effect provided by the coarse graded reinforcing layer, which were the structures actually applied to road pavement in urban areas.

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The pavement specimen No. 1 to 4 in FIG. 22 had the following structure. No. 1: a standard pavement structure

No. 2: a pavement structure having a 80mm-thick coarse graded reinforcing layer composed by using a 30mm-thick old surface layer and a 30mm of upper portion of a old base layer

No. 3: a pavement structure having a reduced bearing capacity with a thickness of sub-base reduced by half compared to the standard pavement structure

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No. 4: a pavement structure where the structure of No. 3 being reinforced by a 80mm-thick coarse graded reinforcing layer
A pavement reinforcing effect was compared by performing a Falling Weight Deflection (FWD) test to each of the pavement specimen for measuring displacement occurred to a surface of each of the pavement specimen.

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The design conditions of the pavement specimen were; a traffic loading of 5-ton wheel load, a design daily traffic volume of 100 to 250 vehicles, and a bearing capacity of a roadbed of CBR=8.

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FIG. 23 shows specification of a quality test performed on pavement specimens.

[0066] A pavement reinforcing effect can be evaluated by a number of wheel loads to fatigue failure of a pavement specimen (also referred to as a number of permissible driving wheels). The number of wheel loads to fatigue failure of pavement specimen is a number of wheels necessary to a moment of a crack occurring on the specimen under a repeated application of wheel loads to the pavement surface, and is calculated using values of a tensile strain at a lower surface and a compressive strain at an upper surface of roadbed of an asphalt mixture of a pavement specimen under a 5-ton wheel loading as shown in FIG. 24. The top left figure in FIG. 24 illustrates a conventional pavement structure and the top right figure shows a pavement structure including a coarse graded reinforcing layer. The equations in FIG. 24 are ones for calculating a number of wheel loads to fatigue failure determined by the NAPA.

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[0067]

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FIG. 25 shows the result of the quality test of the pavement specimen and FIG. 26 shows surface displacement measured at a point immediately below a weight fell down (Do) in an FWD test. A surface displacement is a value

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showing a deflection of an asphalt pavement slab caused by a falling weight, and smaller the value higher the bearing capacity. The specimen No. 2 showed a smaller displacement at all measuring points than any other specimens.

FIG. 26 can be interpreted as follows.

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- (1) A structural difference between the specimen No.1 and No. 2 is that No. 2 had a coarse graded reinforcing layer that replaced a top portion of a base layer of No. 1. Since a displacement measured for No. 2 was smaller than that for No. 1, a coarse graded reinforcing layer improved a bearing capacity of a pavement when bearing capacity of roadbed and sub-base are same.
 - 10 (2) The specimen No. 3 and No. 4 had a sub-base in half a thickness of respective one of the specimen No. 1 and No. 2. The purpose of reducing the thickness of the sub-base was to change bearing capacity at an upper surface of a roadbed of the same structure. The result shows a smaller displacement, i.e. a better bearing capacity provided by the coarse graded reinforcing layer, as in (1) above.
 - 15 (3) As for changes in bearing capacity due the decrease in the thickness of the sub-base, when a thickness of sub-base was decreased by 100mm, the bearing capacity of the sub-base showed about 20% decrease, evaluated with equivalent thickness theory according to the TA method.

[0068] FIG. 27 shows a measured elastic modulus of an asphalt mixture using a specimen prepared with materials used for the test pavement construction. The elastic modulus of the asphalt mixture was measured according to "Test Method for Resilient Modulus of Asphalt Mixture" (Supplement volume to Handbook for test method for road pavement) at 25 degrees Celsius. The measured elastic modulus was used as an input value for calculation of a number of wheel loads to fatigue failure of an asphalt pavement described later. A general elastic modulus of an asphalt pavement is 600 to 12,000 MPa according to "Policies for Design and Construction of Road Pavement" (Japan Road Association). As shown in FIG. 27, the elastic modulus of a recycled coarse graded asphalt mixture and that of a coarse graded reinforcing asphalt mixture was greater than that of a recycled dense graded asphalt mixture. This is considered to be owing to an increase of bulk ratio of aggregate content in an asphalt mixture.

[0069] FIG. 28 shows a tensile strain at a lower surface of an asphalt mixture layer and a compressive strain at an upper surface of a roadbed of the pavement specimens calculated using the GAMES. An elastic modulus of an asphalt mixture measured in a resilient modulus test and a layer thickness of each pavement specimen was used as the input value for a calculation program.

The graph on top of FIG. 28 can be interpreted as follows.

- 35 (1)The higher value of tensile strain at a lower surface of an asphalt mixture layer shows that the asphalt mixture layer is more prone to cracking failure. Comparing the specimen No. 1 and No. 2, the tensile strain of No. 2 was about a half of that of No. 1 indicating that No. 2 was less prone to cracking failure.
- (2) Comparing the specimen No. 2 and No. 4, although the thickness of sub-base of No. 4 was a half of 200mm of No. 2, the value of the tensile strain was similar to that of No. 2. This indicates that even when a bearing capacity of a sub-base was reduced (estimated to be a 20% decrease in this case), a coarse graded reinforcing layer provided a load distribution to improve a resistance against cracking failure of an asphalt mixture.

[0070] The graph on bottom of FIG. 28 can be interpreted as follows.

- 45 (1)The higher value of compressive strain at an upper surface of a roadbed shows that the pavement is more prone to deformation (rutting) caused by wheel loads. Comparing the specimen No. 1 and No. 2, No. 2 shows less compression of the whole pavement owing to a pavement thickness increase provided by the coarse graded reinforcing layer.
- (2) Comparing the specimen No. 1 and No. 4, the total thickness pavement of No. 1 was slightly more than that of No. 4. No. 4 was provided with the coarse graded reinforcing layer though the thickness of the sub-base was reduced to 100mm. The compressive strain measured at the upper surface of the roadbed of No. was slightly smaller than that of No. 1 showing constraining of a compressive deformation provided by the coarse graded reinforcing layer.

[0071] The table in FIG. 29 shows a relationship between a design traffic volume specified in the Policies for Design and Construction of Road Pavement and a number of wheel loads to fatigue failure and the graph in FIG. 29 shows a number of wheel loads to fatigue failure for each specimen calculated by substituting values of tensile strain and compressive strain to the equations shown in FIG. 24. The number of wheel loads to fatigue failure shown in FIG. 29 is a smaller one of N_{fa} or N_{ab} calculated with the equations shown in FIG. 24. FIG. 29 can be interpreted as follows.

(1) The number of wheel loads to fatigue failure for the specimen No. 2 provided with the coarse graded reinforcing layer is about 950,000 that is more than 6 times greater than that of the specimen No. 1. This indicates that the coarse graded reinforcing layer provided improvement durability of an asphalt pavement. As a result, the design traffic volume class of the specimen No. 2 is 1 class higher than that of No. 1.

(2) While the number of wheel loads to fatigue failure for the specimen No. 3 is about 50,000, the number of wheel loads to fatigue failure for the specimen No. 4 provided with the coarse graded reinforcing layer is about 250,000 that is about 5 times greater than that of the specimen No. 3.

This indicates that even when a bearing capacity of a sub-base was reduced due to the reduced thickness of the sub-base, a coarse graded reinforcing layer provided an improvement of durability of a road pavement.

BRIEF DESCRIPTION OF FIGURES

[0072]

FIG. 1 illustrates impact of traffic to an asphalt pavement.

FIG. 2 illustrates a sectional view of a general asphalt pavement.

FIG. 3 shows a particle size distribution of aggregates in an asphalt mixture.

FIG. 4 shows a relationship between a temperature and a viscosity of asphalt.

FIG. 5 illustrates a remixing method (1) and a repaving method (2) for heating on-site pavement recycling methods.

FIG. 6 illustrates a continuous on-site repaving of an asphalt mixture layer of a road pavement by forming a coarse graded reinforcing layer for reinforcing an asphalt mixture layer according to the present invention.

FIG. 7 shows steps of a method for a continuous on-site repaving of an asphalt mixture layer of a road pavement according an embodiment of the present invention.

FIG. 8 is a schematic diagram of a motor-driven vehicle system for a continuous on-site repaving of an asphalt mixture layer of a road pavement according an embodiment of the present invention.

FIG. 9 is a schematic diagram of a heating apparatus 100 of the pre-heater vehicle (A) in the motor-driven vehicle system according an embodiment of the present invention.

FIG. 10 is a schematic diagram of a milling apparatus 300 of the miller vehicle (B) in the motor-driven vehicle system wherein a carry-in opening for a first new material being formed according an embodiment of e present invention.

FIG. 11 is a schematic diagram of a milling apparatus 300 of the miller vehicle (B) in the motor-driven vehicle system wherein a carry-in device for a second new material being formed according an embodiment of the present invention.

FIG. 12 is a schematic diagram of a milling apparatus 300 of the miller vehicle (B) linked with another vehicle according an embodiment of the present invention.

FIG. 13 is a schematic diagram of a heating apparatus 500 of the mixing vehicle (C) in the motor-driven vehicle system according an embodiment of the present invention.

FIG. 14 shows an analysis result of a particle size distribution and a particle distribution of an aggregate wherein 40mm of a surface layer and 20mm of a base layer is mixed with a new material of class #4 ballast at ratio of 7:3.

FIG. 15 illustrates a pavement structure and an analysis result using the GAMES for a standard pavement.

FIG. 16 illustrates a pavement structure and an analysis result using the GAMES for a pavement wherein a surface layer is regenerated with a new asphalt mixture having a substantially same aggregate particle size distribution.

FIG. 17 illustrates a pavement structure and an analysis result using the GAMES for a pavement wherein an asphalt mixture layer for 100mm, a depth exceeding a boundary surface between a surface layer and base layer of a standard pavement model is repaved with the method according to the present invention.

FIG. 18 is a schematic diagram of a pavement structure comparison.

FIG. 19 shows a work flow for preparing a pavement specimen.

FIG. 20 is a schematic diagram of a test for measuring a compressive strain and a tensile strain under 3-point uniform loading using a test machine specified in Method for bending capacity test of asphalt concrete.

FIG. 21 compares measured values from a test based on the GAMES for a conventional 2-layer pavement model and a 3-layer pavement model including a coarse graded reinforcing layer.

FIG. 22 illustrates pavement structures of full size specimens used to quantitatively evaluate a reinforcing effect provided by a coarse graded reinforcing layer.

FIG. 23 is a table showing specifications of a quality test of pavement specimens.

FIG. 24 illustrates locations of a tensile strain and a compressive strain and the equations for calculating a number of wheel loads to fatigue failure of pavement specimens.

FIG. 25 shows the result of a quality test of pavement specimens.

FIG. 26 shows a displacement at a surface of the pavement specimens measured in a FWD test.

FIG. 27 shows a measured elastic modulus of an asphalt mixture using a specimen prepared with materials used for the test pavement construction.

FIG. 28 shows values of a tensile strain and a compressive strain measured for the pavement specimens.
 FIG. 29 shows a relationship between a design daily traffic volume and a number of wheel load to fatigue failure specified in the Policies for Design and Construction of Road Pavement and a number of wheel loads to fatigue failure for each specimen calculated by substituting values of tensile strain and compressive strain to the equations shown in FIG. 24.

Claims

1. A method for continuous on-site repaving of an asphalt mixture layer of a road pavement with a motor-driven vehicle system therefor, comprising the steps of;
 - (a) applying heat to a surface of the asphalt mixture layer so as to allow the heat to reach to a depth exceeding a boundary surface between a base layer and a surface layer of the asphalt mixture layer or to a depth within the asphalt mixture layer equivalent to the depth exceeding the boundary surface and softening the asphalt mixture layer,
 - (b) scarifying the heated and softened asphalt mixture layer to the depth exceeding the boundary surface between the base layer and the surface layer of the asphalt mixture layer or to the depth within the asphalt mixture layer equivalent to that depth exceeding the boundary surface to obtain an old asphalt mixture,
 - (c) adding a first new material to the old asphalt mixture, the first new material being stored in a storage apparatus at a temperature preventing re-aggregation, the first new material being any of a coarse aggregate, a coarse aggregate covered with asphalt or an asphalt mixture having a particle size distribution including coarse aggregate mixed therein,
 - (d) mixing the first new material with the old asphalt mixture to form a reinforcing asphalt mixture,
 - (e) spreading the reinforcing asphalt mixture over the remaining layer of the asphalt mixture layer left un-scarified in the step (b) to form a coarse graded reinforcing layer having an elastic modulus greater than that of the remaining layer,
 - (f) adding a second new material onto the formed coarse graded reinforcing layer, the second new material being stored in storage apparatus at a temperature preventing re-aggregation, the second new material being a fresh asphalt mixture for a new surface layer,
 - (g) spreading the second new material to form the new surface layer, wherein the step of spreading the second new material being linked with the step (e), and,
 - (h) compacting the coarse graded reinforcing layer formed over the remaining layer and the new surface layer together while heat still being stored.
2. The method as defined in claim 1, further comprising a step of carrying in, prior to said step (b), the first new material and the second new material at different timings conveyed from outside the motor-driven vehicle system to respective one of the storing apparatus coincidentally with the different timings.
3. The method as defined in any of claims 1 or 2, wherein the first new material is any one of an aggregate or aggregate covered with asphalt having a greater diameter than the greatest diameter of an aggregate included in the asphalt mixture layer or an asphalt mixture having a particle size distribution including coarse aggregate mixed therein having a greater diameter than the greatest diameter of an aggregate included in the asphalt mixture layer.
4. The method as defined in any of claims 1 to 3, wherein the reinforcing asphalt mixture includes an aggregate having a greater diameter than the greatest diameter of an aggregate included in the asphalt mixture layer for 5 to 35 weight % to the total weight.
5. The method as defined in any of claims 1 to 4, wherein said step (d) further comprises a step of adding an asphalt rejuvenating agent when mixing the old asphalt mixture with the first new material added therein.
6. The method as defined in any of claims 1 to 5, wherein the second new material is an asphalt mixture including an aggregate having a substantially same particle size distribution as that of an aggregate included in the asphalt mixture layer.
7. The method as defined in any of claims 1 to 6, wherein said step (e) further comprises a step of spreading an asphalt emulsion or a material for enhancing water proof property and bonding property over the remaining layer to bond the remaining layer and the coarse graded reinforcing layer.

8. A motor-driven vehicle system for continuous on-site repaving of an asphalt mixture layer of road pavement comprising:

5 a pre-heater vehicle for applying heat to a surface of the asphalt mixture layer of road pavement so as to allow the heat to reach to a depth exceeding a boundary surface between a base layer and a surface layer of the asphalt mixture layer or to a depth within the asphalt mixture layer equivalent to the depth exceeding the boundary surface and thereby to soften the asphalt mixture layer;

a miller vehicle including

10 a first tank for storing a first new material at a temperature preventing re-aggregation, the first new material being any of a coarse aggregate, a coarse aggregate covered with asphalt or an asphalt mixture having a particle distribution including a coarse aggregate,

a scarifying means for scarifying the heated and softened asphalt mixture layer to the depth exceeding the boundary surface e or to the depth within the asphalt mixture layer equivalent to the depth exceeding the boundary surface to obtain an old asphalt mixture, and,

15 a first adding means for adding the first new material stored at a temperature preventing re-aggregation and discharged out of the first tank to the old asphalt mixture;

and,

a mixer vehicle including;

20 a second tank for storing a second new material at a temperature preventing re-aggregation, the second new material being a fresh asphalt mixture for a new surface layer,

a mixing means for receiving the old asphalt mixture which the first new material is added therein and mixing the first new material with the old asphalt mixture to obtain a reinforcing asphalt mixture,

25 a first screed for spreading the reinforcing asphalt mixture over a remaining layer of the asphalt mixture layer left un-carified by the scarifying means to form a coarse graded reinforcing layer having an elastic modulus greater than that of the remaining layer,

a second adding means for adding the second new material stored at a temperature preventing re-aggregation and discharged out of the second tank over the coarse graded reinforcing layer, and,

30 a second screed for spreading the added second new material to form a new surface layer, an operation of the second screed being linked with an operation of the first screed.

9. The motor-driven vehicle system as defined in claim 8, further comprising a compacting means for compacting the coarse graded reinforcing layer formed over the remaining layer and the new surface layer formed over the coarse graded reinforcing layer together while heat still being stored.

- 35 10. The motor-driven vehicle system as defined in any of claims 8 or 9, wherein the miller vehicle further comprises a relaying receiving-discharging apparatus for receiving and discharging the first and the second new material carried in at different timings from outside the motor-driven vehicle system, and a new material conveying apparatus including at least 2 continuous conveying paths and having a switching apparatus for carrying the first and the second new material discharged from the relaying receiving-discharging apparatus respectively into the first and the second tank coincidentally with the different timings, wherein, when the first new material is carried from the relaying receiving-discharging apparatus to the first tank, the switching apparatus disconnects the at least 2 continuous conveying paths of the new material conveying apparatus to form a carry-in opening and the first new material is carried into the first tank via the carry-in opening wherein, when the second new material is carried from the relaying receiving-discharging apparatus into the second tank, the switching apparatus closes the carry-in opening formed in the new material conveying apparatus to form 1 conveying path by connecting the at least 2 conveying paths and the second new material is carried from the relaying receiving-discharging apparatus into the second tank via the 1 conveying path.

- 50 11. The motor-driven vehicle system as defined in any of claims 8 to 10, wherein the first new material is any one of an aggregate or aggregate covered with asphalt having a greater diameter than the greatest diameter of aggregate included in the asphalt mixture layer or an asphalt mixture having a particle size distribution including coarse aggregate mixed therein having a greater diameter than the greatest diameter of an aggregate included in the asphalt mixture layer.

- 55 12. The motor-driven vehicle system as defined in any of claims 8 to 11, wherein the reinforcing asphalt mixture includes an aggregate having a greater diameter than the greatest diameter of an aggregate included in the asphalt mixture layer for 5 to 35 weight % to the total weight.

EP 2 221 415 A1

13. The motor-driven vehicle system as defined in any of claims 8 to 12, wherein the second new material is an asphalt mixture including an aggregate having a substantially same particle size distribution as that of an aggregate included in the asphalt mixture layer.

5 **14.** The motor-driven vehicle system as defined in any of claims 8 to 13, wherein the mixer vehicle further comprises a rejuvenating agent adding means for adding an asphalt rejuvenating agent when mixing the old asphalt mixture with the first new material added therein.

10 **15.** The motor-driven vehicle system as defined in any of claims 8 to 14, wherein the mixer vehicle further comprises a third tank for storing an asphalt emulsion for bonding the remaining layer and the coarse graded reinforcing layer or a material for enhancing water proof property and bonding property.

15 **16.** The motor-driven vehicle system as defined in any of claims 8 to 15, wherein the mixer vehicle further comprises a storing space arranged between the mixing means and the first screed, for adjusting a supply volume of the reinforcing asphalt mixture onto the remaining layer.

20 **17.** The motor-driven vehicle system as defined in any of claims 8 to 16, wherein the mixer vehicle further comprises a storing space arranged between the first screed and the second screed, for adjusting a supply volume of the second material onto the coarse graded reinforcing layer.

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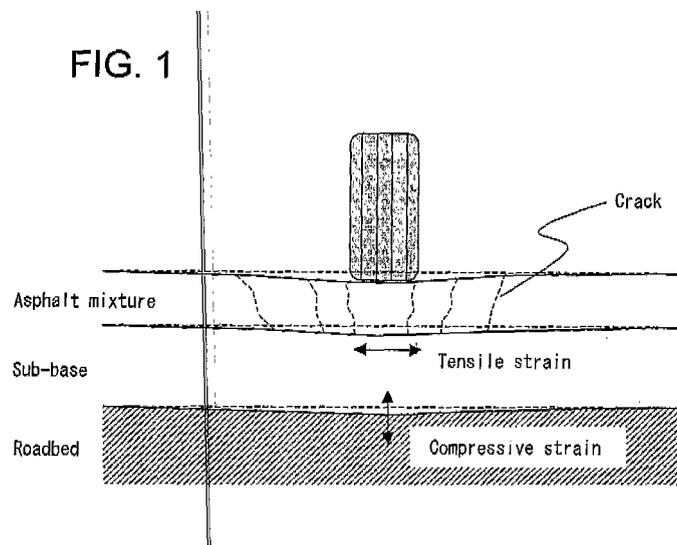
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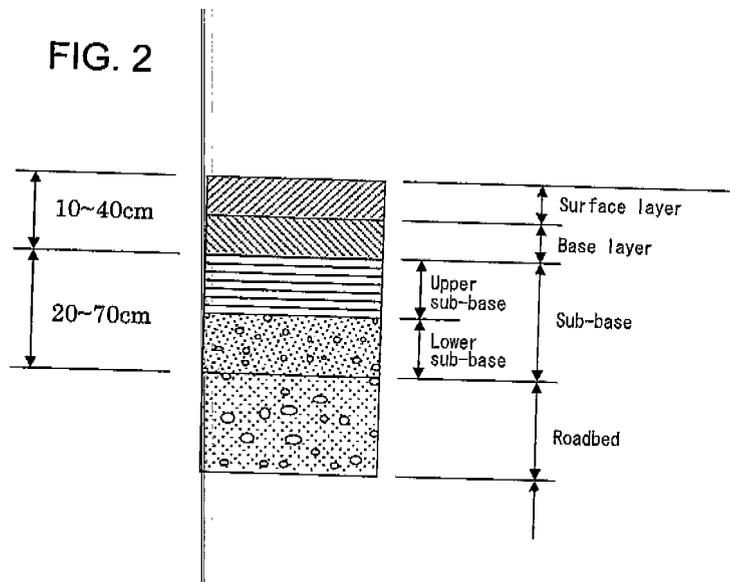


FIG. 3

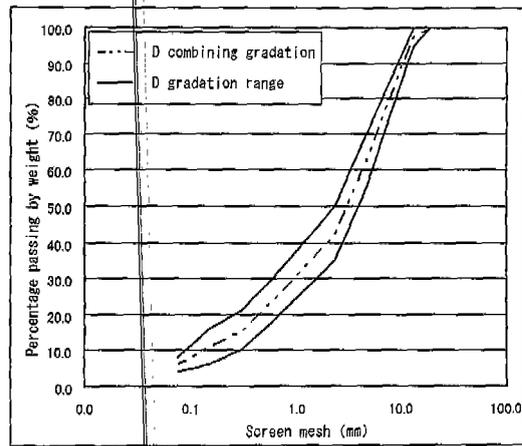


FIG. 4

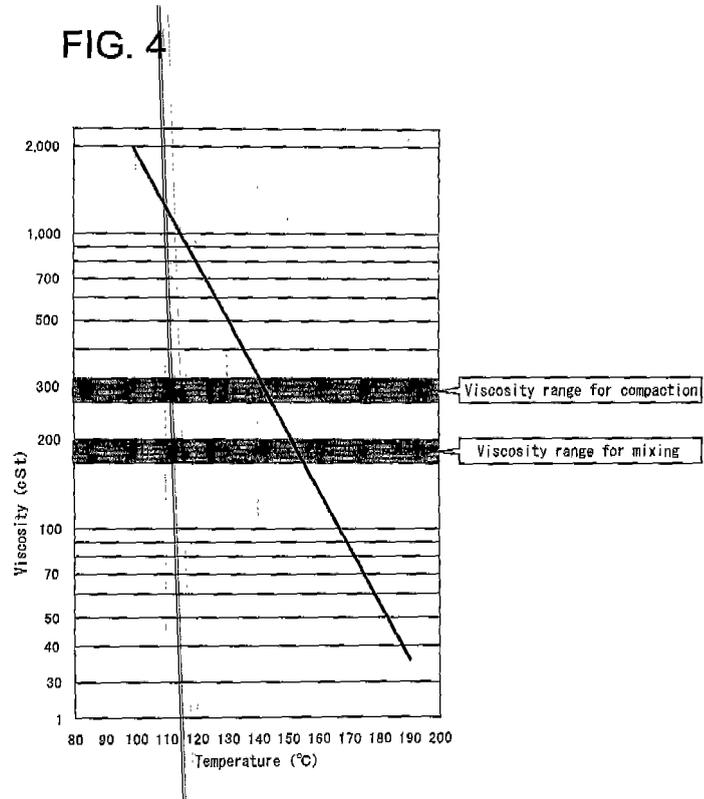
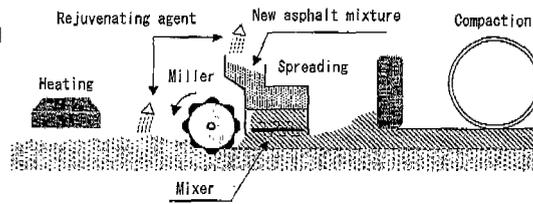


FIG. 5

HIR(Hot in Place Recycling)

(1) Remixing method



(2) Repaving method

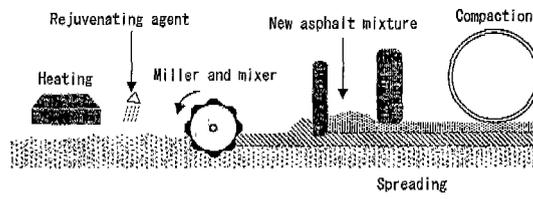


FIG. 6

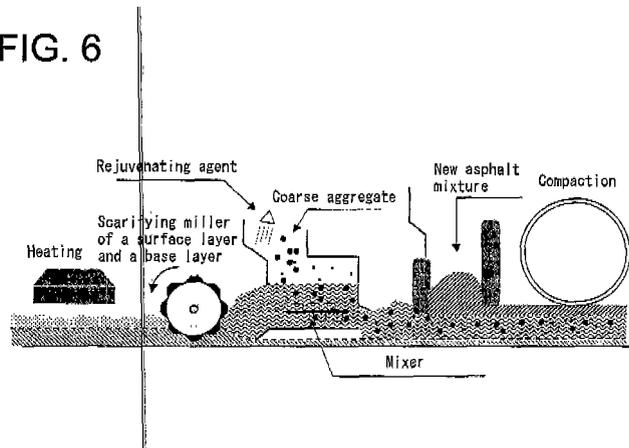


FIG. 7

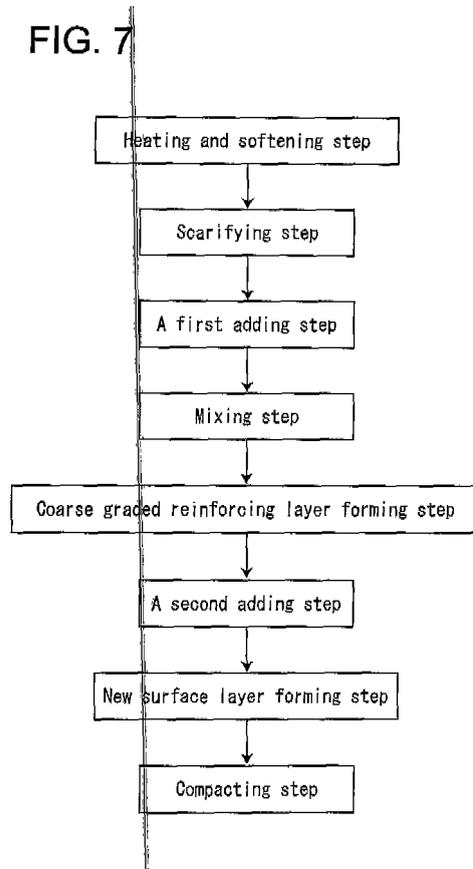
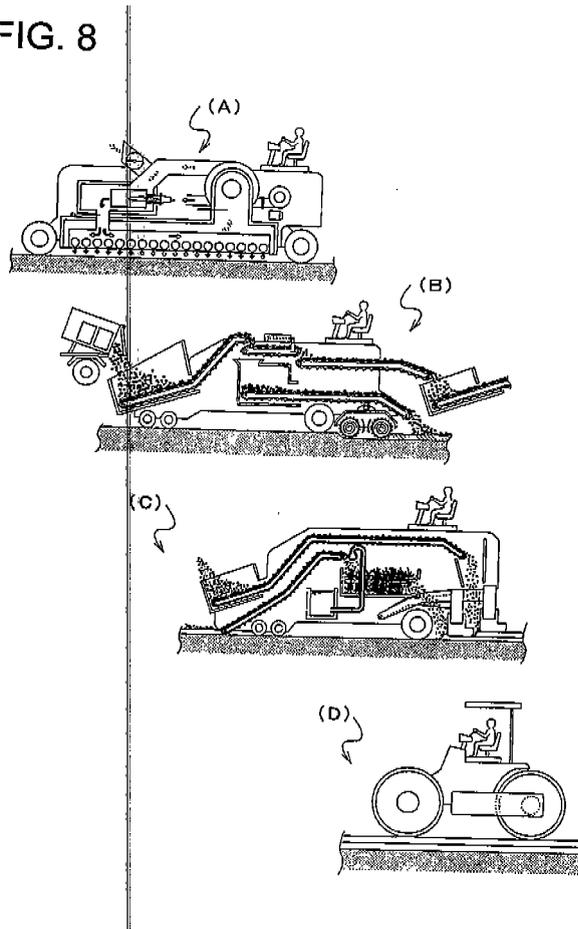
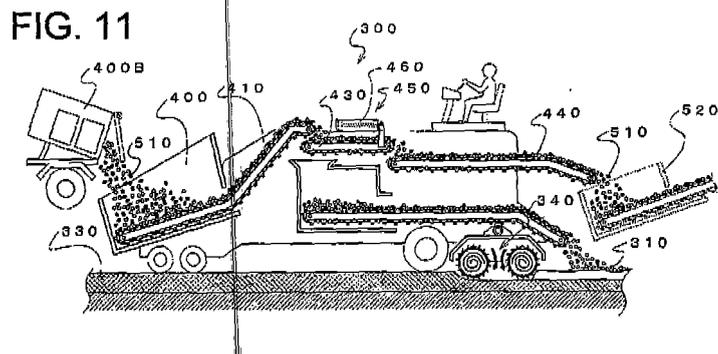
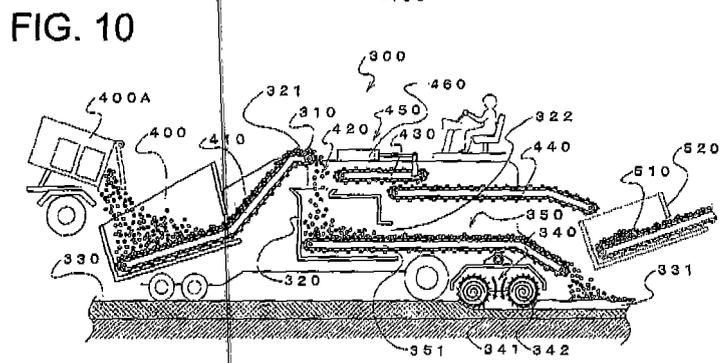
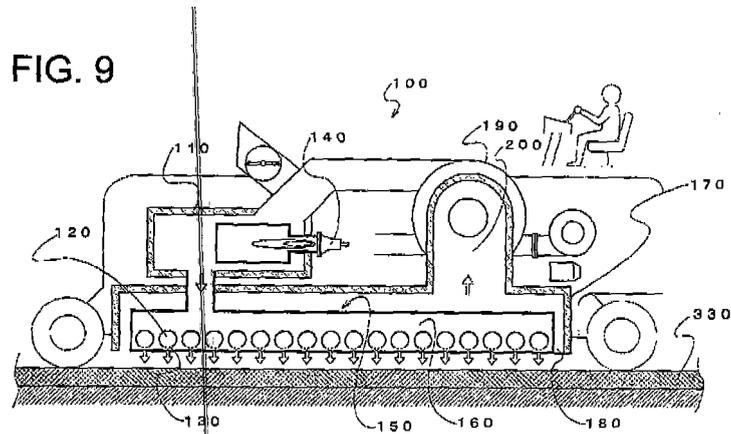


FIG. 8





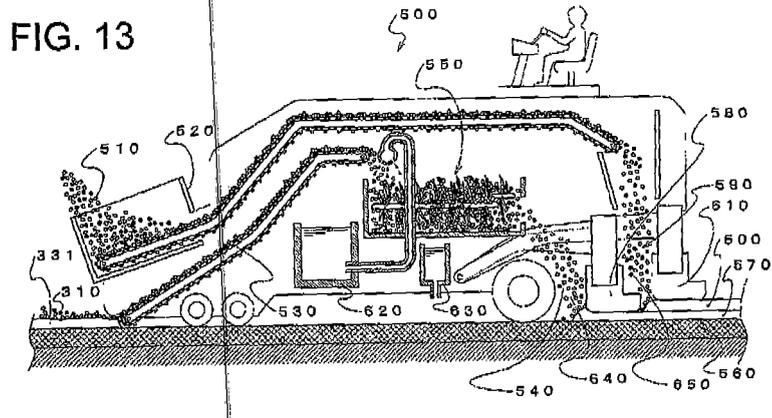
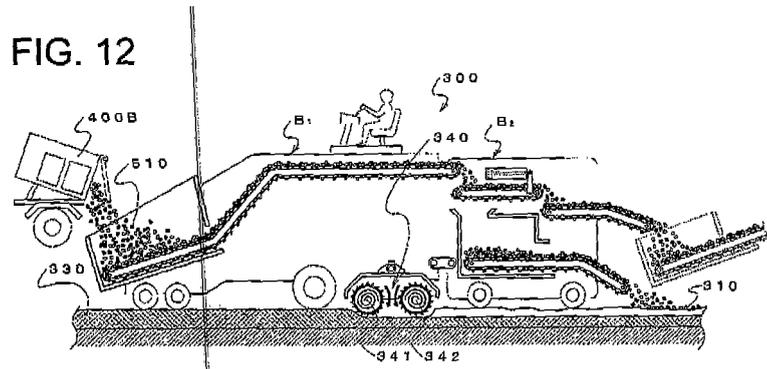


FIG. 15

An arbitrary pavement structure

Pavement model Classification of traffic volume C-class traffic volume
(1000~3000vehicles/daydirection)

Wheel load (P) 5t

Wheel contact radius (r) $r = P + 12$

Pavement model 4-layer model

		E (kgf/cm ²)	(cm)	
Surface layer	Dense graded asphalt mixture	E1	24000	5
Base layer	Coarse graded asphalt mixture	E2	24000	12
Upper sub-base	Particle size adjusted ballast	E4	5000	25
Lower sub-base	Crusher-run	E5	4000	35
Roadbed	CBR=10	E6	1000	

Pavement model: Load bearing capacity evaluation of an asphalt pavement by Falling Weight Deflection (FWD) test
Fukuoka Public Works Office, Fukuoka Prefectural Government: Chikushino-Koga Line (pavement constructed in 1999)

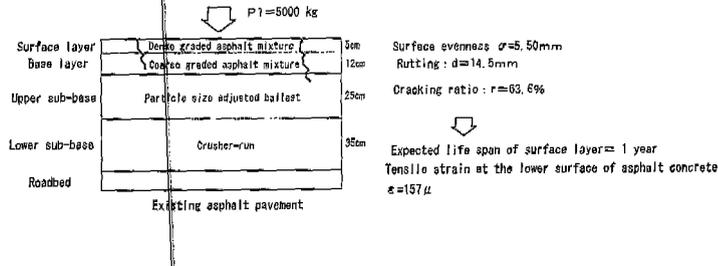


FIG. 16

Pavement structure by milling and overlaying method

Pavement model 4-layer model Milling and overlaying

		E (kgf/cm ²)	(cm)
Surface layer	Dense graded asphalt mixture	E1	35000
Base layer	Coarse graded asphalt mixture	E2	24000
Upper sub-base	Particle size adjusted ballast	E4	5000
Lower sub-base	Crusher-run	E5	4000
Roadbed	CBR=10	E6	1000

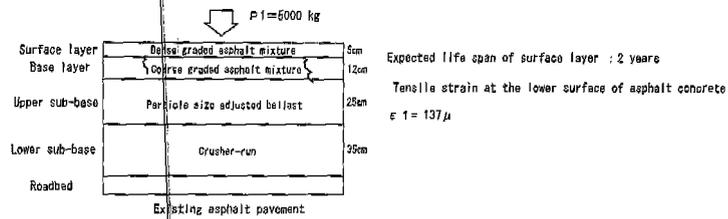


FIG. 17

Pavement structure by HI-S reinforcing method

		E (kgf/cm ²)		(cm)
Surface layer	Dense graded asphalt mixture	E0	24000	3
Middle layer	Coarse graded reinforcing layer	E1	50000	14
Base layer	Coarse graded asphalt mixture	E2	2400	7
Upper sub-base	Particle size adjusted ballast	E4	5000	25
Lower sub-base	Crusher-run	E5	4000	35
Roadbed	CBR=10	E6	1000	

Structure change: 5cm of surface layer and 5cm of base layer were replaced with coarse graded pavement

Wheel load (P): The current elastic modulus is used for calculation for 7cm from the bottom of the old base layer

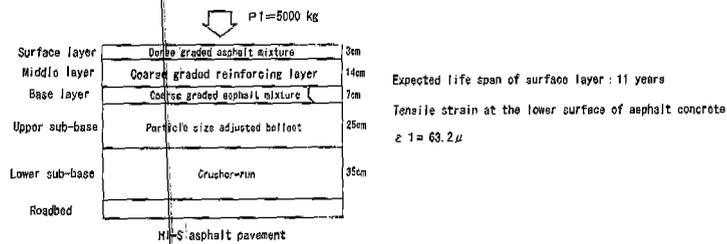


FIG. 18

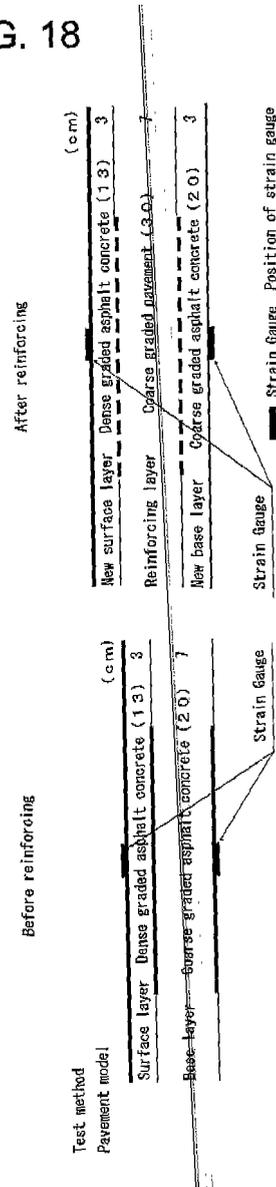


FIG. 19

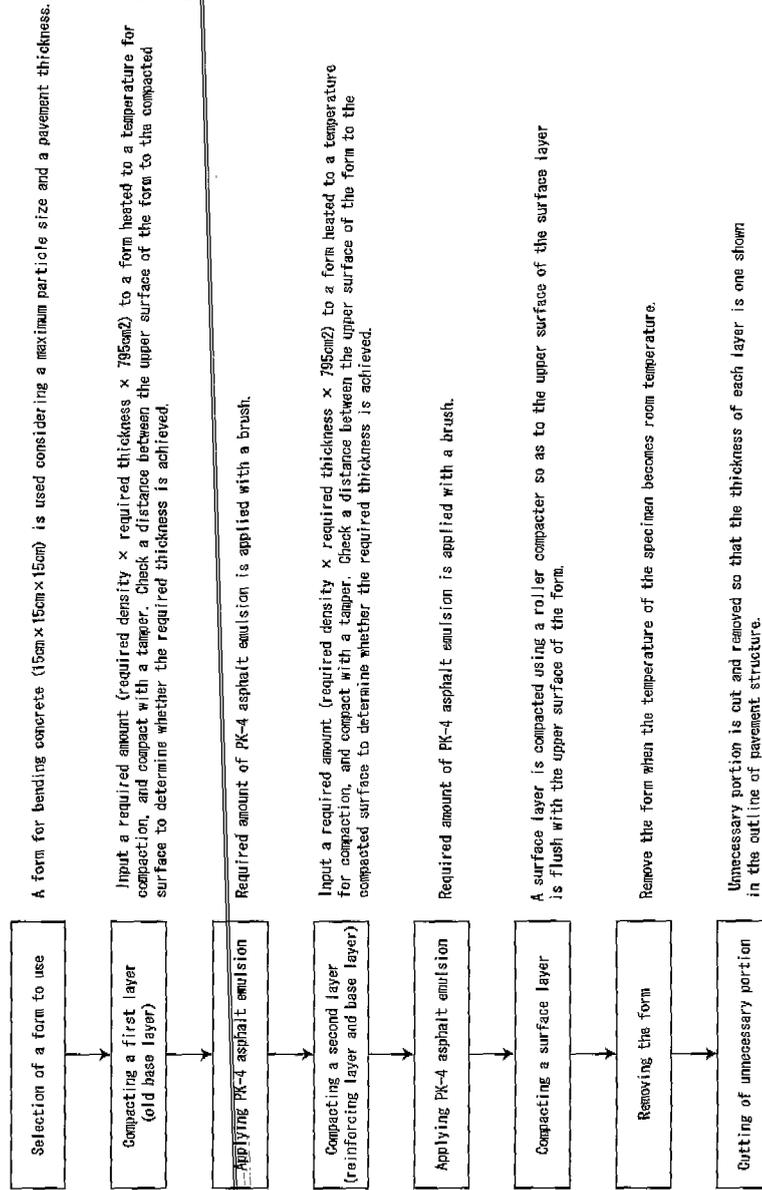


FIG. 20

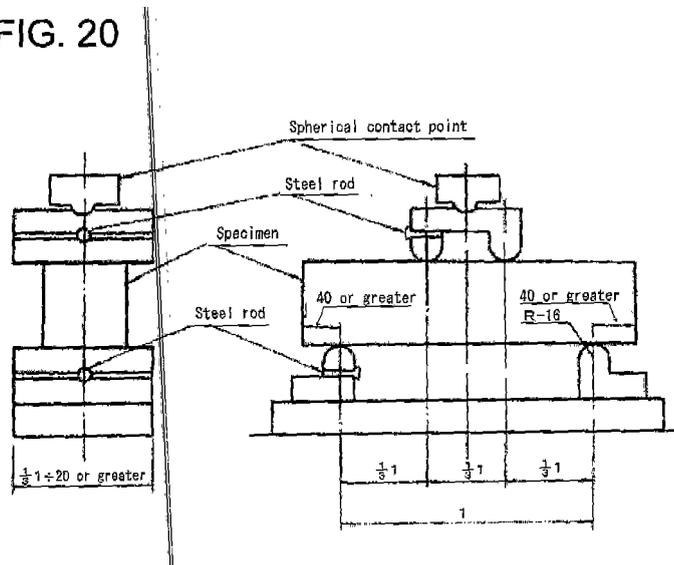
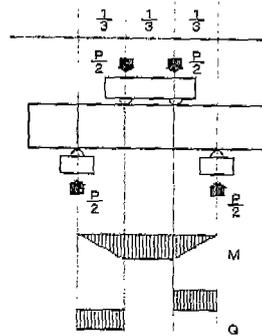


FIG. 21



2-point concentrated loading

Elastic modulus and strain specific to a surface layer and a base layer in 2-layer pavement model, or a surface layer, a middle layer and a base layer in 3-layer model were calculated based on a bending capacity, a strain at the upper surface of the specimen, a strain at the lower surface of the specimen, and a thickness of each layer obtained in the bending capacity test of the specimen. As a result, the elastic modulus used in a numerical analysis was found similar to that calculated from the bending capacity test to confirm that a deformation resistance of an asphalt pavement can be improved by reinforcing a middle layer, which was a condition of the analysis.

2-layer model

	Measured value				Calculated value				Remark Elastic modulus of each layer used for analysis E_n N/mm ²		
	Measured bending capacity σ N/mm ²	Strain in specimen		Thickness t	Elastic modulus of each layer E_n N/mm ²	Combined elastic modulus E_{ALL} N/mm ²	Bending stress of each layer σ N/mm ²	Strain in each layer			
		Position	μ					Position		μ	
Surface layer	8.4	Upper surface	-	1.13E-03	3	3,920	3.63	Upper	-	1.13E-03	3430
		Lower surface	+	6.76E-04				Lower	+	6.76E-04	
Base layer		Upper surface	-	1.91E-03	7	2,185	6.48	Upper	-	1.20E-03	2352
	Lower surface	+	2.03E-03	Lower				+	2.03E-03		

3-layer model

	Measured value				Calculated value				Remark Elastic modulus of each layer used for analysis E_n N/mm ²		
	Measured bending capacity σ N/mm ²	Strain in specimen		Thickness t	Elastic modulus of each layer E_n N/mm ²	Combined elastic modulus E_{ALL} N/mm ²	Bending stress of each layer σ N/mm ²	Strain in each layer			
		Position	μ					Position		μ	
Surface layer	8.1	Upper surface	-	1.50E-03	3	3,920	7.21	Upper	-	1.50E-03	3430
		Lower surface	+	1.84E-03				Lower	+	1.84E-03	
Middle layer		-	-	-	7	5,390	4,798	Upper	-	1.34E-03	4900
	Lower surface	+	1.34E-03	Lower				+	1.34E-03		
Base layer		Upper surface	-	1.63E-03	3	4,410	8.32	Upper	-	1.63E-03	2352
	Lower surface	+	1.89E-03	Lower				+	1.89E-03		

FIG. 22

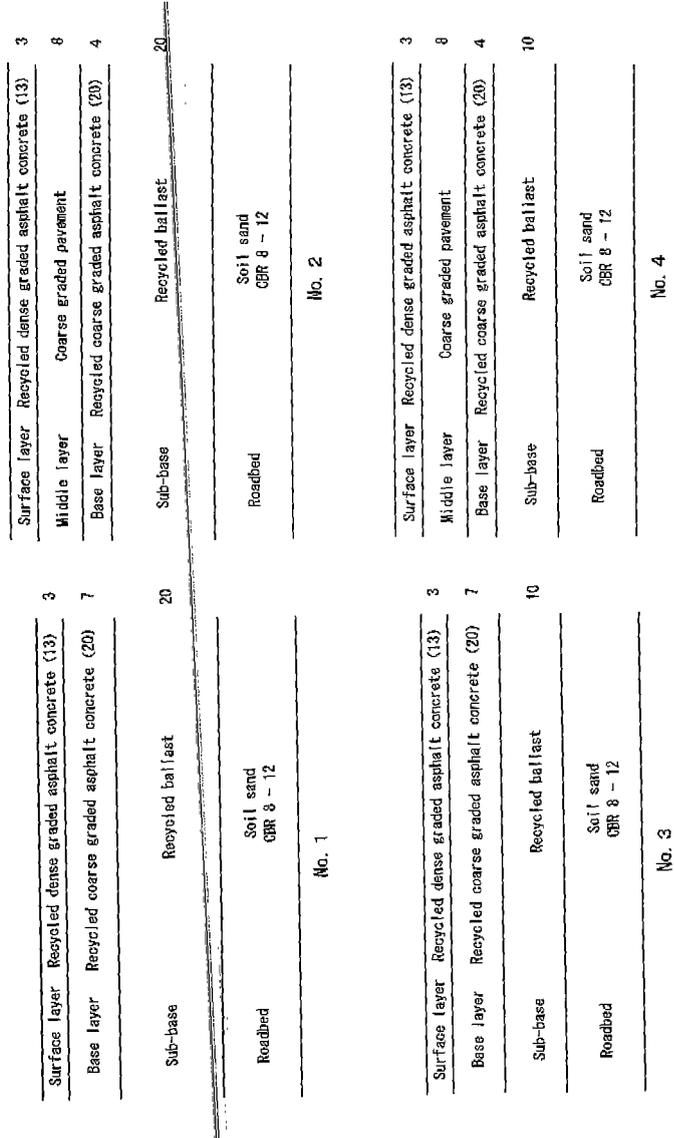
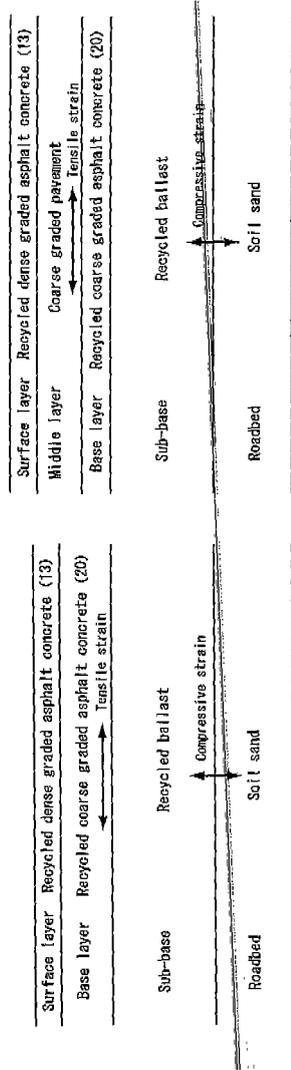


FIG. 23

Test name	Test period	Test location	Test specification
1 Roadbed California Bearing Ratio (CBR) test	When a roadbed was constructed	Within 1 m from the upper surface of the roadbed	CBR test method (JIS A 1211) CBR, one of the indices of a supporting capacity of a roadbed, is measured.
2 Plate loading test	After a sub-base was constructed	Upper surface of the sub-base	Plate loading test (JIS A 1205) A supporting capacity coefficient, one of the indices of a supporting capacity of a roadbed, is measured.
3 Compaction test			Sand replacing method (JIS A 1204) On-site density of a sub-base is obtained.
4 Falling Weight Deflection test	After asphalt pavement was constructed	Upper surface of the surface layer	Supporting capacity characteristics of pavement is tested.
5 Asphalt mixture test	Sampled when asphalt pavement was constructed		Measurement of elastic modulus Elastic modulus of an asphalt mixture is obtained.

FIG. 24



$$N_{fa} = \frac{8.108 \times 10^{(M-3)}}{\varepsilon_t^{3.291} \times E^{0.854}} \quad N_{fs} = \frac{1.365 \times 10^{-9}}{(\varepsilon_c \times 10^{-6})^{4.477}}$$

$$M = 4.84 \times \left\{ \left[\frac{V_b}{(V_p - V_b)} \right] - 0.69 \right\}$$

- ε_t Tensile strain at the lower surface of an asphalt mixture
- ε_c Compressive strain at the upper surface of roadbed
- EA Elastic modulus of an asphalt mixture
- M A function of an asphalt amount and porosity of an asphalt mixture
- V_p Porosity of an asphalt mixture
- V_b Asphalt amount in an asphalt mixture
- N_{fa} Number of wheel loads for fatigue failure by the tensile strain at the lower surface of an asphalt mixture
- N_{fs} Number of wheel loads for fatigue failure by the compressive strain at the upper surface of roadbed

FIG. 25

Test name	Test period	Test location	Unit	Test result				
				No. 1	No. 2	No. 3	No. 4	Average value
1 Roadbed CBR test	When a roadbed was constructed	Within 1 m from the upper surface of the roadbed	CBR	7.3	8.4	6.6	9.8	8.0
2 Plate loading test	After a sub-base was constructed	Upper surface of the sub-base	K30	86.4	170	78	114.8	112
3 Compaction test			%	98.8	99.6	99.5	99.5	99.4
4 FWD test	After an asphalt pavement was constructed	Upper surface of surface layer	D0	0.96	0.95	1.17	1.00	1.00
			D20	0.817	0.613	0.978	0.845	0.81
			D150	0.067	0.03	0.116	0.069	0.07

FIG. 26

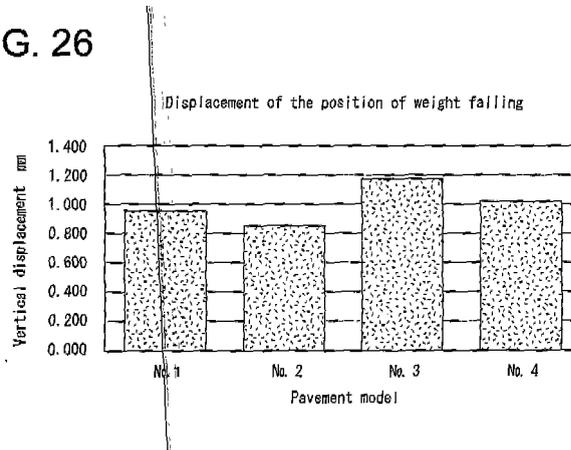


FIG. 27

Test name	Test period	Test location	Unit	Test result
			M Pa	Recycled dense graded asphalt concrete 4486
Asphalt mixture test	Sampled when an asphalt pavement was constructed	Measurement of elastic modulus	M Pa	Recycled coarse graded asphalt concrete 4760
			M Pa	Coarse graded pavement 4850

FIG. 28

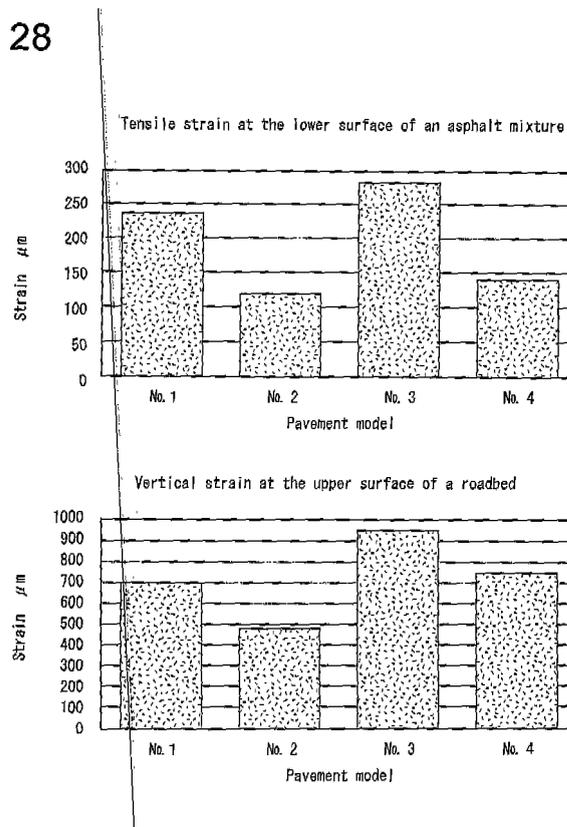
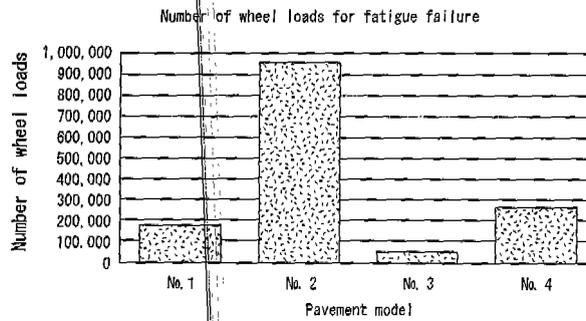


FIG. 29

Designed daily traffic volume	Number of wheel loads for fatigue failure (wheels/10 years)	Remark
$3000 < T$	35,000,000	
$1000 < T < 3000$	7,000,000	
$250 < T < 1000$	1,000,000	Pavement model No. 2
$100 < T < 250$	150,000	Pavement model No. 1
$T < 100$	30,000	



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2008/003292

A. CLASSIFICATION OF SUBJECT MATTER <i>E01C23/00</i> (2006.01) i		
According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED		
Minimum documentation searched (classification system followed by classification symbols) <i>E01C23/00</i>		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched Jitsuyo Shinan Koho 1922-1996 Jitsuyo Shinan Toroku Koho 1996-2009 Kokai Jitsuyo Shinan Koho 1971-2009 Toroku Jitsuyo Shinan Koho 1994-2009		
Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) CiNii		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 3849124 B1 (Green Arm Co., Ltd.), 22 November, 2006 (22.11.06), Full text; all drawings (Family: none)	1-17
A	JP 2004-124549 A (NIPPO Corp.), 22 April, 2004 (22.04.04), Full text; all drawings (Family: none)	1-17
A	JP 2004-011406 A (Hidemi YOSHIKAWA), 15 January, 2004 (15.01.04), Full text; all drawings (Family: none)	1-17
<input checked="" type="checkbox"/> Further documents are listed in the continuation of Box C. <input type="checkbox"/> See patent family annex.		
* Special categories of cited documents: "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier application or patent but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family		
Date of the actual completion of the international search 10 February, 2009 (10.02.09)		Date of mailing of the international search report 24 February, 2009 (24.02.09)
Name and mailing address of the ISA/ Japanese Patent Office		Authorized officer
Facsimile No.		Telephone No.

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INTERNATIONAL SEARCH REPORT

International application No. PCT/JP2008/003292
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C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	Hisashi HOSOKAWA, Atsuki GOMI, "Rojo Hyoso Saisei Koho ni yoru Kankyo Fuka Teigen -Minaosareru Rojo Hyoso Saisei Koho-", Kensetsu no Seko Kikaku, The July issue, Japan Construction Mechanization Association, 25 July, 2005 (25.07.05), pages 42 to 46	1-17

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REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- US 4534674 A [0012] [0014]
- JP 4024293 B [0013] [0014]