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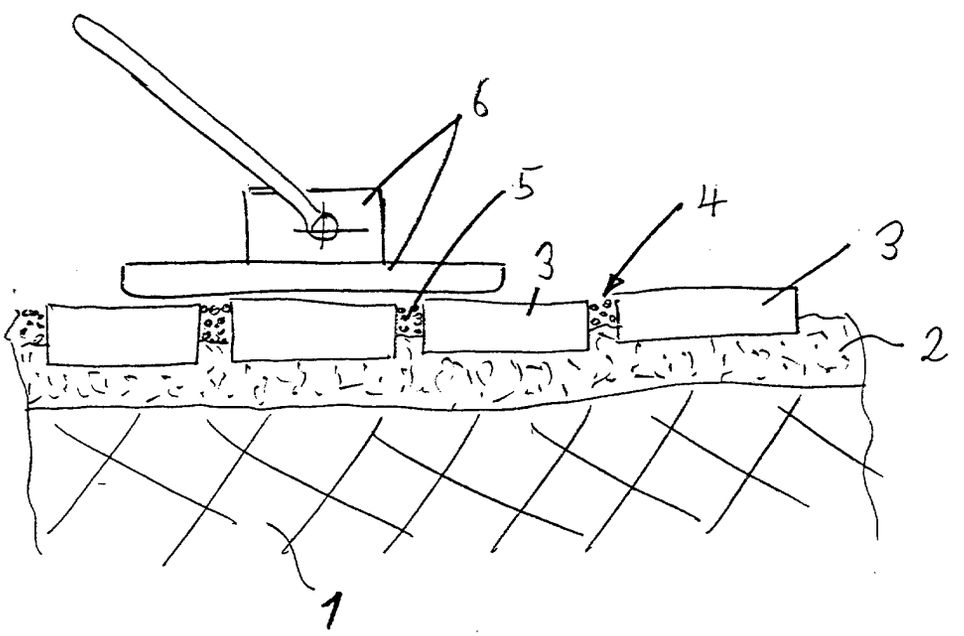
(54) Road surface and method for its construction

(57) A road surface for areas used by vehicular traffic comprises a pavement which is supported by a roadbed (1) and is made of prefabricated paving stones (3), in particular concrete paving stones, that are laid on a bituminous sand bed (2), wherein the weight of the bitumen component of the sand bed (2) amounts to between about 1.5% and 2.5% of the overall weight of the sand bed.



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Description

[0001] The invention relates to a surface for roads used by vehicular traffic, comprising a road pavement which is supported by a roadbed and comprises prefabricated paving stones made of natural or artificial materials, in particular concrete paving stones, that are laid on a bituminous sand bed, as well as a method for the construction of such a road surface.

[0002] The known coverings designed to strengthen roads used by vehicular traffic, in addition to uninterrupted surfaces made of material that becomes hard, such as concrete or asphalt, also include surfaces made of paving stones, in particular concrete paving stones. Surfaces of the latter type have proved useful in particular for courtyards, the entrances to petrol stations, streets where traffic is restricted and the like. The advantage is that when individual stones become damaged, the roadway can be fully repaired merely by replacing these particular stones. Furthermore, when work on the roadbed is to be carried out it can be accessed without problem and, when the work is completed, the road surface can be restored to its original state. Because there are gaps between the individual paving stones, which are usually filled with sand, it is characteristic of such road surfaces that they allow rain and melted snow to flow directly into the ground below, which is desirable in many cases and makes stone pavements particularly valuable from the viewpoint of protecting the environment. However, there is an associated risk that the soil will become contaminated by harmful fluids or solid materials, which can be carried into the ground by the flowing water. For this reason it is problematic to build the roadbed for stone pavements out of demolition products, which are very often contaminated.

[0003] Accordingly, the object of the present invention is to provide a construction that is substantially watertight, but nevertheless preserves the advantages of stone paving as cited above.

[0004] This object is achieved by the characterizing features of Claim 1, insofar as the road surface itself is concerned, and by those of Claim 11 with regard to the method for construction of such a road surface.

[0005] An extremely surprising finding has been that a sand bed with a bitumen component amounting to between 1.5% and 2.5% by weight behaves similarly to a conventional sand bed containing no binding agents at all; that is, even after the bed has been laid and the paving stones vibrated into place, with a corresponding compaction of the sand bed, the latter retains its free-flowing property and does not form solid clumps. Despite this characteristic, the bituminous sand bed provides a layer that is nearly impermeable to water. It should be kept in mind here that the water permeability of a conventional asphalt surface is about 20 to 25%. In contrast, the sand bed in accordance with the invention has a water permeability of maximally 6 to 7%. In comparison with an asphalt surface, therefore, the road surface with a sand bed in accordance with the invention is practically impermeable to water. If the bitumen component amounts to less than 1.5% by weight, the water permeability increases appreciably. On the other hand, with a bitumen component of more than 2.5% by weight there is a risk that the individual sand grains will stick together, in particular after they have been warmed by prolonged insolation. Furthermore, while the sun is shining on the surface a sand bed with a relatively high proportion of bitumen is in danger of "softening", with the consequence that when it is exposed to fairly large forces, in particular a stream of traffic, it will become deformed and make the road surface uneven. This danger exists especially when some of the traffic passing over the road surface consists of heavy goods vehicles.

[0006] That contamination of the soil by percolating water that passes through the gaps in a paving-stone surface can be a problem has of course been recognized before. To solve this problem, EP 0 456 035 A2 proposes that clay minerals should be added to the sand in the roadbed, for example montmorillonite and mineral aggregates, in a proportion of up to about 30%. The aim is to produce a sand bed that is relatively watertight. To achieve a sufficiently dense consistency, the proportion of clay minerals and mineral aggregates must be relatively high, with the consequence that the sand-bed mixture is correspondingly expensive. Furthermore, experiments have shown that the water-impermeability of such a sand bed corresponds at most to that of a conventional asphalt road surface.

[0007] DE-AS 1 093 396 describes a method of laying down pavement with bituminously bound sand that is characterized by the use of a known binding agent with at least two components, one of which is a powdery, bituminous material and the other an oily, high-boiling-point liquid capable of dissolving the bituminous material. This method is likewise distinguished by the relatively large effort and expense required to construct the sand bed, and the method is designed not to produce a sand bed that is substantially watertight but rather to allow the paving stones to be more firmly embedded in the sand bed, so that it is no longer necessary to fill the gaps between adjacent paving stones. For this purpose the mixture described above is preferably supplemented with adhesive agents such as hydrated lime powder. This adhesive agent is intended to promote fixation of the pavement in the sand bed. The oily additive serves to preserve the mobility or fluidity of the sand components.

[0008] The object of the method proposed in DE-AS 1 093 396 thus has nothing to do with the construction of a largely watertight sand bed and correspondingly watertight road surface.

[0009] The method in accordance with the invention is distinguished by the fact that on top of a roadbed, which can even be made of demolition products, a sand bed is constructed that in addition to raw sand contains bitumen in a proportion of between 1.5 and 2.5% by

weight. Subsequently paving stones are laid down on this sand bed, in such a way that there are gaps between adjacent stones. Prior to the laying of the paving stones the sand bed has not yet been compacted. After laying, the paving stones are vibrated or hammered into the sand bed described here in such a way that bituminous sand rises into the gaps between adjacent stones. At the end of this process the sand bed has become sufficiently compacted, by about 10 to 20%. Because of this compaction, and owing to the bitumen component, the sand bed becomes largely watertight while retaining a flexibility similar to that of a conventional sand bed.

[0010] After the paving stones have become fixed within the sand bed, the gaps between them can be filled with conventional jointing sand, which where necessary can also be bituminized. In a preferred embodiment for road construction the sand bed is spread out with a thickness of about 3.0 to 5.0 cm. In the region of the paving stones the sand bed becomes compacted by about 0.5 to 1.0 cm.

[0011] Furthermore, experience has shown that when the sand has the preferred granulation and grain-size distribution, as specified in Claim 3, during fixation of the paving stones in the sand bed by vibration or hammering the sand of the bed rises into the gaps between adjacent paving stones by about 0.3 to 0.6 cm, given a gap width of about 0.2 to 0.5 cm. As a result, the paving stones are sufficiently stabilized in the horizontal direction, i.e. in the direction parallel to the road surface, with no need for filling the gaps.

[0012] With regard to a preferred sand composition and to preferred compositions of the bitumen component, reference is made to Claims 3, 6, 8 and 9.

[0013] In the following, preferred exemplary embodiments are described in detail with reference to the attached drawing. This shows a road surface on a roadbed 1, which can comprise demolition products; the road surface comprises a sand bed 2 and, laid thereon, concrete paving stones 3. The concrete paving stones are laid in such a way that between adjacent stones there are gaps 4 with a width of 0.2 to 0.5 cm. In the illustrated embodiment the gaps 4 have been filled from above with jointing sand 5. After the paving stones 3 are placed on the originally uncompacted sand bed 2, the paving stones 3 are vibrated or hammered into the sand bed 2 by means of a surface vibrator 6. The action of the vibrator 6 causes the sand bed in the region of the paving stones 3 to become condensed by at least about 10 to 20%, in particular about 15%. That is, a sand bed with an initial thickness or height of about 3 to 5 cm is compacted in the region of the paving stones so that its thickness or height becomes about 0.5 to 1.0 cm smaller than the initial thickness or height. During this compaction process displaced sand flows from below into the gaps 4 between adjacent paving stones 3 and ascends within these gaps, by about 0.5 cm when the gap width is 0.2 to 0.5 cm.

[0014] Experiments have shown that compaction of the sand bed is particularly great in the region of the edges of the paving stones that lie within the sand. That is, the sand of the sand bed 2 is particularly strongly compacted in the region of the gaps; as a result, in combination with the presence of a bitumen component in accordance with the invention and the quality and grain-size distribution of the sand, which are described below, the sand bed is particularly watertight in this region. Surprisingly, with a sand bed in accordance with the invention a water permeability of maximally 6.0 to 7.0% can be achieved, whereas the water permeability of a conventional asphalt surface is up to 25%.

[0015] In order further to increase the degree of water impermeability in the joint region, the gaps 4 between adjacent paving stones 3 can additionally be filled from above with jointing sand, in particular bituminous jointing sand.

[0016] It is especially advantageous for the weight of the bitumen component of the sand bed 2 to amount to between about 1.8 and 2.2% of the total weight of the sand bed.

[0017] Furthermore, the distribution of coarse and fine grains in the sand bed 2 is preferably chosen to be such that the action of a surface vibrator 6 on paving stones 3 laid on the originally uncompacted sand bed causes the sand to become compacted by about 10 to 20%, in particular about 15%.

[0018] The grain-size distribution of the sand bed 2 for a maximal grain size of 2.0 to 4.0 mm, in particular about 3.0 mm, and for a minimal grain size of about 0.05 to 0.1 mm, in particular about 0.07 to 0.1 mm, is as follows:

Ca. 0-5% of the grains are smaller than 0.10 mm
Ca. 0-15% of the grains are smaller than 0.15 mm
Ca. 5-30% of the grains are smaller than 0.30 mm
Ca. 30-55% of the grains are smaller than 0.50 mm
Ca. 55-80% of the grains are smaller than 1.00 mm
Ca. 80-95% of the grains are smaller than 2.00 mm
Ca. 95-100% of the grains are smaller than 3.00 mm
Ca. 100% of the grains are smaller than 4.00 mm

[0019] Expressed somewhat more generally, the grain-size distribution chosen for the sand bed 2 is such that the grain size increases approximately as follows:

In the fine-grain region: linearly to progressively
In the intermediate region: approximately linearly
In the coarse-grain region: regressively

[0020] As mentioned above, the gaps 4 between adjacent paving stones can be filled from above with jointing sand 5, in which the proportion of finest grains (grain size $\leq$ 0.10 mm) is about twice as large as that in the sand bed 2. The grain size of the jointing sand preferably increases slightly progressively throughout.

[0021] Another factor of significance for the low water permeability of the road surface from 0.01 to 6.0% and

in particular from 0.10 to 3.50%, is the quality of the bitumen for the sand bed 2. The bitumen used here preferably has a density of 1.0 to 1.06 g/cm^3 at 25°C, a paraffin component of about 2.0 to' 2.5% by weight, a needle penetration at 25°C of about 60 to 200 dmm (= 1/10 mm), a ductility at 25°C of about 90 to 100 cm, and a viscosity at 135°C of about 200 to 250 mm^2/s. Bitumen of this quality permanently encloses the sand grains in such a way that they cannot adhere to one another and form clumps. Sand to which such bitumen has been added remains substantially as free-flowing as raw sand, even after it has been compacted as described above by vibration of the paving stones.

[0022] Preferably as the starting material for the sand bed a crushed sand is used, with a grain-size distribution such that the empty-space content of a dry-compacted sample is maximally about 37.0 to 39.0, in particular about 38.5% by volume.

[0023] The construction of a road surface with paving stones laid on a sand bed 2 of the kind described here has been described in detail above. Here reference is explicitly made to that description.

[0024] Regarding the grain-size distribution for the jointing sand used to fill the gaps, it should be mentioned that this is preferably as follows:

Ca. 0 to 15% of the grains are smaller than 0.07 mm
Ca. 10 to 15% of the grains are smaller than 0.15 mm
Ca. 20 to 30% of the grains are smaller than 0.30 mm
Ca. 35 to 60% of the grains are smaller than 0.6 mm
Ca. 50 to 75% of the grains are smaller than 1.00 mm
Ca. 70 to 90% of the grains are smaller than 2.00 mm
Ca. 85 to 100% of the grains are smaller than 3.00 mm
Ca. 100% of the grains are smaller than 4.00 mm

[0025] Intra-plant experiments have shown that the water permeability of a sand bed with an original thickness or height of about 4 cm, with grain sizes and distribution as given in Claim 3, and in which the bitumen component amounted to about 2.0% by weight, was on average about 0.05%. This slight water permeability, in comparison to conventional asphalt or tar surfaces, is practically equivalent to 100% watertightness, so that the road surface in accordance with the invention is considerably better suited for covering contaminated roadbeds than conventional road surfaces made of asphalt or tar. The impermeability of the road surface described here is almost the same as that of concrete. However, the road surface described here offers the great advantage over concrete, as well as over an asphalt or tar surface, that an opening made in the surface can be closed again with no difficulty, so that the original quality of the road surface is preserved. In particular it is surprising that the flexibility of the bituminated sand corresponds closely to that of dry raw sand, even when the road surface described here has been in use for a long time and/or is continuously in use.

[0026] In the gap region the compaction of the sand bed is somewhat higher than in the region below the paving stones.

[0027] All the characteristics disclosed in the application documents are claimed as essential to the invention insofar as they are new to the state of the art individually or in combination.

List of reference numerals

[0028]

1 Roadbed
2 Sand bed
3 Concrete paving stones
4 Gaps
5 Jointing sand
6 Surface vibrator

Claims

1. Road surface for areas used by vehicular traffic, comprising a pavement which is supported by a roadbed (1) and which comprises prefabricated paving stones (3) made of natural or artificial materials, in particular concrete paving stones, that are laid on a bituminous sand bed (2),
characterized in that
the bitumen component of the sand bed (2) with respect to the overall weight of the latter amounts to between about 1.5% and 2.5%, in particular about 1.8% to 2.2%,' by weight.

2. Road surface according to Claim 1,
characterized in that
the distribution of coarse and fine grains in the sand bed (2) is such that under the action of a vibrator on paving stones (3) laid on the originally uncompacted sand bed, the sand can be compacted by about 10 to 20%, in particular about 15%.

3. Road surface according to Claim 1 or 2,
characterized in that
the grain-size distribution of the sand bed (2) for a maximal grain size of 2.0 to 4.0 mm, in particular about 3.0 mm, and for a minimal grain size of about 0.05 to 0.10 mm, in particular about 0.07 to 0.01 mm, is as follows:

Ca. 0 to 5% of the grains are smaller than 0.10 mm
Ca. 0 to 15% of the grains are smaller than 0.15 mm

Ca. 5 to 30% of the grains are smaller than 0.30 mm
Ca. 30 to 55% of the grains are smaller than 0.50 mm
Ca. 55 to 80% of the grains are smaller than 1.00 mm
Ca. 80 to 95% of the grains are smaller than 2.00 mm
Ca. 95 to 100% of the grains are smaller than 3.00 mm
Ca. 100% of the grains are smaller than 4.00 mm

4. Road surface according to one of the claims 1 to 3, **characterized in that**
the paving stones (3) on the sand bed (2) are laid in such a way that they are separated by gaps (4) and are kept apart from one another by sand that rises into the gaps (4) from below.

5. Road surface according to Claim 4, **characterized in that**
the gaps (4) between adjacent paving stones (3) are filled from above with jointing sand (5), in which the proportion of the finest grains (grain size ≤ 0.10 mm) is about twice as large as that in the sand bed (2).

6. Road surface according to one of the claims 1 to 5, **characterized in that**
the grain size increases approximately as follows:

Sand bed:

In the fine-grain region: linearly to progressively
In the intermediate region: approximately linearly
In the coarse-grain region: regressively

Jointing sand:

Progressively increasing throughout the range

7. Road surface according to one of the claims 1 to 6, **characterized in that**
it has a water permeability of maximally between 0.01 and 6.00%, in particular 0.10 to 3.50%.

8. Road surface according to one of the claims 1 to 7, **characterized in that**
the bitumen for the sand bed (2) has a density of about 1.0 to 1.06 g/cm^3 at 25°C, a paraffin component of about 2.0 to 2.5% by weight, a needle penetration at 25°C of about 60 to 200 dmm (= 1/10 mm), a ductility at 25°C of about 90 to 100 cm, and a viscosity at 135°C of about 200 to 250 mm^2/s.

9. Road surface according to one of the claims 1 to 8, **characterized in that**
for the sand bed (2) a crushed sand is used with a grain-size distribution such that the proportion of empty space within a dry-compacted sample is maximally about 37.0 to 39.0, in particular about 38.5% by volume.

10. Road surface according to one of the claims 1 to 9, **characterized in that**
the roadbed (1) beneath the sand bed (2) is constructed of demolition products.

11. Method for the construction of a road surface with paving stones (3) laid on a sand bed (2), in particular a road surface according to one of claims 1 to 10, **characterized by** the following steps:

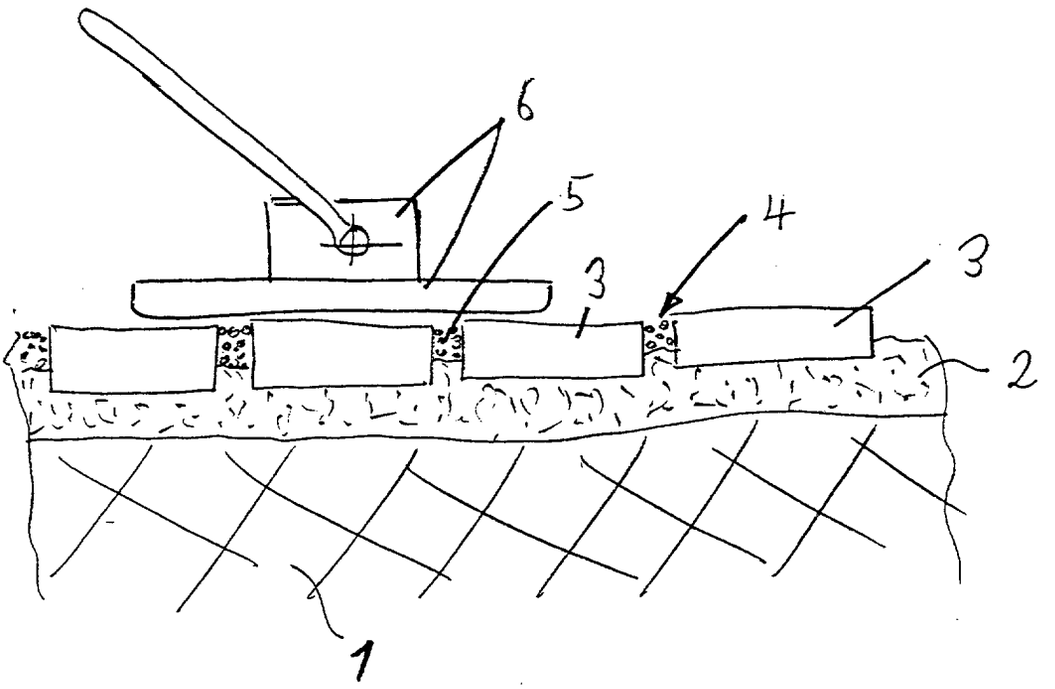
a. the erection on a roadbed of an overlying sand bed containing bitumen in a proportion of 1.5% to 2.5% by weight;
b. the placement of paving stones on the still uncompacted sand bed, so as to leave gaps between adjacent paving stones;
c. the vibration or the hammering of the paving stones into the sand bed in such a way that bituminized sand ascends into the gaps between adjacent paving stones.

12. Method according to Claim 11, **characterized in that**
the process of vibrating or hammering the paving stones into the sand bed compacts the sand bed by about 10 to 20%.

13. Method according to Claim 12, **characterized in that**
when the paving stones are vibrated or hammered into the sand bed, bituminized sand ascends into the gaps between adjacent paving stones by a distance of about 0.3 to 0.6 cm, given a gap width of about 0.2 to 0.5 cm.

14. Method according to one of the claims 11-13, **characterized in that**
the sand bed is spread out in a thickness of about 3.0 to 5.0 cm.

15. Method according to one of the claims 11-14, **characterized in that**
after the paving stones have become fixed within the sand bed, the gaps between adjacent paving stones are filled with jointing sand, in particular bituminized jointing sand.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European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 01 10 2333

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
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TECHNICAL FIELDS SEARCHED (Int.Cl.7)

E01C

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	3 July 2001	Dijkstra, G

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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03-07-2001

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