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(54) A pavement with photocatalytic effect

(57) Described herein is a pavement with photocatalytic effect of the type comprising a bituminous substrate (2) made of bituminous conglomerate and a photocatalytic covering (3) made of cementitious material englobing material with photocatalytic effect, there being set between the bituminous substrate (2) and the photocatalytic covering (3) an intermediate layer (4) made of cementitious material and means of reinforcement comprising a foundation net (5) made of alkali-resistant roving, and there being moreover provided means for fixing the foundation net (5) both to the intermediate layer (4) and to the bituminous substrate (2).

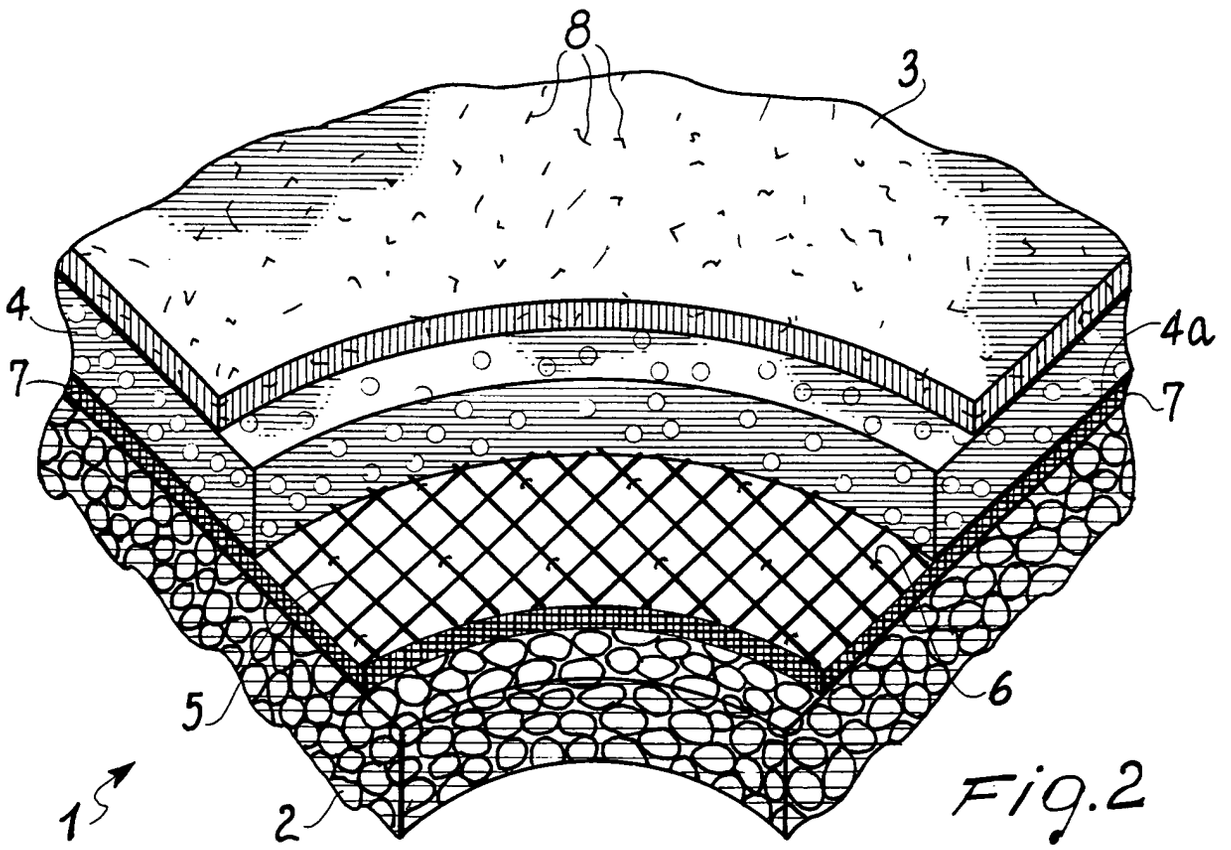

Fig.2

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Description

[0001] The subject of the present invention is a pavement with photocatalytic effect, of the type specified in the preamble of Claim 1.

[0002] Currently known is the process of photocatalysis, which enables oxidation of polluting or soiling substances.

[0003] Photocatalysis is based upon the use of electrical charges or electrons made available by appropriate semiconductors when the latter are excited by appropriate electromagnetic waves.

[0004] A preferred semiconductor, for activation of the process of photocatalysis, is titanium dioxide (TiO_2), preferably in the form of anatase.

[0005] The electrons made available by titanium dioxide constitute a negative electrical charge that binds readily to other molecules present in the environment. In particular, it binds to the molecules of oxygen (O_2) present in the atmosphere, constituting negative ions (O_2^- or O^-).

[0006] The ions O_2^- and O^- are very reactive and bind to the molecules of the polluting substances present in the environment, in particular to the nitrogen oxides (NO_x), which are principally nitrogen monoxide and nitrogen dioxide (NO or NO_2), forming negative NO_3^- ions, or else with carbon monoxide (CO), giving rise to a molecule of carbon dioxide CO_2.

[0007] When photocatalytic substances are set in a basic cementitious matrix, the negative NO_3^- ions in turn bind readily to the positive calcium or sodium ions (Ca^{++} or Na^+) dissociated from the compounds (calcium carbonate, gypsum, etc.) present in the basic cementitious matrix.

[0008] The latter passage is of fundamental importance because it enables acids not to be obtained at the end of the process of photocatalysis, but innocuous salts, such as sodium nitrate $NaNO_3$ and calcium nitrate $Ca(NO_3)_2$, which precipitate in the environment.

[0009] Not only are the nitrogen oxides and carbon oxides oxidized through the photocatalytic process, but many other noxious substances such as: benzene, toluene, ethyl-benzene, m-xylene, ozone, sulphur dioxide, formaldehyde, acetaldehyde, PM x, methanol, and ethanol.

[0010] Various experiments have been conducted for evaluation of the abatement of nitrogen oxides and other polluting substances through the covering of roads or walls with a coating having a photocatalytic effect.

[0011] The most important experiment has been performed in the open in Lombardy, in the town of Segrate (Province of Milan).

[0012] Part of a stretch of bituminous asphalt road carrying a considerable flow of motor-vehicle traffic was covered with a photocatalytic-effect coating.

[0013] The stretch of road forming the subject of the test had a length of 250 m and a width of 17 m, for a total area of approximately 4000 m^2, in a context of traffic of approximately 15 000 motor vehicles per day.

[0014] Through the use of two pieces of chemiluminescence machinery positioned one on a non-treated part of the asphalt and the other in the area covered by the photocatalytic-effect coating there were noted reductions in polluting elements of up to 62%.

[0015] Furthermore, there were obtained positive results also in terms of adherence of the tyres of the motor vehicles to the road covering.

[0016] The experimentation referred to above has, however, highlighted a number of important drawbacks.

[0017] In fact, to present all the advantages listed above, the photocatalytic substances must be englobed in a basic substrate, such as cement and mortar. Otherwise, the negative NO_3^- ions do not bind with the positive ions of calcium or sodium (Ca^{++} or Na^+) present in the basic cementitious matrix, and at the end of the process of photocatalysis noxious acids are obtained. The basic substrates are not always present on the roads, which, instead, are prevalently made of bituminous conglomerate and not of cementitious material.

[0018] It is therefore necessary in the majority of cases - such as, for example, in the aforesaid experiment in the open - to lay on top of the bituminous conglomerate a cementitious layer that will define the basic substrate for the photocatalytic substances.

[0019] The remaking of the entire pavement, when this is already made of bituminous conglomerate, would in fact prove too costly.

[0020] However, it is noted that mortars and cements, when they are laid on top of a layer of bituminous conglomerate, do not present a satisfactory mechanical behaviour.

[0021] In fact, these different types of bituminous and cementitious materials have very different elastic modulus and mechanical characteristics; in particular mortars and cements are much more rigid than the underlying bituminous layer.

[0022] Roughly speaking, defining simply the elastic modulus as the force per unit surface (in cross section) necessary to obtain a unit lengthening of the material in question, it emerges that a cementitious conglomerate can have an elastic modulus comprised between approximately 20 000 and approximately 40 000 MPa (megaPascal, or Newton per mm^2).

[0023] This elastic modulus can be more than twenty times greater than the elastic modulus of bituminous conglomerates.

[0024] The latter, therefore, are deformed easily in the presence of marked stresses.

[0025] It follows that the bottom bituminous conglomerates are unable to sustain in a reliable way the top cementitious layer when the latter, if substantially thin, is unable to withstand the heavy loads that are exerted, in particular, by lorries. This failure to withstand dynamic loads and the consequent bending of the layer made of concrete takes the form of surface cracks.

[0026] The experiment of Segrate described above

provides evidence of this mechanical drawback of the pavement: the cementitious surface layer, which englobes the photocatalytic material, is markedly cracked at the points of transit of vehicles.

[0027] In order to overcome this serious drawback and consequently to be able to exploit effectively the enormous environmental benefits that emerge from the same experiment, it is possible to increase considerably the thickness of the photocatalytic cementitious layer.

[0028] However, by so doing, both the costs of the raw materials used and the costs for spreading, which, among other things, would call for a major scraping of the base of bituminous material and a subsequent application of a thick cementitious layer with the same technique of formation of the roads made of cementitious material, are found to be very high.

[0029] In practice, pavements made of concrete are obtained that are substantially complete, superimposed on pavements made of bituminous conglomerate that are in turn substantially complete.

[0030] It may also be noted that the costs for the use of photocatalytic material are added to the costs for the construction of pavements and that it is appropriate not only to contain these costs but also to make pavements having a long service life in order to spread out the expenses over a considerable length of time.

[0031] In this situation the technical task underlying the present invention is to devise a pavement with photocatalytic effect capable of substantially overcoming the drawbacks mentioned above.

[0032] In the framework of said technical task, an important purpose of the invention is to devise a pavement with photocatalytic effect which, albeit presenting a basic substrate of a cementitious type, applied to a base made of bituminous material, will present good characteristics of resistance to mechanical stresses.

[0033] Another important purpose of the invention is to devise such a pavement that will present contained costs.

[0034] A further purpose is to devise a pavement made in part of bituminous material and in part of cementitious material that will present a long service life.

[0035] Not the least important purpose is to devise such a pavement that will be applicable readily and in a generalized way to roads made of bituminous material.

[0036] The technical task and the purposes specified are achieved by a pavement with photocatalytic effect as claimed in the annexed Claim 1.

[0037] Preferred embodiments are defined in the subclaims.

[0038] Further characteristics and advantages of the invention are clarified more fully hereinafter by the detailed description of a preferred embodiment of the invention, with reference to the annexed drawings, in which:

- **Figure 1** is a schematic illustration of the amount of nitrogen oxides in the presence (solid line) and in the absence (dashed line) of asphalt coated with a photocatalytic substance, with appearing on the abscissa is the time of day and appearing on the ordinate the amount of nitrogen oxides in parts per billion;
- **Figure 2** presents schematically, in exploded perspective view, a cross section of a pavement according to the invention;
- **Figure 3** illustrates a detail of the pavement of Figure 2;
- Figure 4 is a detailed cross-sectional view of the pavement illustrated schematically in Figure 2;
- **Figure 5** brings out, at a further enlarged scale, a detail of the pavement;
- **Figure 6** is a cross-sectional view of another preferred embodiment of the invention; and
- **Figure 7** is a cross-sectional view of a further embodiment of the invention, similar to that of Figure 6.

[0039] With reference to the above figures, the pavement with photocatalytic effect according to the invention is designated as a whole by the reference number 1.

[0040] It comprises, in general, a bituminous substrate **2** made of bituminous material or bituminous conglomerate.

[0041] The bituminous substrate 2 is in itself known: it is used to make the majority of pavements and may also be made up of numerous layers.

[0042] The pavement 1 then comprises, in a way once again in itself known, a surface layer formed by a photocatalytic covering 3, with photocatalytic effect, made of cementitious material.

[0043] Between the bituminous substrate 2 and the photocatalytic covering 3 there are provided: at least one intermediate layer 4, which is also made of cementitious material; and means of reinforcement comprising at least one base net 5, which presents an elastic modulus higher than that of the intermediate layer 4.

[0044] There are then provided means for fixing between the intermediate layer 4 and the bituminous substrate 2, which selectively comprise engagement elements 6 developing between the net 5 and the bituminous substrate 2 and an adhesive layer 7 set between the intermediate layer 4 and the bituminous substrate 2.

[0045] In detail, the photocatalytic surface covering 3 is, for example, made of cementitious mortar, and the photocatalytic effect is obtained preferably by means of particles 8 made of semiconductor material, appropriately consisting of titanium dioxide, present conveniently in the form of anatase. The semiconductor material is effective (as shown by Figure 1) even though in relatively small amounts, for example smaller than 3 wt% with respect of the photocatalytic covering 3.

[0046] In addition, the photocatalytic covering 3 is substantially "micro-reinforced" and rendered more resistant to wear and to tensile stress via dispersion therein of strands 9 made of alkali-resistant (AR) roving.

[0047] This is a roving having a diameter of preferably

fourteen micron and any length, for example several millimetres. On account of its large diameter it does not present any danger for breathing, even in the case where it is broken down into very small fragments. In particular, the roving produced by Saint-Gobain Vetrotex under the trade-mark name Cem-FIL® is chosen. The strands 9 are provided in amounts preferably comprised between 2 wt% and 10 wt% with respect to the overall weight of the cementitious material forming the photocatalytic covering 3.

[0048] It is pointed out that the photocatalytic covering 3 may also be substantially a paint or the like and that hence its thickness can vary considerably, for example between approximately one and ten millimetres.

[0049] The minimum thickness is the one typical of paints, whilst the maximum thickness generally refers to mortars.

[0050] The intermediate layer 4 made of cementitious material is preferably a typical cementitious conglomerate or concrete normally used for pavements. Its bottom face, designated by **4a,** faces the bituminous substrate 2.

[0051] It is free from particles 8 of semiconductor material, but preferably it is also "micro-reinforced" by means of the aforesaid strands 9 made of alkali-resistant roving.

[0052] It preferably has a thickness greater than that of the photocatalytic covering 3 and for example has a thickness comprised between five and thirty millimetres.

[0053] A preferred choice, in the case of a pavement with a covering, which is very light and inexpensive, of the bituminous substrate 2, envisages a photocatalytic covering 3 of a thickness of approximately three millimetres and an underlying intermediate layer 4 of a thickness of approximately seven millimetres.

[0054] The foundation net 5 is preferably set in the vicinity or in an area corresponding to the bottom face 4a of the intermediate layer 4.

[0055] It is preferably made of alkali-resistant roving, with an elastic modulus higher than that of the cementitious material of the intermediate layer.

[0056] As has already been mentioned, the elastic modulus is comprised between approximately 20 000 and approximately 40 000 MPa, without said "micro-reinforcement".

[0057] In particular, as foundation net 5 a net or mesh is chosen produced by Saint-Gobain Vetrotex and called Cem-MESH®, currently designed for example to be set as reinforcement for plates or prefabricated products or to be draped vertically on the side of a building for being incorporated in a coating.

[0058] This net has a high elastic modulus (72 000 MPa) and a high resistance to fracture due to tensile stress.

[0059] It moreover has a minimum weight of approximately one hundred and forty grams per square metre.

[0060] It is supplied in rolls with a mesh of a substantially square shape, for example having a side of one hundred millimetres.

[0061] On account of its lightness, resistance, minimum encumbrance and ease of applicability by simple spreading, a number of nets can be used within each pavement.

[0062] For example, said reinforcement means may comprise, in addition to the foundation net 5, also a top net 10 substantially set between the intermediate layer 4 and the photocatalytic covering 3, as highlighted in Figure 7.

[0063] It is envisaged that the top net 10 will be structurally identical to the foundation net 5.

[0064] As emerges clearly in particular from Figure 4, said means for fixing the foundation net 5 to the bituminous substrate 2 envisage that the foundation net 5 will be englobed in the intermediate layer 4, preferably at a distance of a few millimetres from the bottom face 4a, and moreover that the net itself will be fixed directly to the underlying bituminous substrate 2 by means of the engagement elements 6.

[0065] The latter have a bottom portion 6a, which is shaped like a prod and is at least in part embedded in the bituminous substrate 2, and a top portion 6b, which projects from the bituminous substrate 2 and is designed to hook to the foundation net 5.

[0066] For the above purpose, the top portion is substantially a partially open hook (Figures 3 and 5).

[0067] The engagement elements 6 can be made of plastic or metal material and are preferably provided in a relatively large number.

[0068] The means for fixing the foundation net 5 to the bituminous substrate envisage then, additionally or alternatively, that an adhesive layer 7 will be provided between the bottom face 4a of the intermediate layer 4 and the bituminous substrate 2.

[0069] The adhesive layer 7 acts both directly on the intermediate layer 4 and on the foundation net 5 when the latter is in an area corresponding to the bottom face 4a, as illustrated in Figure 6, or else set at a minimal distance from said bottom face 4a.

[0070] If it is envisaged that the foundation net 5 is in a substantial continuity with the adhesive layer 7, the engagement elements 6 can be omitted.

[0071] It is envisaged that said adhesive layer 7 will be made of an epoxy-resin-based material, possibly mixed with mineral fillers, vitreous fillers, diluents, etc., which, on the one hand, isolates the bituminous substrate 2 from the rest of the pavement, enabling a more convenient and cleaner spreading of the pavement and, on the other, engages by adhesion the intermediate layer 4, setting itself also in the strict vicinity of the net 5.

[0072] Epoxy resin is a thermosetting plastic material which can be applied simply by pouring and is characterized by a considerable mechanical resistance, resistance to aggressive chemical agents, resistance to low temperatures, and resistance to water.

[0073] It has a strong adhesive power and, as such, is used in the formulation of adhesives, in paints, and

as a coating for metal materials to obtain films of great hardness, adherence, flexibility, water-resistance and resistance to ageing.

[0074] A second adhesive layer 11 having an epoxy-resin base may be advantageously provided also between the photocatalytic covering 3 and the intermediate layer 4, possibly in combination with the top net 10, as shown in Figure 7.

[0075] The invention comprises a new process for formation of a pavement with photocatalytic effect, in which a photocatalytic covering 3 of a cementitious type is provided on top of a bituminous substrate 2.

[0076] According to the process, it is envisaged that between the photocatalytic covering 3 and the bituminous substrate 2 there will be inserted an intermediate layer 4 made of cementitious conglomerate and at least one foundation net 5 made of alkali-resistant roving, and that the intermediate layer 4 and the bituminous substrate 2 will be engaged to the foundation net 5.

[0077] Engagement is obtained by setting the foundation net 5 in the vicinity of or in a position corresponding to the bottom face 4a of the intermediate layer 4 facing the bituminous substrate and by applying selectively engagement elements 6 and an adhesive layer 7.

[0078] In detail, the foundation net 5 is fixed by means of engagement elements 6 to the bituminous substrate 2 in a raised position with respect to the bituminous substrate 2 itself.

[0079] There is then cast the intermediate layer 4 made of cementitious material, and this penetrates the open structure of the meshes of the net 5, in a raised position, and embeds the net inside it.

[0080] The adhesive layer 7 is inserted between the intermediate layer 4 and the bituminous substrate 2 before the intermediate layer 4 is cast, and also this fastens the foundation net 5 to the bituminous substrate 2.

[0081] The process may possibly be perfected by means of insertion of a top net 10 between the photocatalytic covering 3 and the intermediate layer 4.

[0082] The invention enables important advantages to be achieved.

[0083] The photocatalytic covering 3 enables reactions of photocatalysis to take place, which, as has been explained in the introductory part of the present patent, oxidize the polluting substances, which are converted into acidic substances. The acidic substances are neutralized by the basic cementitious substances present in the photocatalytic covering and give rise to the process described previously of formation of innocuous salts.

[0084] The overall effect is advantageously similar to the one obtained with the aforementioned experiments conducted at Segrate.

[0085] In detail, Figure 1 shows data acquired in Segrate on September 16, 2003. Schematically represented with a solid line is the amount of nitrogen oxides existing in the presence of a layer of photocatalytic substance, whilst the dashed line indicates the amount of nitrogen oxides in the absence of the photocatalytic layer. On the abscissa there appears the time of day and on the ordinate the amount of nitrogen oxides in parts per billion.

[0086] At the same time, the structure described ensures a considerable resistance and an excellent distribution of stresses.

[0087] In fact, the stresses that are exerted on the surface layer 3 by motor vehicles and lorries are widely distributed and spread out over a vast area of pavement 1, in particular thanks to the foundation net 5, which has excellent mechanical characteristics, and to the bonding obtained by the adhesive layer 7.

[0088] On account of this new distribution, the stresses do not present peaks of high intensity and, consequently, do not bring about high strains in the pavement 1.

[0089] The consistent gradient of strains between the bituminous substrate 2 and the cementitious layer 4, which was the cause of the short service life of the roadway and of surface cracking, is considerably flattened out thanks to the phenomenon described.

[0090] In addition, it should be noted that not only does the cementitious part of the pavement present a good resistance to stresses, but also the bituminous part.

[0091] This is due to the action of the fixing means that engage the top portion of the bituminous substrate to the foundation net 5. The foundation net 5 is in fact close to the bituminous substrate, and the engagement elements 6, as likewise the adhesive layer 7, constrain the movements of the bituminous substrate itself to the foundation net 5.

[0092] The pavement 1 can hence guarantee a much longer service life: its mean life can pass from one to two years in the case of the method according to the prior art, to five to eight years, thus reducing the costs and the number of cycles of repair of the pavement 1, which are frequently the cause of undesirable interruptions in the transit of vehicles.

[0093] In addition, for laying the pavement described, reconstruction of the roadway is not necessary, but a removal of a surface layer of tarmac of a thickness of approximately 1 cm is sufficient. There are hence guaranteed low installation costs.

[0094] The net 5 further presents excellent characteristics of resistance to corrosion, which is ideal in an aggressive environment, on account of the presence of the photocatalytic substances 8 and of components having different chemical characteristics.

[0095] The invention may undergo variations, all of which fall within the scope of the inventive idea.

[0096] For example, the intermediate layer may be variously structured and even be divided into various superimposed portions. It can moreover be made either totally or partially of the same material as that of the photocatalytic covering.

[0097] There can then be arranged a number of nets made of alkali-resistant roving in various positions, and

also the adhesive layer can be repeated in a number of positions, between the various layers or in areas corresponding to the various nets.

Claims

1. A pavement with photocatalytic effect of the type comprising at least: one bituminous substrate (2) made of bituminous conglomerate; and a photocatalytic covering (3) made of cementitious material englobing a material with photocatalytic effect, said pavement being **characterized in that** set between said bituminous substrate (2) and said photocatalytic covering (3) are at least one intermediate layer (4) made of cementitious material and means of reinforcement comprising at least one foundation mesh or net (5) made of alkali-resistant roving, and **in that** there are provided means for fixing said foundation net (5) both to said intermediate layer (4) and to said bituminous substrate (2).

2. The pavement according to Claim 1, in which said foundation net (5) is embedded in said intermediate layer (4) in a raised position with respect to said bituminous substrate (2) and in which said fixing means comprise engagement elements (6) developing between said foundation net (5) and said bituminous substrate (2).

3. The pavement according to Claim 2, in which said engagement elements (6) have a bottom portion (6a), which is shaped like a prod and is at least in part embedded in said bituminous substrate (2), and a top portion (6b), which projects from said bituminous substrate (2) and can be engaged to said foundation net (5).

4. The pavement according to Claim 1, in which said intermediate layer (4) has a bottom face (4a) facing said bituminous substrate (2), in which said foundation net (5) is in a position corresponding to said bottom face (4a), and in which said fixing means comprise an adhesive layer (7) set between said bottom face (4a) and said bituminous substrate (2).

5. The pavement according to Claim 4, in which said adhesive layer (7) has an epoxy-resin base.

6. The pavement according to Claim 1, in which said means of reinforcement further comprise a top mesh (10) made of alkali-resistant roving set between said photocatalytic covering (3) and said intermediate layer (4).

7. The pavement according to Claim 1, in which there is provided a second adhesive layer (11) having an epoxy-resin base set between said photocatalytic covering (3) and said intermediate layer (4).

8. The pavement according to Claim 1, in which said photocatalytic covering (3) is made of cementitious mortar including particles (8) of titanium dioxide, and in which said intermediate layer (4) is made of concrete.

9. The pavement according to Claim 1, in which said cementitious material of said photocatalytic covering (3) and of said intermediate layer (4) includes a dispersion of strands (9) made of alkali-resistant roving.

10. The pavement with photocatalytic effect according to Claim 1, in which said photocatalytic covering (3) has a thickness comprised between one and ten millimetres, and in which said intermediate layer (4) has a dimension comprised between five and thirty millimetres.

11. A process of formation of a pavement with photocatalytic effect of the type comprising at least one bituminous substrate (2) made of bituminous conglomerate and a photocatalytic covering (3) made of cementitious material englobing material with photocatalytic effect, said process being **characterized in that** it consists of: laying between said photocatalytic covering (3) and said bituminous substrate (2) an intermediate layer (4) made of cementitious conglomerate and at least one foundation net (5) made of alkali-resistant roving; and engaging said foundation net (5) both to said intermediate layer (4) and to said bituminous substrate (2).

12. The process according to Claim 11, in which said foundation net is fixed by means of engagement elements (6) to said bituminous substrate (2) in a raised position with respect to said bituminous substrate (2) and is then englobed in said intermediate layer (4).

13. The process according to Claim 11, in which set between said intermediate layer (4) and said bituminous substrate (2) is an adhesive layer (7) and in which said foundation net (5) is located in a position corresponding to said adhesive layer (7).

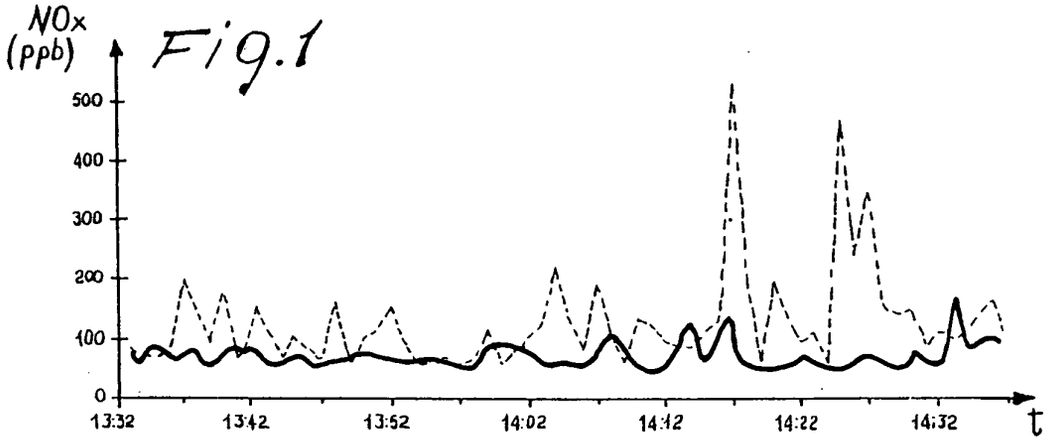
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Fig.1

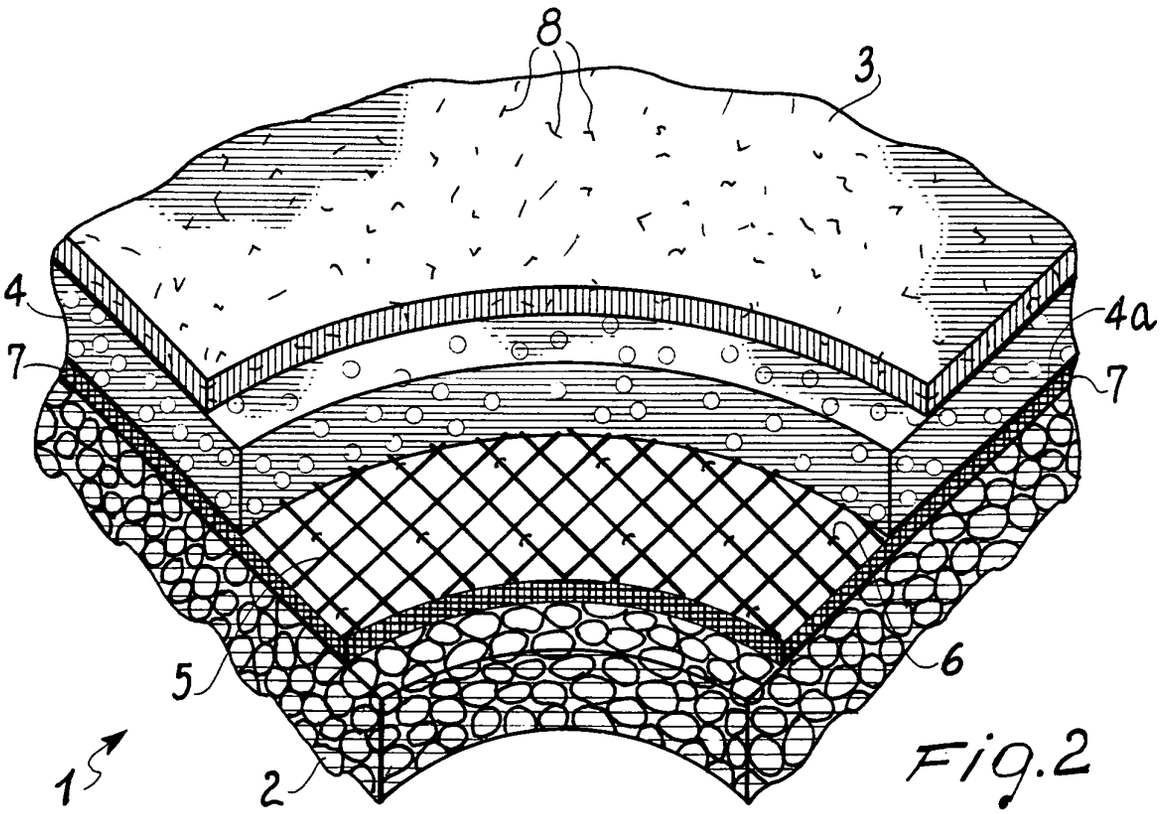
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Fig.2

Fig. 3

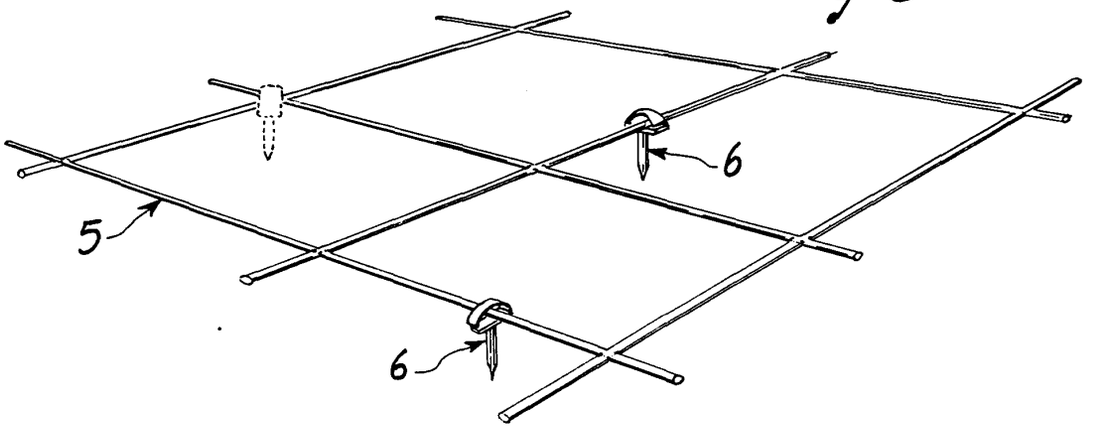
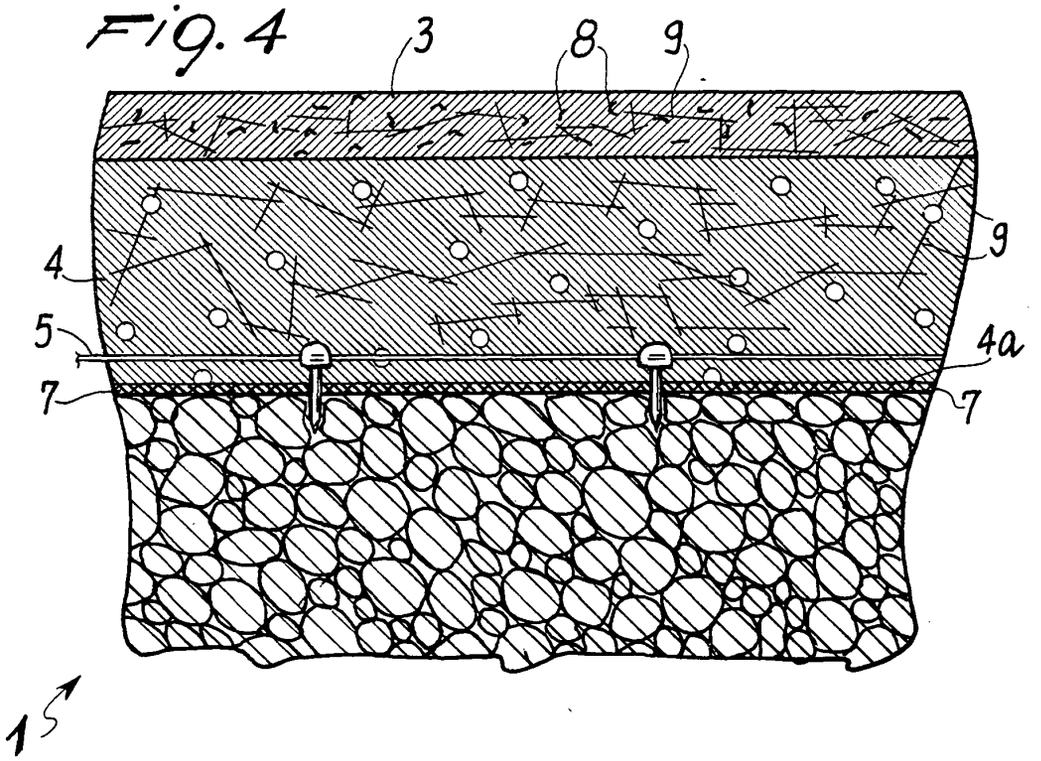


Fig. 4



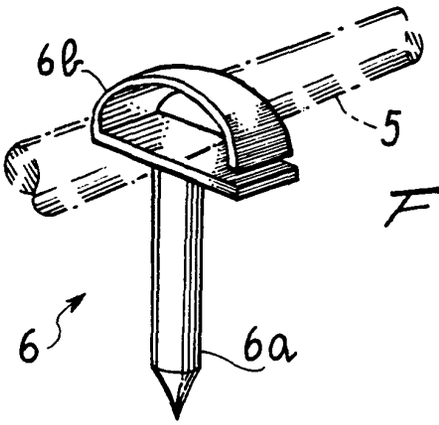


Fig.5

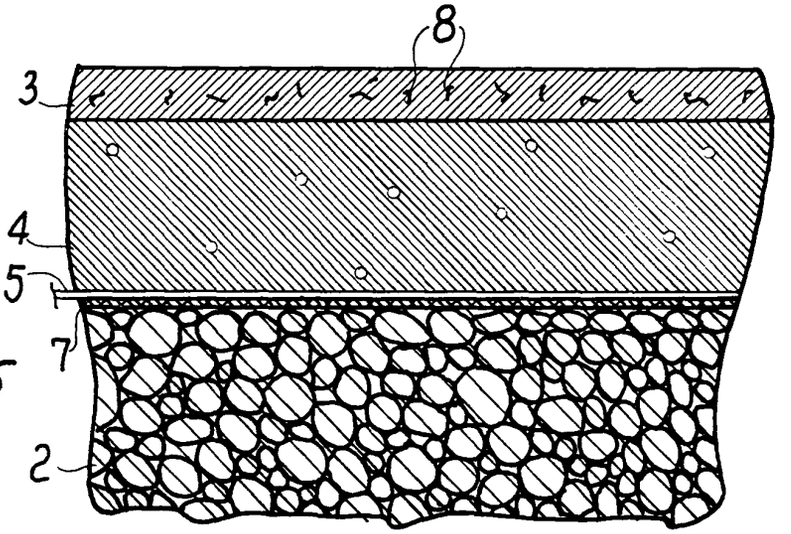


Fig.6

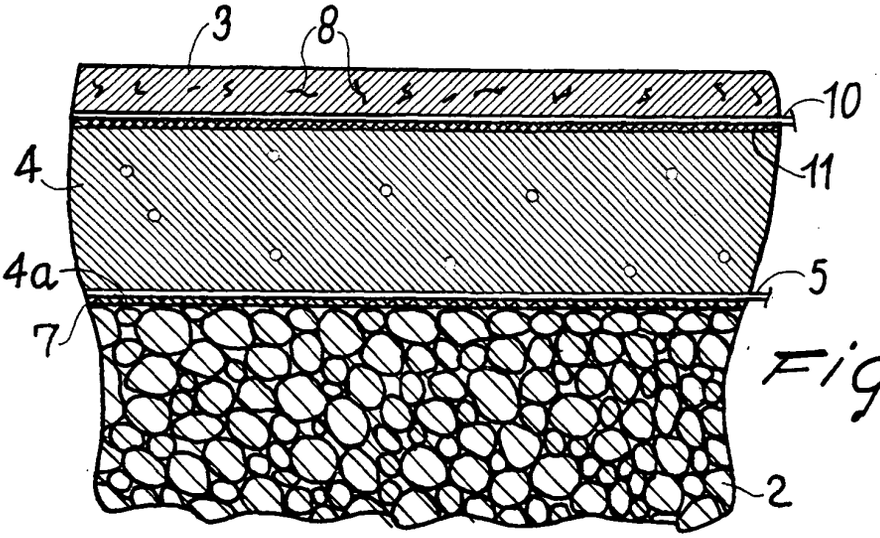


Fig.7

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 04 42 5457

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)
X	EP 0 919 667 A (MITSUBISHI MATERIALS CORP) 2 June 1999 (1999-06-02) * page 3, line 18 - line 49 * * paragraph [0023] * * paragraph [0047] - paragraph [0049] * * paragraph [0060] - paragraph [0063]; figures; examples 7,9 *	1-13	E01C7/35 E01C11/18 E01C7/32
A	GB 2 105 391 A (DANSK BETON TEKNIK APS) 23 March 1983 (1983-03-23) * abstract * * example *	1	
A	EP 0 505 010 A (BEKAERT SA NV ; MOBILMAT NV (BE)) 23 September 1992 (1992-09-23) * column 4, line 31 - column 5, line 25 * * column 6, line 31 - line 44; compounds *	1	
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A	EP 1 020 564 A (ISHIHARA SANGYO KAISHA) 19 July 2000 (2000-07-19)		E01C
A	PATENT ABSTRACTS OF JAPAN vol. 2003, no. 08, 6 August 2003 (2003-08-06) & JP 2003 096707 A (BAU KENSETSU KK; FUKUDA ROAD CONSTRUCTION; NISSHIN KASEI KK), 3 April 2003 (2003-04-03) * abstract *		

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	26 November 2004	Movadat, R

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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