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PAVING METHOD OF WATER-PERMEABLE CONCRETE

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to a paving method of water-permeable concrete, particularly to a paving method of water-permeable concrete which can be used for expressways, highways, roadways, sidewalks, bikeways, parking lots, public squares, etc. with smooth road surfaces to which various colors and patterns can be applied, as well as with high-strength with minimum surface porosity.

Description of the Prior Art

In the present invention, the meaning of water-permeable pavement is water-draining pavement which lets water such as rainwater flow in the pavement itself through small spaces formed between the particles of the pavement material and lets the water sink into the ground. Such water-permeable pavement is very effective for the protection of ecological system of underground nature, for the prevention of hydroplaning, and for the reduction of noise due to friction between wheels and road surfaces, etc.

In this connection, many inventions have been made and introduced in this field. For example, Korean Patent No. 36,315 (registered September 27, 1990, published June 23, 1990 under Publication No. 90-4390) as well as water-permeable asphalt concrete and water-permeable ceramic are related to water-permeable pavement material.

3-1101739

However, these conventional water-permeable pavement materials have had the following problems.

Firstly, as seen in a sieve analysis curve in FIG. 3, the particle pass rates of aggregate having the maximum particle size of 13mm used for the invention of Korean Patent No. 36, 315 were 95-100% measured by a 13-mm sieve, 5-40% by Sieve No. 4 (4.76mm), 0-27% by Sieve No. 8 (2.5mm), 0-14% by Sieve No. 30 (0.6mm), 0-2% by Sieve No. 100 (0.15mm), and 0-1% by Sieve No. 200(0.074 mm). Since the range of the particle size is relatively narrow (13mm to 4.76mm), this water-permeable concrete had the problems that the surface of the concrete was rather rough due to high surface porosity, particles would easily be broken away, and the strength of the concrete would easily be lowered by water penetrated into the pavement material. Therefore, the water-permeable concrete of Korean Patent No.36315 was not proper for the pavement of general roadways, but for that of lightly used sidewalks, public squares, parking lots, and roadways for small-sized automobiles.

Secondly, the pavement process of conventional water-permeable asphalt concrete includes mixing asphalt, aggregate of 13mm size, and  $\text{CaCO}_3$  at 140-180°C, spreading, and finishing by roller pounding. For roadway pavement, the strength, i. e., the stability of asphalt concrete should be more than 500 kg; however, this asphalt concrete has a stability of less than 300kg, and therefore, a further strengthening process is necessary for roadway pavement. Furthermore, this asphalt concrete is soft, and therefore, its water permeability would be rapidly lowered. Especially during summer time, minute materials such as dust tend to be attached to the asphalt to fill up the pores formed on the surfaces of road.

Thirdly, a conventional water-permeable ceramic pavement material is manufactured by mixing artificial aggregate with various colors and an epoxy resin. The costs for constructing this water-permeable ceramic pavement is more expensive than others because the prices of artificial aggregate and epoxy are very high and further this construction requires plastering.

### SUMMARY OF THE INVENTION

It is an object of the present invention to provide a paving method of water-permeable concrete which can be used for heavy traffic roads as well as highways by increasing fineness and strength of surface particles.

It is another object of the present invention to provide a paving method of water-permeable concrete of which the thickness is relatively thin with high density of particles, which has fast construction speed, low production cost, lasting various colors and superior strength by using glass powder, sand, cement, pigment, etc.

The paving method of water-permeable concrete to achieve the first object of the present invention comprises of the steps of:

- i) spreading and pounding of a sand filter layer having a coefficient of water permeability of more than  $10 \times 10^{-4}$  cm/sec and a rubble layer having a coefficient of water permeability of more than  $10 \times 10^{-2}$  cm/sec on the consolidated ground;
- ii) mixing crude aggregate (for base layer), cement of 250 to 500 kg/m<sup>3</sup>, and water at a water-cement ratio of 25-40%, spreading the mixture on the rubble base layer, and pounding the materials;
- iii) mixing crude aggregate (for surface layer), cement of 250 to 500 kg/m<sup>3</sup>,

water at a water-cement ratio of 25-40%, and at least one polymer selected from a group consisting of an emulsion-type acrylic resin, emulsified asphalt, and SBR latex of less than 20% of the weight of the cement used, spreading the mixture on the base layer of the water-permeable concrete, and paving the surface layer of the water-permeable concrete by pounding, and covering the paved surface layer of the water-permeable concrete with vinyl or the like and aging for more than one day; and

iv) mixing at least one polymer selected from a group consisting of an emulsion-type acrylic resin, an epoxy resin, urethane, emulsified asphalt and latex, with water, spreading the mixture on the base layer of the water-permeable concrete, and aging the concrete.

The above aggregate for the base layer has the maximum particle size of 40mm, and has the particle pass rates in weight % of 100% measured by a 50-mm sieve, 95-100% by a 40-mm sieve, 75-95% by a 25-mm sieve, 15-55% by a 10-mm sieve, 0-2% by Sieve No.4, 0-10% by Sieve No.10, and 0-5% by Sieve No.40.

The above aggregate for the surface layer has the maximum size of 19mm, and has the particle pass rates in weight % of 100% measured by a 25-mm sieve, 95-100% by a 19-mm sieve, 20-60% by a 10-mm sieve, 0-20% by Sieve No.4, 0-10% by Sieve No.10, and 0-5% by Sieve No. 40.

The paving method of water-permeable concrete to achieve the second object of the present invention comprises of the steps of:

i) spreading and pounding of a sand filter layer having a coefficient of water permeability of more than  $10 \times 10^{-4}$  cm/sec and a rubble layer having a coefficient of water permeability of more than  $10 \times 10^{-2}$  cm/sec;

ii) mixing crude aggregate, cement and water in a proper ratio to have porosity of 10-20% and a coefficient of water permeability of more than  $10 \times 10^{-2}$  cm/sec, spreading the mixture on the rubble base layer, and paving the base layer of the water-permeable concrete by pounding;

iii) mixing crushed waste glass, fine rubble, cement of 250-500 kg/m<sup>3</sup>, water at a water-cement ratio of 25-40%, and at least one polymer selected from a group consisting of an emulsion-type acrylic resin, emulsified asphalt, and SBR latex of 10-50% of the weight of the cement used with respect to 50% of solid material, spreading the mixture on the base layer of the water-permeable concrete within an hour after its paving, and paving the surface layer of the fine water-permeable concrete by pounding, and covering the paved surface layer of the water-permeable concrete with vinyl or the like and aging for more than one day; and

iv) mixing at least one polymer selected from a group consisting of an emulsion-type acrylic resin, an epoxy resin, urethane, emulsified asphalt and latex, with water, spreading the mixture on the base layer of the water-permeable concrete, and aging the concrete.

The above waste glass powder and fine rubble have particle pass rates in weight % of 80-100% measured by a 3-mm sieve, and less than 10% by a 1-mm sieve.

#### BRIEF DESCRIPTION OF THE DRAWINGS

A more complete appreciation of this invention, and many of the attendant advantages thereof, will be readily apparent as the same becomes better understood by

reference to the preferred embodiments of the invention when considered in conjunction with the accompanying drawings in which:

FIG. 1 is a schematic cross-sectional diagram of a general pavement, a water-draining pavement, and a water-permeable pavement for comparison;

FIG. 2 is a block diagram of construction order for a water-permeable pavement according to the present invention;

FIG. 3 is a sieve analysis graph of conventional water-permeable concrete having the maximum particle size of 13mm;

FIG. 4 is a sieve analysis graph of water-permeable concrete for a base layer having the maximum particle size of 40mm according to the present invention;

FIG. 5 is a sieve analysis graph of water-permeable concrete for middle and surface layers having the maximum particle size of 25mm according to the present invention;

FIG. 6 is a sieve analysis graph of water-permeable concrete having the maximum particle size of 19mm according to the present invention;

FIG. 7 is a cross-sectional view of a water permeability detector used in the present invention;

FIG. 8 is a cross-sectional view of a pavement constructed according to the first preferred embodiment of the present invention; and

FIG. 9 is a schematic cross-sectional view of fine water-permeable concrete constructed according to the second preferred embodiment of the present invention.

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DESCRIPTION OF THE PREFERRED EMBODIMENTS

Hereinafter preferred embodiments of the present invention are described with reference to the accompanying drawings.

FIG. 1 is a schematic comparative cross-sectional diagram of a general pavement A, a water-draining pavement B, and a water-permeable pavement C. In this figure, arrows show the passage of water.

A general pavement A is comprised of the consolidated ground 1, a bass layer and its auxiliary 2, and an asphalt or cement concrete layer 3 accumulated in order as well as water drain outlets 4 formed at one edge, through which rain water outflows to watercourses, public sewage disposal plants, rivers, etc.

A water-draining pavement B is comprised of the consolidated ground 1, a water-impermeable cement stabilization treatment layer 5, a drainage layer 6 made of granular materials, a water-permeable concrete layer 7 for a base layer, and a water-permeable concrete layer for a roadway pavement accumulated in order. If water such as rain water is flowed into the water-draining pavement B, it move through a water-permeable concrete layer 8 for a roadway pavement, a water-permeable concrete layer 7 as a base layer, and a drainage layer 6 made of granular materials, and a portion of water is evaporated into air according to capillary phenomenon.

Lastly, a water-permeable pavement C is comprised of the consolidated ground 1, a filter layer 9, a granular material layer 10, a water-permeable concrete layer 11 for a base layer and a thin water-permeable concrete layer 12 for a surface layer accumulated in order. If water such as rainwater is flowed into a water-permeable pavement C, it moves to the ground 1 through a thin water-permeable concrete layer 12

for a surface layer, a water-permeable concrete layer 11 for a base layer, a granular material layer 10, and a filter layer 9, and a portion of water is evaporated into air.

FIG. 2 is a block diagram of construction order for a water-permeable pavement according to the present invention. Each process is depicted as follows:

#### Process No. 1

Construction of a water-permeable concrete pavement is planned to achieve water permeability, and to maintain flatness, strength, porosity, color, etc. According to the construction planning, the ground is consolidated and pounded as in a conventional water-permeable paving method.

A filter layer is then spread on the ground. For a filter layer, sands having a coefficient of water permeability of more than  $10 \times 10^{-4}$  cm/sec are used. A filter layer is to prevent mixing of earth with an upper base layer as well as to purify contaminated water.

On the filter layer, a rubble base layer is spread in order to distribute an upper load and to store a constant amount of water for a certain period of time. The rubble base layer has a coefficient of water permeability of more than  $10 \times 10^{-2}$  cm/sec, and is pounded sufficiently to obtain the maximum density at the optimum functional rate after being spread.

#### Process No. 2

The aggregate for water-permeable concrete for a base layer or for a roadway pavement should have the maximum dimensions of 40mm, 25mm and 19mm. To the

aggregate, 250-500 kg/m<sup>3</sup> of cement, water at a water-cement ratio of 25-40%, and a cement delaying agent of less than 1% with respect to the weight of the cement used are mixed.

Aggregate has significant influence on water permeability and strength, and is classified according to its use and shape. FIG. 4 shows particle size distribution of crude aggregate having the maximum dimension of 40mm. As seen in FIG. 4, the particle pass rates in weight % were 100% measured by a 50-mm sieve, 95-100% by a 40-mm sieve, 75-95% by a 25-mm sieve, 15-55% by a 10-mm sieve, 0-2% by Sieve No. 4, 0-10% by Sieve No. 10, and 0-5% by Sieve No. 40.

FIG. 5 shows particle size distribution of crude aggregate having the maximum dimension of 25mm. As seen in FIG. 5, the particle pass rates in weight % were 100% measured by a 40-mm sieve, 95-100% by a 25-mm sieve, 65-90% by a 19-mm sieve, 40-80% by a 13-mm sieve, 0-10% by Sieve No. 10, and 0-10% by Sieve No. 40.

Further, FIG. 6 shows particle size distribution of crude aggregate having the maximum dimension of 19mm. As seen in FIG. 6, the particle pass rates in weight % were 100% measured by a 25-mm sieve, 95-100% by a 19-mm sieve, 20-60% by a 10-mm sieve, 0-20% by Sieve No. 4, 0-10% by Sieve No. 10, and 0-5% by Sieve No. 40.

The above three kinds of aggregates are to be used selectively according to the needs of specific occasions.

Water-permeable concrete for a roadway pavement should have a compression strength of more than 260 kg/cm<sup>2</sup> or a bending strength of more than 40 kg/cm<sup>2</sup>; however, in the present invention, the compression strength is determined to be more

than  $200 \text{ kg/cm}^2$  and the bending strength to be more than  $30 \text{ kg/cm}^2$  for the sake of varieties of the products.

Cement can be used between the scope of 250 to  $500 \text{ kg/cm}^3$  to be fitted to the situation. A water-cement ratio is determined to be 25-40%, a porosity to be 10-20%, and a coefficient of water permeability to be  $10 \times 10^{-2} \text{ cm/sec}$  taken into consideration of the quality of the aggregate, planned strength, a coefficient of water permeability, etc.

The amount of the aggregate included in water-permeable concrete is computed according to the following equation assuming that the amount of the cement used and the water-cement ratio are determined based on the strength.

$$\begin{aligned} &\text{Amount of aggregate to be used} \\ &= [880 - (\text{weight of water} + (\text{amount of cement/gravity of cement})] \\ &\quad \times \text{gravity of aggregate} \end{aligned}$$

In the above formula, the figure 880 is the volume of water-permeable concrete for a roadway pavement per  $1 \text{ m}^3$ , which means there is 12% of pores in  $1 \text{ m}^3$  of pavement.

In water-permeable concrete for a surface layer, a polymer is mixed into to control the strength and durability. Such polymer includes emulsion-type acrylic resins, emulsified asphalt, SBR latex, etc. The amount of the polymer to be used is within the range of 20% of the weight of the cement. In economical aspect, it is desirable to use emulsified asphalt. In water-permeable concrete for a surface layer, a pigment is mixed

into for coloring.

An inorganic pigment within 10% range of the weight of cement used may be used. In water-permeable concrete for a surface layer, about 1.5 kg/m<sup>3</sup> of a reinforcement agent can be used for the compensation of a bending strength. Such reinforcement agent includes polypropylene fibers, polyethylene fibers, and carbon fibers, and in some case, iron fibers can also be used. For a cement delaying agent, KSF 2560 (chemical admixture for concrete, JIS standard A 6204) or ASTM C 494 (chemical admixture for concrete, standard specification) can be used within the range of 1% of the amount of cement used. SiO<sub>2</sub>, Fly ash, and micro silica fume can also be used.

Each of the above-described materials are measured, mixed together, transported to the working site by a dump truck. And, the mixed concrete is spreaded by using a finisher for asphalt concrete, and is pounded by a tandem roller, a tire roller, etc.

Water-permeable concrete has to be pounded sufficiently to achieve the density of more than that of standard. The standard of pounding differs according to the aggregate used, conditions of working sites, heaviness of equipments used, etc., and therefore, is determined in accordance with the specific situation of each construction. However, generally, 8-12 pounding by a 8-ton tandem roller or 4 pounding by a 12-ton tire roller are regarded to be proper for 15 cm-thick pavements.

#### Process No. 2-1

The water-permeable concrete prepared in Process No. 2 can be used for a base layer of a thin fine water-permeable concrete layer, not for a surface layer of roadways.

For this purpose, after completion of Process No. 2, fine water-permeable concrete has to be spread before surface moisture is evaporated or within an hour after completion of pounding of Process No. 2 in order to improve binding strength.

Fine water-permeable concrete, after aging, should have a porosity of more than 7%, a coefficient of water permeability of more than  $10 \times 10^{-3}$  cm/sec. In order to meet these requirements, cement of 250-500 kg/m<sup>3</sup> is used, a water-cement ratio is determined within the range of 25-40% taking into consideration of a coefficient of water permeability, and the amounts of crushed waste glass and fine rubble are calculated according to the following equation:

Amount of aggregate to be used

$$= [930 - (\text{weight of water} + (\text{amount of cement/gravity of cement})) \\ \times \text{gravity of aggregate to be used}]$$

In the above formula, the figure 930 is the volume of fine water-permeable concrete for a roadway pavement per 1 m<sup>3</sup>, which means there is 7% of pores in 1 m<sup>3</sup> of pavement. Accordingly,

$$G_{\max} = [930 - ((250 \times 0.25) + 250/3.15)] \times 2.70 \\ = 2129 \text{ kg/m}^3$$

$$G_{\min} = [930 - ((500 \times 0.40) + 500/3.15)] \times 2.50 \\ = 1428 \text{ kg/m}^3$$

Therefore, the amount of the aggregate to be used is determined within the range of 1,430 - 2,100 kg/m<sup>3</sup>, and the amounts of crushed waste glass and fine rubble are then determined accordingly.

The crushed waste glass to be used should have a pass rate in weight % of 80-100% measured by a 3-mm sieve and of less than 10% by a 1-mm sieve, and its amount to be used is 10-50% of the total weight of fine rubble to be used. The fine rubble to be used should have a pass rate in weight % of 80-100% measured by a 3-mm sieve and of less than 10% by a 1-mm sieve, and their used amount is 50-90% of the total weight of the aggregate used.

In case of using crushed waste glass, the foams within the concrete is increased five times to ten times comparing to when using a general rubble aggregate, which contributes to water permeability. If glass is not used, in order to obtain the same degree of water permeability, a water-cement rate should be lowered by more than 5%. In this case, however, evaporation of moisture during construction creates difficulties in achieving such water-permeability.

For more strong binding of this thin fine layer with the base layer (water-permeable concrete layer) and for improving the strength of this thin fine water-permeable concrete, an emulsion-type polymer is used, which includes epoxy resins, acrylic resins, asphalt, latex, etc. The polymer should have superior durability against weather. The amount of the polymer (50% of the solid material) to be used is 10-50% of the weight of cement to be used. The amount of a cement delaying agent to be used should be less than 2% of the weight of cement to be used taking into consideration of transportation, spreading, pounding time, etc., and for coloring, an

inorganic coloring agent having superior durability against weather is used in an amount of less than 20% of the weight of cement to be used.

The materials selected and measured as described above are mixed by a mixer, and thin fine water-permeable concrete is spread in a thickness of less than 3 cm on the base layer (water-permeable concrete for roadway pavement) by using a thin-layer spreader or manually. After spreading, the concrete is pounded twice to five times using a roller or a compactor to obtain a density required for maintaining flatness.

### Process No. 3

After completion of Process 2 or 2-1, the concrete is aged for more than one day covered by vinyl or the like. After aging, a polymer is spread to be absorbed, and small pores of water-permeable concrete are filled with the polymer. By the spread of polymer, the strength of the concrete can be enforced, because the polymer covering the inside of each pores improves the strength of the concrete and prevents the corrosion due to moisture.

Examples of a polymer for adsorption process include emulsion-type acrylic resins, epoxy resins, urethane, emulsified asphalt, latex, etc. It is desired to mix an emulsion-type acrylic resin which has superior durability with water, at a resin to water ratio of 1:5 to 1:10, and to spread the mixture more than twice for sufficient adsorption into water-permeable concrete.

After spreading, in accordance with conventional (general) way, vertical and horizontal lines are impressed generally at intervals of 3-10m for contraction horizontal lines, of 30-100m for expansion horizontal lines, and of 2.5-5m for vertical lines.

Accordingly, spreading of a thin fine water-permeable concrete layer having a compression strength of 150-400 kg/cm<sup>2</sup>, a porosity of more than 7%, and a coefficient of water permeability of more than  $10 \times 10^{-3}$  cm/sec is completed.

The water-permeable concrete for roadway pavement constructed as described above is subject to testing of compression strength, functional rate, and porosity; and further after completion of paving, density, pounding rate, coefficient of water permeability, and color.

For testing of compression strength, water-permeable concrete for roadway pavement is pounded 50 times each for three separate layers by using a 2.5 kg pounding rod on a 50mm circular pounding plate from a height of 300mm in case of using a 10-20 cm sampling mold. A sample is manufactured by filling the cylinder with water-permeable concrete and pressing its surface sufficiently by a triangular rod. At this time, the bottom and upper portion of the sample should be covered by cement powders and should not show any pores on their surfaces. After two days, molding is released, and a sample is immersed into a mixture of an acrylic resin and water at a resin to water ratio of 1:5 to 1:10 based on 50% of solid material under the same conditions as actual conditions.

A sample for testing bending strength is constructed by pounding the concrete in two layers by using a 4.5 kg pounding rod on a 50mm circular pounding plate from a height of 450mm. The number of pounding is determined from the area of a testing mold, and finishing is the same as for a sample for compression testing.

The strength of fine water-permeable concrete is tested according to KSL 5105 (testing method of compression strength of hydraulic cement mortar, cement testing

method ISO 699 standard, strength measurement method).

The cylinder thus formed is tested 28 days after being aged by atmospheric moisture for compression strength testing method KSF 2405 (concrete compression strength testing method, ISO 3893 standard concrete - classification according to compression strength, ISO 4012 standard concrete - compression strength measurement method of reagent), KSF 2408 (testing method for bending strength of concrete, ISO 4013 standard concrete - measurement method of bending strength of reagent), and KSL 5105 (testing method of compression strength for hydraulic cement mortar).

A functional rate is for maintaining a constant water-cement ratio for water-permeable concrete which is difficult in slumping test. It is computed according to the following equation from the weights of water-permeable concrete in wet and dry states:

$$\text{Functional rate} = \frac{[(\text{weight in wet state} - \text{weight in dry state}) / \text{weight in wet state}] \times 100}{}$$

Porosity of water-permeable concrete is computed from a ratio of theoretical unit volume weight of absolute unit volume weight of wet water-permeable concrete and actual unit volume test employs unit volume for the manufacturing method of a sample for compression strength measurement.

The unit volume weight is the weight of concrete per  $1 \text{ m}^3$  when packed without air and pores, and its unit is  $\text{kg/m}^3$ .

Therefore, porosity is computed according to the following equation:

$$\text{Porosity} = 100 - \left[ \frac{\text{unit volume weight of water-permeable concrete}}{\text{unit volume weight for absolute unit volume weight}} \times 100 \right]$$

The products at the time of construction are classified according to pounding rate, coefficient of water permeability, and color. The pounding rate depends on density and is computed from the density of the sample for compression strength test as well as that of the core product at working sites.

$$\text{Pounding rate} = \left( \frac{\text{density of core product at working sites}}{\text{density of sample}} \right) \times 100$$

A more accurate pounding rate can be obtained by sampling the core product from a mold for strength testing.

The density of water-permeable concrete is computed using a paraffin as it has a large number of pores.

$$\text{Density} = \frac{A}{(D - E) \left( \frac{(D - A)}{F} \right)}$$

where A is the weight of sample in air, D is the weight of covered sample in air, E is the weight of covered sample in water, and F is gravity of a paraffin.

A coefficient of water permeability depends on the water permeability testing method at working sites by a detector shown in FIG. 7, and is computed according to the following equation:

$$KP = [(L \times a) / A (t_2 - t_1)] \log e^{18} (h_1/h_2)$$

where L is the height of paving material, a is a cross-sectional area of a container, A is a water-permeated cross-sectional area,  $t_2$  and  $t_1$  are duration of water permeation,  $h_1$  is a water level at the beginning of testing, and  $h^2$  is a water level at the completion of testing.

Color of the concrete is determined by consulting the user, and its samples are made and compared with the products.

Hereinafter examples of the present invention are illustrated.

#### Example 1:

Red-colored water-permeable pavement having compression strength of 240 kg/cm<sup>2</sup> was planned to be constructed for a traffic paving material for Traffic B roadway of 10 m width and 10 km length. Here, Traffic B roadway refers to a roadways of which the volume of traffic would be 250-1000 large-sized automobiles per day after five years.

FIG. 8 is a standard cross-sectional diagram of water-permeable concrete for roadway pavement constructed by this example 1.

#### Process No. 1

The ground was consolidated and sufficiently pounded, and sands of 5,000 m<sup>3</sup>

were spread as a filter layer F in a thickness of 5 cm using a grader and pounded by a roller. A rubble base layer RB of 30,000 m<sup>3</sup> was spread by a grader using rubble of 40mm, water was sprayed, and pounded. At this time, a rubble base layer has to be spread and pounded for the coefficient of water permeability to be more than  $10 \times 10^{-2}$  cm/sec.

#### Process No. 2

A water-permeable concrete base layer CB in a thickness of 40mm was spread as follows:

General Portland cement was used in an amount of 350 kg/m<sup>3</sup>. A water-cement ratio was determined to be 35% taking into consideration of the functional rate, and the unit weight of water 122 kg/m<sup>3</sup> was determined accordingly.

The amount of the aggregate used was 1,714 kg/m<sup>3</sup> according to the equation, and 1.75 kg/m<sup>3</sup> of a cement delaying agent was used. These materials were mixed by a mixer, transported to working sites by a dump truck. The total 20,000 m<sup>3</sup> of asphalt was spread by a finisher, and pounded 10 times by a tandem roller.

Table 1 and Table 2 below show particle size distribution and mixing rate, respectively, of the above water-permeable concrete of 40mm.

Table 1

| % of Aggregate passed through Sieve |             |             |             |             |             |            |            |
|-------------------------------------|-------------|-------------|-------------|-------------|-------------|------------|------------|
| Sieve Size                          | 50-mm Sieve | 40-mm Sieve | 25-mm Sieve | 10-mm Sieve | Sieve #4    | Sieve #10  | Sieve #40  |
| Actual %                            | <u>100</u>  | <u>98.5</u> | <u>80.4</u> | <u>30.2</u> | <u>14.7</u> | <u>6.4</u> | <u>2.2</u> |
| Expected %                          | 100         | 95-100      | 75-95       | 15-55       | 0-20        | 0-10       | 0-5        |

Table 2

| Mixing Rates | Weight of Components (kg/m <sup>3</sup> ) |        |           |                |
|--------------|-------------------------------------------|--------|-----------|----------------|
|              | water                                     | cement | aggregate | delaying agent |
| 40-240       | 122                                       | 350    | 1,714     | 1.75           |

(Compression strength 240 kg/m<sup>2</sup>)

On the base layer of water-permeable concrete, a surface layer CS of water-permeable concrete, i.e., a water-permeable concrete layer of 19mm, was spread.

General Portland cement was used in an amount of 360 kg/m<sup>3</sup>, and a water-cement ratio was determined to be 36% taking into consideration of the functional rate to have a unit weight of water 130 kg/m<sup>3</sup>. The amount of the aggregate used was 1,685 kg/m<sup>3</sup> according to the equation, and an emulsion-type acrylic resin of 10 kg/m<sup>3</sup> based on 50% solid material was used taking into consideration of durabilities against weather and shocks. 0.9 kg/m<sup>3</sup> of reinforcement fibers of 12mm length, 1.8 kg/m<sup>3</sup> of a delaying agent, and 18 kg/m<sup>3</sup> of a red inorganic coloring agent were used.

These materials were mixed by a mixer, transported to working sites by a dump truck. The total 10,000 m<sup>3</sup> of asphalt was spread by a finisher, pounded eight times by a tandem roller, and again pounded four times by tire roller.

Table 3 and Table 4 below show particle size distribution and mixing rate, respectively, of the above water-permeable concrete of 19mm.

Table 3

| % of Aggregate passed through Sieve |             |             |             |          |           |           |
|-------------------------------------|-------------|-------------|-------------|----------|-----------|-----------|
| Sieve Size                          | 25-mm Sieve | 19-mm Sieve | 10-mm Sieve | Sieve #4 | Sieve #10 | Sieve #40 |
| Actual %                            | 100         | 100         | 40.5        | 16.4     | 7.2       | 3.0       |
| Expected %                          | 100         | 95-100      | 20-60       | 0-20     | 0-10      | 0-5       |

Table 4

| Mixing Rates | Weight of Components (kg/m <sup>3</sup> ) |        |           |                |       |              |         |
|--------------|-------------------------------------------|--------|-----------|----------------|-------|--------------|---------|
|              | water                                     | cement | aggregate | delaying agent | resin | reinf. fiber | pigment |
| 19-240       | 122                                       | 360    | 1,685     | 1.8            | 10    | 0.9          | 18      |

(compression strength 240 kg/m<sup>2</sup>)

### Process No. 3

The surface layer of the concrete was pounded, covered by vinyl, and aged for three days. After aging, vinyl was uncovered, 300 kg of an emulsion-type acrylic

resin based on 50% solid material and 2, 000 kg of water were spread twice, compression lines were impressed at 5 m intervals up to one third portion from the surface layer, vertical and horizontal lines were impressed at 50 m intervals cutting through more than 7 mm, and filled with a back-up agent and silicon. After 14 days, the construction was completed and ready to be used.

The result of a quality test for water-permeable concrete thus constructed is shown in Table 5 below.

Table 5

|                  |      | Compression<br>Strength<br>(kg/cm <sup>2</sup> ) | Porosity<br>(%) | Pounding<br>Rate(&) | Coefficient<br>of Water<br>Permeability<br>(cm/sec) | Color                                   |
|------------------|------|--------------------------------------------------|-----------------|---------------------|-----------------------------------------------------|-----------------------------------------|
| Actual<br>Values | 40m  | 265                                              | 13.7            | 101.4               | $4.1 \times 10^{-1}$                                | good<br>(compar-<br>ing with<br>sample) |
|                  | 19mm | 271                                              | 12.6            | 102.5               | $5.5 \times 10^{-1}$                                |                                         |
| Standard         |      | >240                                             | >10             | >100                | $>10 \times 10^{-2}$                                | sample                                  |

#### Example 2:

In this example 2, construction of a parking lot of 100 m<sup>2</sup> by using a green fine water-permeable concrete layer was planned to be constructed. For this purpose,

paved were a filter layer of 5 cm, a rubble base layer of 15 cm, a 25 mm base layer of water-permeable concrete of 9 cm having compression strength of  $210 \text{ kg/cm}^2$ , and fine water-permeable concrete of 1 cm having compression strength of  $210 \text{ kg/cm}^2$ ; and after aging, the concrete was to have a coefficient of water permeability of more than  $10 \times 10^{-3} \text{ cm/sec}$  and porosity of more than 7%.

FIG. 9 shows a standard cross-sectional view of fine water-permeable concrete constructed according to this embodiment of the present invention.

#### Process No. 1

The ground was consolidated, and a sand filter layer F of  $5 \text{ m}^3$  having a coefficient of water permeability of  $10 \times 10^{-3} \text{ cm/sec}$  was spread and pounded by a roller. Then a rubble base layer RB of  $15 \text{ m}^3$  having a coefficient of water permeability of more than  $10 \times 10^{-2} \text{ cm/sec}$  was spread to have the maximum density which is dependent on the maximum functional rate.

#### Process no. 2

Water-permeable concrete of  $9 \text{ m}^3$  for a base layer CB was prepared by mixing  $120 \text{ kg/m}^3$  of water,  $320 \text{ kg/m}^3$  of cement,  $1,712 \text{ kg/m}^3$  of aggregate and  $0.96 \text{ kg/m}^3$  of a delaying agent to have a coefficient of water permeability of  $10 \times 10^{-2} \text{ cm/sec}$ , a porosity of more than 10%, and a strength of more than  $210 \text{ kg/cm}^2$ . The concrete was then spread and pounded.

Process NO. 2-1

After completion of pounding of the base layer CB of water-permeable concrete, a surface layer TC of fine water-permeable concrete was spread within an hour after pounding. In order to spread the surface layer TC of fine water-permeable concrete, 150 kg/m<sup>3</sup> of water, 370 kg/m<sup>3</sup> of white cement, and waste glass and fine rubble which have pass rates in weight % of 80-100% measured by a 3-mm sieve and of less than 10% by a 1-mm sieve were mixed. The proportion between the amount of waste glass and that of fine rubble was 30:70. As the amount of the aggregate (waste glass and fine rubble) G is computed according to an equation:

$$G = [930 - (150 + (370/3.15))] \times 2.60 = 1,723 \text{ kg/m}^3$$

According to the above equation, the amount of waste glass to be used is 517 kg/m<sup>3</sup> (1,723 kg/m<sup>3</sup> x 0.3), and that of fine rubble is 1,206 kg/m<sup>3</sup> (1,723 kg/m<sup>3</sup> x 0.7)

As a polymer, an acrylic resin of 50% solid material in an amount of 20% of the weight of cement, namely 370 kg/m<sup>3</sup> x 0.2 = 74 kg/m<sup>3</sup> was used. A delaying agent in an amount of 0.3% of the weight of cement, namely 370 kg/m<sup>3</sup> x 0.03 = 11.1 kg/m<sup>3</sup> was used. As a coloring agent, chromium oxide, which is a green inorganic compound, was used in an amount of 3% of the weight of cement, namely 370 kg/m<sup>3</sup> x 0.03 = 11.1 kg/m<sup>3</sup>. 1 m<sup>3</sup> of the raw materials was mixed sufficiently by a mixer.

The mixed fine water-permeable concrete was spread manually on the base layer CB of water-permeable concrete prepared in process No. 2, and pounded compactly to have a sufficient strength, a porosity of more than 7%, a coefficient of water

permeability of  $10 \times 10^{-3}$  cm/sec, and a sufficient density. After pounding, the concrete was covered by vinyl to prevent evaporation of moisture, was sprayed by water after one day, and was dried after two days.

### Process No. 3

After the surface of the concrete was dried, an epoxy primer based on 50% solid material was sprayed on the surface of fine water-permeable concrete by a sprayer. 30kg of the compound was used in order to reach the base layer of water-permeable concrete. The concrete was aged in air for more than 7 hours, after which walking thereon was allowed, lines were impressed at 5m intervals, and traffic was allowed after 14 days. The test result of a thin pavement layer of fine water-permeable concrete is shown in Table 6.

Table 6

|                                                         |                 | Compression<br>Strength<br>(kg/cm <sup>2</sup> ) | Porosity<br>(%) | Coefficient<br>of Water<br>Permeability<br>(%) |
|---------------------------------------------------------|-----------------|--------------------------------------------------|-----------------|------------------------------------------------|
| Water-permeable<br>concrete<br>base layer               | Actual<br>value | 264                                              | 17              | $5.1 \times 10^{-1}$                           |
|                                                         | Standard        | >210                                             | >10             | $>10 \times 10^{-2}$                           |
| Fine<br>water-permeable<br>concrete<br>surface<br>layer | Actual<br>value | 247                                              | 11              | $9.7 \pm 10^{-1}$                              |
|                                                         | Standard        | >210                                             | >7              | $>10 \times 10^{-3}$                           |

|                                             |              | Color                 | Flatness                                               | Pounding Rate |
|---------------------------------------------|--------------|-----------------------|--------------------------------------------------------|---------------|
| Water-permeable concrete base layer         | Actual value | -                     | 3                                                      | 103           |
|                                             | Standard     | -                     | within $\pm 5\text{mm}$ measured by 3-m straight ruler | >100          |
| Fine water-permeable concrete surface layer | Actual value | same                  | 2                                                      | 102           |
|                                             | Standard     | comparing with sample | within $\pm 3\text{mm}$ measured by 3-m straight ruler | >100          |

While the present invention has been described in terms of examples, those skilled in the art will recognize that the invention can be practiced with modification within the spirit and scope of the appended claims.

**WHAT IS CLAIMED IS:**

1. A paving method of water-permeable concrete, comprising the steps of:  
  
spreading and pounding a sand filter layer having a coefficient of water permeability of more than  $10 \times 10^{-4}$  cm/sec and a rubble base layer having a coefficient of water permeability of more than  $10 \times 10^{-2}$  cm/sec on consolidated ground;  
  
paving a base layer of water-permeable concrete by mixing crude aggregate for said base layer, 250-500 kg/m<sup>3</sup> of cement, and water at a water-cement ratio of 25-40% by site standard, spraying a mixture of said crude aggregate, said cement and said water, and pounding said mixture;  
  
paving a surface layer of water-permeable concrete by mixing crude aggregate for said surface layer, 250-500 kg/m<sup>3</sup> of cement, water at a water at a water-cement ratio of 25-40% by site standard, and at least one polymer selected from a group consisting of an emulsion-type acrylic resin, emulsified asphalt, and SBR latex in an amount of less than 20% of a weight of cement used, spreading a mixture of said crude aggregate, said cement, said water, and said polymer on said base layer of water-permeable concrete, and pounding said mixture, and aging said surface layer of water-permeable concrete for more than one day after covering said surface layer with vinyl; and  
  
mixing at least one polymer selected from a group consisting of an emulsion-type acrylic resin, an epoxy resin, urethane, emulsified asphalt, and latex, with water, spreading the mixture on said base layer of water-permeable concrete, and aging said water-permeable concrete.



2. The paving method of water-permeable concrete as defined in claim 1, wherein:

said crude aggregate for said base layer has a maximum particle size of 40 mm, and has particle pass rates in weight % of 100% measured by a 50-mm sieve, 95-100% by a 40-mm sieve, 75-95% by a 25-mm sieve, 15-55% by a 10-mm sieve, 0-2% by sieve No. 4, 0-10% by sieve No. 10, and 0-5% by sieve No. 40; and

said crude aggregate for said surface layer has a maximum particle size of 19 mm, and has particle pass rates in weight % of 100% measured by a 25-mm sieve, 95-100% by a 19-mm sieve, 20-60% by a 10-mm sieve, 0-20% by sieve No. 4, 0-10% by sieve No. 10 and 0-5% by sieve No. 40.

3. The paving method of water-permeable concrete as defined in claim 1, further comprising the step, after paving said base layer, of:

paving a middle layer of water-permeable concrete by mixing crude aggregate for said middle layer, 250-500 kg/m<sup>3</sup> of cement, and water at a water-cement ratio of 25-40% by site standard, spraying a mixture of said crude aggregate, said cement, and said water on said rubble base layer, and pounding said mixture.

4. The paving method of water-permeable concrete as defined in claim 3, wherein 3, wherein said crude aggregate for said middle layer has a maximum particle size of 25mm, and has particle pass rates in weight % of 100% measured by a 40-mm sieve, 95-100% by a 25-mm sieve, 65-90% by a 19-mm sieve, 40-80% by a 13-mm sieve, 0-10% by Sieve No. 10, and 0-5% by Sieve No. 40.



5. The paving method of water-permeable concrete as defined in claim 1, wherein an amount of cement used and said water-cement ratio are determined after pounding to have porosity of 10-20% and a coefficient of water permeability of more than  $10 \times 10^{-2}$  cm/sec.

6. The paving method of water-permeable concrete as defined in claim 1, wherein an amount of aggregate used is computed, after an amount of cement used and said water-cement ratio are determined, according to an equation:

$$\text{Amount of aggregate to be used} = [880 - (\text{weight of water} + (\text{amount of cement/gravity of cement}))] \times \text{gravity of aggregate to be used}$$

where 880 is a volume of  $1 \text{ m}^3$  of water-permeable concrete for a roadway pavement excluding porosity of 12%.

7. The paving method of water-permeable concrete as defined in claim 1, further comprising the step, at a step of mixing raw materials for said surface layer of water-permeable concrete, of mixing additionally an inorganic pigment for coloring said surface layer in an amount of less than 10% of a weight of cement used.

8. The paving method of water-permeable concrete as defined in claim 1, further comprising the step, at a step of mixing raw materials for said surface layer of water-permeable concrete, of mixing additionally, for reinforcement of a bending strength



of said surface layer, at least one reinforcement agent selected from a group consisting of polypropylene fibers, polyethylene fibers, and carbon fibers is mixed in an amount of  $1.5 \text{ kg/m}^3$ .

9. A paving method of water-permeable concrete, comprising the steps of:

spreading and pounding a sand filter layer having a coefficient of water permeability of more than  $10 \times 10^{-4} \text{ cm/sec}$  and a rubble base layer having a coefficient of water permeability of more than  $10 \times 10^{-2} \text{ cm/sec}$  on consolidated ground;

paving a base layer of water-permeable concrete by mixing crude aggregate in a predetermined amount, cement, and water to have porosity after pounding of 10-20% and a coefficient of water permeability of more than  $10 \times 10^{-2} \text{ cm/sec}$ , spraying a mixture of said crude aggregate, said cement, and said water on said rubble base layer, and pounding said mixture;

paving a surface layer of fine water-permeable concrete by mixing crushed waste glass, fine rubble,  $250\text{-}500 \text{ kg/m}^3$  of cement, water at a water-cement ratio of 25-40% by site standard, and at least one polymer selected from a group consisting of an emulsion-type acrylic resin, emulsified asphalt, and SBR latex in an amount of 10-50% of a weight of cement used based on 50% solid material, spreading a mixture of said crushed waste glass, said fine rubble, said cement, said water, and said polymer on said base layer of water-permeable concrete within an hour after paving said base layer of water-permeable concrete, and pounding said mixture, and aging said surface layer of fine water-permeable concrete for more than one day after covering said surface layer with vinyl; and



mixing at least one polymer selected from a group consisting of an emulsion-type acrylic resin, an epoxy resin, urethane, emulsified asphalt, and latex, with water, spreading the mixture on said base layer of water-permeable concrete, and aging said water-permeable concrete.

10. The paving method of water-permeable concrete as defined in claim 9, wherein said crushed waste glass and fine rubble have particle pass rates in weight % of 80-100% measured by a 3-mm sieve, and less than 10% by a 1-mm sieve.

11. The paving method of water-permeable concrete as defined in claim 9, wherein an amount of cement used and said water-cement ratio are determined after aging to have porosity of more than 75, a coefficient of water permeability of  $10 \times 10^{-3}$  cm/sec, and compression strength of 150-400 kg/cm<sup>2</sup>.

12. The paving method of water-permeable concrete as defined in claim 9, wherein an amount of aggregate used is computed, after an amount of cement used and said water-cement ratio are determined, according to an equation:

$$\text{Amount of aggregate to be used} = [930 - (\text{weight of water} + (\text{amount of cement/gravity of cement}))] \times \text{gravity of aggregate to be used}$$

where 930 is a volume of 1m<sup>3</sup> of fine water-permeable concrete excluding porosity of 7%.



13. The paving method of water-permeable concrete as defined in claim 12, wherein:

an amount of said fine rubble used is determined to be within a range of 50-90% of an amount of said crude aggregate used; and

an amount of said crushed waste glass used is determined to be within a range of 10-50% of an amount of said fine rubble used.

14. The paving method of water-permeable concrete as defined in claim 9, further comprising the step, at a step of mixing raw materials for said surface layer of fine water-permeable concrete, of mixing additionally an inorganic pigment for coloring said surface layer in an amount of less than 20% of a weight of cement used.