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This invention relates to a method of lightweight concrete paving offering excellent water permeability and retention, as well as a water-retentive/permeable concrete block, the combination of which, when applied on a rooftop in particular, can provide the same cooling and heat-insulating effects achievable with a rooftop garden.

Concrete, due to its strength, is used in various applications. However, concrete paving provides poor drainage due to the low water-permeability of concrete and is prone to ponding during periods of rain. Therefore, to ensure safety, water-permeable concrete is used in the paving of some public roads.

Rooftop gardens are generally constructed by first providing a concrete planting base on the mortar surface of the roof in a manner that allows such planting base to remain completely separate from the surface of the roof, and then laying earth onto the planting base.

Because porous concrete is made of cement and a natural aggregate such as crushed stone, it is heavy and difficult to transport, handle and install. Moreover, portland cement, which is highly alkaline, inhibits the budding of plant seeds, and the plant fibers and seeds filled/planted in the planting base made using portland cement are easily washed away by rainwater.



Given the above-mentioned reasons, a “lightweight porous concrete material” has been developed as described in the literature specified below. This lightweight porous concrete material is made by blending portland cement with one or more of diatomaceous earth, perlite pumice, artificial aggregate and other mineral-based lightweight aggregates having low specific gravity. These lightweight aggregates should ensure water absorbency. Particularly, the specific gravity of aggregate or aggregates should be 0.38 to 0.5 and the aggregate grain size should be in the range of 5 to 20 mm. The blending ratio should be 15 percent for portland cement, 80 percent for aggregate(s), and five percent for conditioner(s) (all based on weight ratio). The compressive strength of the lightweight porous concrete material is 15 to 25 kg/cm², and its void ratio is 30 to 40 percent.

Normally, water-permeable concrete uses a binder and/or other organic additives for the purpose of enhancing its strength.

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However, a rooftop garden requires that a planting base be formed and plants placed within the base, and that the plants thereafter receive constant care. If upkeep is neglected, the rooftop garden cannot be maintained.

Drainage and the load placed on the roof, however, are particularly important in the construction of a rooftop garden. In reality the Enforcement Ordinance of the Construction Standard Law specifies the maximum allowable loading capacity of a rooftop surface as 130 kg/m², which incidentally is the maximum allowable seismic load of such surface. The roofs of high-rise buildings where rooftop gardens are needed are generally flat roofs without any peripheral railings, which are not designed to sustain a load. Therefore, to grow plants on such a roof a method that minimizes the load must be employed.

Planting also requires that drainage paths be provided to draw off the water present in the earth. To that end, drainage outlets are generally provided as necessary at the bottoms of the walls surrounding the plants, and netting is used to cover the drainage outlets to prevent the earth from flowing out with the drainage water. However, this method leads to poor drainage efficiency. Although the drainage outlets are covered with netting, it is impossible to block all waste matter released from earth. As a result, the conventional rooftop drains have been subject to frequent clogging.

Summary of the Invention

To address the above problems, the method of water-retentive/permeable concrete paving proposed through the present invention is intended to provide the same cooling and heat-insulating effects that can be achieved by a rooftop garden in a manner that imposes a minimal load on the roof and further obviates the need for plantings.

The method of water-retentive/permeable concrete paving proposed through the present invention comprising mixing 50 to 62 percent by weight of pumice with a grain size of 3 to 20 mm and 50 to 38 percent by weight of portland cement without adding any strength-enhancing additives, kneading the mixture with the addition of 40 to 50 percent by weight of water, and then laying the freshly mixed concrete.

The water-retentive/permeable concrete block proposed through the present invention is produced by mixing 50 to 62 percent by weight of pumice with a grain size of 3 to 20 mm and 50 to 38 percent by weight of portland cement without adding any strength-enhancing additives, kneading the mixture with the addition of 40 to 50 percent by weight of water, and then pouring the freshly mixed concrete into a mold and allowing it to harden.

The water-retentive/permeable concrete proposed through the present invention provides a pavement offering both water retentiveness and permeability. Since the temperature of the concrete surface is lowered by means of heat of vaporization that occurs when the water stored within the pavement evaporates, the heat island effect can be prevented.

The water-retentive/permeable concrete proposed through the present invention uses pumice of relatively small specific gravity as an aggregate, and can therefore be used on a roof having a limited allowable load. Since no planting is required on the roof, water is not required in the spring, autumn or winter, when the heat island effect does not occur. This contributes to the conservation of water.

A block made of the water-retentive/permeable concrete proposed through the present invention is lightweight and strong. It provides sufficient water retention as well as permeability, and can therefore be laid over the roof's entire surface.

Brief Description of the Drawings

Fig. 1 is a sectional view of a rooftop paved with a water-retentive/permeable concrete according to a first embodiment of the present invention;

5 Fig. 2 is a plan view illustrating the rooftop of Fig. 1 paved with a water-retentive/permeable concrete according to the present invention; and

Fig. 3 is a sectional view (a) of a mold for making a water-retentive/permeable concrete block according to the present invention, and a sectional view (b) of the concrete block according to a second embodiment of the
10 present invention.

Detailed Description of the Preferred Embodiment

In a first embodiment of the present invention as shown in the sectional view in Fig. 1, the method of water-retentive/permeable concrete paving proposed through
15 the present invention does not use binder or sand. Instead, a freshly mixed concrete comprising pumice of large grain size (11), portland cement and water is laid over the entire surface of the roof (3) to form a pavement (1).

Specifically, based on the results of various experiments, this paving method is comprised of mixing 50 to 62 percent by weight of pumice with a grain size of 3 to
20 20 mm (dry specific gravity: approx. 0.4) and 50 to 38 percent by weight of portland cement, kneading the mixture by adding 40 to 50 percent by weight of water, and then laying the freshly mixed concrete. Although the specific gravity of dry pumice may vary depending on the place of production, the range of variation should be minimal.

When the blending ratios of the ingredients are expressed in terms of volume,
25 the above description can be rephrased as "mixing 70 to 85 percent by volume of pumice (dry specific gravity: 0.4) and 30 to 15 percent by volume of portland cement, and then kneading the mixture with the addition of 20 to 30 percent by volume of water.

A study concerning the physical properties of the pavement (1) formed by
30 laying the aforementioned freshly mixed concrete found that the specific gravity of normal concrete was approximately $2,300 \text{ kg/m}^3$, while the specific gravity of a water-permeable concrete made using only natural aggregate and portland cement but without using sand was approximately $2,000 \text{ kg/m}^3$ when wet and approximately

1,800 kg/m³ when dry. On the other hand, the specific gravity of a water-retentive/permeable concrete using an aggregate comprising pumice of an equivalent volume was approximately 1,200 kg/m³ when wet and approximately 900 kg/m³ when dry.

The wet specific gravity of the aforementioned concrete using pumice aggregate is approximately 60 percent of the wet specific gravity of the water-permeable concrete made using only natural aggregate and portland cement. The dry specific gravity of the former is approximately 50 percent of the dry specific gravity of the latter.

Regarding water retention, the wet specific gravity of the water-retentive/permeable concrete using pumice aggregate was approximately 1,200 kg/m³, meaning that water of around 300 kg/m³ or more can be retained by the concrete. As for water permeability, the aforementioned concrete provides water permeability equivalent to a water-permeable concrete using any of the conventional natural aggregates, since only the excess water not retained in pumice is allowed to permeate the concrete.

When this water-retentive/permeable concrete using pumice aggregate is employed in a pavement of 50 mm thick, for example, the wet weight becomes 60 kg/m³ while the dry weight becomes 45 kg/m³. In other words, 15 liters of water can be retained in the concrete per square meter of area.

Next, a strength test of the concrete made using pumice and portland cement found that the compressive strength and bending strength of the concrete were 3.22 N/mm² (36 kg/cm²) and 1.47 N/mm² (16 kg/cm²), respectively. Although this bending strength is lower than the bending strength (2.25 N/mm² or 25 kg/cm²) of the water-permeable concrete made using only natural aggregate and portland cement, a 7-cm thick concrete block made using the pumice/portland cement concrete was able to withstand, for a long period, the assumed load of a parking structure surface or the like on which passenger cars are driven (assuming a roadbed CBR of 10). Therefore, the concrete made using pumice and portland cement is suitable for the construction of a rooftop parking facility.

As confirmed through testing, the method of water-retentive/permeable concrete paving proposed by the present invention can provide the strength required

of the paving material, such strength being achieved by adjusting the blending ratios of the portland cement and pumice, as well as the grain size of the pumice.

The water-retentive/permeable concrete paving proposed through the present invention can lower the surface temperature of the concrete by means of the heat of vaporization that occurs when the water stored within the pavement evaporates. As a result, the heat island effect can be prevented.

The water-retentive/permeable concrete using pumice aggregate as proposed by the present invention is porous and therefore provides such beneficial properties as lightness, heat insulation, and water permeability and retentiveness. Therefore, covering the water-resistant concrete surface of the roof of a building will insulate heat and thus prevent the heat island effect without the need to place plants on the roof and also by minimizing the load to which the roof is subjected.

An exposed water-resistant asphalt layer is a common feature on rooftops. However, exposing a water-resistant asphalt layer is not desirable from the standpoint of fire prevention.

As an alternative method, a water-retentive/permeable concrete using pumice aggregate can be laid over the exposed water-resistant asphalt layer. This way a lightweight, heat-insulating layer can be provided that can preserve the heat on the rooftop and also protect the exposed water-resistant asphalt layer from fire, while at the same time minimizing the load to which the roof is subjected.

Unlike a rooftop garden, earth is not required and dead leaves are not generated. Therefore, the drain pipes will remain free from clogging.

When installing the water-retentive/permeable concrete (1) proposed through the present invention, as shown by the plan view in Fig. 2, a synthetic resin pipe (4) having many small holes can be buried in wet concrete and then water can be introduced to the pipe (4) once the concrete is dry, so that the water-retentive/permeable concrete can be saturated with water. Rainwater stored in a reservoir (6) can be used as the water in this application.

If a synthetic resin pipe (4) having many small holes is buried in concrete when the water-retentive/permeable concrete is installed, the use of sand becomes unnecessary. As a result, many small holes will allow water to pass through, although some of them may become clogged.

In a second embodiment of the present invention, a freshly mixed concrete comprising pumice, portland cement and water is poured into a mold (5) with tapered corners, as shown by the sectional view in Fig. 3 (a), so as to form a concrete block (2) offering water retention and permeability, as shown by the sectional view in Fig. 3 (b).

Specifically, the freshly mixed concrete is poured into the mold (5) in such a way that a thin layer of freshly mixed concrete comprising pumice aggregate (12) with a small grain size of 3 to 6 mm is poured in first, whereupon a thick layer of freshly mixed concrete comprising pumice aggregate (11) with a larger grain size is poured on top of the thin layer, so as to form a concrete block (2) that is lightweight yet offers water retention and permeability.

As described above, the use of pumice with small grain size (12) to form the top face and corners of the water-retentive/permeable concrete block (2) will enhance the strength of the block and prevent the corners from chipping.

When this concrete block is laid over the entire surface of a roof to form a water-retentive/permeable pavement, it will provide the same effects that can be achieved by the first embodiment of the invention. Additionally, such paved area can be used as a parking facility.

The method of water-retentive/permeable concrete paving and a water-retentive/permeable concrete block described in this section utilizes two embodiments of the invention to illustrate how the disadvantages of convention concrete paving methods are addressed. Although only two embodiments of the invention are disclosed, numerous modifications can be made to the embodiment without departing from the spirit and scope of the invention.

WHAT IS CLAIMED IS:

1. A method of water-retentive/permeable concrete paving, comprising the steps of:
 - 5 mixing 50 to 62 percent by weight of pumice with a grain size of 3 to 20 mm and 50 to 38 percent by weight of portland cement without adding any strength-enhancing additives;
 - kneading the mixture with the addition of 40 to 50 percent by weight of water; and
 - 10 laying the resultant freshly mixed concrete.
2. The method as described in Claim 1, wherein a pipe having numerous small holes is buried in wet concrete and then water is introduced to the pipe once the concrete is dry, in order to impregnate the water-retentive/permeable concrete with
15 water.
3. A water-retentive/permeable concrete block produced by mixing 50 to 62 percent by weight of pumice with a grain size of 3 to 20 mm and 50 to 38 percent by weight of portland cement without adding any strength-enhancing additives, kneading
20 the mixture with the addition of 40 to 50 percent by weight of water, and then pouring the freshly mixed concrete into a mold and allowing it to harden.
4. The block as described in Claim 3, wherein the top layer of the block comprises pumice of small grain size while the middle and bottom layers comprises
25 pumice of large grain size.