

DESCRIPTION

AGGREGATE PARTICLES, METHOD OF MANUFACTURING THE SAME, AND HEAT SHIELD PAVEMENT

5 FIELD

[0001] The present invention relates to aggregate particles having a good reflectance of solar radiation, a method of manufacturing the same, and a heat shield pavement containing the aggregate particles.

10 BACKGROUND

[0002] Heat shield functions for asphalted roads are drawing attention and have recently been making progresses for the purpose of reducing an urban heat island phenomenon. Most of them are conventionally known heat shield coating, which is heat shield paint dispersed directly to a pavement asphalt surface to form a pavement structure
15 having a heat shield property (refer to Patent References 1 to 4, for instance).

PRIOR ART REFERENCE

PATENT REFERENCE

[0003] Patent Reference 1: Japanese Patent No. 4118090 (B)
20 Patent Reference 2: JP-A 2004-251108
Patent Reference 3: Japanese Patent No. 4401171 (B)
Patent Reference 4: WO 2014/077332 A1

SUMMARY OF THE INVENTION

25 PROBLEMS TO BE SOLVED BY THE INVENTION

[0004] However, the heat shield paint by nature is low in strength because it is a resin film, and when applied on a road surface, incessantly receives external force due to vehicle passage and so on and further receives deformation force that is generated because the

asphalt pavement itself is not rigid, and as a result easily breaks or abrades. As for the abrasion out of wear-out forms, there is a technique to improve abrasion resistance by compounding hard ceramic powder in the resin, but there still remains a problem that the resin itself cracks to break and fall off.

5 Further, it is known that properties of lightness and reflectance of solar radiation of a pavement have mutual correlation. That is, a white pavement has a high reflectance of solar radiation.

[0005] However, on road surfaces, there are white line marking materials for lane demarcation and stop line markings, and distinction from the white lines are required for
10 traffic safety, and this background does not permit the heat shield pavement surfaces to be white. In accordance with the lightness of the pavement, there has been a certain limit to the upper limit of the reflectance of solar radiation that can be imparted. That is, the heat shield property that can be imparted to the pavement is also limited.

[0006] Under such circumstances, it is an object of the present invention to provide
15 aggregate particles that can form a high-strength pavement having heat shield performance and that have lightness (whiteness) equivalent to that of conventionally known aggregate particles, yet have an improved heat shield effect and are capable of imparting a good heat shield property to a pavement, instead of directly applying a low-strength heat shield paint directly on an asphalt surface. It is also an object to provide a heat shield pavement that
20 includes an aggregate course containing such aggregate particles and has an improved heat shield effect.

MEANS FOR SOLVING THE PROBLEMS

[0007] Aggregate particles of the present invention satisfy the following expression (1) and expression (2),

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$$y \geq 1.505x - 56.4 \dots (1)$$

$$80 \leq x \leq 95 \dots (2)$$

where y (%) is reflectance of solar radiation and x is a lightness L* value.

[0008] A method of manufacturing aggregate particles of the present invention

includes: a pressing step of press-forming a mixture of raw material powders; and pulverizing and then firing a compact formed in the pressing step, or firing and then pulverizing the compact, to manufacture the above-described aggregate particles of the present invention, wherein a firing temperature in the firing is 1250°C or lower.

- 5 [0009] A heat shield pavement of the present invention includes: a base course made of asphalt or concrete; and an aggregate course formed as an upper course of the base course and including the aggregate particles of the present invention fixed to the base course by a binder.

EFFECTS OF THE INVENTION

- 10 [0010] The aggregate particles of the present invention have lightness (whiteness) equivalent to that of conventionally known aggregate particles, yet have a high reflectance of solar radiation and accordingly a good heat shield property. The method of manufacturing the aggregate particles of the present invention is capable of manufacturing the above-described aggregate particles having the good heat shield property.
- 15 [0011] Further, in the heat shield pavement of the present invention, the aggregate course containing the aggregate particles of the present invention is formed as the upper course of the base course, making it possible to reduce a temperature increase of the base course. This can also reduce damage to the base course due to, for example, a load applied thereto, enabling the extension of the life of the pavement itself.
- 20 [0012] As described above, in the present invention, instead of directly applying a low-strength heat shield paint directly on an asphalt surface as has been done conventionally, a high-strength ceramic aggregate having heat shield performance is found, and only by attaching it to an asphalt paved surface, it is possible to form a pavement structure having a heat shield effect. Its construction method may be in conformity to a
- 25 construction method widely used in a colored anti-skid pavement field that does not aim at a heat shield function, and by doing so, this structure receives external force by the ceramic aggregate particles, and accordingly long-term durability can be obtained.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] Fig. 1 is an explanatory view of a schematic structure of a heat shield pavement of the present invention.

Fig. 2 is an explanatory view of a schematic structure of another heat shield pavement of the present invention.

Fig. 3 is a graph illustrating relations between reflectance of solar radiation and lightness L^* of aggregate particles obtained in examples 1-1 to 1-10.

Fig. 4 is a graph illustrating relations between reflectance of solar radiation and lightness L^* of aggregate particles obtained in examples 1-11 to 1-16.

DETAILED DESCRIPTION

[0014] Hereinafter, aggregate particles of the present invention, a method of manufacturing the same, and a heat shield pavement will be described in detail, with reference to the drawings when necessary.

[0015] [Aggregate Particles]

The aggregate particles of the present invention satisfy the following expression (1) and expression (2),

$$y \geq 1.505x - 56.4 \dots (1)$$

$$80 \leq x \leq 95 \dots (2)$$

where y (%) is reflectance of solar radiation and x is a lightness L^* value.

[0016] Regarding a white pigment used as a pigment having a heat shield property, it is known that reflectance of solar radiation and lightness L^* have a certain degree of mutual correlation and are proportional to each other. In contrast, in the present invention, aggregate particles have been newly found that exhibit a high reflectance of solar radiation that could not be achieved so far and have an improved heat shield property, as compared with conventional aggregate particles having equivalent lightness L^* .

[0017] Specifically, as aggregate particles used for a predetermined purpose, it is possible to obtain those having a more excellent heat shield effect even though their

appearance gives similar impression, and therefore, by scattering and fixing the aggregate particles of the present invention on the surface of, for example, a pavement to form an aggregate course, it is possible for the pavement to have a good heat shield effect.

[0018] Here, the reflectance of solar radiation in the present specification refers to a

reflectance of solar radiation in the whole wavelength region, that is calculated using a spectral reflectance measuring and calculating method specified in JIS K 5602, unless otherwise specified. The whole wavelength region mentioned here refers to a 300 to 2500 nm wavelength region including the near-ultraviolet and visible regions (300 to 780 nm) and the near-infrared region (780 to 2500 nm). However, since the aggregate particles of the present invention are particles, a sample used for the measurement of the reflectance of solar radiation in this specification is a plate-shaped sample formed through the pulverization and dry-pressing of the aggregate particles, which is different from a paint film specified in JIS.

[0019] Further, since sunlight has energy not only in the visible region but also in the infrared region, taking the reflectance of solar radiation in the near-infrared region into consideration is effective for evaluating the heat shield property (influence on heat storage).

Here, the reflectance of solar radiation in the near-infrared region is preferably 80% or more, and more preferably 90 to 99%. The reflectance of solar radiation in the near-infrared region is measured and calculated under the same condition and by the same method as those described above except that the wavelength range for the measurement is 780 to 2500 nm.

[0020] The L^* value of the aggregate particles of the present invention preferably falls within a range of 80 to 95, and more preferably 82 to 92. This range of the L^* value is set as a practical range in consideration of the heat shield property, brightness, and so on as the pavement of the present invention. When the L^* value is 80 or more, the heat shield property and brightness are good. When the L^* value is 95 or less, the distinguishing from white line markings is possible. Here, the L^* value in the present specification is psychometric lightness determined based on CIE 1976 $L^*a^*b^*$ color space. The CIE

1976 L*a*b* color space is a color space recommended by CIE (the International Commission on Illumination) in 1976, where L* represents lightness whereas a* and b* represent hue and saturation as chromaticity, and is presently widely used in various fields. However, since the aggregate particles of the present invention are particles, the sample used for the measurement of the lightness L* in the present specification is a plate-shaped sample formed through the pulverization and dry-pressing of the aggregate particles, unless otherwise specified.

[0021] Preferably, the aggregate particles of the present invention contain 5 to 70% by mass Al₂O₃ and 15 to 75% by mass SiO₂ as their chemical components, and the total amount of Al₂O₃ and SiO₂ is preferably 75% by mass or more. These chemical components will be described. Note that in the present specification, “% by mass” will be hereinafter abbreviated simply to “%”. Note that in the present specification, the content of each of the components of the aggregate particles refers to an equivalent content, assuming that each of the components in the aggregate particles exists as an indicated oxide. For example, “contain 0.001 to 5% Fe₂O₃” means that the Fe content when it is assumed that the whole Fe in the aggregate particles exists in a Fe₂O₃ form, that is, the Fe₂O₃-equivalent content of Fe is 0.001 to 5%.

[0022] Al₂O₃ is a component forming a skeletal structure of the aggregate particles by alumina crystals. The content of Al₂O₃ in the aggregate particles is preferably 5 to 70%. When this content is less than 5%, the strength of the aggregate becomes low, and when this content is over 70%, low-temperature sintering becomes difficult. The content of Al₂O₃ in the aggregate particles is more preferably 5 to 50%, and still more preferably 10 to 45%.

[0023] SiO₂ is an amorphous component that exists as a mullite structure or fills the alumina crystals, and with SiO₂ contained, an irregular crack in the pulverization process reduces. The content of SiO₂ in the aggregate particles is preferably 15 to 75%. When this content is less than 15%, the low-temperature sintering is difficult, and when this content is over 75%, the strength of the aggregate becomes low. The content of SiO₂ in

the aggregate particles is more preferably 25 to 75%, and still more preferably 35 to 70%.

[0024] Here, the total amount of Al_2O_3 and SiO_2 ($\text{Al}_2\text{O}_3 + \text{SiO}_2$) is preferably 80% by mass or more, still more preferably 85% by mass or more, and even more preferably 90% by mass or more. When the total amount is within such a range, the low temperature
5 sintering is possible and aggregate particles having a good aggregate strength can be obtained.

[0025] In the aggregate particles, Fe_2O_3 is a component causing coloring, and with this component being contained, the aforesaid L^* value tends to decrease. Therefore, Fe_2O_3 is preferably contained in the aggregate particles as little as possible. The content of Fe_2O_3
10 is preferably 5% or less, more preferably 3% or less, still more preferably 1% or less, even more preferably 0.5% or less, especially preferably 0.3% or less, and most preferably 0.1% or less.

[0026] In the aggregate particles, oxides of transition metal elements are components causing coloring, and the total content of the oxides of all the transition metal elements
15 (including the Fe_2O_3 component) is preferably 5% or less, more preferably 3% or less, still more preferably 1% or less, even more preferably 0.5% or less, especially preferably 0.3% or less, and most preferably 0.1% or less. Specific examples of the oxides of the transition metal elements other than Fe_2O_3 include TiO_2 , MnO , Co_2O_3 , NiO , CuO , and ZnO .

[0027] An average particle size D_{50} of the aggregate particles is not limited, and preferably falls within a range of, for example, 0.1 μm to 10 mm, and can be appropriately decided according to their use. The aggregate particles whose average particle size D_{50} is 0.1 μm or more are easy to handle, and the aggregate particles whose average particle size D_{50} is 10 mm or less are easily fixed to the surface of the pavement. For example, in a
20 use application where the dispersed aggregate particles are fixed to the surface of the pavement by a resin binder or the like, the average particle size D_{50} preferably falls within a range of 0.5 mm to 5 mm.
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[0028] Further, for example, in a use application where they are contained in a resin

coating material for coating the surface of a pavement, the average particle size D_{50} preferably falls within a range of 0.1 to 80 μm in order to make their dispersibility in the paint high and achieve a uniform shield effect of a paint film. In this use application, in view of easy handling and a cost reduction, the average particle size D_{50} is preferably 1 μm or more, more preferably 5 μm or more, and especially preferably 10 μm or more.

Further, the average particle size D_{50} is preferably 50 μm or less, more preferably 40 μm or less, and especially preferably 30 μm less. However, the particle size to be used is selected according to an adopted film thickness, and in a case where, for example, a thin paint film such as a film with an about 25 μm thickness is to be formed, the average particle size D_{50} is preferably 10 μm or less.

[0029] Note that the average particle size D_{50} mentioned in the present specification refers to a particle size corresponding to a 50% cumulative amount on a volume base in a cumulative particle size curve of particle size distribution measured using a laser diffraction/scattering particle size distribution analyzer.

[0030] [Method of Manufacturing Aggregate Particles]

Next, a method of manufacturing the aggregate particles of the present invention will be described. In this manufacturing method, for example, an alumina raw material, a siliceous raw material, and other necessary raw materials are mixed, and a raw material mixture powder in which the chemical components with the aforesaid contents are blended is prepared. Next, this raw material mixture powder is pressed into a predetermined shape, with a predetermined amount of water added thereto, and raw material particles are obtained. In order for the raw material particles to have a desired size, it is preferable that the particles are fined down by net cutting, pulverization, or the like after the pressing, followed by sieving, whereby the raw material particles having a uniform size are obtained.

[0031] At this time, the pressing is performed under the condition of 5 to 35°C and 100 to 500 MPa to produce a lump-like compact of the raw material mixture, and the cutting is achieved by pressing the lump-like compact produced by the pressing against a

net with 0.2 mm x 0.2 mm to 15 mm x 15 mm meshes. The purpose of the sieving is to obtain the raw material particles with the desired size, and the size of meshes of a sieve may be selected according to the purpose. As the sieve for use, for example, a sieve with 20 μm x 20 μm to 15 mm x 15 mm is usable. For the sieving, a plurality of sieves may be used to pick up particles in a specific particle size range.

[0032] The raw material particles obtained in this manner are sintered into the aggregate particles of the present invention. A significant characteristic in this manufacturing method is that a sintering temperature is 1250°C or lower. This temperature is lower than a typical sintering temperature, and the treatment at such a temperature can improve the reflectance of solar radiation even if the lightness is equivalent to conventional one. The sintering temperature at this time is more preferably 1000 to 1200°C, and still more preferably 1050 to 1150°C.

[0033] Treating the aggregate particles at a high temperature exceeding 1250°C causes a decrease of the reflectance of solar radiation, a possible reason for which may be that, for example, such high-temperature treatment causes Fe_2O_3 contained in the aggregate particles to change into Fe_3O_4 whose reflectance of solar radiation in the near-infrared region is lower. Therefore, in order to improve the reflectance of solar radiation, it is preferable to reduce the content of Fe in the raw material, or to set the sintering temperature low as in the above-described manufacturing method.

[0034] Further, at the time of cooling down to around room temperature after the sintering, slow cooling at a cooling rate of 300°C/h or less (gradual cooling) is also effective for keeping the reflectance of solar radiation high. A possible reason for this is that the slow cooling can decrease an amount of Fe_3O_4 higher in heat ray absorption than Fe_2O_3 , in iron contained in the aggregate particles. Normally, the reduction of iron oxide progresses like $\text{Fe}_2\text{O}_3 \rightarrow \text{Fe}_3\text{O}_4 \rightarrow \text{FeO} \rightarrow \text{Fe}$ as the temperature becomes higher. This change is reversed when the temperature becomes lower, but rapid cooling does not enable Fe_3O_4 to change into Fe_2O_3 and it remains.

[0035] Then, by sieving the particles obtained by the sintering operation, it is possible

to obtain aggregate particles with a desired particle size.

[0036] Incidentally, in the above, the raw material particles with the desired size are obtained before the sintering as a result of the pressing against the net, but without the pressing operation, the aggregate particles with the desired particle size may be obtained
5 through the pulverization and sorting after the sintering. Examples of a means for fining down the aggregate particles include a pulverizing means such as a vibrating mill, a ball mill, or an air-flow jet mill.

[0037] [Heat Shield Pavement]

The heat shield pavement of the present invention includes: a base course made of asphalt
10 or concrete; and an aggregate course formed as an upper course of the base course and including the above-described aggregate particles fixed to the base course by a binder.

[0038] Fig. 1 illustrates an example of the heat shield pavement. A heat shield pavement 10 illustrated in Fig. 1 includes a base course 11 and an aggregate course 12 formed as an upper course of the base course 11 and including aggregate particles 12a
15 fixed to the base course 11 by a binder 12b. The composing elements will be hereinafter described with reference to the heat shield pavement in Fig. 1.

[0039] <Base Course>

The base course 11 is, for example, one that is well-known as a base course in a conventional pavement, and is a base course made of asphalt or concrete. More
20 specifically, examples of the base course made of asphalt include those formed of a dense graded asphalt mix, a fine graded asphalt mix, a porous asphalt mix, a modified asphalt mix, and a guss asphalt mix. Further, examples of the base course formed of concrete include those made of normal concrete, high-early-strength concrete, and pavement concrete.

25 [0040] Incidentally, the base course 11 may be formed of a stack of a plurality of kinds of the aforesaid materials for forming the base course. Examples of this structure include various kinds of overlay structures such as a two-course structure formed of guss asphalt as a lower portion of the base course and modified asphalt concrete thereon as an upper

portion of the base course.

[0041] Then, on any of these base courses 11, the aggregate course 12 exposed to the surface of the pavement is formed as the upper course (surface course) of the base course 11.

5 [0042] <Aggregate Course>

The aggregate course 12 is provided as the upper course of the base course 11 and as a surface course of the pavement. This aggregate course 12 includes the aggregate particles 12a fixed to an upper surface of the base course 11 by the resin binder 12b. It is possible to easily obtain the aggregate course 12 by applying the resin binder 12b on the upper
10 surface of the base course 11, thereafter dispersing the above-described aggregate particles 12a of the present invention, and solidifying the resin binder 12b.

[0043] Examples of the resin binder 12b used here include (meth)acrylic resin such as MMA resin, and epoxy resin.

[0044] Further, before the resin binder 12b is applied, a primer course may be
15 provided for better fitting to the base course 11. As the primer course, a well-known primer course is usable, and examples thereof include urethane modified methacrylic resin.

[0045] The aggregate course provided as the surface course of the pavement can reduce a temperature increase of the base course 11 even when the pavement is exposed to sunlight or the like, to reduce a strength decrease of the base course 11 and its deformation
20 caused by an applied load, or the like. It is also possible to reduce damage such as rutting formed in the base course 11 by the application of a load or the like, enabling the extension of the life of the pavement itself.

[0046] Here, guss asphalt which has almost no pore and is hardly water-permeable is used in, for example, the lower portion of the base course 11 as a water-proof course of a
25 steel floor of an elevated road.

An elevated road is likely to undergo a temperature increase of its road surface because it is exposed to sunlight without any shading building or the like therearound, and if the road temperature becomes higher than 60°C, the guss asphalt becomes high in

fluidity to suffer a strength decrease, and may become unable to support the asphalt concrete or the like used in the upper portion of the base course 11, because of the weight of automobiles running on the paved surface or a load caused by braking. In this case, the life of the pavement is sometimes shortened. A possible solution to this is to reduce the temperature increase of the road surface to reduce the softening of the guss asphalt.

[0047] To reduce the temperature increase of the road surface, providing the aggregate course 12 is effective as described above. Specifically, the heat shield pavement of the present invention includes the aggregate course 12 as its surface course, which makes it possible to reduce the softening of the base course 11 to extend the life of the pavement even if, for example, guss asphalt is used in the lower portion of the base course 11.

[0048] In the heat shield pavement 10, a primer is applied on the surface of the base course 11 when necessary, and the resin binder 12b is applied to fix the aggregate particles 12a to the surface of the base course 11. The resin binder 12b is preferably applied with a uniform film thickness using a coating machine. The resin binder 12b preferably has a film thickness large enough for 1/2 to 1/3 of the aggregate particles 12a to be buried therein.

[0049] Next, the aggregate particles 12a are dispersed onto the resin binder 12b. The dispersing of the aggregate particles 12 preferably comes immediately after the application of the resin binder 12b. With the time, the solidification of the resin binder 12b

progresses and its fixing force lowers. A disperse amount of the aggregate particles 12a is preferably 2 to 8 kg per square meter, and especially preferably 6 to 7 kg per square meter. When the disperse amount of the aggregate particles 12a is 2 kg or more per square meter, gaps between the aggregate particles 12a do not become too large, leading to a great heat shield effect of the heat shield pavement 10. When the disperse amount of the aggregate particles 12a is 8 kg or less per square meter, the aggregate particles 12a are easily fixed to the surface of the heat shield pavement 10.

[0050] Curing follows the dispersing of the aggregate particles 12a to sufficiently harden the resin binder 12b. As a result of this hardening, the aggregate particles 12a are

fixed on the surface of the heat shield pavement 10, so that the aggregate course 12 is formed. This aggregate course 12 is capable of imparting a good heat shield property to the heat shield pavement 10.

[0051] Incidentally, as illustrated in Fig. 2, a top coat course 21 may be further formed on the surface of the aggregate particles 12a after the aggregate particles 12a are fixed.

Fig. 2 illustrates a heat-shield pavement 20 as an example of a mode in which the top coat course 21 is further formed on the surface of the aggregate course 12 of the heat-shield pavement 10 in Fig. 1. The top coat course 21 is not limited, and any well-known top coat course provided on a surface course of a pavement is usable. Here, examples of

resin forming the top coat course 21 include MMA resin, acrylic resin, and urethane resin.

[0052] Further, the top coat course 21 can contain aggregate fine particles smaller in particle size than the aforesaid aggregate particles 12a used in the aggregate course 12. In order for the aggregate fine particles to be contained, after the resin for top coat course is applied, the aggregate fine particles may be dispersed to form the top coat course 21, or after the aggregate fine particles are contained and dispersed in the resin for top coat course in advance to form aggregate fine particle-containing resin, the aggregate fine particle-containing resin may be applied on the aggregate course 12 to form the top coat course 21.

[0053] The aggregate fine particles used here may be any well-known aggregate particles, but are preferably the above-described aggregate particles of the present invention. An average particle size of the aggregate fine particles used here is preferably 1 to 100 μm , and more preferably 1 to 30 μm . The pavement thus including the aggregate particles of the present invention in the uppermost surface can have a good heat shield property, with its temperature increase being effectively reduced.

EXAMPLE 1

[0054] Hereinafter, the present invention will be specifically described using examples (examples 1-1 to 1-5, examples 1-11 to 1-13) of the present invention and comparative

examples (examples 1-6 to 1-10, examples 1-14 to 1-16), but the present invention is not limited at all by the description of these.

[0055] (Example 1-1)

As raw materials, non-calcined kaolin (manufactured by China Tianjin Ze Rare Minerals Processing Corporation, brand name: SNOWHITE 90) and a black pigment (manufactured by Dainichiseika Color & Chemicals Mfg. Co., Ltd., brand name: DAIPYROXIDE BLACK # 9596) which are commercially available were used. These raw materials were mixed at a predetermined ratio into a raw material mixture, the raw material mixture was pressed into a predetermined shape with a predetermined amount of water added thereto and thereafter was pulverized into particles, and raw material particles were obtained by sieving. At this time, the pressing was performed under the condition of 10°C and 100 MPa, the pulverization was performed by pressing the lump-like raw material obtained by the pressing against a net with 1.92 mm x 1.92 mm meshes, and the sieving was performed using a sieve with 0.85 mm x 0.85 mm.

[0056] The obtained raw material particles were fired at 1000°C for two hours and were sieved again, whereby aggregate particles with a 1.5 mm average particle size D_{50} were obtained. In the sieving here, a sieve with 0.85 mm x 0.85 mm was used.

[0057] The chemical composition of the obtained aggregate particles was 43% Al_2O_3 and 53% SiO_2 . Fe_2O_3 which causes a decrease of reflectance of solar radiation and lightness was 1.2%.

[0058] (Examples 1-2 to 1-6)

An addition amount of a black pigment was adjusted and raw materials were mixed into mixtures having the compositions written in Table 1, and by the same operation as that in the example 1-1, aggregate particles were manufactured. The chemical compositions of these aggregate particles are summarized in Table 1. Note that the example 1-6 is an example using only non-calcined kaolin as the raw material without the black pigment being mixed.

[0059] (Examples 1-7 to 1-10)

The chemical compositions of existing aggregates available on the market are summarized in Table 1. Here, the example 1-7 is MULCOA 60 (manufactured by IMERYS REFRACTORY MINERALS JAPAN K.K.), the example 1-8 is MULCOA 45 (manufactured by IMERYS REFRACTORY MINERALS JAPAN K.K.), the example 1-9 is 85% RK Bauxite (manufactured by FUJI KOZAI CO., LTD.), and the example 1-10 is CB (manufactured by AGC Ceramics Co., Ltd., brand name: Corhart Black),

[0060] (Property Test)

Regarding the aggregate particles of the example 1-1 to the example 1-10, properties of lightness L^* and reflectance of solar radiation were examined and their results are shown in Table 1. From relations between the lightness L^* and the reflectance of solar radiation in these examples, it has been confirmed that the obtained aggregate particles tend to have a good reflectance of solar radiation even through having lightness L^* equivalent to that of the conventionally known aggregate particles.

[0061] [Table 1]

	Composition			Properties		
	Al ₂ O ₃	SiO ₂	Fe ₂ O ₃	Lightness L^*	Reflectance of solar radiation (%)	1.505x-56.4
Example 1-1	43.0	53.0	1.2	82.9	70.6	68.4
Example 1-2	44.0	54.0	1.1	84.1	72.4	70.2
Example 1-3	44.0	54.0	1.0	84.2	72.6	70.3
Example 1-4	44.0	54.0	0.9	84.9	73.5	71.4
Example 1-5	44.0	54.0	0.5	90.0	81.2	79.1
Example 1-6	44.0	54.0	0.4	98.3	95.7	91.5
Example 1-7	61.0	34.0	1.5	79.0	55.0	62.5
Example 1-8	46.0	50.0	0.9	86.0	67.9	73.0
Example 1-9	85.0	9.0	1.5	77.5	52.4	60.2
Example 1-10	78.0	16.0	2.1	77.5	52.3	60.2

[0062] [Reflectance of Solar Radiation]

The obtained aggregate particles were pulverized into powders with an agate mortar, the powders were subjected to dry-press forming while given a 30 ton pressing pressure, to be formed into disk-shaped test formed bodies with 40 mm diameter x 4 mm thickness.

Regarding these test formed bodies, a spectral reflectance in 300 nm to 2500 was measured with a spectrophotometer (manufactured by Hitachi High-Technologies Corporation, brand name: U-4100) and the reflectance of solar radiation was calculated using a weight value coefficient of reference solar radiation, according to JIS K 5602.

5 [0063] [L* Value in CIE 1976 L*a*b* Color Space]

Regarding the same test formed bodies as those in the above Reflectance of Solar Radiation, a spectral reflectance in the visible region was measured with a spectrophotometer (manufactured by Hitachi High-Technologies Corporation, brand name: U-4100) and the L* value was calculated, according to JIS K 5602. This measurement
10 was conducted in parallel with the measurement of the reflectance of solar radiation.

[0064] (Examples 1-11 to 1-16)

By the same operation as that in the example 1-1, non-calcined kaolin (manufactured by China Tianjin Ze Rare Minerals Processing Corporation, brand name: SNOWWHITE 90) and a black pigment (manufactured by Dainichiseika Color & Chemicals Mfg. Co., Ltd.,
15 brand name: DAIPYROXIDE BLACK #9596) which are commercially available were mixed into raw material mixtures of the respective examples shown in Table 2. Here, the composition was the same between the example 1-11 and the example 1-14, between the example 1-12 and the example 1-15, and between the example 1-13 and the example 1-16. The raw material used here before the black pigment was mixed therein has the same
20 composition as that of the example 1-6.

[0065] From the obtained raw material mixtures, aggregate particles were obtained by the same operation as that in the example 1. However, the firing temperature was set to 1100°C in the examples 1-11 to 1-13, and the firing temperature was set to 1300°C in the examples 1-14 to 1-16.

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[0066] [Table 2]

	Composition			Properties		
	Al ₂ O ₃	SiO ₂	Fe ₂ O ₃	Lightness L*	Reflectance of solar radiation (%)	1.505x-56.4
Example 1-11	41.0	51.0	4.3	88.0	77.9	76.0
Example 1-12	41.0	51.0	4.6	85.6	74.8	72.4
Example 1-13	41.0	51.0	4.9	83.7	72.0	69.6
Example 1-14	41.0	51.0	4.3	91.8	80.8	81.8
Example 1-15	41.0	51.0	4.6	91.9	81.8	81.9
Example 1-16	41.0	51.0	4.9	90.8	79.3	80.3

[0067] The relations between the reflectance of solar radiation and the lightness L* are plotted on graphs, Fig. 3 illustrating the relations in the aggregate particles obtained in the examples 1-1 to 1-10, and Fig. 4 illustrating the relations in the aggregate particles obtained in the examples 1-11 to 1-16. The above results show that the aggregate particles of the present invention have an improved reflectance of solar radiation as compared with the conventional aggregate particles having equivalent lightness, and adjusting the firing temperature is effective for obtaining such aggregate particles. The aggregate particles obtained in the example 1-6 are not distinguishable from white line markings because the L* value thereof is over 95.

Further, in Fig. 3 and Fig. 4, $y = 1.505x - 56.4$, where y is the reflectance of solar radiation and x is the lightness L*, was set as a boundary, and aggregate particles having a reflectance of solar radiation (%) equal to or more than this boundary were defined as aggregate particles having an excellent relation between the lightness L* and the reflectance of solar radiation that has not been achieved conventionally.

EXAMPLE 2

[0068] [Example 2-1]

As raw materials, refractory clay (produced in Shandong, China) and a black pigment (manufactured by China Tianjin Ze Rare Minerals Processing Corporation) which are commercially available were used. These raw materials were mixed at a predetermined

ratio into a raw material mixture, the raw material mixture was pressed into a predetermined shape with a predetermined amount of water added thereto and thereafter was pulverized into particles, and raw material particles were obtained by sieving. At this time, the pressing was performed under the condition of 100 MPa, the pulverization was performed by pressing the lump-like raw material obtained by the pressing against a net with 4 mm x 4 mm meshes, and the sieving was performed using a sieve with 2 mm x 2 mm.

[0069] The obtained raw material particles were fired at 1180°C for three hours and were sieved again, whereby aggregate particles with a 2.5 mm average particle size D_{50} were obtained. In the sieving here, a sieve with 2 mm x 2 mm was used.

[0070] The chemical composition of the obtained aggregate particles was 17% Al_2O_3 , 68% SiO_2 , and 0.4% Fe_2O_3 . Lightness L^* was 90.5 and reflectance of solar radiation was 81.8%. This example also had the reflectance of solar radiation (%) equal to or more than $y = 1.505x - 56.4$ set as a boundary, where y is the reflectance of solar radiation (%) and x is the lightness L^* .

[0071] (Example 2-2)

For comparison, commercially available aggregate particles having similar color (manufactured by BISHU KOSAN CO., LTD., brand name: CERASAND HC-AL) were prepared as an example 2-2. As is seen in Table 3, a value of the reflectance of solar radiation y of the commercially available aggregate particles is not over $1.505x - 56.4$.

[0072] [Table 3]

	Properties		
	Lightness L^*	Reflectance of solar radiation (%)	$1.505x - 56.4$
Example 2-1	90.5	81.8	79.8
Example 2-2	88.3	74.4	76.5

[0073] Three asphalt pavements each with a 5 cm thickness and a length and a width of 30 cm were prepared, on each of two out of these, a 170 g (1.9 kg per m^2) epoxy binder

for anti-skid pavement (manufactured by NISSHIN KASEI CO., LTD., REBCOLOR binder) was applied and spread with a uniform thickness. Before the binders hardened, the aggregate particles of the example 2-1 and the aggregate particles of the example 2-2 each in an amount of 585 g (6.5 g per m²) were dispersed to one of these and to the other one respectively, and by three-hour curing, the binders were hardened, whereby two heat shield pavements having the aggregate particles on the surfaces were fabricated. Further, they were both coated with 135 g (1.5 kg per m²) of the same heat shield binder (manufactured by NISSHIN KASEI CO., LTD, REBCOLOR COOL), whereby top-coated heat shield pavements were fabricated. Here, the untreated asphalt pavement is an example 2-3.

[0074] Regarding totally three asphalt pavements, that is, the two obtained top-coated heat shield pavements and the untreated asphalt pavement as a blank, heat shield performance was measured according to the procedure specified in Design and Construction Guidelines for Thermally Insulated Pavement (issued by Road and Street Administration Division, Tokyo Metropolitan Bureau of Construction) used in Tokyo. Specifically, the blank asphalt body not having undergone the heat shield treatment was exposed to a light source, a light quantity of light source energy under which the surface temperature increased to 60°C in three hours was determined, and under the same light quantity, temperature increases of a front surface and a rear surface of each of the pavements having undergone the heat shield treatment were measured.

[0075] As a result, as shown in Table 4, in the heat shield pavements (the example 2-1, the example 2-2), temperatures to which the front surface temperature and the rear surface temperature increase in three hours are both lower than those of the untreated asphalt pavement (the example 2-3) by 10°C or more. Further, in the heat shield pavement of the example 2-2, the rear surface temperature three hours later was 11.2°C lower than that in pavement of the example 2-3, while in the heat shield pavement of the example 2-1 of the present invention, the rear surface temperature three hours later was 12.3°C lower than that in the pavement of the example 2-3. That is, the obtained result shows that the heat shield

pavement of the example 2-1 of the present invention has an about 10% higher heat shield effect than the conventional heat shield pavement (example 2-2).

[0076] [Table 4]

Time (minute)	Front surface temperature (°C)			Rear surface temperature (°C)		
	Example 2-1	Example 2-2	Example 2-3	Example 2-1	Example 2-2	Example 2-3
0	30.0	30.0	29.8	30.1	29.9	30.4
30	39.9	39.5	42.2	33.6	33.7	39.2
60	42.5	42.5	48.3	37.7	38.2	46.2
90	44.9	44.9	52.8	41.1	41.8	51.4
120	46.5	46.7	56.2	43.7	44.5	55.2
150	47.8	48.2	58.5	45.6	46.6	57.9
180	48.7	49.2	60.1	47.1	48.1	59.4

5 EXAMPLE 3

[0077] Four asphalt pavements each with a 5 cm thickness and a length and a width of 30 cm were prepared, and on each of three out of these, a 170 g (1.9 kg per m²) epoxy binder for anti-skid pavement (manufactured by NISSHIN KASEI CO., LTD., REBCOLOR binder) was applied and spread with a uniform thickness. Before the binders hardened, aggregate particles fabricated in the same manner as in the example 2-1 and a white aggregate (manufactured by AGC Ceramics Co., Ltd., brand name: Tough Bahn white; lightness L* 96.9, reflectance of solar radiation 92.2%) each in an amount of 585 g (6.5 g per m²) were dispersed to two of these and to the other one respectively, and by three-hour curing, the binders were hardened, whereby three heat shield pavements having the aggregate particles on the surfaces were fabricated. Further, one out of the two heat shield pavements to which the aggregate particles of the example 2-1 were dispersed was coated with an 18 g (0.4 kg per m²) existing acrylic resin-based heat shield top coat (manufactured by NISSHIN KASEI CO., LTD, REBCOLOR COOL), whereby a top-coated heat shield pavement was fabricated. Here, the heat shield pavement including the aggregate particles of the example 2-1 and not top-coated is an example 3-1, the top-coated heat shield pavement is an example 3-2, the heat shield pavement including the white aggregate and not top-coated is an example 3-3, and the untreated pavement is an

example 3-4.

[0078] A construction method of the aforesaid three pavement structures having undergone the heat shield treatment is in conformity to a construction method certified and widely used as a colored anti-skid construction method, and has immediate practicability for use on roads.

(reference document 1) (Technical Association of Resin Pavement) Manual for NEAT Method/Anti-skid Resin Pavement

(reference document 2) (Tokyo Metropolitan Bureau of Construction) Public Work Material Specifications Reference Materials Hard Aggregate

[0079] Regarding totally four asphalt pavements, that is, the three obtained heat shield pavements and the untreated asphalt pavement as a blank, heat shield performance was measured according to the procedure specified in Design and Construction Guidelines for Heat Shield Pavement (issued by Road and Street Administration Division, Tokyo Metropolitan Bureau of Construction) used in Tokyo. Specifically, the blank asphalt body not having undergone the heat shield treatment was exposed to a light source, a light quantity of light source energy under which the surface temperature increased to 60°C in three hours was determined, and under the same light quantity, surface temperature increases in the heat shield pavements were measured.

These four pavements naturally differ in appearance color, and their L^* , a^* , b^* values were also measured with a colorimeter from their upper portions.

[0080] As a result, as shown in Table 5, as compared with the heat shield pavement of the example 3-3, the heat shield pavement of the example 3-1 is lower in L^* by 24 but achieves a substantially equal surface temperature increase reduction. That is, it can be confirmed that the heat shield effect of the aggregate particles used in the heat shield pavement of the example 3-1 achieves heat shield performance higher than that expected from the lightness. It can be also confirmed that the heat shield pavement of the example 3-2 provided with the top coat course has a higher heat shield effect than the example 3-1.

[0081] [Table 5]

			Example 3-1	Example 3-2	Example 3-3	Example 3-4
Color system	L*		50.0	44.0	74.0	26.0
	a*		0.6	1.8	-0.1	1.1
	b*		8.5	0.3	6.3	-0.2
Heat shield property	Surface temperature (°C) after lamp irradiation	0 minute	29.8	30.0	30.5	29.9
		90 minutes	47.6	45.7	47.3	53.1
		180 minutes	52.8	50.0	52.5	60.2
	Temperature increase reducing effect (°C)		-7.4	-10.2	-7.7	—

[0082] As described above, the aggregate particles of the present invention have a high reflectance of solar radiation and are suitable as aggregate particles for heat shield, and therefore are suitable especially in a use application where a temperature increase needs to be reduced, such as in a pavement exposed to long-time sunlight radiation.

INDUSTRIAL APPLICABILITY

[0083] According to the present invention, it is possible to provide aggregate particles suitable for forming an aggregate course that imparts a heat shield property to an asphalt pavement, a building, or the like. Having a high lightness and whiteness, the aggregate particles are also usable as ordinary aggregate particles other than those for heat shield.

WHAT IS CLAIMED IS:

1. Aggregate particles satisfying the following expression (1) and expression (2),

5
$$y \geq 1.505x - 56.4 \dots (1)$$

$$80 \leq x \leq 95 \dots (2)$$

where y (%) is reflectance of solar radiation and x is a lightness L* value.

2. The aggregate particles according to claim 1, wherein 5 to 70% by mass Al₂O₃, 15 to 75% by mass SiO₂, and 5% by mass or less Fe₂O₃ are contained as chemical
10 components.

3. The aggregate particles according to claim 2, wherein a total amount of the Al₂O₃ and the SiO₂ is 80% by mass or more.

4. A method of manufacturing aggregate particles, the method comprising:
a pressing step of press-forming a mixture of raw material powders; and
15 pulverizing and then firing a compact formed in the pressing step, or firing and then pulverizing the compact, to manufacture the aggregate particles according to any one of claims 1 to 3,

wherein a firing temperature in the firing is 1250°C or lower.

5. The method of manufacturing the aggregate particles according to claim 4,
20 wherein, in the firing, cooling after the firing is gradual cooling at a cooling rate of 300°C/hour.

6. A heat shield pavement comprising:
a base course made of asphalt or concrete; and
an aggregate course formed as an upper course of the base course and including
25 the aggregate particles according to any one of claims 1 to 3 fixed to the base course by a binder.

7. The heat shield pavement according to claim 6, wherein the base course includes: a lower course formed of guss asphalt; and a surface course formed on the lower

course and made of modified asphalt concrete.

8. The heat shield pavement according to claim 6 or 7, comprising a top coat course as a surface course of the aggregate course.