Application of waste glass fragment to base course material considering heat island

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ABSTRACT

This study dealt with coloured bottles is rapidly desire to find out the effective uses, because of abolishing to reclamations far from recycling. In this study, we aim at the effective use of waste glass fragment produced in breaking the coloured bottles. Firstly the basic mechanical properties of waste glass fragment are examined from the permeability and compaction tests to apply it to soft clay layer by improvising method. Secondly the bearing capacity of waste glass fragment is made clear by modified CBR, and evaluates the application to base course material. The laboratory and field tests were carried out to evaluate the heat properties of these materials. Through this study, we examined as a good base course material not to cause heat island phenomena, namely gentle to environment of sidewalk construction.

1 INTORODUCTION

There are two disposal methods of discarded glasses. These are a foaming method by calcinations processing and the crushing method which takes advantage of coloured glass. The former is waste glass aggregate which was already published (Suzuki etc. 2006), the latter is waste glass fragment adopting in this study. The waste glass aggregate already made clear to utilize as a base course material for taking measure of heat island because of excelling heat and mechanical properties (Suzuki etc. 2006), but waste glass fragment is not enough studied until now.

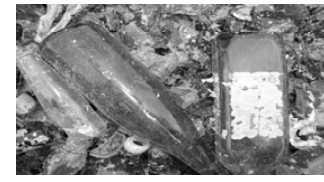


Photo1: colour bottle

In this study, we examine the permeability, retention of water, soil compaction and CBR of waste glass fragment as the mechanical properties. The heat properties of waste glass fragment are compared with waste glass aggregate in this heat laboratory tests. These tests are very important for considering to heat environment, and the field tests are carried out for obtaining actual heat properties. We explain the situations of the field tests and measure changing temperatures in fine and rainy weathers.

Photo 2: Waste glass fragment

2 PHYSICAL AND MECANICAL PROPERTIS OF THE SAMPLES

2.1 Outline of waste glass

The waste glass fragment is the fine powders (photo 2) which are a by-product in making use of a coloured glass pavement material made by waste coloured bottles which are not reuse(photo 1). This waste glass fragment can be dealt with safety like sand in spite of making glass. When the particles size is more than 2.5mm, we use as a glass colour pavement and produce bright block

Table 1: Densities of materials

Material name	Density (g/cm^3)
Waste glass fragment	2.513
Natural sand	2.427

mixed with concrete owing to not uniform colours, but it is not applied to ground materials. In this study, we research the fragment which dose not entirely use for everything, because the particles size have below 2.5mm.

2.2 Physical properties

Table 1 shows the results of the density tests of waste glass fragment which is artificial sand and natural sand. Their values are almost same. As the raw material of waste glass fragment is coloured bottles, this is able to cause particle breakage by compaction. When the particle breakage occurs, it widely influences to the properties of permeability and CBR. Therefore, we perform grain size analysis for evaluating the particle breakage quantitatively.

Firstly, the sample of waste glass fragment before compaction is carried out grain size analysis, secondly the sample after compaction is performed the analysis. Fig.1 shows the grain size accumulations of the two samples. As shown this figure, we understand that the particle breakage does not occur owing to almost any changes of the grain size accumulations.

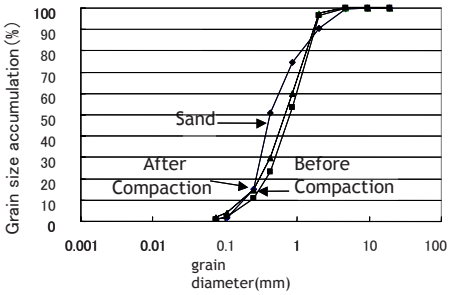


Figure 1: Grain distributions of samples

2.3 Properties of permeability and retention of water

2.3.1 Significance of moisture properties

In this study, we try to apply waste glass fragment to base course material. If waste glass fragment has high permeability property, we expect not only a construction of a permeable sidewalk and a exercise ground but also promotion of rainfall seepage. If it has high retention of water property, we expect to restore moisture supplying trees in a park and to reduce temperature of road surface by the heat of vaporization.

2.3.2 Results

The properties of permeability and retention of water are measured by constant head permeability test and water retentively test of soil, respectively. The result value of permeability of waste glass fragment is equal to 2.8×10^{-2}(cm/sec). The value of retention moisture is equal to 15.3%. This value of waste glass fragment becomes three times the value of Tottori dune sand. Therefore, waste glass fragment is the high permeable and retentive material.

2.4 Properties of CBR

The modified CBR tests are performed to examine the property of bearing capacity because of considering the degree of application waste glass fragment to base course material. Fig.1 shows the results of the CBR of waste glass fragment under conditions of S_r=100 and 0, and sands which are natural materials. Some ◆in this figure express the result of the penetration tests for saturated samples, and same ○are natural water content samples. From Fig.1, the values of CBR become constant at the border which is 42 times compactions in spite of increasing the compaction energies. On the other hand, the values of CBR are proportionally increasing in the case of the saturated samples. The saturated waste glass fragment is expected to improve the bearing capacities, this tendency is desirable for base course material. The bearing capacity of waste glass fragment is clearly higher compared with the natural sand. Waste glass fragment is very similar to the natural sand, because

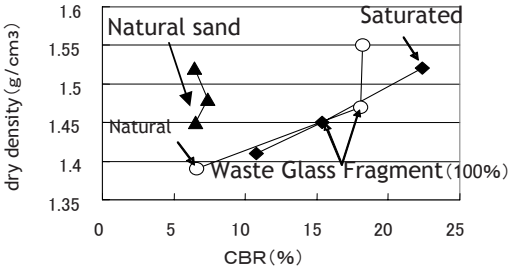


Figure2: Results of modified CBR tests

Table 2: Standard values of modified tests

Repartition		General road	Simple pavement road
Period		Japanese road society	Japanese road society
Roadbed	Upper class	More than 80%	More than 60%
	Substratum	More than 20%	More than 10%

the both material are almost same the distribution of soil particles. Namely, waste glass fragment is more desirable than the natural sand
as a base course material.

According to Table 2, the value of the modified CBR is more than 10% as a material of lower part of simple pavement road. Therefore, the saturated waste glass fragment can be applied to this base course material.

3. LOBORATORY TESTS FOR HEAT PROPERTIES OF GROUND MATERIALS

3.1 Significance of heat tests

In this study, the heat environment must be examined by laboratory tests for applying waste glass fragment to base course material of big cities. If this material is used at a downtown area of big cities, heat island phenomena is considered. Even if a site is district, to become of high temperature of ground materials by solar heat is not also desirable from view point of global warming. It is desirable for the gentry to environment ground materials. We compare the heat properties of the recycle materials which are waste glass fragment, aggregate and RC material from the laboratory tests.

3.2 Outline of Experimental Apparatus

Fig.3 shows the apparatus for measuring the temperatures of the soil samples under the constant quantity of heat. The samples are compacted into the mold used in the standard compaction test. The heat is supplied by the heater (100V, 375W) over 40 cm from the surface of the sample. As shown this figure, the three temperature sensors are installed the locations which are the surface of the sample, 3cm and 7cm depths from the surface respectively. These temperatures are automatically measured and recorded at 30 seconds intervals.

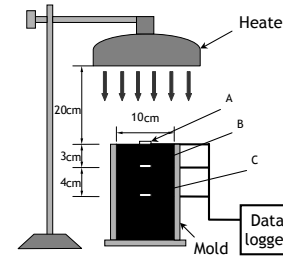


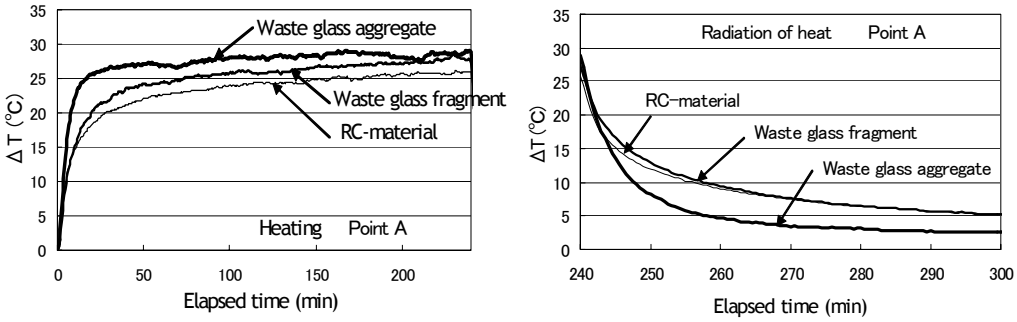
Figure3: Laboratory test for evaluating heat priorities grand materials

3.3 Procedure of Experiments

We explain the outline of the laboratory tests from obtaining heat properties of ground materials. The tests are performed by 4 hours heating and then 2 hours radiation of heat for the specimens. In general, the time ～ temperature curves of these tests rapidly increase in the first stage, and then gradually approach equilibrium condition with the elapsed times. Supplying of heat for all specimens were stopping to examine the heat properties of the radiation of heat.

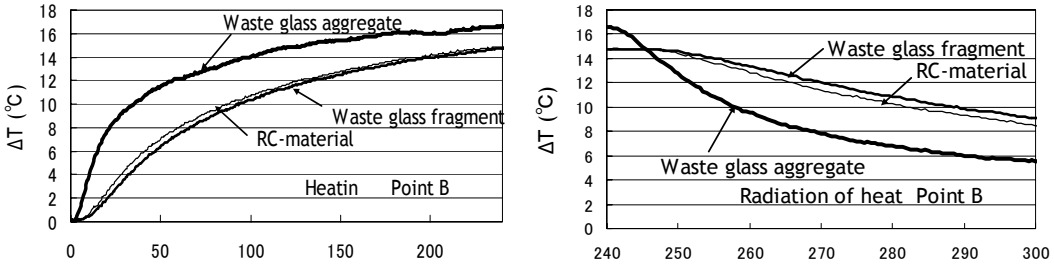
3.4 Experimental Results and considerations

Fig.4 shows the relationships between elapsed time and temperature of waste glass aggregate and fragment at point A in heating and radiation of heat, respectively. RC-material is recycled concrete structure which is widely used in construction of general roads. As shown this figure, the temperatures after the beginning of the heating become high waste glass aggregate, fragment and RC-materials in turn. The increase velocity of temperature of waste glass aggregate is most rapid, the increase velocity of temperature RC-material latest. From this tendency, the heat capacity of waste glass aggregate is smallest and in turn waste glass fragment and RC-material. Figs 5 and 6 show the same results as mentioned above the heat properties.



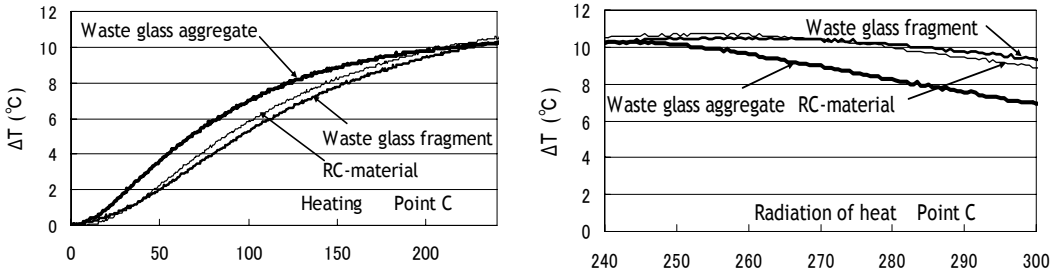
(a) Heating (b) Radiation of heat

Figure 4: Temperature at Point A



(a) Heating (b) Radiation of heat

Figure 5: Temperature at Point B



(a) Heating (b) Radiation of heat

Figure 6: Temperature at Point C

4. FIILD TESTS FOR OBTAINING THE HEAT PROPERTIES OF GROUND MATERIALS

4.1 Outline of field tests

The underground temperature sensors are installed by the same processes of the same process compared with the construction of actual sidewalk. We use waste glass fragment and RC-material as base course materials. The sections of these yards have the surface layer of 30mm, the base course material of 100mm and subgrade. As we also examine the heat properties of surface layer, we use fiber resin pavement and asphalt used general road pavement. Fig.7 shows the combinations of the base course material and the surface layer.

As shown Fig.7, the underground temperature sensors are installed three in each yard, which are ①ground surface, ②boundary between surface layer and base course material, ③center of base course material. The sensors are given names to simplify our explanations. Namely, the temperature sensors corresponding to ①～③ are named to FG1～FG3 in No.1 yard. By the same rule, the sensors of No.2 and No.3 are named to FR1～FR3, AR1～AR3 in No.2 and No.3 yards, respectively. We provide the wooden frame to be not existence of heat interactions in three yards. Of cause, shades do not cause and sunshine conditions are same in every yards.

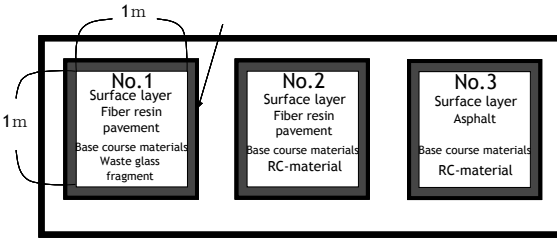


Figure 7: Outline of field tests

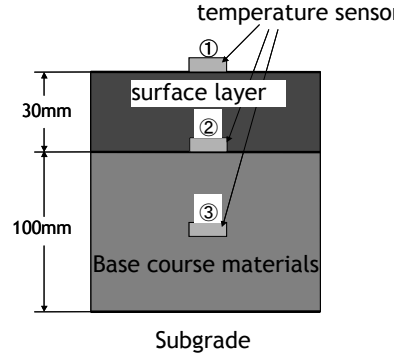


Figure 8: Arrangement of under ground temperature sensors

4.3 Measurement results

4.3.1 Fine weather

As shown Fig.8, the temperatures of sensor FR1 clearly become the lowest in the heavy sunshine, the ground surface temperature of the other yards are similar to same temperatures each other. As solar heat directly shines at the surface of ground, the differences of temperatures do not usually occur. The combination of fiber resin pavement and RC-material becomes the lowest temperatures, because RC-material has thermal storage amount. The combination of fiber resin pavement and waste glass fragment show the lowest temperatures in no sunshine in spite of the hottest temperature in heavy sunshine. As fiber resin pavements constructed in the surface layers are same at No.1 and No.2 yards, this tendency causes by the difference of the heat capacities between waste glass fragment and RC-material. Namely, the heat capacity of waste glass fragment is small and the heat capacity is large, far from the results of the laboratory test. We must rely on the field tests than laboratory test. The TR1 which is the most common structure of sidewalk shows the properties of the high temperature through day and night.

As shown Fig.9 (b), the sensor FG2 becomes the highest temperature in heavy sunshine. There is the difference of almost 5 degrees compared FR2 with FG2. Comparing waste glass fragment with RC-material, waste glass fragment easily increase the temperature in heavy sunshine. Considering temperatures from 20 o'clock to 6 o'clock of the next day, FG2 indicates the lowest temperatures. Waste glass fragment has the small heat capacity because of lowering the temperatures without the

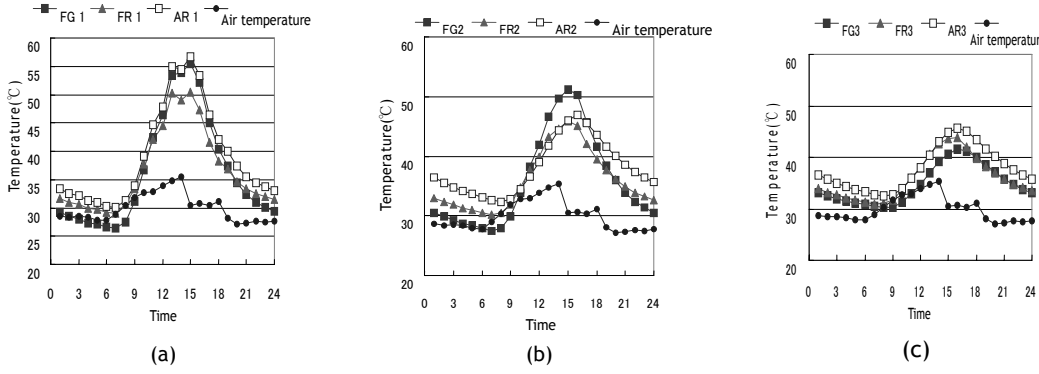


Figure 9: comparison with under ground temperature

sunshine in spite of increasing the temperature with heavy sunshine. This heat property dissolves the problem of sultry night. The heat property corresponding to AR2 which is usually used as a sidewalk is same to (a).

In Fig.9(c), comparing FG3 with other sensors in other yards, the temperatures of FG3 become the lowest through the day. This is depending on the effect of the insulation of fiber resin pavement in addition to the small heat capacity of waste glass fragment.

5. CONCLUSIONS

This paper is examined the application of waste glass fragment which is a recycle material of coloured glass bottles to ground materials not only mechanical properties but also considering heat environment.

1) From physical properties tests of waste glass fragment, we recognized the density of it was similar to that of natural clay. The particle breakage of waste glass fragment does not occur by compaction in spite of the glass which is easily smashed.

2) Waste glass fragment indicated the high permeability from the constant head permeability test. The value of water retention moisture of waste glass fragment were obtained from water retentively test. The value is three times of Totori dune sand. Namely, waste glass fragment has the good properties which are the high permeability and high retention moisture.

3) The application of waste glass fragment to base course material was examined by the modified CBR test. The values of the CBR of saturated waste glass fragment are more than 10%, therefore, satisfied with the standard value of a low base course material of simple pavement road. It obtained the high bearing capacity comparing with natural sand. We are very interested in the results that waste glass fragment which is an artificial and recycle material has higher than the natural sand.

4) We preformed the heat laboratory tests to get fundamental heat properties of waste glass fragment. The heating and radiation of heat tests were carried out to examine heat capacities of waste glass fragment, the aggregate and RC-material. The temperatures of waste glass aggregate went up and down hard, therefore, we recognized that this material has the small heat capacity. The heat capacities of the remaining two materials are not different from each other.

5) The field tests were performed for construction of sidewalk considering heat environment at the actual field, based on laboratory test mentioned above. Although waste glass fragment became the highest temperature in strong sunshine, became the lowest temperature in the night without sunshine. Therefore, waste glass fragment is desirable material for preventing a sultry night.

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