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Development of Sharpness Measuring Method for Glass Aggregate Particle made from Waste Glass Bottle

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In Japan in of today, there is no aspect in which the quantity of waste glass bottle discharged from ordinary homes decreases. Moreover, the kind of shape and color of the waste glass bottles are increasing little by little. In the recycling of the glass bottle, it becomes a problem that many kind of the color is abounding. It is possible to use the transparent glass bottle as raw material of the glassware. Since the reproduction of the color is difficult, the colored glass bottle is not possible to use as a raw material. Therefore, the processing of these glass bottles entirely depends on the reclamation. In Japan, the security of the new reclaimed land is very difficult for the reason of the environmental damage. Moreover, the life expectancy in many reclaimed lands is anticipated with within two years. Therefore, the development of the processing method of glass bottle other than reclamation becomes a rapid problem.

At present, it is examined that it is used of an aggregate of the colored pavement, as one of the application methods of colored glass bottle. The particle size of produced glass aggregate is also 5mm or less, because the thickness is 5mm or less on almost glass bottles. And almost glass particles have the sharp tip. The application as the aggregate is limited for this sharpness of the particle. This study was carried out for the purpose of the establishment of sharpness measuring method of the glass aggregate particle. It is possible that the injury degree to human in the handling is known, if showing the sharpness of the aggregate particle at the objective numerical value is possible. And the application of the glass aggregate is spread. In this research, the balloon fracture method was used for the sharpness measurement of the glass particle.

This method is based on the completely new idea, and it is possible to express completely the possibility of injury to the human. It is reported with the detailed result in full paper, because this study is continuous in order to get the JIS which is industrial standard of Japan.

Introduction

Until about 3 or 4 years ago, postwar Japan saw the increased usage of glass bottles in both shops and homes and, consequently, an increase of scrap glass. In the past 3 or 4 years, as a result of the declining business atmosphere, in Japan, the widespread use of PET bottles (polyethylene terephthalate) has become remarkable. Glass bottle production has remained even at 2,440,000 tons[1)]. Beer bottle production has decreased, drink bottle production has increased and other kinds of bottles have remained the same. However, for the most part, only beer bottles and the 1.8 liter sake bottles are returnable[1)]. Other drink bottles or alcoholic beverage bottles, excluding some transparent ones, are used in reclaimed landfill. Recently, a small percentage of scrap glass is being used to add color to some roadways or as reflective material in walls. Some companies have been given management expenses in order to encourage the recycling of bottles (for example crushing and selling crushed glass products). Such recycling projects have great value when it is understood that the capacity for scrap bottles, in reclaimed land, in the larger cities, will expire in 1 to 2 years. In addition to the ecological benefits recycling has, the destruction caused by the reclaimed land is also worthy of consideration.

With concern to crushing and reproducing waste glass, the machine used to crush glass soon wears down which causes a problem with the glass particles. For example , when the particles are smoother (less angular) the adhesion in asphalt is reduced. The configuration of the particles is what we are concerned with. A way to measure the particles has not been developed yet. We tried to measure the angles that demonstrate the possibility of injuries when handling glass bottles and we got excellent results[2)]. This report describes these results as well as a new method of measuring angles that we are presently examining.

The new method is called the "Balloon Rupture Method". We attached a double-sided tape onto a plastic board and on the tape we put glass particles. We, then, rubbed a balloon, that was inflated to a certain air pressure, along the length of the tape, counting the number of times it took until it ruptured. The sharpness of the particles was defined as the reciprocal of the frequency of times the balloon was rubbed till rupturing. We also learned that the angle of the balloon makes a great difference in the number of times it can be rubbed and so we added an experiment that changes the angle of the balloon.

1. Samples

We broke dark-colored liquor bottles, with an iron bar, and sifted the glass particles to a maximum size of 2~4 mm. We found these particles to be the sharpest. Next, we tried using a small-sized magnetic ball-mill to form another glass particle group. We stirred some glass particles for a certain amount of time and produced a rounded particle group. With yet another particle group, which had a broader sample of shape distribution, we added glass beads and pebbles worn down by ocean waves. When measuring glass particles we could only imagine the influence of the particle diameter and hardness but glass particles are larger diameter and have a tendency to be big.

To determine the influence of the various diameters ranging from 0.5 ~ 2 mm, we stirred each group in an iron vessel and made various groups with various angles. Also, we thought the hardness influenced the particle sharpness so we prepared particles with the same diameters and different hardness according to Vickers Hardness scale.

2. Measuring Method and the Results

2-1 The Correlation of the Sharpness an the Circularity

We examined the circularity of each glass particle group, which had the rough edges taken off, with a picture analysis device (Luzex FS made by Nireko). We calculated the average circularity of each glass particle group using the Hausner Surface index. Circularity was defined using the following equation.

$\phi = 4\pi$ (projected area of the particle) / (circumference of projection)^2.

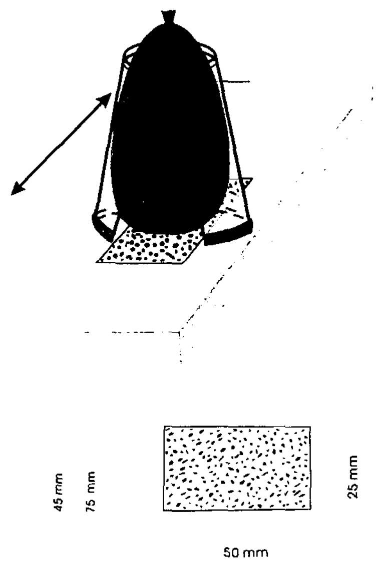


Fig.1 Balloon Rupture Method

If the projection shadow of the particle is circular, the particle is round (ϕ =1). If the particle projections are jagged to large unevenness ϕ becomes less than 1 (an equilateral triangle ϕ = 0.604; a square ϕ = 0.785; an equilateral hexagon ϕ = 0.906). We decided to measure more than 500 particles to calculate the circularity. This was done to make the unevenness less at the measurement stage. For the measurement of the particle group sharpness, we used the "Balloon Rupture Method" devised by our laboratory. This method is pictured in figure 1. This method has the benefits of being both inexpensive and easy. The method employs a piece of double-sided tape 25mm wide by 100mm long. We adhered the tape to a plastic board and then we added a particle group on top of the tape. As in the direction of the arrow in figure 1 we slid the balloon back and forth. One direction is counted as one and the reciprocal of the frequency has been defined as the degree of sharpness. If a balloon ruptured after being rubbed more than 10 times, it was counted as 10 (maximum). When we examined how the balloons ruptured, after being rubbed more than 10 times, it was discovered that there were scratches which we decided was an indication of partial wear destruction. The sharpness we determined by the friction method and the roundness we obtained from picture analysis. The internal pressure of the balloons was 7kPa. A straight line (figure 2) in this case, shows the correlation of the sharpness and the circularity. Through experience, when we grabbed glass particles, with a sharpness of less than 0.5, we experienced little pain.

We observed that the rupture point for balloons was between 15 to 27 kPa (shown in figure 3). Also, we measured no natural ruptures of balloons at 7 kPa. We confirmed that all balloons ruptured with more than 15kPa of pressure. However, the inconsistent rate for ruptures maybe a result of particle size distribution, hardness and the wall thickness of the balloons. We want to do more experimentation on this matter.

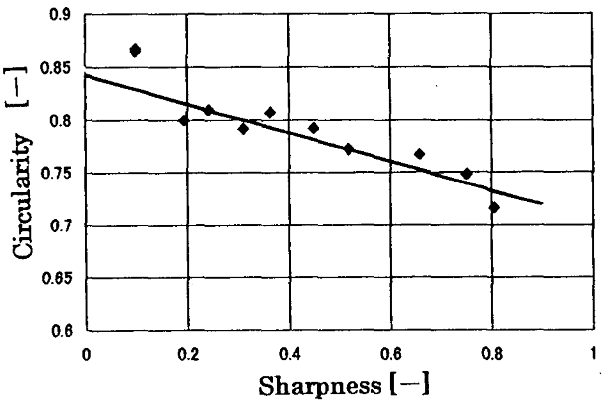


Fig.2 Correlation of Sharpness and Circularity

2-2 The Correlation of Sharpness and Particle Size

In 2.1, we showed the correlation between the sharpness and circularity in the particle groups of 2mm to 4mm. We measured only these groups because of the practical use of this range of particle sizes. This does not mean there is no influence of particle size in this range but, in the particle groups of less than 2mm, we can't feel the sharpness when particles are held in our hands. Indeed, particle size does make a difference. The average diameters of the particle groups that we used were 1.7, 1.2, 0.85, and 0.6mm. The average degrees of circularity are 0.76, 0.73, 0.65, 0.68.

The range of the distribution of circularity is narrow. We thought the influence of the particle size was of greater consequence (see figure 4). In figure 3, we can see clearly the influence of the particle size in respect to sharpness. The particle size is around 1.4mm. Sharpness is 0.5mm. It indicates that the danger of injury becomes less. When the particle size is less than 1mm, the sharpness is 0.1 to 0.2. We can see the roundness of the particles by picture analysis and we can sense the sharpness by touch. We also consider the correlation of the wall of an inflated balloon and the particle size.

2-.3 Correlation of the Sharpness and Vickers Hardness

We have been examining the influence of the particle shape (circularity) and the hardness as well as the correlation to particle size. In this experiment we speculated how the hardness of the particles (Vickers hardness) influences the sharpness even if they're the same particle group or they show the same degree of circularity. We prepared particle groups of various hardness (rocks, glass, ceramics etc.) and measured the correlation of sharpness and circularity in the same sized groups. Figure 5 shows the correlation of sharpness and hardness when each sample particles are 0.8 degrees of circularity.

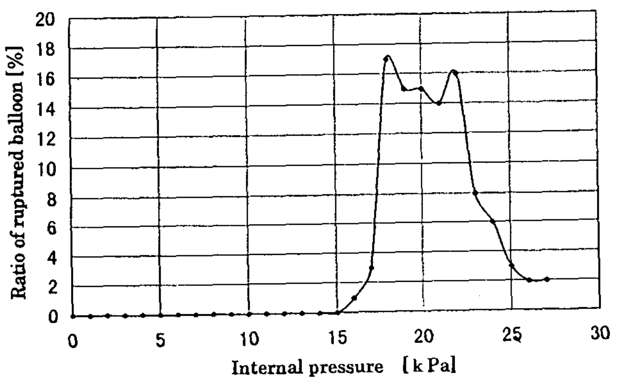


Fig.3 Correlation of Internal Pressure and Ruptured Balloon Ratio

3. Another Balloon Rupturing Method

Until now, we had been rubbing the balloons vertically (nipple end up) however, this part of the balloon has an unevenly thick wall. Although this method is useful, when rubbing the balloons on smaller particles the results varied. Therefore we tried rubbing the balloons laterally (see figure 6). We made a rectangular hole in an acrylic cylinder to expose the balloon to the particle surface and we used the same rubbing method as in figure 1. The improvement in this method is that there is, comparatively, no uniformity in the balloon's sidewall so when the balloon is rubbed, on smaller particles, the balloon rupturing becomes more consistent. Part of the results, from this newer method of measurement, is shown in figure 7. With this newer method the number of times the balloon is rubbed has decreased indicating a more uniform thickness of balloon.

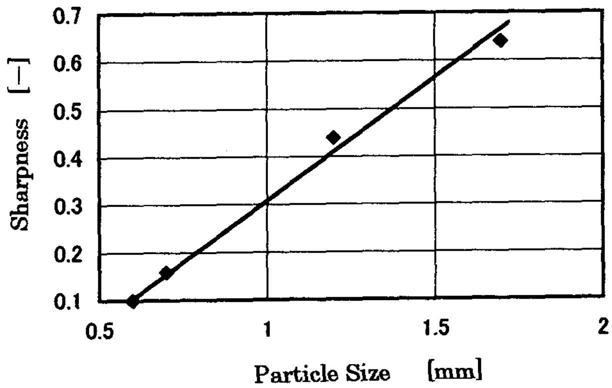
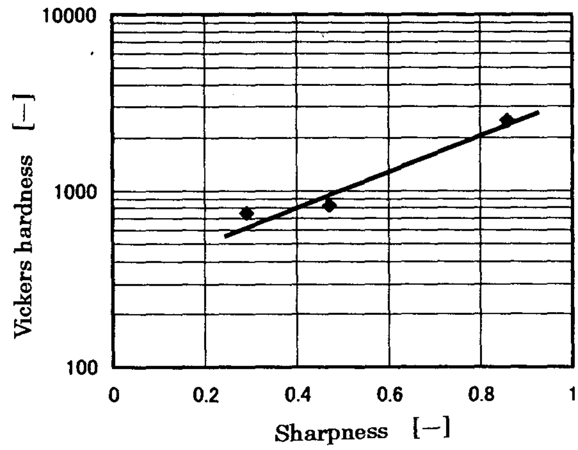


Fig.4 Correlation of Sharpness and Particle Size



Fi.5 Correlation of Sharpness and Vickers Hardness

4. Conclusions

In order to produce and reuse glass particles, we observed the following:

1) When breaking and crushing the bottles for reuse, the wear on the machine seems to be the biggest problem, however, the problem is alleviated when the inside of the mill and the pins are made of ceramics.
2) The shape of the glass particles has the potential for injury so the sharpness of the particles is an indicator of the quality of the glass particles used as an aggregate.
3) The information on sharpness that we obtained has a correlation to the circularity (Hausner Surface index) when the particle size is 2 to 4mm. Through experience, when we grasped glass particles of less than 0.5mm, no pain or was felt.
4) If the particle size is less than 2mm, the particle group with the same roundness shows very little sharpness so there is little danger of injury.
5) The newer method, of rubbing the balloon (see figure 7), decreases the number of times a balloon is rubbed, before rupturing, as a result of the comparatively thin, uniform balloon walls.

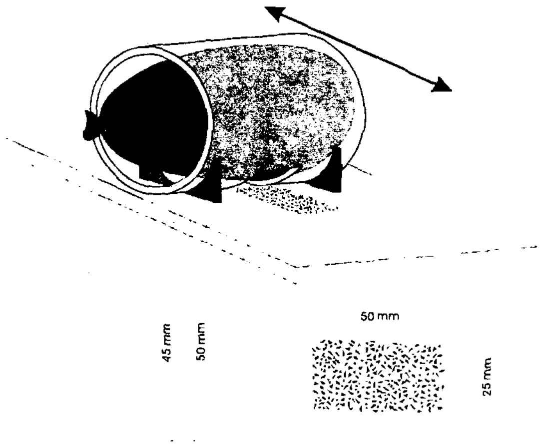


Fig.6 New Type of Balloon Rupturing Method

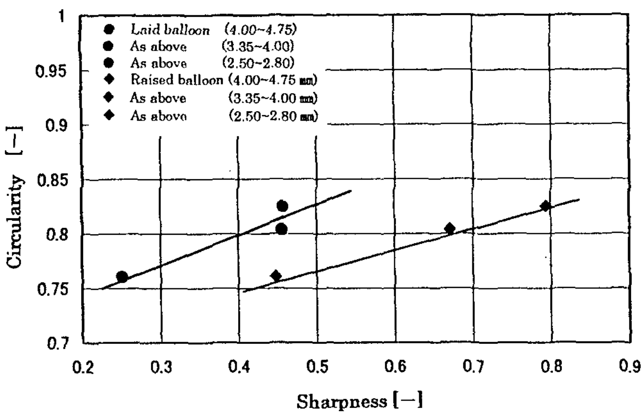


Fig.7 Correlation of Sharpness and Particle Size by New Method

5. Considering the Recycling of Waste Glass Bottles

It seems necessary to develop a method for measuring glass particle sharpness. Companies that crush, process and sell glass cullet particles, with funding from self-governing bodies, are increasing. A major problem is the shape of the glass particles, which is an indicator of the standard of quality of the particles. At present, the only method to test the quality of glass particles is the hand-grasp method. We think it's necessary to develop a measuring method to evaluate glass particles in order to recycle glass bottles more effectively. I think our measuring method is a useful one for such an evaluation.

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