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Preliminary Study on Compressive Strength of Modified Polystyrene (MPS) as Lightweight Aggregate

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***Abstract*—This research investigates the possibility of making polystyrene as lightweight aggregate. Low density is the advantage of polystyrene. Waste polystyrene foam is modified and sintered in the furnace at the temperatures varying from 130 °C to 220 °C. After sintering process, polystyrene undergo shrinkage until 97 % and become harder. To determine the strength of MPS aggregate, modified compression test is used since the usual tests to determine the strength of normal aggregate are not applicable to the lightweight aggregate, however an attempt is tried to examine the strength of MPS aggregate using Aggregate Crushing Value (ACV). From the ACV test, the result cannot be obtain since the MPS aggregate gets harden and unified with each other thus the value cannot be calculated. It appears that MPS has big potential to be artificial lightweight aggregate.**

***Keywords*: Compressive Strength, Modified Polystyrene, and Lightweight Aggregate**

I. Introduction

POLYSTYRENE has become a phenomena in packing world. It's light, practical, economical and sanitary is the most considerable factors for food packaging. But its generated waste is not balancing the reuse action, although many organizations campaigned for reuse and reduce act. Since polystyrene is a non biodegradable material, thus polystyrene waste becomes big environmental concern.

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On the other hand, natural lightweight aggregates have problems in sustaining its resource. To reduce the dependence on natural lightweight aggregates and also natural lightweight aggregates are rather limited in their geographic distribution [1], many researches have been conducted on producing new kind of lightweight aggregates especially from waste materials.

Low density is the advantage of polystyrene and making a lightweight aggregate from polystyrene showed a great possibility. Polystyrene's property in lightweight is its best advantage to produce lightweight aggregate. Lightweight aggregate concrete reduces building costs, eases construction and has the advantage of being relatively 'green' building material [2].

The uses of lightweight concrete has been increasing especially in the construction of high rise building, off shore structures and long span bridges due to the advantage of its low density, whish results in a significant benefit in terms of load bearing elements of smaller cross section and a corresponding reduction in the size of the foundation [3]

However, the strength of lightweight aggregate cannot be estimated adequately using methods such as the Los Angeles Abrasion test for normal aggregates. The values obtained from these tests cannot be correlated sensibly with the strengths of concretes made using these aggregates. Thus, to evaluate the effects of different lightweight aggregates on concrete strength, it is necessary to do comparison of otherwise identical mixes [4].

II. Methodology

- **Producing modified polystyrene lightweight aggregate**

Common waste polystyrene foam is too big to fit into crushing machine so it had to be cut manually by hand into small pieces of about 60mm -80mm. Then these pieces were sintered in the furnace at temperature ranging from 130 °C to 220 °C for about 3 minutes.

After sintering process, polystyrene foam will undergo shrinkage until 97 % and become harder.

The shape of this MPS will be irregular but for the compression test purpose, the shape is designed rectangular. Which initial dimension is 5 cm x 5 cm x 2.4 cm, but after sintering process the dimension will be vary according the temperature used to sinter.

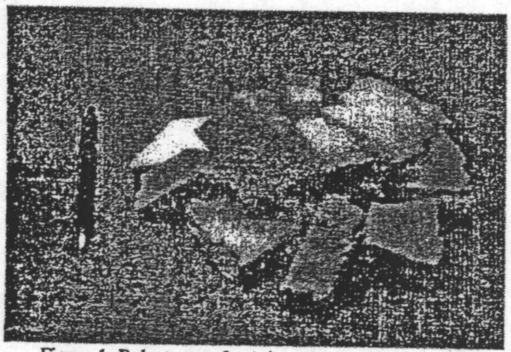

Figure 1. Polystyrene foam is cut manually by hand.

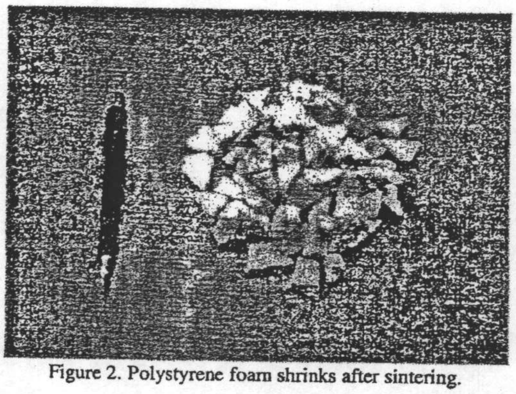

Figure 2. Polystyrene foam shrinks after sintering.

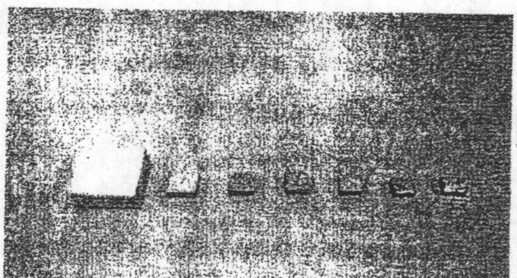

Figure 3. Initial size and after sintering size that will be used in compression test.

This dimension is designed to pass the sieve 20 mm regarding its shrinkage effect, since this project limited the size of the MPS aggregate from 14 mm to 20 mm. However, for the concrete mix, MPS aggregates tears up manually by hand, thus the size will vary and the grading test is necessarily conducted.

- **Compression test**

Usual tests to determined the strength of the aggregate such as *Aggregate Crushing Value (ACV), 10 Per Cent Fines Aggregate Crushing Test (10 % FACT), Aggregate Impact Value (AIV) or Los Angeles Abrasion Test*, are not applicable because these tests requires certain amount of fine materials obtained from the test, whereas for the MPS aggregate those certain amount of fine materials cannot be obtained since the MPS will harden and unified with each other if certain load is given.

Thus, to determine the strength of MPS, modified compression test is used. By using Universal Testing Machine (UTM) Gotech, the compression test for plate form is applied.

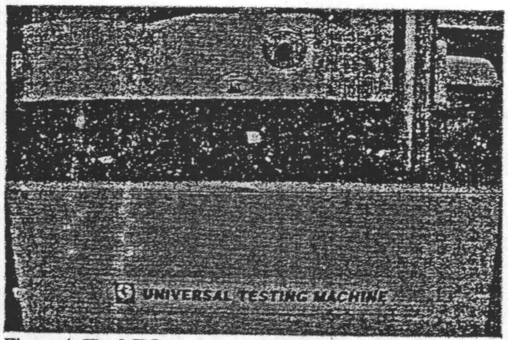

Figure 4. The MPS aggregate given load in UTM Gotech for compression test.

The MPS aggregate is put between the plates for compression test and then input the data such as width, height, length and weight of the aggregate to the computer. After the entire thing is set, then start to give the load to the MPS aggregate for about 30 seconds. The compressive strength is obtained by read the result in the computer output.

- **Aggregate crushing value (ACV) test**

The aggregate crushing value is the amount of fine materials (>2.36 mm) produced by crushing, expressed as a percentage of the sample mass. Lower ACV values represent aggregates more resistant to crushing [5].

This test is refer to the British Standard (BS) 812 : Part 3 : 1975, where the MPS aggregate applied to 400 kN force and operated in uniform rate of loading so that this force is reached 10 minutes.

But in UK and South Africa, this test is no longer widely used, because the ACV is sensitive to the strength of weaker aggregates (with ACV value greater than about 25) which tend to crush before the maximum load is achieved [5].

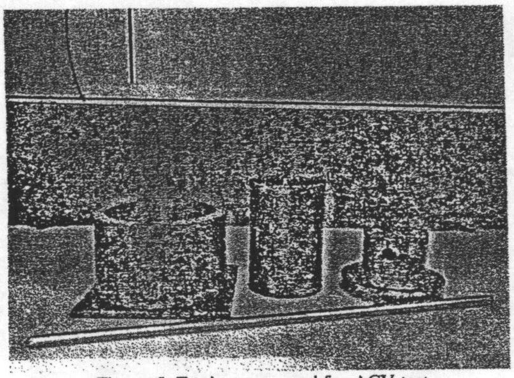

Figure 5. Equipments used for ACV test.

- **Bulk density**

Bulk density is measured by weighed the mass of aggregate particles that occupying a certain volume, where the material is in bulk granular form and in a dry condition. In this project the loose bulk density (LBD) form was used according to BS 3681 : Part 2.

$$P_{bulk} = \frac{M_T}{V_T}$$

Where M_T = Total mass of the granular sample (the mass of solids).

V_T = Total volume occupied by the sample.

III. Result and Discussion

From the experiment, the compressive strength of the MPS from the compression test is ranging from 33.6 MPa to 117.4 MPa as shown in figure 5 below.

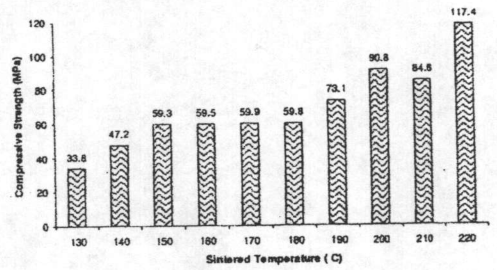

Figure 6. Compressive strength of the MPS aggregates.

The strength of a material is defined as the ability to resist stress without failure [6]. Thus, even though the highest strength of MPS achieved by aggregate sintered at temperature 220 °C as shown in table 1 below, but the aggregate experienced failure. In fact *the failure start from aggregate sintered at temperature 180 °C.*

Bulk density of MPS aggregate showed that the higher temperature used to sinter the polystyrene, the bigger bulk density achieved by the MPS aggregates.

Table 1. Compressive strength of MPS aggregate.

Sintering temperature (°C)	Compressive Strength (MPa)	Bulk Density (kg/m³)
130	33.6	98.1
140	47.2	125.6
150	59.3	145.5
160	59.5	162.5
170	59.9	154.6
180	59.8	202.4
190	73.1	200.0
200	90.8	207.2
210	84.6	243.4
220	117.4	270.1

It means the optimum strength obtained by MPS is 59.9 MPa, achieved by aggregate sintered at temperature 170 °C.

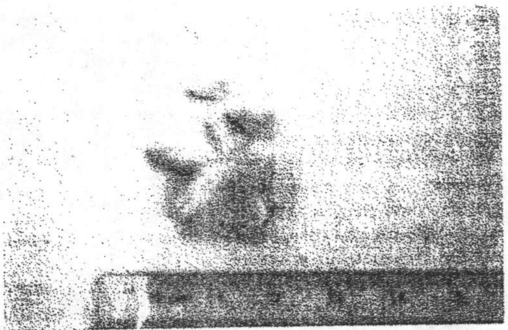

Figure 7. MPS aggregate experience failure after given load above temperature 180°C.

Meanwhile from the aggregate crushing value (ACV) test, the result cannot be obtained because the MPS aggregate they simply compact therefore the ACV value cannot be calculated.

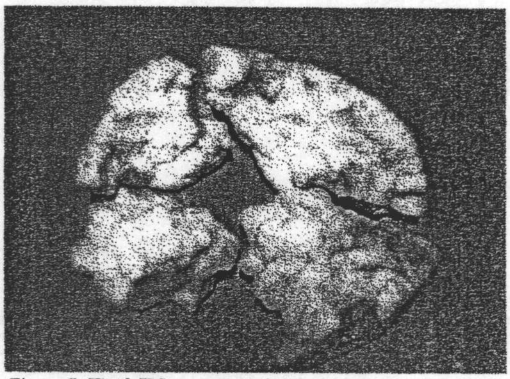

Figure 7. The MPS aggregate simply compact after the load is given at ACV test.

IV. Conclusion

Even though common tests to determine the strength of normal aggregate are not applicable to lightweight aggregate, but modified compression test can be used to measure the strength of lightweight aggregate in this case MPS aggregate.

The aggregate form used in this experiment is plate and design to pass sieve 20 mm, regarding aggregate size used is ranging from 14 mm to 20 mm.

Although these are just preliminary experiments, modified polystyrene has potential to become artificial lightweight aggregate considering its strength. From the compression test, the MPS achieve its optimum compressive strength at 59.9 MPa while sintering at temperature 170 °C.

Due to its lightweight, MPS aggregate will reduce the dead weight and material handling cost for multi-storeyed constructions. However, further research will play very important role to determine the real potential of this sintered polystyrene, especially at the concrete stage such as compressive strength of the concrete.

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