

PROPERTIES OF MODIFIED POLYSTYRENE LIGHTWEIGHT AGGREGATE IN CONCRETE

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ABSTRACT

Several experiments were conducted to characterize the properties of modified polystyrene lightweight aggregate in concrete. Microstructure of modified polystyrene lightweight aggregate in concrete can be assessed by the result from SEM. Porous modified polystyrene lightweight aggregates were mixed with ordinary portland cement (OPC), sand and water to form lightweight concrete. Compressive strength, flexural strength, distribution of aggregate and the interfacial zone were connected to SEM result. The results showed that modified polystyrene lightweight aggregate concrete was not satisfied the minimum requirement strength for structural concrete.

KEYWORDS: *modified polystyrene, lightweight aggregate, compressive strength, flexural strength, distribution of aggregate, interfacial zone.*

1.0 INTRODUCTION

Polystyrene is playing an important role in the instant way of life nowadays. It is best known for its efficiency, cost-effectiveness and lightweight. The exceptional insulating capabilities of polystyrene can maintain the temperature hot or cold. Thus, polystyrene meets all the requirement of economical packaging and consequently, its waste mounted day after day.

This research comprised the effort to reuse the polystyrene waste and at the same time trying to reduce the dependence on natural lightweight aggregates. The uses of lightweight aggregate 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, which 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 (Babu *et.al.*, 2006).

2.0 METHODOLOGY

2.1 Compressive Strength

Compressive strength was determined by using compression machine specially design for concrete and is called cube test. Compressive strength was tested based on 3, 7, 14 and 28 days strength on 150 mm x 150 mm x 150 mm cube.

The specimen was placed between the bars then the load was given. At certain point, the load would remove automatically if the specimen experienced failure. Figure 1 showed compressive test for concrete cube.



FIGURE 1
Determining compressive strength of polystyrene lightweight aggregate concrete.

The value of compression strength defined as the force divided by the area at the start of the experiment.

$$\sigma = \frac{F}{A} \quad (1)$$

where :

σ = stress (MPa)

F = load Applied (N)

A = area (m²)

2.2 Flexural Strength

Flexural strength is also known as modulus of rupture, bend strength, or fracture strength. Flexural strength is measured in terms of stress, and thus is expressed in Pascal (Pa) in the SI system. The value represents the highest stress experienced within the material at its moment of rupture. In a bending test, the highest stress is reached on the surface of the sample. For a rectangular sample under a load in a 3 point bend setup, the flexural strength was given by equation (2).

$$= \frac{FL}{bd^2} \tag{2}$$

Where:

σ = Flexural strength (Mpa)

F = the load (force) at the fracture point (N)

L = the length of the support span (m)

b = width (m)

d = thickness (m)

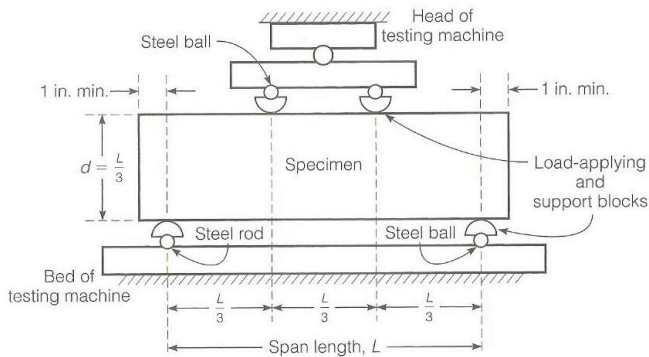


FIGURE 2
Scheme of flexural test

The beam dimension used for this test was 100 mm x 100 mm x 500 mm. The load is continuously applied at a specified rate until rupture. Note that equation 3.5 is valid as long as fracture occurs in the middle third of the specimen. Figure 2 show how flexural test was carried out.

If fracture occurs slightly outside the middle third of the specimen, the result can still be used with some corrections. Otherwise the result discarded (Mamlouk *et.al.*, 1999).

2.3 Scanning Electron Microscope

Scanning electron microscope with 30X, 100X, 500X and 1000X magnification was used in this experiment. The observation of the samples under SEM displays the interfacial zone between aggregate and cement paste.

3.0 RESULT AND DISCUSSION

3.1 Compressive Strength

From the experiment, the compressive strength of the MPS from the compression test is ranging from 6 MPa to 9.8 MPa as shown in Figure 3. It is obvious that the compressive strength increased with age.

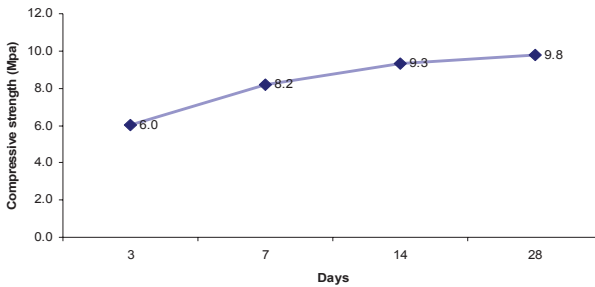


FIGURE 3
Compressive strength of the MPS aggregate concrete

Apparently the strength of this concrete is not sufficient to make it as structural concrete due to the minimum strength requirement for structural concrete. ACI 213R-8, Guide for Structural Lightweight Aggregate Concrete defines structural lightweight aggregate concretes as those having a 28-day compressive strength in excess of 17 MPa and air dried weight not exceeding 1850 kg/m³.

Strength of a material is defined as the ability to resist stress without failure. Failure is sometimes identified with the appearance of cracks (Mehta *et.al.*, 2005).



FIGURE 4
Concrete cube under compression test

Figure 4. exhibit cracks for full height of concrete cubes under compression test. The length of propagation of cracks disperses to all direction. The failure mode of this concrete indicates that polystyrene lightweight aggregate concrete experienced failure spread all over direction. The resulting failure was found to be more brittle (more incompressible manner) and this kind of failure is dangerous for construction.

3.2 Flexural Strength

Flexural strength of polystyrene lightweight aggregate concrete were ranging from 0.02 MPa to 7.29 MPa where the flexural strength for the early days (3 and 7 days) below 0.1 MPa as shown in Figure 5. It means that fresh polystyrene lightweight aggregate concrete does not have tensile strength in bending.

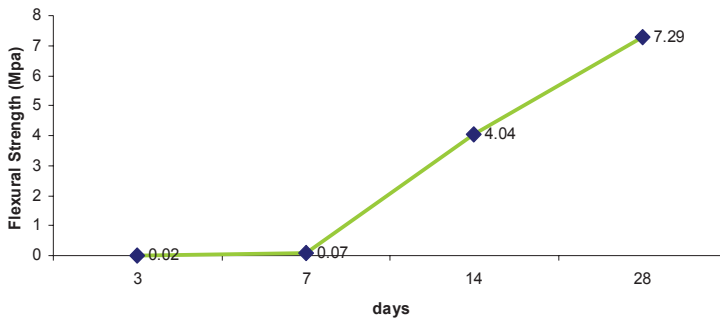


FIGURE 5
Flexural strength of polystyrene lightweight aggregate concrete

Given by flexural stress, concrete experienced tensile stress in the convex side and compression stress in the concave side and the crack propagated from the bottom to the top of the beam as shown in Figure 6.



FIGURE 6.
Flexure test on concrete beam

Figure 7 shows fracture surface of polystyrene lightweight aggregate concrete under flexural test. Noticed the remarks left showed the aggregate pulled out and separated from cement paste completely and indicated by green round line. However, some aggregates were broken indicates by white round line.



FIGURE 7
Fracture surface under flexural test

3.3 Distribution of Aggregate

By visual observation, the polystyrene aggregate, without adding special bonding agents or admixtures apparently showed an even distribution in the mortar and concrete matrix as shown in figure 8. In general, polystyrene lightweight aggregate concrete showed good workability and could be easily compacted and finished.



FIGURE 8

Cross section of polystyrene lightweight aggregate concrete evenly dispersed to all direction

Although the polystyrene aggregate is lighter than crushed stone, but no significant segregation of aggregates were observed. Aggregates were all evenly dispersed to all direction, occupying the whole area of mold. In another word, the polystyrene lightweight aggregate concrete mixture is practically homogeneous.

As stated by Syukri (Syukri, 2008) besides enhancing the mechanical bonding between aggregates and cement paste, this also gives an aesthetic value to the concrete to serve not only as a structural part but also as a decorative product.

4.0 MICROSTRUCTURAL ANALYSIS

From scanning electron microscope observation in the broken fragment showed that cement paste occupied all the voids and open pore of polystyrene in contact zone (Figure 9).

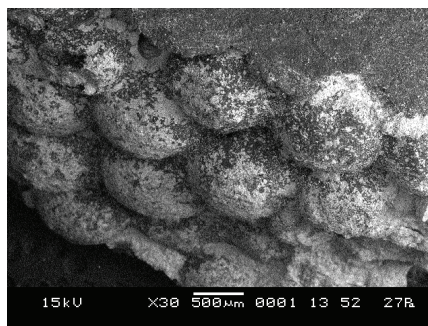


FIGURE 9

Aggregate covered by cement paste in the broken fragment of concrete

Nevertheless, Figure 10 showed the mechanical bonding between aggregate and cement paste was not completely interlocked to each other. Aggregate and cement paste looks separated.

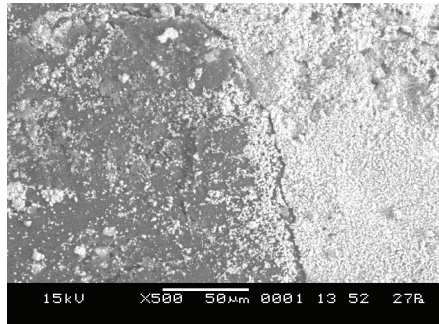


FIGURE 10

Morphology of MPS lightweight aggregate concrete under SEM with 200x magnification

This may be caused by the cohesive bonding in aggregate and cement paste itself is stronger than adhesive bonding between aggregate and cement paste. Besides in the formation of interfacial transition zone there is the so-called 'wall effect', whereby packing constraints of small cement particles against larger aggregate surfaces cause less efficient geometrical arrangement of the cement. This produced fewer cement particles near the aggregate surface than in the bulk paste. Bleeding tends to exaggerate this effect by forming a layer of water on the aggregate surface which also increases the water cement ratio locally.

Furthermore, there is 'one-sided growth effect' mechanism in the formation of interfacial transition zone, whereby reactive growth of the cement particles occurs only from the paste side, rather than from all directions. These two effects increase the porosity of the interfacial transition zone relative to the bulk paste. The interfacial transition zone around a single particle is itself highly variable due to trapped water below the coarse aggregate particles (Alexander *et.al.*, 2005a).

The interfacial transition zone is generally weaker than the bulk paste. In most conventional concrete, failure and fracture by cracking first takes place predominantly in the interfacial transition zone, before branching into the bulk paste (Alexander *et.al.*, 2005b). This explained the pulled out aggregate instead of broken aggregate in the concrete beam fracture as the result of flexural test.

(Jamkar *et.at.*, 2004) stated that the mechanical bond between the

aggregate surface and cement paste, by virtue of interlocking, influences the strength of concrete.

5.0 CONCLUSION

The compressive strength of this polystyrene lightweight aggregate concrete (9.8 MPa) does not meet the requirement strength for structural concrete (17 MPa), thus the application should be for non structural concrete.

Fresh MPS lightweight aggregate concrete does not have tensile strength in bending since the flexural strength for early days (3 and 7 day) below 0.1 MPa.

From SEM result, the morphology of MPS lightweight aggregate concrete in the interfacial transition zone showed the mechanical bonding between aggregate and cement paste was not completely interlocked to each other, because the interfacial transition zone is generally weaker than the bulk paste.

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