PROPERTIES OF LIGHTWEIGHT AGGREGATE CELLULAR CONCRETE WITH POLYPROPYLENE FIBER

1AQEEl HATEM CHKHEIWER, 2MAZEN DEWANABBULLAH, 3MAZINABDULIMAM ALMAZENI

Civil Engineering Department, University of Basrah /Iraq /Basrah

Abstract- The aim of this study is to investigate the effect of adding Polypropylene fibers on the properties of Lightweight Aggregate Cellular Concrete (LWACC) with mix proportion of 1:2.2: 0.3 by volume (cement: fine crushed thermstone: coarse crushed thermstone) and with addition 2% foaming agent by weight of water. The water to cement ratio was 0.55 to give slump of 100 mm.

The properties of lightweight aggregate Cellular concrete reinforced with different percentages of Polypropylene fiber (0, 0.5, 0.75, and 1% by volume) were investigated. The studied properties were Compressive strength, splitting tensile strength, flexural strength, dry density, ultrasonic pulse velocity, impact resistance, initial surface absorption, water absorption and acoustic impedance tests were carried out on four different mixes at ages of 7, 28, 56 and 180 days.

The results of this study exhibited that impact resistance, splitting tensile strength, flexural strength and water absorption increase with increasing of percentages of Polypropylene fiber. While the compressive strength, ultrasonic pulse velocity, dry density and acoustic impedance of the composites have been reduced when the Polypropylene fiber volume fraction increases.

Keyword- Lightweight Aggregate, Cellular Concrete, Polypropylene Fiber.

I. INTRODUCTION

In construction projects, the main use of lightweight concrete is to reduce the dead load of concrete structures resulting in reduction in the size of columns, beams, foundations and other load bearing elements [1]. Cellular (aerated) concrete is a lightweight material composed of cementitious mortar surrounding disconnected bubbles which are a result of either physical or chemical processes during which either air is introduced into the mortar mixture or gas is formed within it [2]. Although aerated concrete is known as an insulation material, its structural features are also of considerable interest [3]. Indeed, the future need for construction materials which are light, durable, economic and environmentally sustainable has been identified by many groups around the world [4].

With the possibility of producing a wide range of densities (400-1600) kg/m3 and also of achieving a strength of at least 25 MPa, foamed concrete has the potential to fulfill these requirements and it is now widely used in the construction industry [4], [5]. Furthermore, with foamed concrete, sustainability can be enhanced because no coarse aggregate is required in its manufacturing and there is also the possibility of partially or fully replacing fine aggregate with recycled or secondary materials [6].

Balaguru and Foden (1996)[7] investigated the behavior of fiber reinforced lightweight concrete with different fiber content. It was found that, the increase in strength provided by fibers was much higher for concrete without silica fume. Also, increase in fiber content results in an increase in compressive strength.

The conclusion for the splitting tensile strength tests was that the addition of fibers results in a substantial increase (more than 100%) in this strength and modulus of rupture. Fibers 50 mm (2.0 in) long that had a longer aspect ratio, provided better strength increases than 60 mm (2.4 in) long fibers. Findings for toughness were that fibers are very effective in improving toughness, indicating strain-hardening behavior, and sustaining loads equal to racking load even under large deformations.

II. RESEARCH SIGNIFICANT

The thermal insulation is one of the main problems facing the engineers working in building and housing sector. More recently, there has been a great interest in the production of lightweight building components, which can be used for the purpose of the thermal insulation and acoustic impedance.

The use of such components in buildings has great advantages and causes a great reduction in the energy required for heating and cooling and, consequently, results in cost reduction to a great extent. Such type of lightweight concrete is very much needed in many buildings of importance are present. But due to brittleness of lightweight aggregate foamed concrete, it is suggested to reinforce this concrete with fiber, thus enhancing its properties.

III. EXPERIMENTAL PROGRAM

3.1 Materials
1- Cement
Ordinary Portland cement type I, was used in all mixes throughout this investigation. The percentage oxide composition and physical properties indicate...
that the adopted cement conforms to the Iraqi specification No. 5/1984 [8], as shown in Tables (1)&(2).

<table>
<thead>
<tr>
<th>Physical properties</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sitting time (min)</td>
</tr>
<tr>
<td>Initial</td>
</tr>
<tr>
<td>Final</td>
</tr>
<tr>
<td>Compressive strength(MPa)</td>
</tr>
<tr>
<td>7 days</td>
</tr>
<tr>
<td>28 days</td>
</tr>
<tr>
<td>Specific surface, Blaine, cm²/g</td>
</tr>
</tbody>
</table>

Table (1) - Physical properties of the cement

<table>
<thead>
<tr>
<th>Chemical analysis, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lime (CaO)</td>
</tr>
<tr>
<td>Silica (SiO2)</td>
</tr>
<tr>
<td>Alumina (Al₂O₃)</td>
</tr>
<tr>
<td>Iron Oxide (Fe₂O₃)</td>
</tr>
<tr>
<td>Magnesia (MgO)</td>
</tr>
<tr>
<td>Sulfate (SO₃)</td>
</tr>
<tr>
<td>Loss on Ignition (LOI)</td>
</tr>
<tr>
<td>Insoluble residue (I.R.)</td>
</tr>
<tr>
<td>Lime saturation factor (L.S.F)</td>
</tr>
<tr>
<td>Tricalcium silicate (C₃S)</td>
</tr>
<tr>
<td>Dicalcium Silicate (C₂S)</td>
</tr>
<tr>
<td>Tricalcium Aluminate (C₃A)</td>
</tr>
<tr>
<td>TetracalciumAluminoFerrite (C₄AF)</td>
</tr>
</tbody>
</table>

Table (2) - Chemical properties of the cement

3- Foaming Agent
Foaming agent type EUCO from Swiss Chemistry Factory is chloride free Table (4). It was used to produce lightweight concrete by entraining a controlled amount of air bubbles to concrete mix that was brought from Ideal Building Corner (IBC) in Iraq.

<table>
<thead>
<tr>
<th>Properties</th>
<th>Monofilament polypropylene micro fiber</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fiber type</td>
<td></td>
</tr>
<tr>
<td>Fiber length</td>
<td>(19 mm)</td>
</tr>
<tr>
<td>Specific gravity</td>
<td>0.91</td>
</tr>
<tr>
<td>Alkali resistance</td>
<td>Excellent Alkali resistance</td>
</tr>
</tbody>
</table>

Table (4): Properties of the foaming agent used

4- Fibers
Polypropylene fiber for reinforcement was used; it was brought from Sika Company. It was crimped with aspect ratio of 63. The specifications and properties of fiber used throughout the experimental work are illustrated in Table (5)

5-Mixing Water
Ordinary tap water was used throughout this investigation for mixing and curing for all concrete mixes.

3.2. Mixes
In this study, lightweight Aggregate Cellular Concrete (LWACC) with mix proportion of 1:2.2: 0.3 by volume (cement: fine crushed Thermostone: coarse crushed Thermostone) and with addition 2% foaming agent by weight of water. The water to cement ratio was 0.55 to give slump of 100 mm. The details of the mixes used throughout this investigation are given in Table (6).

3.3. Casting and Curing
Casting procedure is important to obtain the required workability and homogeneity of concrete mixes. Mixing was performed by an electric tilting mixer. The aggregate was used in a saturated surface dry (SSD) condition.

3.4 Tests
1- Determination of the Workability of Concrete
The slump test was carried out in accordance with the procedure described in ASTM C143M-03 [9]. Generally, the slump of all mixes was near 100 mm.

2- Dry Density Test
The dry density test was determined from the dried weight (105°C for 24 hrs) and the measured volume. Three (150) mm cubes were measured in each sample tested. The density was found by weighing the specimens and dividing the weight by the measured volume of the specimens. The dry density was tested at age (7, 28, 60 and 180) days.

3- Water Absorption
The test was carried out according to ASTM C642-97[10] on 150 mm cubic specimens. Absorption of each specimen was calculated as the increase in
weight resulting from the immersion, expressed as a percentage of the weight of the dry specimen. The test was conducted at age of 7, 28, 60 and 180 days.

4- Compressive Strength:
This test was conducted on 150 mm using a digital compression testing machine of 2000 kN capacity at fixed load according to B.S. 1881: part 116:1989 [11]. The test was conducted at ages of 7, 28, 60 and 180 days, and three specimens were tested at each age.

5- Splitting Tensile Strength
The splitting tensile strength test was performed according to ASTM C496 -04 [12]. This test was conducted at ages of (7, 28, 60 and 180) days. The average splitting tensile strength of three cylinders was calculated.

6- Flexural Strength
Flexural strength of concrete was measured on (100*100*500) mm prism specimen in conformity with ASTM [13]. The specimens were tested at age of (7, 28, 60 and 180) days and the average of three specimens in each mix were taken.

7- Impact Resistance
The drop weight test was conducted following the test technique suggested by the ACI committee 544-1996 [14] on fiber reinforced concrete. The specimens used in impact resistance test 150 mm in diameter and 63.5 mm in thick. This test rests a specimen on the base plate within four positioning lugs. The specimen bottom covered with a thin layer of a heavy grease to reduce the friction between the specimen and the base plate. Then, a 4.54 kg hammer consecutively fields from a 457 mm height on a 50.8 mm diameter steel ball standing at the center of the specimen, subjecting the specimen to repeated impact blows. The number of blows developing the first visible crack on the specimen top is the first-crack strength. The falling operation continuous to trigger the ultimate failure is the opening up of the specimen to touch three of the four lugs. The number of blows triggering the ultimate failure is the failure strength. The test was conducted at age of 28 days. The result represents the average of three specimens.

8- Ultrasonic Pulse Velocity (UPV)
The ultra-sonic pulse velocities of the concrete cubes were measured according to ASTM C597-02[15] using transducers with frequency (54) kHz, as shown in Fig.(2). Two readings on each cube were measured (using the opposite smooth surfaces of the cube). Thus each mix result of ultrasonic pulse velocity represents an average of nine readings.

IV. RESULTS AND DISCUSSIONS

4.1. Dry Density
Figure (3) shows the effect of volume fraction of polypropylene fiber on the dry density. It is found that the dry density reduced as the percentage of fiber increased for different ages. This can be attributed to the high air content and large volume of voids present in the mix having high volume fraction.

4.2. Water Absorption
From Fig (4) can be observed that with increasing volume fraction of fibers, the water absorption increased. This may due to the high air content and large volume of voids present in the mixes with increasing volume fraction.
4.3 Compressive Strength
The effects of volume fraction of steel crimped plastic fibers on compressive strength at different ages are shown in Fig. (5). It can be seen from Fig. (5) that the compressive strength decreases with the increase of fiber percentage. The reduction in compressive strength is probably due to the same reasons in the dry density.

4.4 Splitting Tensile Strength
Fig. (6) illustrates the effect of volume fraction of plastic fiber on the splitting tensile strength. In general, it can be seen that the splitting tensile strength improves by the addition polypropylene fiber to the foam concrete mix. This increment in tensile strength by addition of fiber is may be due to the well bond of fiber to the matrix, the total length has been corrugated which means multiple interaction points which led more batter mechanical anchorage. The specimen without fiber failed suddenly once the concrete cracked, while the fiber reinforced concrete specimens were still intact together. This different mode of failure is due to that, when the specimen reinforced with fiber is forced to split apart in the tensile strength test, the load is transferred into the fibers as a pullout behavior when the concrete matrix began to crack where it exceeded the pre-crack state.

4.5 Flexural Strength
Fig. (7) represents the development of flexural strength with age of cellular concrete containing different amounts fibers. The same figure also reveals that the flexural strength increases with the increase of amount of fiber volume fractions.

4.6 Impact Resistance
From Figure (8) it can be seen that, the average number of pulses which caused the first crack were not affected by the fiber content, but the average number of pulses which caused the ultimate failure increased as the fiber content increased.

4.7 Ultrasonic Pulse Velocity
Figure (9) demonstrates the ultrasonic pulse velocity for cellular concrete containing different percentages of volume fraction (VF %) of fibers. Generally, the values of velocity of ultrasonic waves for all specimens increase slightly with the increase in age 28 days. This is because of the progress of hydration; which decreases the voids space within the concrete mass. On the other hand, the (UPV) value of all mixes decreases with the increase of fiber volume fraction in concrete. This behavior in reducation in (UPV) is similar to that in dry density.
CONCLUSIONS

This investigation covers several factors affecting the properties of foamed concrete, and studies the effect of plastic fiber on properties of foamed concrete. From the test results and discussion, the following some conclusions are demonstrated:

1. The use crimped plastic fiber by volume decreased the compressive strength, ultrasonic pulse velocity, and acoustic impedance, but the increase in splitting tensile strength, flexural strength, impact resistance, and water absorption.
2. The increase of crimped plastic fiber (Vf = %) decreases the compressive strength, dry density, ultrasonic pulse velocity, and acoustic impedance, but the increase in splitting tensile strength, flexural strength, impact resistance, and water absorption.
3. In impact strength test, the first crack was not effected with increasing of fiber content ,but the ultimate failure increased as the fiber content increases.

REFERENCES


★★★