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Size and shape effect of specimen on the compressive strength of HPLWFC reinforced with glass fibres

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KEYWORDS

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Abstract High performance lightweight foamed concrete (HPLWFC) have a structural strength with low density and high flowability. HPLWFC is used in modern concrete technology and extensively in the construction applications of high-rise buildings, long-span concrete structures and road sub-bases among others. This present work investigated the effect of size and shape specimen on the compressive strength of HPLWFC reinforced with glass fibres. Foam agent (organic material) was used to obtain lightweight concrete. The volume fractions of the glass fibres used were: 0.0%, 0.06%, 0.2%, 0.4%, and 0.6% by total volume of concrete. The fresh properties of HPLWFC were measured by flowability and fresh density tests. In this study, the size and shape of specimens used for compressive strength were cubes by size (150 × 150 × 150, 100 × 100 × 100 and 50 × 50 × 50 mm) and cylinders by size (150 × 300 and 100 × 200 mm). The results of HPLWFC mixes showed the increase in the compressive strength for all sizes of specimens with glass fibre content. The small size of specimens gave higher compressive strength in comparison with other sizes. The disparity in the compressive strength for two sizes and shapes (cubes and cylinders) were reduced with a rise in the volume fraction of the glass fibres.

1. Introduction

Lightweight concrete (LWC) is a versatile material that has created a great interest and large industrial demand in recent years in a wide range of construction projects, despite its known use dated back to 2000 years. LWC is a concrete, which by one means or another has been made lighter than conventional (normal weight aggregate) concrete (El-Zareef, 2010; Babu, 2008). LWC has an oven dry density range of about 300 to not exceed 2000 kg/m^3, with a compressive strength of a cube about 1 to more than 60 MPa. Lightweight foamed concrete has high flowability, low self-weight, minimum consumption of aggregate, controlled low strength, and excellent thermal insulation properties (Neville and Brooks, 2010). Lightweight foamed concrete (LWFC) is a cellular material composed of cement–sand matrix enclosing a large number of small pores roughly (0.1–1.0) mm size, uniformly distributed

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in a matrix. The LWFC consists of Portland cement paste or cement filler matrix (mortar) with a homogeneous void or the pore structure created by introducing air in the form of small bubbles (Mydin and Wang, 2011, 2012).

The concrete is considered as a brittle material and has some disadvantages such as poor fracture toughness, poor resistance to crack propagation and low impact strength. The function of using fibres in concrete is to enhance the mechanical properties of concrete. Fibres are used to modify the tensile strength, flexural strengths, toughness, impact resistance, fracture energy, arrest cracks formation and propagation and improve strength and ductility (Nahhas, 2013; Bagherzadeh et al., 2012; Dawood and Ramli, 2011; Mehta and Monteiro, 2006).

The cylinder specimen of concrete (150 diameter and 300 height) is a standard specimen to test the compressive strength in United States. While in Britain and Europe, the standard specimen for testing the compressive strength is a cube specimen of concrete by size 150 × 150 × 150 mm (Kim and Seong-Tae, 2002). The cubes are smaller compared with the cylinder specimen of concrete, and the advantages of cylinders do not depend on the quality and condition of the moulds and that their density can be more readily and accurately established by weighing and measuring (Day, 2006).

The main difference between cylinder and cube specimens is that the cylinder specimens need capping before loading because the top surface of the cylinder finished by the trowel causes no plane for testing. Two methods are used to obtain the plane surface of the cylinder. (i) Capping method: sulphur mortar, high strength gypsum plaster and cement paste in order to have plain loading surfaces, the thickness of the capping should be 1.5–3 mm and have the same strength of the concrete. (ii) Grinding method: is satisfactory but expensive (Al-Sahawneh, 2013; Neville and Brooks, 2010; Kim and Seong-Tae, 2002). Cubes do not require capping as they are turned over on their sides, when being loaded. The height/diameter ratio equal to 2, the compressive strength of cylinder specimens with varying diameter, the larger the diameter, the lower will be the strength (Kim and Seong-Tae, 2002). The cylinders are cast and tested in the same position, but the cubes are cast in one direction and tested at right angles to the position cast and thus no need of capping or grinding. In actual structures in the field, the casting and loading are similar to those of the cylinder and not like the cube (Shetty, 2005). The comparison between the compressive strength of cube and compressive strength of cylinder, a factor of 0.8 to the cube strength is often applied for normal strength concrete (Al-Sahawneh, 2013). Fig. 1 shows the influence of the aspect ratio of the compressive stress assuming that the value of the slope, was approximately selected as 45° since the confinement effects of frictional force would be negligible if the aspect ratio h/d becomes very large. Therefore, a cylinder with an aspect ratio $h/d = 1$ will be able to resist higher loads than a cylinder with an aspect ratio of 2 (Al-Sahawneh, 2013; Kim and Seong-Tae, 2002).

The usual fracture of cylinder specimens is cone and there are other types of concrete cylinders specimens fracture as shown in Fig. 2(a) (ASTM C 39). Fig. 2 (b) shows the typical failure modes of test cubes (Neville and Brooks, 2010; BS EN 12390-3, 2002). This paper was conducted to study the size and shape effect on the high performance lightweight foamed concrete with the addition of glass fibres. The shapes used were the cubes and cylinders. The size of specimen's cubes was 150 × 150 × 150 mm, 100 × 100 × 100 mm and 50 × 50 × 50 mm against the size of specimen's cylinders which was 150 × 300 mm and 100 × 200 mm. These sizes were chosen because it represented the sizes that are most commonly used locally and universally in the construction research. Additionally, glass fibres were added to high performance lightweight foamed concrete with different ratios and study the effect of glass fibres on compressive strength.

2. Materials and mix proportions

2.1. Materials

Ordinary Portland Cement (OPC) was used in different lightweight foamed concrete mixes. Such cement was taken from Badoosh Cement Factory in the Nineveh Province – Iraq. The physical characteristics are shown in Table 1. Besides, the chemical compositions of cement are shown in Table 2. Both physical and chemical characteristics are in compliance with the standard specification ASTM C 150. The natural river sand used as fine aggregate was supplied from the Kanhash Region – Mosul City. The specific gravity and fineness modulus of sand are 2.63 and 2.69, respectively. The grading limits are according to ASTM C 33 as given in Table 3. Normal tap water was used in this study for mixing and curing.

Foam agent was used to obtain lightweight foamed concrete. The type of foam agent (NEOPOR) (leycoChem LEYDE GmbH Germany) is an organic material, which has no chemical reaction but serves solely as wrapping material for the air to be induced in the concrete. The foaming agent has to be diluted in 40 parts of water before using it according to the manufacturer.

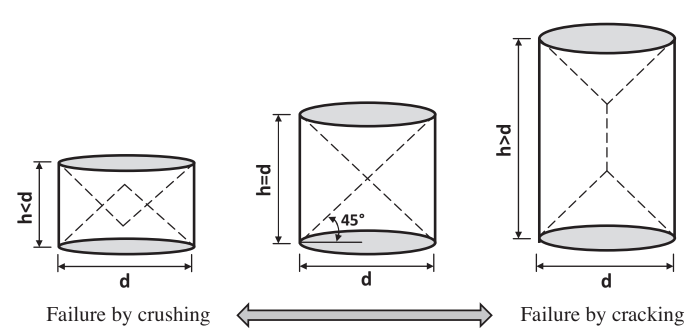

Figure 1 Effect of the specimen size and failure modes.