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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

Compressive strength;
Size effect;
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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.

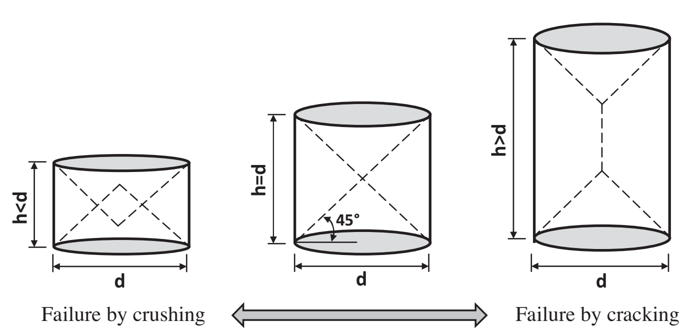

Figure 1 Effect of the specimen size and failure modes.

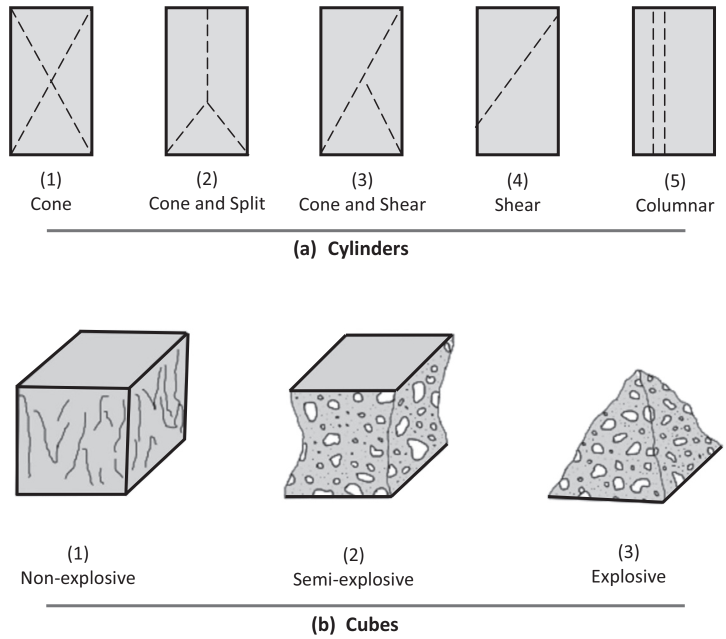

Figure 2 (a) Sketches of types of cylinders fracture (ASTM C 39) and (b) typical failure mode of test specimen cube according to (BS EN 12390-3, 2002; Neville and Brooks, 2010).

Table 1 Physical characteristics of cement used.

Test	Results	ASTM C 150 limits
Initial setting time (minutes)	220	Not less than 45 min. Not more than 375 min.
Fineness (Blaine m^2/kg)	300	Min. 280 m^2/kg
Compressive strength of 50 mm cubic mortar specimen (MPa)		
3 days	21	Min. 12 MPa
7 days	29	Min. 19 MPa

Glass fibres (GF) were used in the lightweight foamed concrete, the properties of the glass fibres are listed in Table 4.

Table 2 Chemical properties of cement used.

Constituent	Component of use cement (%)	ASTM C 150 limits
SiO_2	21.31	–
Al_2O_3	5.89	–
Fe_2O_3	2.67	–
CaO	62.2	–
MgO	3.62	⩽6%
SO_3	2.6	⩽3.5%
Loss of ignition	1.59	⩽3%
Insoluble residue	0.24	⩽0.75%
Free CaO	1.74	–
L.S.F.	0.8818	0.66–1.02
C_3S	33.37	–
C_2S	35.92	–
C_3A	11.09	–
C_4AF	8.12	–

2.2. Mix proportions

The mix proportion by volume used in this study was 1:2.25 cement: sand, respectively (ACI 211-2, 2002; Ramamurthy et al., 2009). The water requirement for a mix depends upon the composition and the amount of foam agent which is governed by the consistency and stability of the mix (Ramamurthy et al., 2009). The selection of water cement ratio in this study depended on three parameters: the optimum oven dry density (less than 1850 kg/m^3), flowability (equal or more than 110% flow) and compressive strength (equal or more than 17 MPa). This mix proportion is considered as shown in Table 5. Furthermore, fibres were incorporated in the lightweight foamed concrete mixes to produce different mixes. Different volume fractions of glass fibres were used as presented in Table 6.

3. Specimens

Different specimen shapes (i.e., cubes and cylinders) with different sizes for cubes and cylinder specimens were used. Three different cube specimens in size were used for each mix as shown in Table 6. Two different cylinder specimens in size were used for each mix as shown in Table 6.

4. Experimental work

4.1. Mix procedure

The procedure of mixing was achieved by blending the cement with sand according to the mix proportion as shown in Table 5, and then water was added to prepare the mortar. After that, the foam was added to the mortar to obtain lightweight foamed concrete. It should be mentioned that the preparation

Table 3 Grading of fine aggregate.

Sieve No. (mm)	Passing (%)	ASTM C 33 limits
No.4 (4.75)	100	95–100
No.8 (2.36)	81	80–100
No.16 (1.18)	66	50–85
No.30 (0.6)	52	25–60
No.50 (0.3)	25	5–30
No.100 (0.15)	7	0–10

Table 4 Properties of glass fibres.

Fibre properties	Quantity
Fibre length	12 mm
Aspect ratio	857
Specific gravity	2.68 g/cm^3
Modulus of elasticity	72 GPa
Tensile strength	1700 MPa
Chemical resistance	Very high
Electrical conductivity	Very low
Softening point	860 °C
Material	Alkali Resistant Glass
Shape	Straight

of the foam was done using the foam agent which was diluted in 40 parts of water according to the manufacturer. Such water was calculated as a part of the total water of the mix. As the foam was added to the mortar, they were blended in the mixer to obtain a homogeneous mixture. Finally, the fibres were added to the mix (lightweight foamed concrete). Glass fibres were included in different proportions of volume fractions, as shown in Table 6. The total mixing time was about 6 min. The mix should have a uniform dispersion of the fibres in order to prevent segregation or balling of the fibres during mixing. Most balling occurs during the fibres' addition process.

4.2. Casting, curing, and testing of lightweight foamed concrete specimens

Before casting, the fresh properties of lightweight foamed concrete were tested after completely mixing the materials. The fresh properties consist of flowability test and fresh density test. Each mix proportion was measured in terms of flowability by using flow table according to ASTM C 1437. The Fresh density was carried out according to ASTM C 138. It was measured by determining the net weight of freshly mixed concrete divided into the volume of concrete produced from a mixture at the moment of casting.

Three cubes were cast for compressive strength at age 7 and 28 days for each mix and size. Three cylinders were cast for compressive strength at age 7 and 28 days for each mix and size. The size of cubes and cylinders is presented in Table 6. All specimens were cast in one layer with compaction by vibration for about 10 s. The use of vibration was just for filling the mould and levelling. The specimens were kept in the laboratory for about 24 ± 8 h. The specimens were stripped approximately for 24 h after casting and placed in the water basin as a curing method with a controlled temperature of 23 °C ± 2 °C according to ASTM C 192.

The average of three cubes and cylinders was tested according to BS EN 12390-3 and ASTM C 39, respectively, to determine the compressive strength for each mix and size at age 7 and 28 days. The uniaxial testing machine with 2000 kN capacity was used and loading rate of 0.4 MPa/s was applied.

5. Results and discussion

5.1. Flowability and fresh density

The flowability (flow) was measured according to ASTM C 1437, the flowability of high performance lightweight foamed concrete reinforced with glass fibres varied among mixes depending on the volume fraction of glass fibres, the flow of mixes is as given in Table 7. The flow varied between (130–100%), the flow was about 130% for control mix (0.0% glass fibres), and flow reduced with the increase in glass fibres. Thus, the use of 0.6% of glass fibres reduced the flow to 100%. The addition of fibres may cause a decrease in flowability of concrete. Fibres hindered the flowability of fresh concrete and this caused a significant decrease in the flowability of concrete (Widodo, 2012; Dawood and Ramli, 2011; Neville and Brooks, 2010; Topcu and Canbaz, 2007).

The fresh density of high performance lightweight foamed concrete varied depending on the percentage of fibres. The high performance lightweight foamed concrete reinforced with glass fibres showed that the density of such concrete was greatly affected by the inclusion of glass fibres. And thus, the inclusion of glass fibres would significantly affect the density of such concrete as seen in Table 7. However, such results are attributed to the specific gravity of fibres.

5.2. Compressive strength

The compressive strength test results for different size cubes and different size cylinders are shown in Table 8. The compressive strength of high performance lightweight foamed concrete is affected by the added fibres. The compressive strength increased with the glass fibres percentage increase. The results in Fig. 3 indicate that there is a large increase in compressive strength with increase in fibres content. This increase can be attributed to the reduction in the porosity of high performance lightweight foamed concrete and an enhancement in mechanical bond strength (Miloud, 2005). It was observed that, the formation of cracks is extended in the specimens without glass fibres (control mix) with great numbers. Whereas, they were the least cracks in the specimens reinforced with the maximum

Table 5 Mix proportions.

Mix proportion	*w/c*	Cement (kg/m^3)	Sand (kg/m^3)	Water (kg/m^3)	Foam agent (kg/m^3)	Voids (%)
(1:2.25) (cement: sand)	0.49	465	1046	228	1	23

Table 6 Specimen Size and Shape with volume fraction* of glass fibres.

Sample No.	Specimen Shape	Size (mm)	GF** (%)	No. of specimen concrete for compressive strength		Total No. of test specimens
				7-days	28-days	
S1	Cube	150 × 150 × 150	0	3	3	6
S2	Cube	100 × 100 × 100	0	3	3	6
S3	Cube	50 × 50 × 50	0	3	3	6
S4	Cube	150 × 150 × 150	0.06	3	3	6
S5	Cube	100 × 100 × 100	0.06	3	3	6
S6	Cube	50 × 50 × 50	0.06	3	3	6
S7	Cube	150 × 150 × 150	0.2	3	3	6
S8	Cube	100 × 100 × 100	0.2	3	3	6
S9	Cube	50 × 50 × 50	0.2	3	3	6
S10	Cube	150 × 150 × 150	0.4	3	3	6
S11	Cube	100 × 100 × 100	0.4	3	3	6
S12	Cube	50 × 50 × 50	0.4	3	3	6
S13	Cube	150 × 150 × 150	0.6	3	3	6
S14	Cube	100 × 100 × 100	0.6	3	3	6
S15	Cube	50 × 50 × 50	0.6	3	3	6
S16	Cylinder	150 × 300	0	3	3	6
S17	Cylinder	100 × 200	0	3	3	6
S18	Cylinder	150 × 300	0.06	3	3	6
S19	Cylinder	100 × 200	0.06	3	3	6
S20	Cylinder	150 × 300	0.2	3	3	6
S21	Cylinder	100 × 200	0.2	3	3	6
S22	Cylinder	150 × 300	0.4	3	3	6
S23	Cylinder	100 × 200	0.4	3	3	6
S24	Cylinder	150 × 300	0.6	3	3	6
S25	Cylinder	100 × 200	0.6	3	3	6
Total						150

* Volume fraction of glass fibres taken by total volume of concrete.
** GF: Glass fibres.

Table 7 Flowability and fresh density for each mix.

Fibres (%)	0.0	0.06	0.2	0.4	0.6
Flowability (%)	130	125	120	115	100
Fresh density (kg/m^3)	1755	1765	1790	1825	1860

glass fibres used in this study (0.6% glass fibres). These results are supported by other researches in this regard (Deshmukh et al., 2012; Kannan et al., 2010; Gornale et al., 2012; Al-Qadi and Al-Zaidyeen, 2014). Also the Fig. 3 shows the difference in the compressive strength between all mixes and size, where the small size specimen of cube gives the higher value of compressive strength at 28 days compared with other sizes. The increase in compressive strength of the high performance lightweight foamed concrete was up to for mix S15 (0.6% glass fibres) at 28 days compared with the other mixes and sizes. However, the increase in compressive strength due to glass fibres inclusions can be attributed to the improvement in the mechanical bond strength between the fibres and the matrix where the fibres contribute to delay of micro-crack formation and arrest their propagation afterwards up to a certain extent of fibres volume fraction (Sahmaran and Yaman, 2007; Felekoglu et al., 2007).

The results are conducted to realize the size and shape effect on the compressive strength of high performance lightweight foamed concrete. The compressive strength of 50 mm cube for mix S3 increased by 38% and 15% compared with the same mix, but different in size of 150 mm and 100 mm cube (S1 and S2), respectively. From these results it can be said that the smaller size of specimens give high compressive strength (Celik et al., 2012; Yaqub and Javed, 2006). For the largest percentage of glass fibres (0.6% glass fibres) the compressive strength of 50 mm cube (mix S15) increased by 5.3% and 3.4% compared with the 150 mm and 100 mm cubes (S13 and S14). It can be noticed that the effect of glass fibres reduce the affects the size of the concrete specimens.

The ratio of the compressive strength of the cubes (fcu) in size 100 × 100 × 100 mm to the cubes (fcu) in size 150 × 150 × 150 mm $\left(\frac{fcu(100\times100\times100)}{fcu(150\times150\times150)}\right)$ was between 1.2 and 1.01, and the average of this ratio was 1.1.The ratio of the compressive strength of the cylinders (fc) in size 150 × 300 mm to the cylinder (fc) in size 100 × 200 mm $\left(\frac{fc(100\times200)}{fc(150\times300)}\right)$ was between 1.22 and 1.06, and the average of this ratio was 1.15. Figs. 4 and 5 shows the relationship between

Table 8 Average compressive strength specimens of cubes and cylinders.

Sample No.	Specimen Shape	Size (mm)	GF (%)	Compressive strength (MPa)	
				7-days	28-days
S1	Cube	150 × 150 × 150	0	11.4	15.8
S2	Cube	100 × 100 × 100	0	14.2	19.0
S3	Cube	50 × 50 × 50	0	15.0	21.8
S4	Cube	150 × 150 × 150	0.06	13.5	17.4
S5	Cube	100 × 100 × 100	0.06	16.0	20.5
S6	Cube	50 × 50 × 50	0.06	17.6	24.3
S7	Cube	150 × 150 × 150	0.2	16.2	22.0
S8	Cube	100 × 100 × 100	0.2	18.0	24.4
S9	Cube	50 × 50 × 50	0.2	19.6	26.4
S10	Cube	150 × 150 × 150	0.4	19.4	26.2
S11	Cube	100 × 100 × 100	0.4	21.0	27.1
S12	Cube	50 × 50 × 50	0.4	22.3	28.3
S13	Cube	150 × 150 × 150	0.6	21.5	28.5
S14	Cube	100 × 100 × 100	0.6	22.6	29.0
S15	Cube	50 × 50 × 50	0.6	23.6	30.0
S16	Cylinder	150 × 300	0	10.1	13.5
S17	Cylinder	100 × 200	0	12.4	16.6
S18	Cylinder	150 × 300	0.06	11.8	15.2
S19	Cylinder	100 × 200	0.06	14.0	18.6
S20	Cylinder	150 × 300	0.2	14.3	19.5
S21	Cylinder	100 × 200	0.2	16.0	22.3
S22	Cylinder	150 × 300	0.4	17.6	23.4
S23	Cylinder	100 × 200	0.4	19.0	25.6
S24	Cylinder	150 × 300	0.6	19.5	26.0
S25	Cylinder	100 × 200	0.6	20.4	27.6

the compressive strength of cubes specimens vs cylinders specimens. The ratio of the compressive strength of the cylinders (fc)in size 150 × 300 mm to the cubes (fcu) in size 150 × 150 × 150 mm $\left(\frac{fc(150\times300)}{fcu(150\times150\times150)}\right)$ was between 0.85 and 0.91, and the average of this ratio was 0.88which means the compressive strength of cubes 150 × 150 × 150 mm are greater than the cylinders of size 150 × 300 mm. This is usually attributed to having an overlapped restrained zone in cubes while testing under uniaxial compression, hence a zone of tri-axial compression develops. On the other hand, cylinders with length/diameter ratio of 2 have an unrestrained zone away from the ends (Malaikah, 2005). Also the effect of glass fibres on the compressive strength of the cubes and cylinders specimens can be observed, whereas the disparity in the compressive strength for two sizes reduces with the rise in the volume fraction of glass fibres. The highest percentage of glass fibres which was 0.6% gives the lowest disparity (fc/fcu) (compressive strength of cylinder/compressive strength of cube) compared with other percentages of glass fibres, which means the ratio of (fc/fcu) was nearby 1. The ratio of the compressive strength of the cylinders (fc) in size 150 × 300 mm to the cubes (fcu) in size 100 × 100 × 100 mm was between 0.71 and 0.89, and the average ratio of compressive strength $\left(\frac{fc(150\times300)}{fcu(100\times100\times100)}\right)$ was 0.8. The compressive strength of cubes in size 100 × 100 × 100 mm is greater than the cylinders in size 150 × 300 mm. It can be noticed the ratio value of $\frac{fc(150\times300)}{fcu(100\times100\times100)}$ reduced when compared with $\frac{fc(150\times300)}{fcu(150\times150\times150)}$, this is attributed to the compressive strength of the 100 mm cubes which is greater than the compressive strength of the 150 mm cube. The ratio $\frac{fc(100\times200)}{fcu(150\times150\times150)}$ and $\frac{fc(100\times200)}{fcu(100\times100\times100)}$ was between 1.05–0.96 and 0.87–0.95, respectively, and the average ratio of compressive strength was 1.01 and 0.91 respectively. Overall, the addition of glass fibres to the high performance lightweight foamed concrete increases the compressive strength and reduces the effect of the size and shape of the concrete specimen.

Fig. 6 shows the slenderness ratio (H/D) equal to 2, but there was variation in size of the cylinders. The compressive strength of the cylinder 100 × 200 mm was more than the compressive strength of the cylinder 150 × 300 mm. The addition of glass fibres to the high performance lightweight foamed concrete increases the compressive strength, and also observed to reduce the difference in compressive strength between the two sizes of cylinder (100 × 200 and 150 × 300 mm).

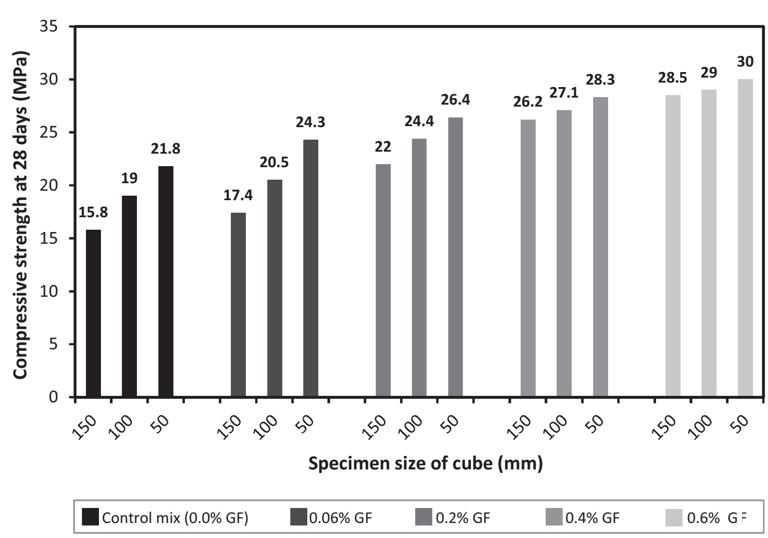

Figure 3 Average compressive strength of cubes specimens at 28 days.

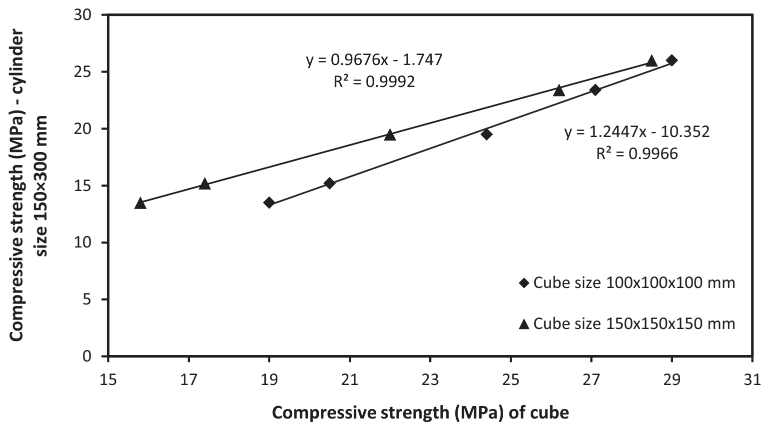

Figure 4 Compressive strength of 150 mm and 100 mm cubes specimens versus 150 × 300 mm cylinders specimens.

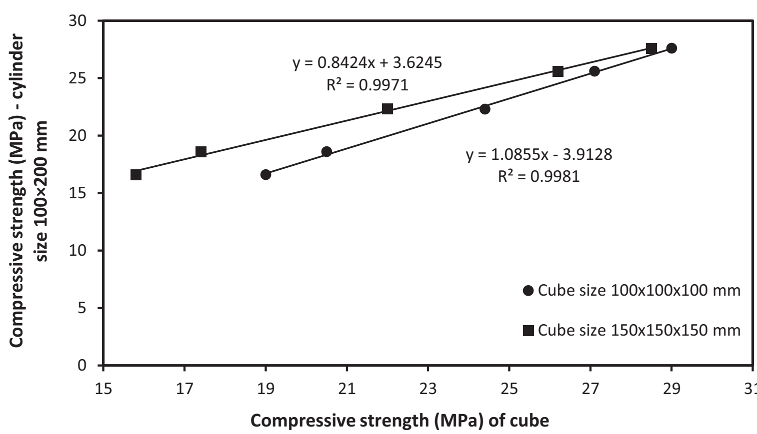

Figure 5 Compressive strength of 150 mm and 100 mm cubes specimens versus 100 × 200 mm cylinders specimens.

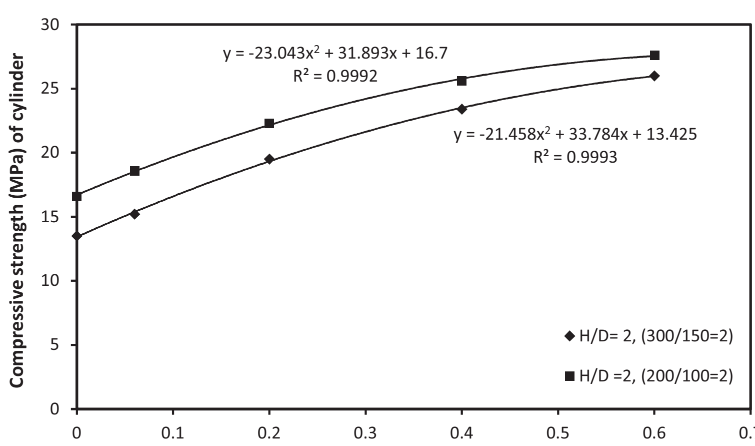

Figure 6 Relationship between glass fibres and compressive strength of cylinders, with influence the size specimen of cylinder.

6. Conclusions

The following conclusions are drawn from the experimental work on size and shape effects found on cube and cylinder of high performance lightweight foamed concrete reinforced with glass fibres.

1. The compressive strength of high performance lightweight foamed concrete increased with rising glass fibres content.
2. The small size of specimen for cubes or cylinder gives higher compressive strength of high performance lightweight foamed concrete compared with other sizes. The compressive strength of 50 mm cube for mix S3 increased

by 38% and 15% compared with the 150 mm and 100 mm cube (S1 and S2), respectively.

3. The average ratio of the compressive strength of high performance lightweight foamed concrete of 150 × 300 mm cylinders to 150 × 150 × 150 mm cubes was 0.88.
4. The average ratio of the compressive strength of high performance lightweight foamed concrete of 100 × 200 mm cylinders to 150 × 150 × 150 mm cubes was 1.01.
5. The average ratio of the compressive strength of high performance lightweight foamed concrete of 150 × 300 mm cylinders to 100 × 100 × 100 mm cubes was 0.8.
6. The average ratio of the compressive strength of high performance lightweight foamed concrete of 100 × 200 mm cylinders to 100 × 100 × 100 mm cubes was 0.91.
7. The average ratio of the compressive strength of high performance lightweight foamed concrete of 100 × 200 mm cylinders to 150 × 300 mm cubes was 1.15.
8. The average ratio of the compressive strength of high performance lightweight foamed concrete of 100 × 100 × 100 mm cylinders to 150 × 150 × 150 mm cubes was 1.1.
9. The disparity in the compressive strength for two sizes and shapes are reduced with the rise in the volume fraction of glass fibres.

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References

ACI 211-2, 2002. Standard practice for selecting proportions for structural lightweight concrete. American Concrete Institute, Farmington Hills, MI, USA.

Al Qadi, A.N.S., Al-Zaidyeen, S.M., 2014. Effect of fibre content and specimen shape on residual strength of polypropylene fibre self-compacting concrete exposed to elevated temperatures. J. King Saud Univ. Eng. Sci. 26 (1), 33–39.

Al-Sahawneh, E.I., 2013. Size effect and strength correction factors for normal weight concrete specimens under uniaxial compression stress. Contemp. Eng. Sci. 6 (2), 57–68.

ASTM C 1437, 2001. Standard test method for flow of hydraulic cement mortar. Annual Book of ASTM Standards, vol. 04.01.

ASTM C 138, 2001. Standard test method for density (unit weight), yield, and air content (gravimetric) of concrete. Annual Book of ASTM Standards, vol. 04.02.

ASTM C 192, 2002. Making and curing concrete test specimens in the Laboratory. Annual Book of ASTM Standards, vol. 04.02.

ASTM C 39, 2003. Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens. Annual Book of ASTM Standards, vol. 04.02.

ASTM C 33, 2002. Standard specification for concrete aggregates. Annual Book of ASTM Standards, vol. 04.02.

ASTM C 150, 2002. Standard specification for Portland cement. Annual Book of ASTM Standards, vol. 04.01.

Bagherzadeh, R., Pakravan, H.R., Masoud Latifi, A.S.M., Merati, A. A., 2012. An investigation on adding polypropylene fibres to reinforce lightweight cement composites (LWC). J. Eng. Fibres Fabr. 7 (4), 13–21.

Babu, D.S., 2008. Mechanical and Deformational Properties, and Shrinkage Cracking Behavior of Lightweight Concretes (Ph.D. thesis). National University of Singapore.

BS EN 12390-3, 2002. Testing hardened concrete. In: Part 3: Compressive Strength of Test Specimens. BSI, London, UK.

Celik, A.O., Kilinc, K., Tuncan, M., Tuncan, A., 2012. Distributions of compressive strength obtained from various diameter cores. ACI Mater. J. 109 (6), 597–606.

Dawood, E.T., Ramli, M., 2011. High strength characteristics of cement mortar reinforced with hybrid fibres. Constr. Build. Mater. 25 (5), 2240–2247.

Day, K.W., 2006, third ed.. In: Concrete Mix Design, Quality Control and Specification Taylor & Francis e-Library.

Deshmukh, S.H., Bhusari, J.P., Zende, A.M., 2012. Effect of glass fibers on ordinary Portland cement concrete. IOSR J. Eng. 2 (6), 308–1312.

El Zareef, M.A., 2010. Conceptual and Structural Design of Buildings Made of Lightweight and Infra Lightweight Concrete'. (Ph.D thesis). Berlin University of Technology.

Felekoglu, B., Turkel, S., Altuntas, Y., 2007. Effects of steel fiber reinforcement on surface wear resistance of self-compacting repair mortars. Cement Concr. Compos. 29 (5), 391–396.

Gornale, A., Quadri, S.I., Quadri, S.M., Ali, S.M., Hussaini, S.S., 2012. Strength aspects of glass fiber reinforced concrete. Int. J. Sci. Eng. Res. 3 (7), 1–5.

Kim, Jin.-keum., Seong-Tae, Y., 2002. Application of size effect to compressive strength of concrete members. India 27 (4), 467–484.

Kannan, S.U., Selvamony, C., Ravikumar, M.S., Gnanappa, S.B., 2010. Investigations and study on the effect of glass polymer fibres in self-compacting self-curing concrete. ARPN J. Eng. Appl. Sci. 5 (2), 41–45.

Malaikah, A.S., 2005. Effect of specimen size and shape on the compressive strength of high strength concrete. Pertanika J. Sci. Technol. 13 (1), 87–96.

Mehta, P.K., Monteiro, P.J.M., 2006. Concrete: Microstructure, Properties and Materials, third ed. McGraw-Hill, New York.

Miloud, B., 2005. Permeability and porosity characteristics of steel fiber reinforced concrete. Asian J. Civil Eng. (Build. Hous.) 6 (4), 317–330.

Mydin, M.O., Wang, Y.C., 2012. Mechanical properties of foamed concrete exposed to high temperatures. Constr. Build. Mater. 26 (1), 638–654.

Mydin, M.O., Wang, Y.C., 2011. Structural performance of lightweight steel-foamed concrete–steel composite walling system under compression. Thin Wall. Struct. 49 (1), 66–76.

Nahhas, T.M., 2013. Flexural behavior and ductility of reinforced lightweight concrete beams with polypropylene fibre. J. Constr. Eng. Manage. 1 (1), 4–10.

Neville, A.M., Brooks, J.J., 2010. Concrete Technology, second ed. Prentice Hall, Pearson Education.

Ramamurthy, K., Nambiar, E.K.K., Ranjani, G.I.S., 2009. A classification of studies on properties of foam concrete. Cement Concr. Compos. 31 (6), 388–396.

Sahmaran, M., Yaman, I.O., 2007. Hybrid fiber reinforced self-compacting concrete with a high-volume coarse fly ash. Constr. Build. Mater. 21 (1), 150–156.

Shetty, M.S., 2005. Concrete Technology, Theory and Practice. S. Chand & Company Ltd, India.

Topcu, I.B., Canbaz, M., 2007. Effect of different fibers on the mechanical properties of concrete containing fly ash. Constr. Build. Mater. 21 (7), 1486–1491.

Widodo, S., 2012. Fresh and hardened properties of polypropylene fiber added self-consolidating concrete. Int. J. Civil Struct. Eng. 3 (1), 85–93.

Yaqub, M., Javed, M.A., 2006. Comparison of Core and Cube Compressive Strength of Hardened Concrete. 31st Conference on Our World in Concrete & Structures, Singapore.