FLEXURAL BEHAVIOR OF STRUCTURAL LIGHTWEIGHT CONCRETE BEAMS

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ABSTRACT

Compressive strength is the most effective mechanical property to produce structural lightweight aggregate concrete, by increasing compressive strength the other mechanical properties such as tensile strength, modulus of elasticity, and flexural strength also increase, it was indicated that the type of lightweight concrete, and the type of lightweight aggregate are the most effective factors on the value of compressive strength, so that structural lightweight aggregate concrete was produced using expanded polystyrene having size less than 4.75 mm as 60% replacement ratio of normal weight fine aggregate (sand) by, cement content 360 Kg/m³, 90 Kg/m³ silica fume was added with 20% replacement ratio of cement by weight, and high range water reducer was used with 2% of cement by weight, and 45% water to cement ratio was used, the experimental work was to determine the compressive strength, tensile strength, and flexural strength of that mix, reinforced concrete beams made from the previous mix were cast and compared with reinforced normal weight concrete beams, lightweight aggregate beams were cast with different shear span to depth ratios (a/d), different reinforcement steel to concrete ratio (μ), different shear reinforcement, different cases of loading, once three points of loading, another time four points of loading, the load deflection curve of concrete was drawn using LVDT, and strain gauges were put on the surface of bottom steel bar in order to measure strain in it subsequently draw load-strain curve for steel.

Key words: Structural Lightweight Aggregate Concrete, Expanded Polystyrene, Flexural Behavior of Lightweight Concrete Beams.

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1. INTRODUCTION

Mechanical properties of Lightweight concrete is less than that for normal weight concrete, using light weight aggregate instead of normal weight aggregate caused a slight reduction in strength of light weight concrete [1], compressive strength is regarded as indicator on the other mechanical properties of Lightweight concrete such as tensile strength, and flexural strength, so that the factors affecting on compressive strength should be studied especially the type of lightweight concrete and type of used lightweight aggregate, Expanded polystyrene particle size and the granules content controls the mechanical properties of Expanded polystyrene concrete [2], compressive strength of light weight expanded polystyrene concrete are negatively affected by increasing the volume of expanded polystyrene in the mix [3], Smaller expanded polystyrene aggregate gives higher compressive strength for expanded polystyrene aggregate concrete, increase in compressive strength is more evident in low density concrete more than high density concrete, bigger size and higher volume of expanded polystyrene aggregate causes higher moisture migration and absorption [4]), "EPS dosage has the most significant effect on compressive strength of EPS lightweight aggregate concrete, then water and cement ratio, while the content of cement and sand ratio play a comparatively less important part. The relationship between density and compressive strength of EPS lightweight aggregate concrete is proposed as $f_c = 2.43 \times \gamma^{2.997} \times 10^{-9}$ " [5], lightweight aggregate concrete strength is inversely proportional to the water/cement ratio [6], the compressive strength of the light weight concrete increases by decreasing the inclusion size [7], The effect of particle size in EPS concrete on compressive strength is more effectual in low porosity concretes and could be neglected in very high porosity concretes [8], higher dry density and longer curing age of expanded polystyrene concrete increases compressive strength [9]. The concrete compressive strength controls coordinates of the key points used for drawing stress-strain curve, the entire curve shape can be predicted according to compressive strength [10], the compressive strength and elastic modulus of concrete are mainly affected by lightweight aggregates properties and the water to binder ratio [11], using polystyrene granules as replacement of aggregates caused reduction in density and mechanical properties of light weight concrete such as compressive strength [12], compressive strength and modulus of elasticity of lightweight aggregate concrete is directly proportional to the particle density, and the possibility of brittle failure occurring increases with increasing the volume content of light weight aggregate [13] larger volume fraction of expanded polystyrene aggregate causes reduction apparent density, tensile strength, compressive strength, elasticity modulus, and fracture toughness [14], splitting tensile strength controls the shear strength of structural lightweight aggregate concrete slabs rather than compressive strength [15], more Brittle failure occurs when the volume content of lightweight aggregate increases, for concretes with the same strength and light weight aggregate concrete is more brittle than normal weight concrete [16], by the time producing structural LWAC it may be used for a lot of purposes, "These lightweight panels produced using Expanded Polystyrene as 50% of the total EPS used in a composite foam concrete can allow rapid construction while reducing the overall weight of the building, these walls can also be used as partition walls of multi storey buildings, it also has a flexural strength comparable with other masonry materials, The EPS based walls can be used as load bearing walls of single storey construction" [17].

2. MATERIALS AND EXPERIMENTAL PROCEDURES

2.1. Materials

Materials used to produce reinforced lightweight and normal weight concrete beams are shown in Table (1) and properties of reinforcement steel are shown in Table (2)

Table 1 Properties of lightweight aggregate concrete raw materials

Property	Crushed Dolomite	Sand	EP	Cement	SF	HRWR
Specific Gravity	2.67	2.53	3.15	3.15	2.15	1.15
Unit weight (Kg/m ³)	1770	1774	17			
Absorption ratio (%)	1.5	5.2	.8			

Table 2 Properties of reinforcement steel

Diameter of steel Bar (mm)	Elastic Modulus E_s (GPa)	Yield stress f_y (MPa)	Yield strain ϵ_y	Ultimate stress f_u (MPa)	% Elongation at failure
12	203	540	0.0027	670	14.5%

2.2 EXPERIMENTAL METHOD

Reinforced concrete beams were cast to study the factors affecting on flexural behavior of beams as following,

- 3 lightweight expanded polystyrene concrete beams with constant (a/d) ratio equals to 5, 4 loading points, and 2%, 1%, and 1.5% steel to concrete ratios μ for beams B1, B2, and B3 respectively to study the effect of steel to concrete ratio μ on flexural behavior of beams,
- 1 lightweight expanded polystyrene concrete beam B4 was cast with the same properties of B3 but it was subjected to 3 loading points, the results of structural behavior of that beam will be determined and compared with that for B3, to determine the effect of cases of loading beams on flexural behavior of beams,
- 2 lightweight expanded polystyrene concrete beams were cast with the same properties of B3 but with different (a/d) ratios equals to 3.6 and 1 for beams B5 and B6 respectively to study the effect of (a/d) ratio on the flexural behavior of beams
- 2 normal weight concrete beams, B7 and B8 with the same properties of B5 and B6 respectively to study the effect of concrete type on the flexural behavior of beams

Beams designation is shown in table 3 and concrete mix design and properties are shown in table 4, and reinforcement details of all concrete beams is shown from figure 1 to figure 5.

Table 3 Designation of Beams

Beam Id	Steel to Concrete Ratio μ %	Shear Span to Depth Ratio (a/d)	Number of Loading Points	Main Steel Reinforcement	Main Steel Reinforcement
B1	2	5	4	4 ϕ 12	7 ϕ 8
B2	1	5	4	2 ϕ 12	7 ϕ 8
B3	1.5	5	4	3 ϕ 12	7 ϕ 8
B4	1.5	5	3	3 ϕ 12	7 ϕ 8
B5	1.5	3.6	4	3 ϕ 12	7 ϕ 8
B6	1.5	3.6	4	3 ϕ 12	7 ϕ 8
B7	1.5	1	4	3 ϕ 12	7 ϕ 8
B8	1.5	1	4	3 ϕ 12	7 ϕ 8

Table 4 Designation of Beams

Mix Type	Cement Content (Kg/m ³)	Silica Fume Content (Kg/m ³)	Water Content (Kg/m ³)	HRWR Content (Kg/m ³)	Weight of Sand (Kg/m ³)	Weight of Crushed Dolomite (Kg/m ³)	Weight of LWA (Kg/m ³)	Compressive Strength (Kg/cm ²)
NWC	350	0	158	0	740	1163	0	253
LWC	360	90	180	9	267	1049	2	194

Figure 1 Reinforcement details of B1

Figure 2 Reinforcement details of B2

Figure 3 Reinforcement details of B3 and B4

Figure 4 Reinforcement details of B5 and B7

Figure 5 Reinforcement details of B6 and B8

Loading details on beams are shown from figure 6 to figure 9

Figure 6 Reinforcement details of B2

Figure 7 Loading on beams with ($a/d=4$) and 4 points of loading

Figure 8 Loading on beams with ($a/d=3.6$) and 4 points of loading

Figure 9 Loading on beams with ($a/d=1$) and 4 points of loading

3. ANALYSIS AND DISCUSSION

3.1. Flexural Strength of Concrete Beams

The results of flexural strength test flexural behavior of reinforced lightweight fine aggregate concrete and normal weight concrete beams crack patterns for beams are shown from figure 10 to figure 17.

Figure 10 Crack pattern for beam B1

Figure 11 Crack pattern for beam B2

Figure 12 Crack pattern for beam B3

Figure 13 Crack pattern for beam B4

Figure 14 Crack pattern for beam B5

Figure 15 Crack pattern for beam B6

Figure 16 Crack pattern for beam B05

Figure 17 Crack pattern for beam B07

Load-deflection curve for concrete and Load_ strain curve for steel for beams are shown from figure 18 to figure 33

Figure 18 Load-deflection curve for beam B1

Figure 19 Load_ strain of steel of B1

Figure 20 Load-deflection curve for Beam B2

Figure 21 Load-strain of steel of B2

Figure 22 Load-strain of steel of B3

Figure 23 Load-strain of steel of B3

Figure 24 Load-deflection curve for beam B4

Figure 25 Load-strain of steel of B4

Figure 26 Load-deflection curve for beam B5

Figure 27 Load_strain of steel of B5

Figure 28 Load-deflection curve for beam B6

Figure 29 Load_strain of steel of B6

Figure 30 Load-deflection curve for beam B7

Figure 31 Load_strain of steel of B7

Figure 32 Load-deflection curve for beam B8

Figure 33 Load-strain of steel of B8

4. CONCLUSION

It was concluded that

- Compressive strength is regarded as indicator on mechanical properties, so that the splitting tensile strength of lightweight aggregate concrete is less than that for normal weight concrete lightweight aggregate concrete has lower ultimate load and less degree of ductility than normal weight concrete,
- Increasing the value of steel to concrete ratio the ultimate load of lightweight aggregate concrete also increases showing shear failure with higher degree of ductility, otherwise flexural tensile failure occurs,
- The ultimate load decreases in case of three points of loading than the four points of loading case, shear reinforcement influences flexural behavior of lightweight aggregate concrete beams slightly.

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