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Flexural Behaviour and Durability Study of Concrete on Using Low Density Aggregates

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Abstract: Structural lightweight aggregate concrete is an important and versatile material, which offers a range of technical, economic and environmental enhancing aspects. A decreased density for the same strength level reduces the self-weight, foundation size and construction costs. Structural lightweight aggregate concrete is generally used to reduce dead weight of structure as well as to reduce the risk of earthquake damages to a structure because the earthquake forces that will influence the civil engineering structures are proportional to the mass of those structures. The focus of present study explores the strength and durability properties of light weight aggregate concrete. Two varied types of light weight aggregates namely vermiculite and perlite is been partially replaced with coarse aggregate. Three different multistage mixing approaches were adopted with these two Light Weight Aggregates by various percentages (of weight), 15%, 20% & 25%, to replace coarse aggregates. On using light weight concrete it has better tensile strain capacity, lower coefficient of thermal expansion and superior heat and sound isolation characteristics due to air voids of the lightweight aggregates. The effects on using light weight concrete were studied by workability, compressive strength & split tensile strength. The durability study by sulphate attack test was performed. The flexural behavior ismonitored in beam by casting it with optimum percentage mix for both replacing materials.

***Keywords:** Light Weight Concrete, Vermiculite Aggregate, Perlite Aggregate, Material Properties, Hardened Concrete Properties*

1. Introduction

Lightweight aggregate concrete (LWAC) has been used successfully for structural purposes for many years, because of their improved properties such as the workability, strength, less dead load and resistance to freezing and thawing of light weight concrete (LWC).LWC is also known for its superior long-term durability. Hence, in many structural applications the use of LWC is increasing rapidly.

Different types of lightweight aggregate (LWA) suitable for construction purposes can be found in the market, varying in their composition, density, surface texture, porosity and water absorption capacity. The most frequently used LWAs are expanded clay, expanded glass, perlite, expanded vermiculite and sintered ash. The advancement in the new construction materials has lead to develop high strength materials, which are generally selected to reduce the weight of the construction.

Lightweight concrete may also contain normal or lightweight, fine or coarse aggregates. The rigid foamair cell system differs from conventional aggregate concrete in the methods of production and in the more extensive range of end uses. Lightweight concrete may be either cast-in-place or pre-cast. Lightweight concrete mix designs in general are designed to create a product with a low density and resultant relatively lower compressive strength (when compared to plain concrete). When higher compressive strength is required, the addition of fine or course aggregate will result in a stronger lightweight concrete with resultant higher densities. When considering the addition of course aggregate, one must consider how appropriate this heavy aggregate will be to a project, which typically calls for lightweight material.

Structural LWC has an in-place density (unit weight) on the order of 1440 to 1840 kg/m³ compared to normal weight concrete a density in the range of 2240 to 2400 kg/m³. For structural applications the concrete strength should be greater than 17.0 MPa. The concrete mixture is made with a lightweight coarse aggregate. Lightweight aggregates used in structural lightweight concrete are typically expanded shale, vermiculite, perlite or slate materials that have been fired in a rotary kiln to develop a porous structure. There are other classes of non-structural LWC with lower density made with other aggregate materials and higher air voids in the cement paste matrix, such as in cellular concrete.

2. Material Properties

The properties of materials used in the concrete are discussed below:

2.1 Cement

Ordinary Portland cement of 53 grades available in local market was used. The specific gravity of cement that was taken was 3.14.

2.2 Fine Aggregate

The sand sieved through 4.75 mm sieve is used having specific gravity of 2.6. The fine aggregates belonged to grading zone I.

2.3 Coarse Aggregate

Locally available coarse aggregate having the maximum size of 20 mm is used. The specific gravity of coarse aggregate that was taken was 2.67.

2.4 Vermiculite Aggregate

Expanded vermiculite of size 12mm heated in rotary kiln is used. The specific gravity of expanded vermiculite that was taken as 0.12.

2.5 Perlite Aggregate

Expanded Perlite of size 10mm heated in furnace is used. The specific gravity of Perlite that was taken as 0.15.

2.6 Water

Water is an important ingredient of concrete as it actually participates in the chemical reaction with cement. Potable water available in the laboratory was used.

3. Experimental Investigation

In this investigation the hardened properties of Light weight concrete for various partial replacement percentages of vermiculite and perlite are determined.

3.1 Mix proportions

Based on the IS guidelines the mix proportions of LWC were prepared for M20 grade.

3.2 Hardened properties of LWC

In order to find the mechanical properties Compressive strength tests were conducted at 7 and 28 days of cube (150 X 150 X 150 mm) specimens. For each combination, two specimens were tested.

In order to find the split tensile strength of concrete 7 and 28 days of cylinder (150 X 300 mm) specimen are cast. For each combination, two specimens were tested.

3.2.1 Compressive Strength Test

The compressive test for various mix of 15%, 20% &25% replacements of coarse aggregates were calculated and described in fig 1.

The following tables show the Compressive strength of LWC:

Table 1: *Compressive strength of LWC with vermiculite*

Sl.no	Percentage of vermiculite in concrete (%)	Compressive strength (mpa)	
		At 7 days	At 28 days
1.	0	11.38	19.9
2.	15	10.48	18.6
3.	20	8.53	16.7
4.	25	6.35	14.5

Figure 1.*Compressive strength test*

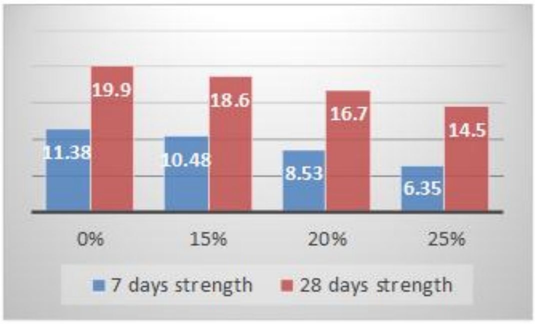

Figure 2.*Chart for compressive strength of LWC with vermiculite*

Table 2: *Compressive strength of LWC with perlite*

Sl.no	Percentage of perlite in concrete (%)	Compressive strength (mpa)	
		At 7 days	At 28 days
1.	0	11.38	19.9
2.	15	7.48	14.82
3.	20	6.04	10.6
4.	25	4.95	8.46

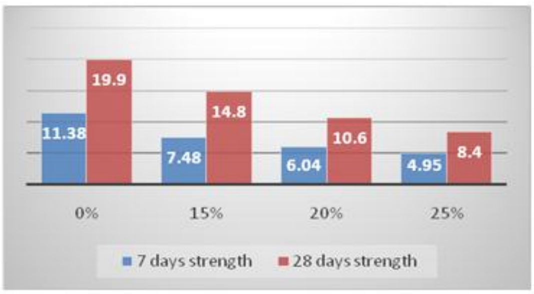

Figure 3.*Chart for compressive strength of LWC with perlite*

3.2.2 Split Tensile Test

The Split Tensile test for various mix of 15%, 20% &25% replacements of coarse aggregates were calculated and described below.

Figure 4.*Split tensile strength*

The following table shows the split tensile strength of LWC:

Table 3: *Split tensile strength of LWC with vermiculite*

Sl.no	Percentage of vermiculite in concrete (%)	Split tensile strength (mpa)	
		At 7 days	At 28 days
1.	0	2.2	2.92
2.	15	1.97	2.6
3.	20	1.63	2.36
4.	25	1.27	2.15

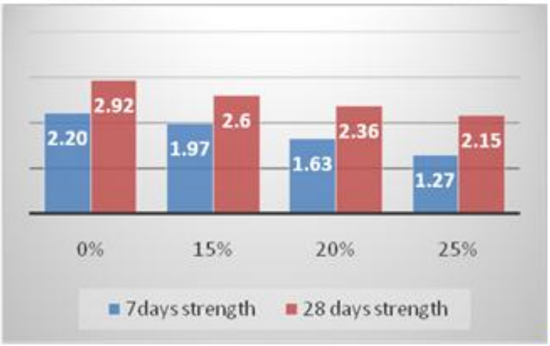

Figure 5.*Chart for split tensile strength of LWC with vermiculite*

Table 4: *Split tensile strength of LWC with perlite*

Sl.no	Percentage of perlite in concrete (%)	Split tensile strength (mpa)	
		At 7 days	At 28 days
1.	0	2.2	2.92
2.	15	1.32	1.93
3.	20	1.12	1.46
4.	25	0.85	1.27

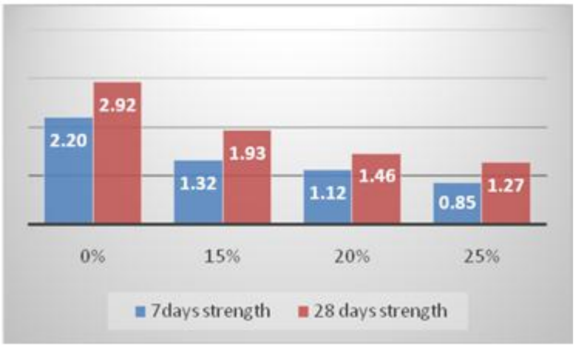

Figure 6.*Chart for split tensile strength of LWC with perlite*

3.2.3 Sulphate Attack Test

Concrete cube specimens 150mm x 150mm x150mm are casted for sulphate attack. The casted specimens are kept at self-curing condition up to 28 days. The specimens were immersed in a solution of 3% of sodium sulphate in distilled water. The solutions were renewed at regular interval for accurate results. At the days of age, at 7& 28 days of exposure, the specimens were weighed and strength loss is calculated and described below.

3.2.3.1 Sulphate attack test for vermiculite

Table 5*: Sulphate attack test with vermiculite*

% Replacements Vermiculite	Weight loss %		Strength loss %	
	7 days	28 days	7 days	28 days
0	0.85	1.51	3.91	5.12
15	0.91	1.56	3.96	5.22
20	0.93	1.574	3.99	5.29
25	0.94	1.594	4.03	5.32

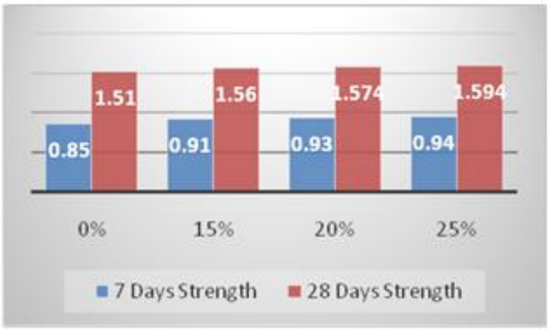

Figure 7: *Chart for % weight loss for vermiculite*

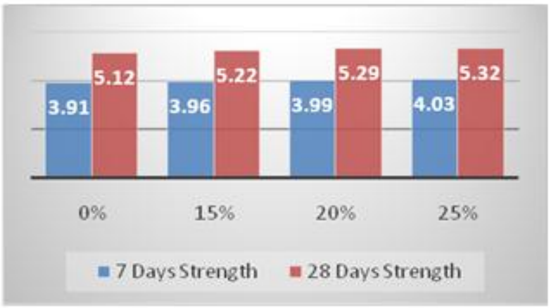

Figure 8: *Chart for % strength loss for vermiculite*

3.2.3.2 Sulphate attack test for perlite

***Table 6**: Sulphate attack test with perlite*

% Replacements Perlite	Weight loss %		Strength loss %	
	7 days	28 days	7 Days	28 Days
0	0.85	1.51	3.91	5.12
15	0.93	1.58	3.98	5.28
20	0.96	1.60	4.01	5.34
25	1.01	1.63	4.23	5.39

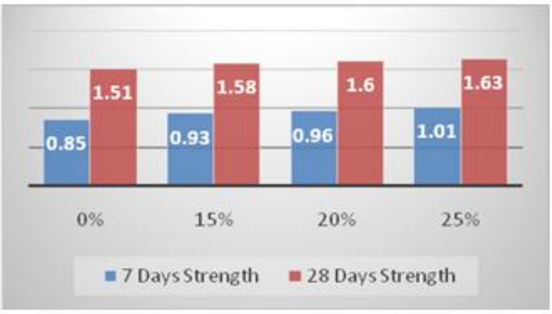

***Figure 9 :** Chart for % weight loss for perlite*

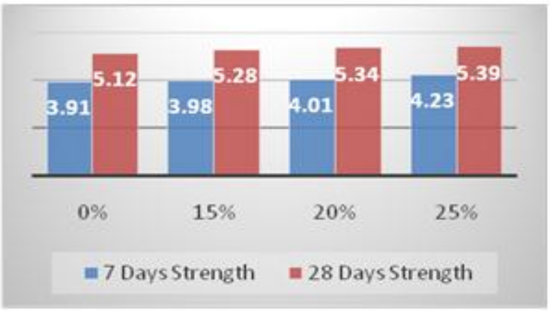

***Figure 10:** Chart for % strength loss for perlite*

3.2.4 Flexural Strength Test

Based on the compressive strength values optimum result was found to be at 15 % replaced mix for both Vermiculite and Perlite aggregates. Specimens were cast with this percentage replacement and flexural strength was calculated and described below.

The following table shows the flexural strength of concrete with Vermiculite Aggregate

***Table 7:** Flexural strength of concrete with vermiculite*

Nominal mix		15% vermiculite	
Load (kn)	Deflection (mm)	Load (kn)	Deflection (mm)
0	0	0	0
10	0.22	10	0.26
20	0.86	20	1.12
30	1.53	30	1.72
40	2.02	40	2.86
50	2.78	50	3.46
60	3.82	60	3.98
70	4.12	55	8.23
65	7.35		

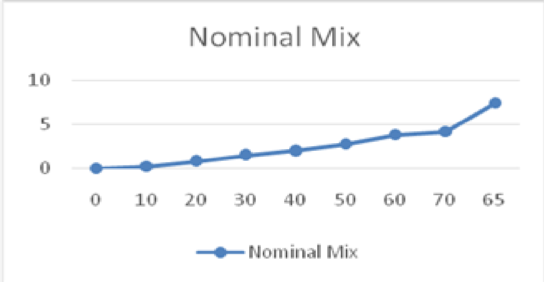

***Figure 11:** Chart for flexural strength of nominal mix*

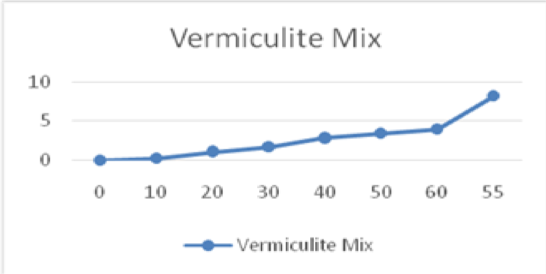

***Figure 12:** Chart for flexural strength of vermiculite mix*

***Table 8:** Flexural strength of concrete with perlite*

Nominal mix		15% perlite	
Load (kn)	Deflection (mm)	Load (kn)	Deflection (mm)
0	0	0	0
10	0.22	10	0.29
20	0.86	20	1.28
30	1.53	30	1.96
40	2.02	40	3.09
50	2.78	50	3.67
60	3.82	60	4.12
70	4.12	55	8.98
65	7.35		

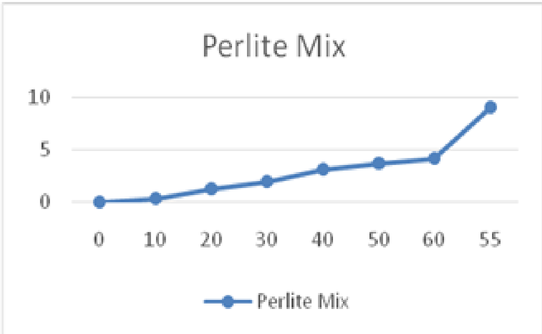

***Figure 13:** Chart for flexural strength of perlite mix*

4. Conclusion

Based on the above experimental study, following conclusions can be drawn regarding the properties of Light Weight Concrete,

- The compressive and tensile strengths of Light Weight Concrete decrease with increase in Light Weight Aggregates content.

- It can be seen that the strength of cylinders compared to that of cubes of the same batch was less.
- Replacement of coarse aggregate such as vermiculite and perlite reduces the density of concrete with minimum reduction in strength aspects.
- The bulk densities of vermiculite and perlite are low, so it reduces the self-weight of concrete by around 20% depending upon the mix proportions.
- 15% replacement of coarse aggregate by Vermiculite shows better strength and durability than 15% replacement of coarse aggregate by Perlite.
- The cost reduction was 15%, 12%, and 10% with the replacement of LWA in concrete for 25%, 20% and 15%replaced mixes respectively.

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