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Experimental Analysis of Light Weight Concrete by Using of Light Weight Aggregat

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1. Abstract

This project investigates light weight concrete by replacing coarse aggregate with Light weight Aggregate (LWA). The methodology involves meticulous data collection, analysis, material selection, and the design of M30 grade concrete. It aims to evaluate how different proportions of LWA replacement affect concrete properties. Beginning with data gathering on conventional concrete mixes and LWA properties, material selection balances structural integrity with light weight characteristics. Varying percentages of LWA replacement (0%, 20%, 40%, and 50%) are then incorporated into the design phase, followed by precise mixing to maintain consistency. Concrete specimens undergo tests including slump, compaction factor, cube casting, and rebound hammer testing to evaluate workability, compact ability, and compressive strength. The project highlights the importance of the compressive test in determining concrete strength. Through meticulous analysis, it discusses LWA's effects on properties like workability, density, and durability, contributing insights into sustainable construction practices and emphasizing empirical analysis for engineering material selection.

2. Key words

LWA-Light Weight aggregate, LWC- Light Weight concrete, LECA- Light Weight expended clay aggregate, conplast SP430(G), Fosroc, SSD – Saturated Surface Dry, DRY WEIGHT – Dry Weight of Material.

3. Introduction

Light weight concrete (LWC) stands as a remarkable innovation in construction, widely utilized across diverse sectors for its versatility. Its applications span frameworks, floors, curtain walls, roofs, bridges, and more. Compared to standard concrete, LWC is notably lighter, boasting a strength ranging from 25% to 40%. Concrete is classified into heavy, normal, and light weight types based on density, with respective densities of 3200-4000 kg/m³, 2400-2600 kg/m³, and 1200-2000 kg/m³. Its formulation involves blending cement, sand, coarse aggregates, and water, solidifying through artificial means and molds. Light weight concrete achieves its reduced weight by incorporating an expanding agent to increase volume.

Materials for LWC vary regionally and include light weight coarse aggregate, air-entraining agent, and admixtures like silica fume and fly ash. Brick ballast serves as a light weight aggregate, while aluminum powder, acting as an air-entraining agent, creates a cellular structure within the concrete. Admixtures enhance various properties, offering design flexibility, cost savings, and improved structural response.

4. Literature Review of The Light weight Concrete

4.1 Smith, Johnson & Williams, (Light weight Concrete Using LECA Aggregate) –

This review paper explores multiple studies on light weight concrete using LWA as aggregate. It delves into LWA's properties, emphasizing its low density, high porosity, and thermal insulation. The paper underscores LWA's role in reducing concrete density while retaining ample compressive strength. It discusses studies examining various factors like aggregate size, curing, and mix ratios. Finally, it suggests further research directions, particularly on the long-term durability and sustainability of LWA-based light weight concrete [1].

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4.2 Garcia, Martinez & Lopez (Mechanical and Durability Properties of Light weight Concrete Incorporating LECA)

The review paper scrutinizes studies on light weight concrete using LWA as aggregate, focusing on LWA's properties like low density, high porosity, and thermal insulation. It emphasizes LWA's role in decreasing concrete density while upholding ample compressive strength, examining factors such as aggregate size, curing, and mix ratios. It suggests further research directions, particularly on LWA-based light weight concrete's long-term durability and sustainability [2].

5. Research Methodology and Materials

5.1 Research Methodology

1) Data Collection, Analysis and Material Selection
2) Design Of M30 Grade Concrete
3) Replacement Of Coarse Aggregate by LWA
4) Mixing Of Concrete At 0%, 20%, 40% And 50% Replacement of Coarse Aggregate By LWA
5) Slump Test of Concrete and Compaction Factor Test of Concrete
6) Casting Of Cube
7) Rebound Hammer Test
8) Compressive Test
9) Result And Discussion
10) Conclusion

5.2 Material Properties

5.2.1 Cement [3]

PROPERTY	CEMENT
Grade	**OPC 43**
Specific Surface Area	**310 m^2/kg**
Fineness Modulus	**4 %**
Normal Consistency of Cement	**34 %**
Initial Setting Time	**30 minutes**
Final Setting Time	**600 min**
Specific Gravity	**3.15**

5.2.2 Coarse Aggregates [4] [5] [6]

PROPERTY	COARSE AGGREGATE
Specific Gravity	**2.68**
Fineness Modules	**7.04**
Water Absorption	**0.50%**
Bulk Density	**1659 kg/m^3**
Impact Value	**29.41%**
Maximum Nominal Size of Aggregate	**20 mm**
Shape	**Crushed Angular**

5.2.3 Fine Aggregate [4] [5] [6]

PROPERTY	FINE AGGREGATE
Specific Gravity	**2.65**
Fineness Modules	**2.83**
Water Absorption	**1.0%**
Bulk Density	**1481 kg/m^3**
Grading Of Sand	**ZONE II**
Sand Type	**River Sand**

5.2.4 Light Weight Aggregate

LWA, Light Weight Aggregate, consists of fired clay particles expanded to create small, lightweight structures filled with air, providing strength and insulation. The manufacturing process involves treating plastic clay, then heating and expanding it before firing at 1100°C. In this study, LWA of 4mm to 10mm size and 480 kg/m3 density is used, causing increased deflection in light weight concrete compared to normal concrete [7].

PROPERTY	LWA
Specific Gravity	**0.44**
Fineness Modules	**5.99**
Water Absorption	**10.0 %**
Bulk Density	**357 kg/m^3**
Impact Value	**16.5 %**
Shape	**Rounded**

5.2.5 Super Plasticizer

The superplasticizer utilized is Conplast SP430 (G) manufactured by Fosroc, boasting a specific gravity of 1.119. Its application involves a dosage of 1% of the weight of cement, resulting in a reduction of water in the design by 23% [7].

5.2.6 Potable Water

Water plays a crucial role as it actively engages in the reaction with cement and contributes to the workability of the mixture. Nonetheless, high-quality concrete can be achieved using water that meets standard requirements for potable consumption [7].

6. Design of M30 Grade Concrete

6.1 Stipulations for Proportioning

1) Grade designation - M30
2) Type of cement- OPC 43 grades (IS 269)
3)Maximum nominal size of aggregate- 20 mm
4) Minimum cement content and maximum water-cement ratio to be adopted and/or Exposure conditions as per Table 3 and Table 5 of IS 456 – Moderate (for reinforced concrete) [8]
5) Workability- 120 mm (slump)
6) Method of concrete placing- Dump
7) Degree of supervision- Good
8) Type of aggregate- Crushed angular aggregate
9) Maximum cement content (OPC)- As per IS 45
10) Chemical admixture- Superplasticizer- normal

6.2 Test Data for Materials

1) Cement used- OPC 43 grade conforming to IS 269
2) Specific gravity of cement- 3.15
3) Chemical admixture-Superplasticizer conforming to IS 9103
4) Specific gravity of
   A) Coarse aggregate (at SSD Condition)- 2.68
   B) Fine aggregate (at SSD Condition)- 2.65
   C) Light weight aggregate- 0.44
   D) Chemical admixture- 1.119
5) Water absorption
   A) Coarse aggregate- 0.5 percent
   B) Fine aggregate- 1.0 percent
   C) Light weight aggregate- 10.0 percent
6) The coarse and fine aggregates are wet and their total moisture content is 2 percent and 5 percent respectively. Therefore, the free moisture content in coarse and fine aggregate shall be as shown in below. Free (surface) moisture
   A) Coarse aggregate free moisture = Total moisture content – Water absorption
   = 2.0 – 0.5 = 1.5 %
   B) Fine aggregate free moisture = Total moisture content – Water absorption
   = 5.0 – 1.0 = 4.0 %

7) Sieve analysis
   A) Coarse aggregate

Sieve (mm)	Weight Retained (gm)	Weight Retained Cumulative (gm)	% Retained	% Passing	Limit (Zone II)
40	0	0	0	100	100
20	278	278	13.9	86.1	85-100
10	1712	1990	99.5	0.5	0-20
4.75	8	1998	99.9	0.1	0-10
Pan	2	2000	100	0	0

   B) Fine aggregate

Sieve (mm)	Weight Retained (gm)	Weight Retained Cumulative (gm)	% Retained	% Passing	Limit (Zone II)
12.5	0	0	0	100	100
10	45	45	4.5	95.5	85-100
4.75	910	955	95.59	4.4	0-20
2.36	42	997	99.79	0.2	0-5
Pan	4	1000	100	0	0

6.3 Target Strength For Mix Proportioning

f’ck = fck + 1.65 S or **f’ck = fck + X**

(whichever is higher) [9]

f‛ck = target average compressive strength at 28 days,
fck = characteristic compressive strength at 28 days
S = standard deviation,
X = factor based on grade of concrete.
From IS code 10262: 2019 Table – 1 and Table – 2, standard deviation, S = 5 N/mm^2, X = 6.5

1) f‛ck = fck+1.65 S
   = 30 + 1.65 × 5
   = 38.25 N/mm^2

2) f‛ck = fck + 6.5
   = 30 + 6.5
   = 36.5 N/mm^2

The higher value is to be adopted. Therefore, target strength will be 38.25 N/mm^2 as 38.25 N/mm^2 > 36.5 N/mm^2 [9]

6.4 Approximate Air Content –

From IS 10262:2019 Table 3, the approximate amount of entrapped air to be expected in normal (non-air-entrained) concrete is 1.0 percent for 20 mm nominal maximum size of aggregate [9].

6.5 Selection of Water-Cement Ratio –

From IS code 10262: 2019 Fig. 1, The free water-cement ratio required for the target strength of 38.25 N/mm2 is 0.42 for OPC 43 grade curve. This is lower than the maximum value of 0.50 prescribed for „Moderate" exposure for reinforced concrete as per Table 5 of IS 456. 0.42 < 0.50, hence OK [9].

6.6 Selection of Water Content –

1) From IS code 10262: 2019 Table 4, water content = 186 kg (for 50 mm slump) for 20 mm aggregate [9].
2) Estimated water content for 120 mm slump (increasing at the rate of 3 percent for every 25 mm slump) = 186 +(8.4 / 100) ×186 = 201.62 kg
3) As superplasticizer is used, the water content may be reduced.
4) Based on trial data, the water content reduction of 23 percent is considered while using superplasticizer at the rate 1.0 percent by weight of cement.
5) Hence the arrived water content = 201.62 × 0.77 = **155.24 kg ≈ 155 kg.**

6.7 Calculation of Cement Content –

1) Water-cement ratio = 0.42
2) Cement content $= \frac{155}{0.42}$ =369.04 kg ≈ 370 kg

From IS code 456:2000 Table 5 of IS 456, minimum cementitious content for „Moderate" exposure condition [8] = 300 kg/m^3

370 kg/m^3 > 300 kg/m^3, hence OK.

6.8 Proportion Of Volume of Coarse Aggregate and Fine Aggregate Content

1) From IS code 10262:2019 Table 5, volume of coarse aggregate corresponding to 20 mm size aggregate and fine aggregate (Zone II) for water-cement ratio of 0.50 = 0.62.
2) In the present case water-cementitious ratio is 0.42. Therefore, volume of coarse aggregate is required to be increased to decrease the fine aggregate content. As the water-cement ratio is lower by 0.08, the proportion of volume of coarse aggregate is increased by 0.016 (at the rate of ∓ 0.01 for every ± 0.05 change in water cement ratio) [9]. Therefore, corrected proportion of volume of coarse aggregate for the water-cementitious ratio of 0.42 = 0.62 + 0.016 = 0.636.
3) Therefore, volume of coarse aggregate = 0.636 m^3
4) Volume of fine aggregate content = 1 – 0.636 = 0.364 m^3

6.9 Mix Calculations –

The mix calculations per unit volume of concrete shall be as follows:

1) Total volume = 1 m3
2) Volume of entrapped air in wet concrete = 0.01 m3
3) Volume of cement $= \frac{Mass\ of Cement}{Specific\ gravity\ of\ cement} \times \frac{1}{1000} = \frac{370}{3.15} \times \frac{1}{1000} = 0.1174$ m^3
4) Volume of water $= \frac{Mass\ of\ water}{Specific\ gravity\ of\ water} \times \frac{1}{1000} = \frac{155}{1} \times \frac{1}{1000} = 0.155$ m^3
5) Volume of chemical admixture (superplasticizer) (@ 1.0 percent by mass of cementitious material) $= \frac{Mass\ of\ chemical\ admixture}{Specific\ gravity\ of\ admixture} \times \frac{1}{1000} = \frac{3.69}{1.119} \times \frac{1}{1000} = 0.00329$ m^3
6) Volume of all in aggregate = [(a - b) - (c + d + e)] = [(1 – 0.01) - (0.1174 + 0.155 + 0.00329)] = 0.7143 m^3
7) Mass of coarse aggregate = g × volume of coarse aggregate × Specific gravity of coarse aggregate × 1000 = 0.7143 × 0.636 × 2.68 × 1000 = 1217.51kg ≈ 1218 kg
   A) By 20 % replacement of coarse aggregate by light weight aggregate –
      a) Volume of coarse aggregate = 0.4543 × 0.80 = 0.3634 m^3
      b) Mass of coarse aggregate = 0.3634 × 2.68 × 1000 = 973.91 kg ≈ 974 kg
      c) Volume of light weight aggregate = 0.4543 × 0.20 = 0.090 m^3
      d) Mass of light weight aggregate = 0.090 × 0.44 × 1000 = 39.97 kg ≈ 40 kg
   B) By 40 % replacement of coarse aggregate by light weight aggregate –
      a) Volume of coarse aggregate = 0.4543 × 0.60 = 0.27258 m^3
      b) Mass of coarse aggregate = 0.27258 × 2.68 × 1000 = 730.51 kg ≈ 730 kg
      c) Volume of light weight aggregate = 0.4543 × 0.30 = 0.1817 m^3
      d) Mass of light weight aggregate = 0.1817 × 0.44 × 1000 = 79.95 kg ≈ 80 kg
   C) By 50 % replacement of coarse aggregate by light weight aggregate –
      a) Volume of coarse aggregate = 0.4543 × 0.50 = 0.22715 m^3
      b) Mass of coarse aggregate = 0.22715 × 2.68 × 1000 = 608.76 kg ≈ 609 kg
      c) Volume of light weight aggregate = 0.4543 × 0.50 = 0.22715 m^3
      d) Mass of light weight aggregate = 0.22715 × 0.44 × 1000 = 99.94 kg ≈ 100 kg
8) Mass of fine aggregate = g × volume of fine aggregate × Specific gravity of fine aggregate ×

$1000 = 0.7143 \times 0.364 \times 2.65 \times 1000 = 689.01$ kg
≈ 689 kg

6.10 Mix Proportions for Trial –

Material	0% Replacement		
	SSD (Kg/M3)	Dry Weight (Kg)	For 0.025m3 (Kg)
Cement	370	370	9.25
Water	155	167.98	4.199
Fine Aggregate	689	682.11	17.052
Coarse Aggregate	1218	1211.9	30.3
Light Weight Agg.	-	-	-
Chemical Admixture	3.7	3.7	0.0925

Material	20% Replacement		
	SSD (Kg/M^3)	Dry Weight (Kg)	For 0.025m^3 (Kg)
Cement	370	370	9.25
Water	155	170.76	4.27
Fine Aggregate	689	682.11	17.05
Coarse Aggregate	974	969.13	24.23
Light Weight Agg.	40	36	0.9
Chemical Admixture	3.7	3.7	0.0925

Material	40% Replacement		
	SSD (Kg/M^3)	Dry Weight (Kg)	For 0.025m^3 (Kg)
Cement	370	370	9.25
Water	155	173.54	4.34
Fine Aggregate	689	682.11	17.052
Coarse Aggregate	730	726.35	18.15
Light Weight Agg.	80	72	1.8
Chemical Admixture	3.7	3.7	0.0925

Material	50% Replacement		
	SSD (Kg/M^3)	Dry Weight (Kg)	For 0.025m^3 (Kg)
Cement	370	370	9.25
Water	155	174.93	4.37
Fine Aggregate	689	682.11	17.05
Coarse Aggregate	609	605.95	15.14
Light Weight Agg.	100	90	2.25
Chemical Admixture	3.7	3.7	0.0925

7. Concrete Test

7.1 Compaction Factor Test [10] –

Type Of Concrete	Compaction Factor Value
0% Replacement by LWA (Conventional) Concrete	0.926
20% Replacement by LWA Concrete	0.9303
40% Replacement by LWA Concrete	0.939
50% Replacement by LWA Concrete	0.947

7.2 Rebound Hammer Test [11]–

0% Replacement by LWA Concrete		
Sample No. - 1 At 7 Days		
Cube No.	Strength (N/mm^2)	Average
1	27.83	
2	26.33	27.83
3	29.33	
Sample No. - 2 At 28 Days		
4	41.4	
5	39.01	41.05
6	42.76	

20% Replacement by LWA Concrete		
Sample No. - 3 At 7 Days		
Cube No.	Strength (N/mm^2)	Average
7	24.5	
8	23.5	24
9	24	
Sample No. - 4 At 28 Days		
10	38.28	
11	35.61	36.78
12	36.43	

40% Replacement by LWA Concrete		
Sample No. - 5 At 7 Days		
Cube No.	Strength (N/mm^2)	Average
13	23.46	
14	21.96	22.006
15	20.6	
Sample No. - 6 At 28 Days		
16	31.8	

17	34.45	33.08
18	33	
50% Replacement by LWA Concrete		
Sample No. - 7 At 7 Days		
Cube No.	Strength (N/mm^2)	Average
19	19.134	
20	18.83	19.64
21	20.96	
Sample No. - 8 At 28 Days		
22	30.1	
23	29.6	29.83
24	29.8	

7.3 Compressive Test [10] –

0% Replacement by LWA Concrete		
Sample No. - 1 At 7 Days		
Cube No.	Compressive strength (N/mm^2)	Density (kg/m^3)
1	25.03	2438.51
2	27.13	2426.67
3	24.99	2456.29
Average	25.71	2440.49
Sample No. - 2 At 28 Days		
4	37.89	2426.67
5	40.23	2432.59
6	38.73	2444.45
Average	38.95	2434.57

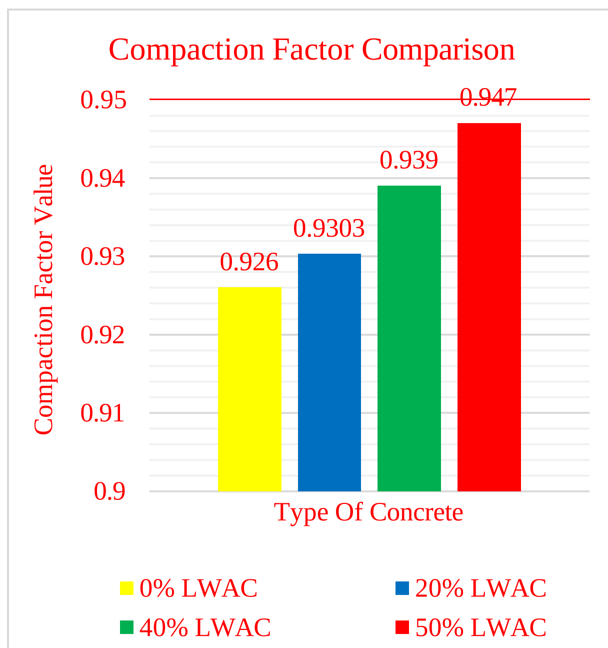
20% Replacement by LWA Concrete		
Sample No. - 3 At 7 Days		
Cube No.	Compressive strength (N/mm^2)	Density (kg/m^3)
7	21.33	2228.14
8	23.98	2219.25
9	23.16	2251.85
Average	22.82	2233.08
Sample No. - 4 At 28 Days		
10	35.47	2216.29
11	36.023	2228.15
12	35.11	2248.89
Average	35.53	2231.11

40% Replacement by LWA Concrete		
Sample No. - 5 At 7 Days		
Cube No.	Compressive strength (N/mm^2)	Density (kg/m^3)
13	20.23	2029.63
14	18.88	2038.52
15	22.43	2044.45
Average	20.51	2037.533333
Sample No. - 6 At 28 Days		
16	31.25	2023.7
17	29.04	2035.56
18	34.14	2029.63
Average	31.47	2029.63

50% Replacement by LWA Concrete		
Sample No. - 7 At 7 Days		
Cube No.	Compressive strength (N/mm^2)	Density (kg/m^3)
19	20.01	1920
20	17.94	1943.7
21	17.03	1949.63
Average	18.33	1937.78
Sample No. - 81 At 28 Days		
22	29.89	1928.89
23	27.9	1920
24	28.89	1937.78
Average	28.89	1928.89

8. RESULT AND DISCUSSION

8.1 Compaction Factor Comparison



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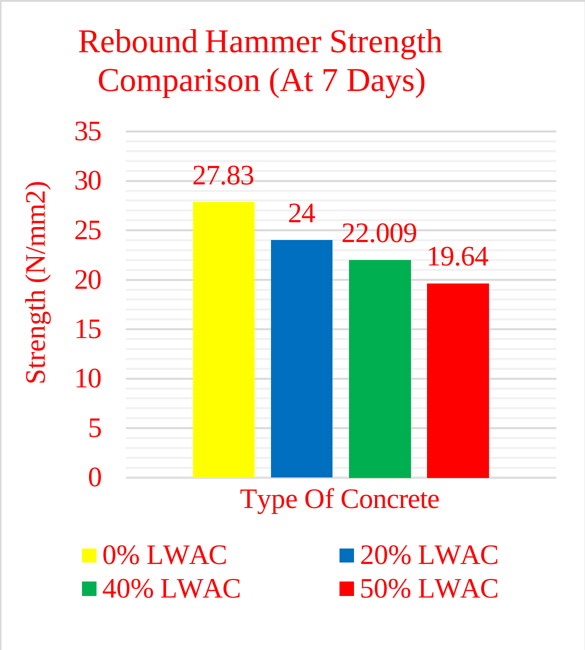
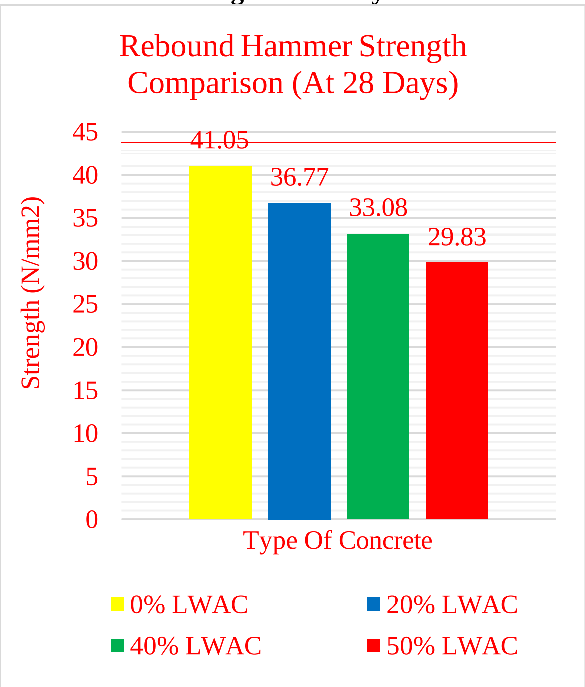
8.2 Rebound Hammer Strength Comparison

8.2.1 Rebound Strength At 7 Days

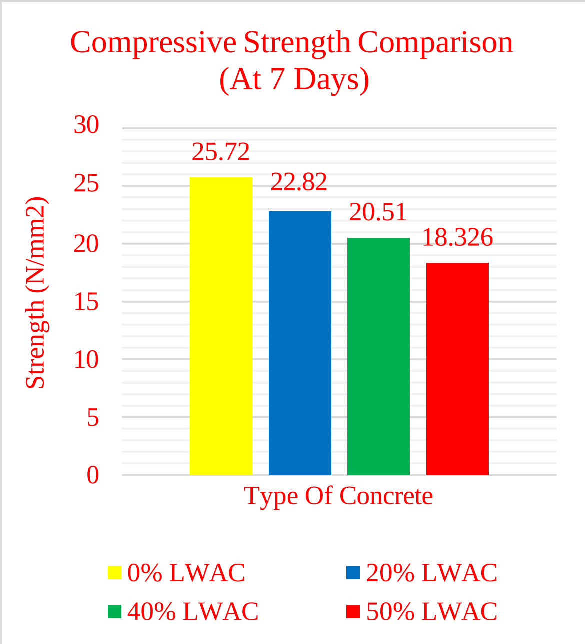


8.2.2 Rebound Strength At 28 Days

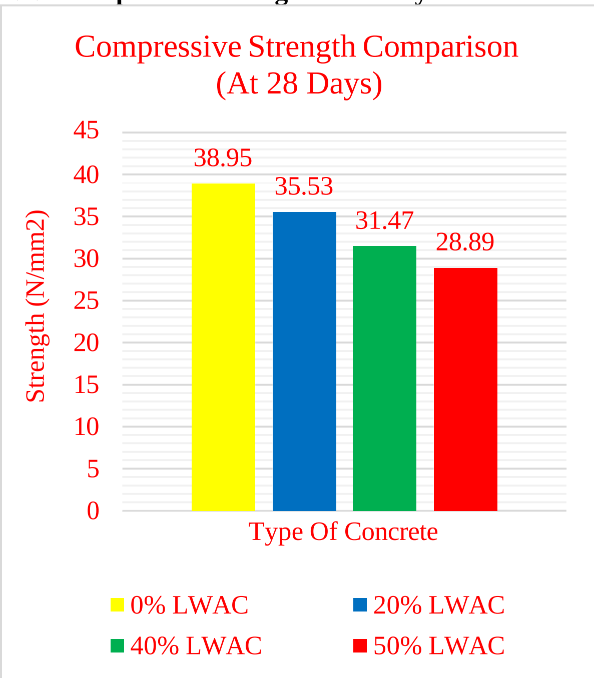


8.3 Compressive Strength Comparison

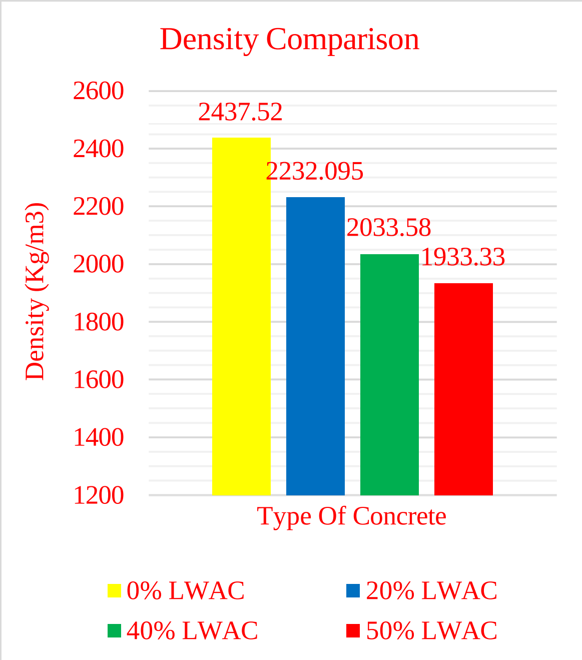
8.3.1 Compressive Strength At 7 Days



8.3.2 Compressive Strength At 28 Days



8.4 Density Comparison –



9. Conclusion

The study demonstrates the impact of replacing coarse aggregate with light weight aggregate in M30 grade concrete. While compaction factor shows minor variation with increasing replacement percentage, substantial decreases are observed in both rebound-hammer strength and compressive strength. This indicates a compromised structural integrity as light weight aggregate content rise. Additionally, density decreases significantly with higher proportions of light weight aggregate, reflecting a decrease in material density. These findings suggest a trade-off between workability and durability, with light weight aggregate enhancing workability but at the expense of concrete strength and density. Therefore, the decision to use light weight aggregate should be made cautiously, considering project-specific requirements. Balance between weight reduction and maintaining structural robustness is essential, ensuring that the chosen mix proportion meets the intended purpose while satisfying durability and strength criteria. Further research could explore optimizing mix designs to mitigate the reduction in strength and density associated with light weight aggregate incorporation, enabling better utilization of this material in concrete applications.

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