EXPERIMENTAL INVESTIGATION ON STRENGTH IMPROVEMENT OF RECYCLED COARSE AND FINE AGGREGATE CONCRETE WITH BASALT FIBER AND NANO $CaCO_3$

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Abstract - *As the need for more sustainable building materials grows, many engineers are turning to recycled aggregate concrete (RAC) instead of traditional cement-based materials to create new structures. Unfortunately, due to the high porosity of recycled aggregates and the adhered mortar that remains in them, RAC has poorer mechanical engineering capabilities than that of a comparable regular concrete, which is something that may impede the Domestication of RAC. This research investigates how basalt fibres and Nano-calcium carbonate (nano-$CaCO_3$) may be able to improve the performance of recycled aggregates. In particular, we look at M40-grade mixes containing recycled coarse aggregates (RCA) and recycled fine aggregates (RFA) along with 0.50% by weight basalt fibres and 2.5% by weight nano-$CaCO_3$. Workable material samples were tested for compressive strength at 7 and 28 days to assess their overall performance. Our findings indicate that nano-$CaCO_3$ will increase the compressive strength of RAC by creating a microstructure densification reaction and that basalt fibres will increase the ductility and crack resistance of RAC. Both additives provide complementary benefits that make up for the shortcomings of the individual types of recycled aggregates on their own. Therefore, we conclude that hybrid modified RAC can perform similarly to regular concrete while helping promote sustainability.*

***Key Words*: Recycled Aggregate Concrete, Basalt Fiber, Nano Calcium Carbonate, Compressive Strength, Sustainable Concrete, M40 Concrete**

1. INTRODUCTION

The fast growth of infrastructure has led to a lot of aggregates being used up and a lot of construction and demolition waste being generated. Recycling this waste into aggregates is a way to help the environment.

Recycled Aggregate Concrete is an alternative. However Recycled Aggregate Concrete has some problems. These problems are:

* High water absorption

* A weak area where the old and new materials meet

* Recycled Aggregate Concrete is not as strong. Does not last as long

Some new ideas suggest that adding fibers and really small materials can make Recycled Aggregate Concrete better. This study looks at what happens when we add basalt fiber and small $CaCO_3$ to Recycled Aggregate Concrete that is M40 grade.

2. EXPERIMENTAL DETAILS

The following materials were used in the present experimental investigation:

2.1 Cement

Ordinary Portland Cement (OPC) 53 Grade conforming to IS 12269:2013 was used.

- Physical Properties of Cement

Property	Test Result	IS Requirement
Specific Gravity	3.15	3.15
Standard Consistency	31%	-
Initial Setting Time	42 min	> 30 min
Final Setting Time	480 min	< 600 min
28-Day Strength	55 MPa	≥ 53 MPa

2.2 Fine Aggregate

Natural river sand conforming to IS 383:2016 was used

1. Specific Gravity

Observation Table:

Sr. No.	Description	Symbol	Value (g)
1	Weight of empty pycnometer	W_1	650
2	Weight of pycnometer + dry sand	W_2	1180
3	Weight of pycnometer + sand + water	W_3	1860
4	Weight of pycnometer + water only	W_4	1530

Calculation:

G=W2−W1/(W2−W1)−(W3−W4)

G=1180−650/(1180−650)−(1860−1530)

=2.65

Result: Specific Gravity = 2.65

2. Water Absorption Test

Observation Table:

Sr. No.	Description	Symbol	Value (g)
1	Oven dry weight	Wd	1000
2	Saturated Surface Dry weight	Wssd	1012

Calculation:

Water Absorption=Wssd−Wd/Wd×100

=1012−1000/1000×100

=1.2%

Result: Water Absorption = 1.2%

3. Fineness Modulus (Sieve Analysis)

Observation Table:

Sieve Size(mm)	Weight Retained (g)	Retained	Cumulative %
4.75	40	4	4
2.36	80	8	12
1.18	120	12	24
600 µm	180	18	42
300 µm	260	26	68
150 µm	290	29	97

Total cumulative % = 265

Calculation:

FM=∑Cumulative % Retained/100

FM=265/100

=2.65

Result: Fineness Modulus = 2.65

- Final Summary Table

Property	Value
Specific Gravity	2.64
Water Absorption	1.2 %
Fineness Modulus	2.65
Zone	II

2.3 Coarse Aggregate

As per Bureau of Indian Standards (IS 2386 Part III)

1. Specific Gravity Test (Wire Basket Method)

Observation Table:

Sr. No.	Description	Symbol	Value (g)
1	Weight of empty basket in water	W_1	500
2	Weight of basket + aggregate in water	W_2	2200
3	Weight of Saturated Surface Dry aggregate	W_3	2700
4	Oven dry weight of aggregate	W_4	2650

Calculation:

G=W4/W3−(W2−W1)

G=2650/2700−(2200−500)

G=2.65

Result: Specific Gravity = 2.65

2. Water Absorption Test

Observation Table:

Sr. No.	Description	Symbol	Value (g)
1	Oven dry weight	Wd	2550
2	Saturated Surface Dry weight	Wssd	2583

Calculation:

Water Absorption=Wssd−Wd/Wd×100

=2583−2550/2550×100

=1.28%

Result: Water Absorption = 1.28%

3. Fineness Modulus (Coarse Aggregate)

Observation Table:

Sieve Size (mm)	Weight Retained (g)	Retained	Cumulative %
40	0	0	0
20	200	20	20
10	500	50	70
4.75	250	25	95
Pan	50	5	100

Total cumulative % = 285

Calculation:

FM=∑Cumulative % Retained/100

FM=285/100

FM=2.85

Result: Fineness Modulus ≈ 2.8–3.0

- Final Summary Table

Property	Value
Specific Gravity	2.65
Water Absorption	1.28 %
Fineness Modulus	2.85
Nominal Size	20 mm

2.4 Recycled Coarse Aggregate (RCA)

As per Bureau of Indian Standards (IS 2386)

1. Specific Gravity Test (Wire Basket Method)

Observation Table:

Sr. No.	Description	Symbol	Value (g)
1	Weight of saturated aggregate in air	W_1	2000
2	Weight of aggregate in water	W_2	1200
3	Oven dry weight of aggregate	W_3	1880

Calculation:

G=W3/W1−W2

G=1880/2000−1200

=1880/800

=2.35

Result: Specific Gravity ≈ 2.30 – 2.40

2. Water Absorption Test

Observation Table:

Sr. No.	Description	Symbol	Value (g)
1	Oven dry weight	Wd	1880
2	Saturated Surface Dry weight	Wssd	2000

Calculation:

Water Absorption=Wssd−Wd/Wd×100

=2000−18801880×100

=6.38%

Result: Water Absorption ≈ 6.3 – 6.5%

3. Aggregate Impact Value (AIV)

AIV=W2/W1×100

Observation Table:

Sr. No.	Description	Symbol	Value (g)
1	Total sample weight	W_1	500
2	Weight passing 2.36 mm sieve	W_2	130

Calculation:

AIV=W2/W1×100

=130/500×100

=26%

Result: AIV = 26%

4. Aggregate Crushing Value (ACV)

Observation Table:

Sr. No.	Description	Symbol	Value (g)
1	Total sample weight	W_1	2500
2	Weight passing 2.36 mm sieve	W_2	700

Calculation:

ACV=W2/W1×100

=700/2500×100

=28%

Result: ACV = 28%

- Final Summary Table

Property	Value
Specific Gravity	2.35
Water Absorption	6.4 %
Aggregate Impact Value	26 %
Aggregate Crushing Value	28 %

RCA shows higher water absorption due to adhered mortar.

2.5 Recycled Fine Aggregate (RFA)

1. Specific Gravity Test (Pycnometer Method)

Observation Table:

Sr. No.	Description	Symbol	Value (g)
1	Weight of empty pycnometer	W_1	650
2	Weight of pycnometer + dry sample	W_2	1150
3	Weight of pycnometer + sample + water	W_3	1850
4	Weight of pycnometer + water only	W_4	1550

Calculation:

G=W2−W1/(W2−W1)−(W3−W4)

Substituting values:

G=1150−650/(1150−650)−(1850−1550)

G=500/500−300

=500/200

=2.50

Result: Specific Gravity = 2.40 – 2.50 (approx.)

2. Water Absorption

Observation Table:

Sr. No.	Description	Symbol	Value (g)
1	Oven dry weight	Wd	1000
2	Saturated Surface Dry weight	Wssd	1065

Calculation:

Water Absorption=Wssd−Wd/Wd×100

=1065−1000/1000×100

=6.5

Result: Water Absorption = 6.5%

3. Fineness Modulus

Observation Table:

Sieve Size (mm)	Weight Retained (g)	Retained %	Cumulative %
4.75	50	5	5
2.36	100	10	15
1.18	150	15	30
600 µm	200	20	50
300 µm	250	25	75
150 µm	200	20	95

Total cumulative % = 245

Calculation:

FM=∑Cumulative % Retained/100

FM=245/100=2.45

Result: Fineness Modulus = 2.45

- Final Summary Table

Property	Value
Specific Gravity	2.40
Water Absorption	6.5 %
Fineness Modulus	2.45

Higher absorption affects workability and effective water-cement ratio.

2.6 Basalt Fiber

- Properties

Property	Value
Length	12 mm
Diameter	13–20 microns
Tensile Strength	3000–4800 MPa
Modulus	85–95 GPa
Density	2.7 g/cm^3

- Fiber Dosage

Fiber was added at:

- 0.50% (Percentage by volume of concrete)

2.7 Nano-Calcium Carbonate

- Properties

Property	Value
Particle Size	20–80 nm
Purity	> 98%
Surface Area	High
Color	White

- **Dosage**

Nano-$CaCO_3$ was added at 2.5% by weight of cement (optimum dosage selected from literature)

- **Replacement Strategy**

Natural aggregates were partially replaced with recycled aggregates:

- RCA 20% 30% 40%
- RFA 10% 20% 30% 40%

Remaining are natural aggregates.

- **Final Mix Proportions**

Material	Quantity (kg/m^3)
Cement	433
Water	209
Natural CA	759
RCA	325
Natural FA	449
RFA	192
Chemical Admixture	0.54

- **Mix Identification**

Table 1: Aggregate Replacement for All Mixes

Mix ID	RCA %	RCA (kg)	NaturalCA (kg)	RFA %	RFA (kg)	Natural FA (kg)
NCF 2.5/20/10	20	217	867	10	64	577
NCF 2.5/20/20	20	217	867	20	128	513
NCF 2.5/20/30	20	217	867	30	192	449
NCF 2.5/20/40	20	217	867	40	256	385
NCF 2.5/30/10	30	325	759	10	64	577
NCF 2.5/30/20	30	325	759	20	128	513
NCF 2.5/30/30	30	325	759	30	192	449
NCF 2.5/30/40	30	325	759	40	256	385
NCF 2.5/40/10	40	434	650	10	64	577
NCF 2.5/40/20	40	434	650	20	128	513
NCF 2.5/40/30	40	434	650	30	192	449
NCF 2.5/40/40	40	434	650	40	256	385

Table 2: Mix Proportion Details for Experimental

Mix ID	RCA (%)	RFA (%)	BasaltFiber (%)	Nano-$CaCO_3$ (%)
NCF 2.5/20/10	20	10	0.50	2.5
NCF 2.5/20/20	20	20	0.50	2.5
NCF 2.5/20/30	20	30	0.50	2.5
NCF 2.5/20/40	20	40	0.50	2.5
NCF 2.5/30/10	30	10	0.50	2.5
NCF 2.5/30/20	30	20	0.50	2.5
NCF 2.5/30/30	30	30	0.50	2.5
NCF 2.5/30/40	30	40	0.50	2.5
NCF 2.5/40/10	40	10	0.50	2.5
NCF 2.5/40/20	40	20	0.50	2.5
NCF 2.5/40/30	40	30	0.50	2.5
NCF 2.5/40/40	40	40	0.50	2.5

3. RESULTS

(A) 7-Day Compressive Strength (N/mm^2)

Mix ID	Trial 1	Trial 2	Trial 3	Average (7-Day)
NCF 2.5/20/10	42.10	41.46	43.20	42.25
NCF 2.5/20/20	40.20	41.85	44.14	42.06
NCF 2.5/20/30	40.63	41.10	40.85	40.86
NCF 2.5/20/40	30.92	32.31	32.56	31.93
NCF 2.5/30/10	38.34	42.22	39.51	40.02
NCF 2.5/30/20	37.52	38.20	38.34	38.02
NCF 2.5/30/30	34.99	37.01	37.45	36.48
NCF 2.5/30/40	29.08	29.69	29.66	29.48
NCF 2.5/40/10	25.84	26.21	26.92	26.32
NCF 2.5/40/20	24.30	24.39	24.59	24.43
NCF 2.5/40/30	21.15	21.88	21.86	21.63
NCF 2.5/40/40	17.45	17.54	18.29	17.86

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(B) 28-Day Compressive Strength (N/mm^2)

Mix ID	Trial 1	Trial 2	Trial 3	Average (28-Day)
NCF 2.5/20/10	49.80	50.07	52.39	50.75
NCF 2.5/20/20	49.54	49.88	50.30	49.91
NCF 2.5/20/30	48.84	49.20	49.83	49.29
NCF 2.5/20/40	37.86	38.07	38.10	38.01
NCF 2.5/30/10	48.50	48.90	49.10	48.83
NCF 2.5/30/20	48.62	46.74	48.88	48.08
NCF 2.5/30/30	32.86	33.11	34.14	33.37
NCF 2.5/30/40	29.70	30.13	30.16	30.00
NCF 2.5/40/10	27.79	28.32	28.68	28.26
NCF 2.5/40/20	25.32	25.68	25.80	25.60
NCF 2.5/40/30	23.33	23.37	23.38	23.36
NCF 2.5/40/40	18.94	19.62	19.68	19.41

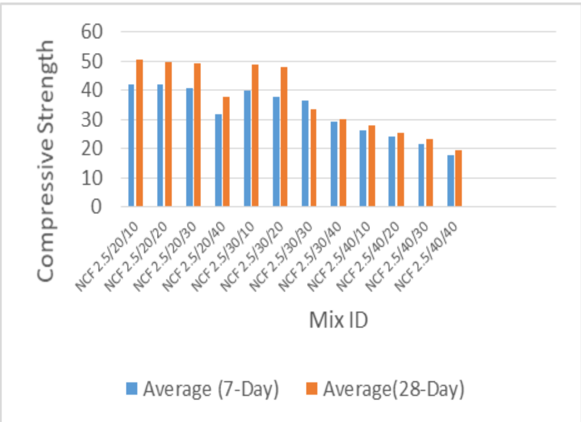

Fig -1: Average Compressive Strength of 7&28 Day

4. CONCLUSIONS

➢ **Major Findings**

We found some things from our experiments:

1. Recycled Aggregate Concrete (RAC) does not perform well as regular concrete because it has more holes absorbs more water and has a weaker bond between the materials.

2. Adding Nano-$CaCO_3$ makes the concrete stronger by making its structure and helping it set faster.

3. Basalt fiber helps the concrete resist cracks, bend without breaking and behave better under tension.

4. Using basalt fiber and Nano-$CaCO_3$ together makes up for the weaknesses of aggregates.

5. Our special RAC mix performs well as regular M40 concrete.

➢ **Workability Conclusions**

1. The recycled aggregate we use the harder it is to work with the concrete.

2. Adding basalt fiber makes it even harder to work with because the fibers get tangled.

3. Nano-$CaCO_3$ needs water because it has a lot of surface area.

4. Even though its harder to work with our concrete is still good enough for building structures.

5. We need to add a liquid to make the concrete easier to work with.

➢ **Strength Conclusions**

1. The recycled aggregates we use the weaker the concrete gets.

2. Mixes with recycled aggregate (20% RCA and 10-20% RFA) are stronger.

3. The strongest concrete we made had a strength of about 50.75 MPa.

4. The concrete gets significantly weaker when we use than 30% recycled aggregates.

5. Our special mix is stronger than RAC.

➢ **Optimum Dosage**

From our experiments we think the best mix is:

* Basalt Fiber: 0.50%

* Nano-$CaCO_3$: 2.5%

* Recycled Aggregate Replacement:

+ RCA: 20-30%

+ RFA: 10-20%

This mix gives us a balance between strength and workability.

➢ **Structural Feasibility**

1. Our special RAC can be as strong as M40 grade concrete.

2. The fibers help the concrete bend without breaking making it better for structures.

3. It's suitable for building beams, slabs and columns (if we don't use much recycled aggregate).

4. This shows promise for real-world construction.

Sustainability Conclusions

1. Using aggregates reduces waste from construction and demolition.

2. It also saves resources like river sand and crushed stone.

3. This reduces the impact and carbon footprint.

4. It promotes sustainable. Eco-friendly construction practices.

5. It supports an economy in the construction industry.

Limitations of Study

1. We only studied M40 grade concrete.
2. We only looked at strength, not flexural or durability tests.
3. We didn't evaluate long-term durability beyond 28 days.
4. This was a laboratory study; we didn't test it in the field.
5. We only analyzed one fiber dosage (0.50%) and nano percentage (2.5%).

Practical Recommendations

1. Soak recycled aggregates before using them to control water absorption.
2. Mix properly to avoid fiber balling.
3. Use superplasticizers to improve workability.
4. Limit recycled replacement to 30% for structural use.
5. Make sure nano-materials are dispersed evenly during mixing.

Future Scope

We can do research in these areas:
1. Study long-term durability (shrinkage, creep, permeability).
2. Investigate concrete grades (M50, M60).
3. Optimize fiber dosages (0.25-0.75%).
4. Use nano-materials like nano-silica.
5. Field implementation and life structural behavior.
6. Cost analysis and economic feasibility study.
7. Study Tensile strength in detail.
8. Microstructural analysis using SEM and XRD techniques.

Final Conclusion

Our study shows that using basalt fiber and Nano-$CaCO_3$ together makes recycled aggregate concrete perform better. This hybrid approach improves both microstructure and crack resistance making RAC suitable, for applications. With mix design and material optimization we can achieve sustainable high-performance concrete contributing to environmental conservation and efficient resource utilization.

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