A Detail Study on Mechanical Properties Of Concrete Utilzing Different Coarse Aggregates

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Abstract - *Concrete has become a basic need for every structure now-a-days. The concrete construction plays a vital role in our daily lives and the society in general. The objective of this study is to derive the alternative sources for coarse aggregate in concrete. In this study, we utilized the different kinds of eco-friendly as well as cheaply available waste broken materials from brick, cudappah and marble wastes were investigated for the replacement as well as sustainable of coarse aggregate in conventional concrete process. The mechanical properties of collected aggregates was assessed. All the investigation was conducted on M20 grade using IS design concept. The control specimens such as cubes, cylinders and prisms were cast to assess the performance of concrete for different coarse aggregates. The compressive strength, split tensile test and flexural strength were conducted after 28 days curing. Suitable conclusions were drawn based on the experimental results*

Key Words: **Concrete, aggregates, wastes, brick, cudappah, marble, strength**

1.INTRODUCTION

Concrete is the widely used construction material for various types of structures. It is one of the most important contemporary civil engineering materials. It is a composite construction material formed by mixing an aggregate with cement and water, then allowing the mixture to dry and harden [Farid Debieb and Said Kenai 2005]. Approximately 60-80% of concrete is made up of aggregates. The cost of concrete and its properties are directly related to the aggregates used. In aggregates the major portion is of coarse aggregates i.e. stone or gravel which are obtained naturally either from river bed or by crushing rocks mechanically up to the required size.

In India construction waste production is 165-175 million tons per year [Zainab Z. Ismail 2007]. However brick, marble and cudappah waste are high resistant to biological, chemical and physical degradation forces.

This project investigates the feasibility of brick waste, marble waste and cudappah waste as partial replacement with coarse aggregate in cement concrete. These wastes falls in the category of construction waste. Replacement of coarse aggregate by waste construction material reduces the construction of fresh raw materials.

1.2 Aggregate

1.2.1 Classification of Aggregates

- Fine aggregate
- Coarse aggregate

Table 1.1 Classification of Fine Aggregate

Fine Aggregate	Size Variation
Coarse Sand	2.0mm – 0.5mm
Medium Sand	0.5mm – 0.25mm
Fine Sand	0.25mm – 0.06mm
Silt	0.06mm – 0.002mm
Clay	<0.002

Table 1.1 Classification of Course Aggregate

Coarse Aggregate	Size
Fine gravel	4mm – 8mm
Medium gravel	8mm – 16mm
Coarse gravel	16mm – 64mm
Cobbles	64mm – 256mm
Boulders	>256mm

1.3 REPLACEMENT FOR COARSE AGGREGATE

The possibility of using substitute for coarse aggregate in concrete serves as one of the possible solutions to the escalating solid waste problem. The disposal of solid wastes in the production of concrete has concentrated mostly on aggregates since they provide the only real potential for using large quantities of waste materials.

The following construction wastes were used as replacement for coarse aggregates,

- Brick
- Cudappah
- Marble

1.3.1 BRICK

A brick is building material used to make walls, pavements and other elements in masonry construction. Traditionally, the term brick referred to a unit composed of clay, but it is now used to denote any rectangular units lay in mortar. A brick can be composed of clay-bearing soil, sand, and lime, or concrete materials. Bricks are produced in numerous classes, types, materials, and sizes which vary with region and time period, and are produced in bulk quantities,

Normally, bricks contain the following ingredients

1. Silica (sand) – 50% to 60% by weight
2. Alumina (clay) – 20% to 30% by weight
3. Lime – 2 to 5% by weight
4. Iron oxide – ≤ 7% by weight
5. Magnesia – less than 1% by weight

1.3.2 CUDAPPAH

Cudappah Black Limestone is one of the most popular lime stone that is available in black colour. It is generally used for interiors as well as exteriors. The main attraction of this black limestone is that it is quite hard and is used in extreme temperatures. This cudappah stone is quarried at Betamcharla, District kadappa, Andhra Pradesh.

COLOR	c-black (cudappah black)
QUALITY	no color tonal variations exist
ALSO KNOW AS	cudappah black, madras black

1.3.3 MARBLE

Marble is metamorphic rock created after the metamorphosis of such rocks as limestone, calcite, dolomite and serpentine under high pressure and high temperature. The main component of marble is calcium carbonate ($CaCO_3$ about 50%), plus a little acidic oxide SiO_2, so marble belongs to alkaline crystalline rock. In stone industry, marble includes all kinds of carbonate rock or magnesium carbonate rock and relevant metamorphic rock which have similar properties with marble.

Marble can be of two types, one composed of calcite and the other of dolomite. Dolomitic marble is much more resistant to acid attack than calcite marble. The color of marble ranges from brilliant white of calcite to black, including blue-gray, red, yellow and green, depending upon the mineral composition.

1.3.3.1 Performances of Marble

1) Even structure, fine and smooth texture and high compressive strength.
2) Dense structure but medium hardness.
3) Weak weather-resistance and weak acid resistance.
4) Excellent decorativeness and good processability. Marble has colorful texture and is beautiful and elegant after being processed.
5) Strong wear resistance, low water absorption and good durability.

1.4 ADVANTAGES OF REPLACED AGGREGATES

- Reduces the amount of virgin aggregates to be created, hence less evacuation of natural resources.
- While being crushed into smaller particles a large amount of carbon dioxide is absorbed. This reduces the amount of CO_2 is the atmosphere.
- Cost saving - few research studies have shown a significant reduction in construction costs if RAC is used.
- Conserves landfill space, reduces the need for new landfills and hence saving more costs.
- Creates more employment opportunities is recycling industry

1.5 DISADVANTAGES OF REPLACED AGGREGATE

- Downgrading of quality of concrete.
- Increase in water absorption capacity ranging from 3% to 9%
- Decrease in compressive strength of concrete (10-30%)
- Reduces workability of concrete.
- Lack of specifications and guidelines.

1.6 APPLICATIONS OF REPLACED AGGREGATE

- Can be used for constructing gutters, pavements etc.
- Large pieces of crushed aggregate can be used for building revetments which in turn is very useful in controlling soil erosion.
- Recycled concrete rubbles can be used as coarse aggregate in concrete.
- Production of RAC also results in generation of many by-products having many uses such as a ground improvement material, a concrete addition, an asphalt filler etc.

In this chapter, basic introduction about coarse aggregate and replacement for coarse aggregates and its advantages, disadvantages and applications have been presented.

2.0 REVIEW OF LITERATURE

To investigate the past literatures and review carried out on the literature of relevance to the study and to compare the results with our study.

2.1 SCOPE AND OBJECTIVE

- To determine the suitability of brick waste, cudappah waste and marble waste as partial replacement of coarse aggregate in concrete production.
- To assess the essential properties of materials used as a replacement for coarse aggregate.
- To investigate the mechanical and physical properties of brick waste, cudappah waste and marble waste concrete.
- To study the behavior of concrete with the replacement of coarse aggregate.
- To evaluate the effect of replacing the coarse aggregate by brick wastes, cudappah waste and marble waste used in concrete.
- To draw the suitable conclusion .
- To propose practical guidelines for making normal strength concrete incorporating waste materials as replacement for coarse aggregate.

3. EXPERIMENTAL PROGRAMME

The casting and testing of specimens are discussed in this chapter. A total of 40 cubes, 40 cylinders and 40 prisms were cast. These specimens were tested to determine the mechanical properties of concrete such as compressive strength, split tensile strength, flexural strength and elasticity modulus.

3.1 Test Plan

Specimens		Tested For	Curing Period (Days)	Number of Specimen
Type	Size (mm)			
Cube	150 x 150	compression	7 28	Conventional Brick (10%, 20%, and 30%) Cudappah (10%, 20% and 30%) Marble (10%, 20%, and 30%)
Cylinder	150 x 300	Tension	7 28	Conventional Brick (10%, 20%, and 30%) Cudappah (10%, 20% and 30%) Marble (10%, 20%, and 30%)
Prism	500 x 100 x 100	flexure	7 28	Conventional Brick (10%, 20%, and 30%) Cudappah (10%, 20% and 30%) Marble (10%, 20%, and 30%)

3.2 MATERIALS USED

3.2.1 Cement

Ordinary Portland cement of grade 43 is used as per IS 455 – 1989

Table 3.2.1.1 Physical Properties of Cement

S. No	Particulars	Test Results	Reference as per IS 455-1989
1	Specific gravity	3.14	3.14
2	Setting time Initial (mins) Final (mins)	30 mins 600 mins	30 (min) 600 (max)
3	Soundness(cm)	0.5	10 (max)

3.2.2 Fine Aggregate

Table 3.2.2.1 Physical Properties of Fine Aggregate

S. No	Characteristics	Test Results	Standard
1	Specific gravity	2.68	IS 383-1970
2	Fineness modulus	2.30	IS 383-1970
3	Grading zone	Zone III	IS 383-1970
4	Water absorption test	1.00%	IS 383-1970

Table 3.2.2.2 Particle Size Distribution

IS sieve	Grading zone III	Our sample
10 mm	100	100
4.75 mm	90-100	100
2.36 mm	85-100	90
1.18 mm	75-100	81.0
600μ	60-79	74.9
300μ	12-40	24.2
150μ	0-10	2.7

Table 3.2.2.3 Sieve Analysis for Fine Aggregate

IS Sieve Size	% Passing	Confirming to Zone III of IS 383-1970
10mm	100	100
4.75mm	100	90-100
2.36mm	90	85-100
1.18 mm	81	75-100
600 micron	74.90	60-79
300micron	24.20	12-40
150 micron	2.70	0-10

3.2.3 Coarse Aggregate

Table 3.2.3.1 Physical Properties of Coarse Aggregate

S.No	Characteristics	Test Results
1	Specific gravity	2.73
2	Water absorption	0.50%
3	Fineness modulus	5.47
4	Impact strength	8.22%

3.2.4 Water

Water confirming to IS 3025-1964 part 22, part 23 and IS 456-2000 was used in this study.

3.2.5 Brick

Table 3.2.5.1 Physical Properties of brick

S.No	Characteristics	Experimental results
1	Specific gravity	1.87

3.2.6. Cudappah

Table 3.2.6.1 Physical Properties of brick

S.No	Characteristics	Experimental results
1	Specific gravity	4.2

3.2.7. Marble

Table 3.2.7.1 Physical Properties of Marble

S.No	Characteristics	Experimental results
1	Specific gravity	2.8

4.0 Mix Design

Mix design is the process of selecting suitable ingredients of concrete and determining their relative proportions with the object of producing concrete of certain minimum strength and durability as economically as possible.

From various test results of ingredients, the ultimate aim is in to determine the concrete mix design for M20 grade. The specimens of M20 grade concrete, designed as per IS 10262-2009. Concrete mix was prepared using the designed proportions, **1: 1.98: 3.38** (One part of cement, 1.98 parts of fine aggregate and 3.38 part of coarse aggregate).

The amount of constituent materials required to make 1 m^3 of conventional concrete is presented below,

- Cement - 349 kg/ m3
- Fine aggregate - 691.28 kg/ m3
- Coarse aggregate- 1179.74 kg/ m3
- Water - 192 lit/ m3

The detailed mix design procedure are presented below,

I Stipulations for Proportioning

1. Grade of concrete = M20
2. Type of cement = PSC - 43 Grade
3. Max. Nominal size of aggregate = 20 mm
4. Minimum cement content = 300 kg/m^3
5. Maximum cement content = 450 kg/m^3
5. Maximum water-cement ratio = 0.55
6. Workability = 75 mm slump
7. Exposure condition = Mild
8. Type of aggregate = Crushed angular aggregate

II Test Data for Materials

1. Specific gravity of cement = 3.14
2. Specific gravity of coarse aggregate = 2.73
3. Specific gravity of fine aggregate = 2.68
4. Sieve analysis of fine aggregate = Confirming to Zone III of table 4 of IS 383:1970

III Target Strength for Mix Proportioning

$f_{ck}' = f_{ck} + 1.65s$

f_{ck}' = Target average compressive strength at 28 days.

f_{ck} = Characteristic compressive strength at 28 days.

s = Standard deviation.

From table-1 of IS 10262: 2009 for M20 Concrete, s = 4 N/mm^2.

$f'_{ck} = 20 + 1.65(4)$

$f'_{ck} = 26.6$ N/mm^2

IV Selection of Water-Cement Ratio

From Table-5 of IS456:2000 for reinforced concrete (M20),

1. Maximum water-cement ratio =0.55
2. Minimum cement content = 300 kg/m^3

From table-2 of IS 10262:2009 maximum water content for 20 mm aggregate is 186 kg/m^3.

Water content can be increased by 3% for every 25mm increase of slump. For 75 mm slump,

Water content = 186+ 5.58
= 191.58 kg/m^3= 192 kg/m^3

V Calculation of Cement Content

Water-cement ratio = 0.55

Cement content $= \frac{192}{0.55}$ = 349 kg/m^3 > 300 kg/m^3.

VI Proportion of Volume of Coarse Aggregate and Fine Aggregate

From table-3 IS 10262:2009 for 20mm aggregate for ZONE II volume of coarse aggregate per unit volume of total aggregate for water-cement ratio 0.5 is 0.62. For water-cement ratio 0.55 it is 0.61. (At the rate of ±0.01 for every ±0.05 changes in water-cement ratio).

Volume of coarse aggregate = 0.64
Volume of fine aggregate = 0.36

VII Mix Calculation

1. Volume of concrete = 1 m^3
2. Volume of cement $= \frac{Mass\ of\ cement}{specific\ gravity\ of\ cement} \times \frac{1}{1000}$
$= \frac{349.091}{3.14} \times \frac{1}{1000}$
= 0.111 m^3
3. Volume of water $= \frac{Mass\ of\ water}{specific\ gravity\ of\ water} \times \frac{1}{1000}$
$= \frac{192}{1} \times \frac{1}{1000}$
= 0.192 m^3
4. Vol of all in aggregate = 1-(0.111+0.192)
= 0.697 m^3
5. Mass of coarse aggregate = 0.697 x 0.64x 2.73 x 1000
= 1217.80 kg/m^3
6. Mass of fine aggregate = 0.697 x 0.36 x 2.68 x 1000
= 672.47 kg/m^3

VIII Mix Proportion

Cement = 349 kg/m^3
Water = 192 kg/m^3
Fine Aggregate = 1217.80 kg/m^3
Coarse Aggregate = 672.47 kg/m^3
Water-Cement ratio = 0.55

IX Mix Ratio

Cement	:	Fine Aggregate	:	Coarse Aggregate
1	:	1.93	:	3.49

5.0 Casting of Test Specimens

Casting is a manufacturing process in which concrete is usually poured into a mould, which contains a hollow cavity of the desired shape, and then allowed to solidify. Casting materials are usually metals or various cold setting materials. The standard size of cube specimen, cylinder specimen, and prism are 150 mm X 150 mm X 150 mm, 150 mm diameter and 300 mm length and 100 mm X 100 mm X 500 mm. Cube, cylinder and prism specimens were cast to obtain the mechanical properties of conventional concrete and the concrete partially replaced by using brick, marble and cudappah aggregates. Totally 36 Nos. of cubes, 36 Nos. of cylinders and 36 Nos. of prisms were cast by replacing the coarse aggregates such as brick, cudappah and marble in different ratio (10%, 20% and 30%). Cubes, cylinders and prisms were tested for their compressive strength, split tensile strength and flexural strength respectively

5.1 MECHANICAL PROPERTIES

5.1.1 Compressive Strength (IS 516-1959)

Compressive strength or compression strength is the capacity of a material or structure to withstand loads tending to reduce size. In other words, compressive strength resists compression (being pushed together).

It is the maximum compressive stress that, under a gradually applied load, a given solid material can sustain without fracture. Compressive strength is often measured on a universal testing machine.

The target mean compressive strength (fck') of the specimen is tested after 7 and 28 days curing, as per the reference of IS 516-1959.

Compressive strength was calculated by dividing the maximum load by its cross-sectional area of the specimen.

$$P_C = \frac{P}{A} \qquad \text{...............(3.1)}$$

where, P_c= compressive strength
P = load at the point of failure
A = initial cross sectional surface area

5.1.2 Split Tensile Strength (IS 516-1959)

Concrete is a material, which is weak in tension. So it becomes very important to know tensile strength for concrete used in designing structures. The tensile strength of concrete is determined by split tensile test.

Tensile strength is the capacity of the material or structure to withstand loads tending to elongate. In other words tensile strength resists tension (being pulled apart).

Tensile strength of the specimen are tested after 7 and 28 days curing, as per the reference of IS 516-1959.Split tensile strength is calculated by,

$$f_t = 2P/\Pi LD \qquad ....(3.2)$$

where, P = compressive load at failure
L = Length of cylinder
D = Diameter of cylinder

Flexural Strength Test (IS 516-1959)

Flexural testing is used to determine the flex or bending properties of a material. A flexure test is more affordable than a tensile test and test results are slightly different. The deflection and cracking behavior of concrete structure depend on the flexural tensile strength of concrete.

This test identifies the amount of stress and force an unreinforced concrete slab, beam or other structure can withstand such that it resists any bending failures.

Flexural strength of the specimens is tested after 7 and 28 days curing, as per the reference of IS 516-1959.

It is calculated by,

$$F = PL/(bd^2) \qquad ....(3.3)$$

Where, F= Flexural strength of concrete (in MPa).
P= Failure load (in N).
L= Effective span of the beam (in mm)
B = Breadth of the beam (in mm)

6.1 RESULTS AND DISCUSSION

The obtained experimental results are presented and discussed in this chapter. The nomenclatures are presented below,

Test specimen	Description
NSC 0%	Conventional concrete specimen
NSCB 10%	Concrete specimen with 10% replacement of brick
NSCB 20%	Concrete specimen with 20% replacement of brick
NSCB 30%	Concrete specimen with 30% replacement of brick
NSCC 10%	Concrete specimen with 10% replacement of Cudappah
NSCC 20%	Concrete specimen with 20% replacement of Cudappah
NSCC 30%	Concrete specimen with 30% replacement of Cudappah
NSCM 10%	Concrete specimen with 10% replacement of marble
NSCM 20%	Concrete specimen with 10% replacement of marble
NSCM 30%	Concrete specimen with 10% replacement of marble

6.1.1 Effect of Brick Waste on Compressive Strength

Table 6.1.1.1 Compressive Strength of Test Specimens for Brick

Sl. No	Test specimen	Brick replacement (%)	Avg. compressive strength (N/mm²)
			At 7 days
1	NSC	0	16.00
2	NSCB 10%	10	10.09
3	NSCB 20%	20	7.99
3	NSCB 30%	30	6.48

6.1.2 Effect of Brick Waste on tensile strength

Table 6.1.2.1 Tensile Strength of Test Specimens for Brick

Sl. No	Test specimen	Brick replacement (%)	Avg. tensile strength (N/mm²)
			At 7 days
1	NSC	0	2.04
2	NSCB 10%	10	1.48
3	NSCB 20%	20	1.31
3	NSCB 30%	30	1.18

6.1.3 Effect of Brick Waste on flexural strength test

Table 6.1.3.1 Flexural Strength of Test Specimens for Brick

Sl. No	Test specimen	Brick replacement (%)	Avg. tensile strength (N/mm²)
			At 7 days
1	NSC	0	2.75
2	NSCB 10%	10	6.25
3	NSCB 20%	20	5.25
3	NSCB 30%	30	5.50

6.1.4 Effect of Cudappah Waste on Compressive Strength

Table 6.1.4.1 Compressive Strength of Test Specimens for Cudappah

Sl. No	Test specimen	Cudappah replacement (%)	Avg. compressive strength (N/mm²) At 7 days
1	NSC	0	16.00
2	NSCC 10%	10	17.20
3	NSCC 20%	20	19.50
3	NSCC 30%	30	11.55

6.1.5 Effect of Cudappah Waste on tensile strength

Table 6.1.5.1 Tensile Strength of Test Specimens for Cudappah

Sl. No	Test specimen	Cudappah replacement (%)	Avg. compressive strength (N/mm²) At 7 days
1	NSC	0	16.00
2	NSCC 10%	10	17.20
3	NSCC 20%	20	19.50
3	NSCC 30%	30	11.55

6.1.6 Effect of Cudappah Waste on Flexural strength

Table 6.1.6.1 Flexural Strength of Test Specimens for Cudappah

Sl. No	Test specimen	Cudappah replacement (%)	Avg. Flexural strength (N/mm²) At 7 days
1	NSC	0	2.75
2	NSCC 10%	10	4.12
3	NSCC 20%	20	6.00
3	NSCC 30%	30	5.87

6.1.7 Effect of Marble Waste on Compressive strength

Table 6.1.7.1 Compressive Strength of Test Specimens for Marble

Sl. No	Test specimen	Marble replacement (%)	Avg. Compressive strength (N/mm²) At 7 days
1	NSC	0	16.00
2	NSCM 10%	10	22.45
3	NSCM 20%	20	18.50
3	NSCM 30%	30	13.80

6.1.8 Effect of Marble Waste on Tensile strength

Table 6.1.8.1 Tensile Strength of Test Specimens for Marble

Sl. No	Test specimen	Marble replacement (%)	Avg. Tensile strength (N/mm²) At 7 days
1	NSC	0	2.04
2	NSCM 10%	10	2.89
3	NSCM 20%	20	1.80
3	NSCM 30%	30	1.64

6.1.9 Effect of Marble Waste on Flexural strength

Table 6.1.9.1 Flexural Strength of Test Specimens for Marble

Sl. No	Test specimen	Marble replacement (%)	Avg. Flexural strength (N/mm²) At 7 days
1	NSC	0	2.75
2	NSCM 10%	10	8.50
3	NSCM 20%	20	8.20
3	NSCM 30%	30	7.70

3. CONCLUSIONS

For the replacement of Brick wastes, the compressive strength, the tensile strength and the flexural strength decreases when the addition of brick increases. A significant increase was observed for 10% replacement of materials. The 10% replacement of materials on brick exhibits a decrease of 36.93% in compressive strength and a decrease of 27.45% in tensile strength and an increase of 127.27% in flexural strength when compared with the control specimen.

For the replacement of cudappah waste, the higher compressive strength, tensile strength and flexural strength was achieved on 20% replacement of materials. The 20% replacement of cudappah exhibits an increase of 21.87% in compressive strength, 31.86% in tensile strength and 118.18% in flexural strength when compared with the control specimen.

For the replacement of Marble wastes, the high compressive strength, the tensile strength and the flexural strength were achieved on 10% replacement of materials. The 10% replacement of materials on Marble exhibits an increase of 40.31% in compressive strength and a decrease of 7.35% in tensile strength and an increase of 209.00% in flexural strength when compared with the control specimen.

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REFERENCES

[1] Akash Rao (2007). Examined the use of aggregates from recycled construction and marble waste in concrete. Waste management, vol.30, pp. 814-825

[2] Chaocan zeng, Cong Lou, Geng Du, Xiaozhen Li, Zhiwu Liu, Liqin Li (2018). Investigated the mechanical properties of recycled concrete with brick aggregate. Conservation and recycling, vol.50, pp.71-81.

[3] Derrick J. Anderson, Scott T. Smith, Francis T.K. Au (2016). Investigated the mechanical properties of concrete utilizing waste marble as coarse aggregate. Construction and Building materials, vol.117, pp.20-28.

[4] Farid Debieb, Said Kenai (2008). Assessed the use of coarse and fine crushed bricks as aggregate in concrete. Construction and building materials, vol.22, pp.886-893.

[5] H. Hebhoub, H. Aoun, M. Belachia, H. Houari, E. Ghorbel (2011). Investigated the use of waste marble aggregates in concrete. Construction and building materials, vol.25, pp.1167-1171.

[6] IS 10262:2009 Concrete Mix Proportioning-Guidelines. Bureau of Indian Standards, New Delhi, India.

[7] IS 383:1970 Specification of Coarse and Fine Aggregate From Natural Source for Concrete. Bureau of Indian standards, New Delhi, India.

[8] IS 456:2000 Plain and Reinforced Concrete-Code of Practice. Bureau of Indian Standards, New Delhi, India.

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