EXPERIMENTAL INVESTIGATION ON CONCRETE USING RECYCLED COARSE AGGREGATE

Sabunam Chettri[1], Aaqib Firdous[2]

[1,2] *PG Student, Department of Civil Engineering, Excel Engineering College. Komarpalayam*

Abstract - *This project deals with the excremental investigation on the properties of concrete using recycled coarse aggregate. In this project the M30 concrete mix is selected and the compression and tensile tests are carried out for the hard concrete. Due to the rapid population growth and rapid urbanization the natural resources are depleting day by day. So the natural aggregates are very hard to obtain. So many people are opting to use recycled aggregates in construction. The cost of good quality crushed aggregates as compared to recycled aggregate is also very high due to the high demand of it in construction works.*

Recycling of stone, aggregate, will reduce the quarrying and mining of stones thereby reducing the use of natural resources excessively. The land surface can be prevented from any unwanted dumping of wastes and hence ecological disturbances will be reduced. To conserve the conventional natural aggregates for other important construction works. The slump test is carried out in the project to investigate the workability of fresh concrete. The slump of the concrete mix is recorded as 130mm.The preliminary tests are also carried out for this project such as, Water absorption test, fineness modulus test, bulk density test etc. Methodology of project, test results and discussion are enclosed in this report.

Key Words*: *Concrete, Compression test, Tensile tests, Aggregate, Recycling of stone.

1. INTRODUCTION

Concrete is the most widely used construction material today. Concrete is a manufactured product, essentially consisting of cement, aggregates, water and admixture. Traditionally aggregates have been readily available at economic price. However, in recent years the wisdom of our continued wholesale extraction and use of aggregates from natural resources has been questioned at an international level. This is mainly because of the depletion of quality primary aggregates and greater awareness of environmental protection.

Global warming has emerged as the most serious environmental issue of our time and since sustainability is becoming an important issue of economic and political debates, many governments throughout the world have now introduced various measures aimed at reducing the use of primary aggregates and increasing reuse and recycling, where it is technically, economically, or environmentally acceptable. Recycled aggregates are the aggregates produced from the processing of previously used construction materials such as concrete or masonry. It consists of hard, graduated fragments of inert mineral materials including sand, gravel, crushed stone, slag, rock dust, or powder.

1.1 Scope of using recycled coarse aggregate

a. Recycling of stone, aggregate, will reduce the quarrying and mining of stones thereby reducing the use of natural resources excessively.
b. The land surface can be prevented from any unwanted dumping of wastes and hence ecological disturbances will be reduced.
c. The availability of land for waste disposal will be increased.
d. To conserve the conventional natural aggregates for other important construction works.
e. To reduce the cost of construction materials.

1.2 Objective of the experimental investigation

a. Investigating the behavior, strength and durability of concrete while replacing the natural aggregates by recycled aggregates in various proportions.
b. To reduce the demand of natural aggregate.
c. To emphasis on the 3R concept (Reduce, Recycle and Reuse) in the construction field.
d. For effective solid waste management.

2. METHODOLOGY

- This chapter deals about the methodology of the use of coarse aggregate in concrete and is as discussed below.
- The used concrete cubes and cylinders were collected from laboratory of excel engineering college komarapalayam. This was of more than two years old.
- The specimens were crushed to obtain the desired size of the aggregate and then the recycled coarse aggregate was extracted.
- The recycled coarse aggregates (RCA) were screened to remove any unwanted materials.

- The RCA was then washed with clear water to remove any mortar attached to the aggregate.
- Then it was heated in a heating oven to remove the moisture content present in it.
- The % of replacement of coarse aggregates by recycled aggregates was 30%, 50% and 70% of coarse aggregate and the specimens were cast.
- The cast specimens are cubes and cylinders. The cast specimens were cured for 3, 7 and 28 days.
- The cast specimens after curing were subjected to compression testing and split tensile testing.
- Test results are obtained and discussed with the help of graphs under 'Result and Discussions'.

3. PRELIMINARY TESTS

3.1 Specific gravity of cement

The specific gravity of cement is determined with the help of Le Chatelier's Flask. IS 4031 Part II is used for the testing of specific gravity of cement.

Sp.Gravity of cement = (Wt.of cement)/(increse in volume in Lechatelier^' s flask)

Values of specific gravity for different kinds of cement are as follows:

OPC = 3.1 to 3.18

PPC = 2.9 to 2.95

Slag = 2.8 to 2.9

3.2 Specific gravity test of aggregate

IS 2386 Part III is used for determining specific gravity of aggregates. Pycnometer is used for the test.

A - sample + water + pycnometer

B - water + pycnometer

C - sample taken after wet condition (24hrs)

D - weight of sample after dried in oven after 24 hrs.

Sepcific Gravity = D/(C-(A-B))

3.3 Bulk density test

IS 2386 Part III is used for determining bulk density of aggregates.

The bulk density for river sand is given by
Bulk density=weight/volume
Where volume=π/4×D^2×h
D = diameter of cylinder
h = height of cylinder

3.4 Water absorption test

IS 2386 Part III is used for determining water absorption of aggregates.
Water absorption = C-D/D *10

4. EXPERIMENTAL INVESTIGATION

4.1 Preparation of materials

Sample of aggregate for each batch of concrete shell be of desired grading and in air-dried condition. In general, the aggregate shall be separated into fine and coarse fraction and recombined for each concrete batch in such a manner so as to produce the desired grading..

Collection of aggregates

4.2 Proportioning

The proportioning of the materials including water in concrete mixes for determining the suitability of the material available shall be similar in all aspects to those to be employed in work. Where the proportions of the ingredient of concrete used on the site are to specified by volume, they shall be calculated from the proportional by weight used in the test cubes and the unit weight of the materials.

4.3 Weighing

The quantities of cement, each size of aggregate and water for each batch shall be determined by weight to an accuracy of 0.1 per cent of the total weight of the batch.

4.4 Mixing of concrete

The concrete shall be mixed by hand or perfectly in laboratory batch mixer in such a manner so as to avoid loss of water or other materials. Each batch of concrete shall be of such a size so as to leave about 10 per cent excess after moulding the desired number of test specimen.

Mixing of concrete

4.5 Compaction

When compaction by hand, the standard tamping rod shall be used and the stokes of the rod shall be distributed in a uniform manner over the cross section of the mould. The number of stokes per layer required to produce specified condition will vary according to the type of concrete. For cubical specimen, the concrete shall be subjected to 35 stokes per layer for 15cm cubes. The stokes shall touch the surface of underlying layer. Where voids are left by tamping rod, the sides of the mould shall be tapped to close the voids.

4.6 Curing of test specimens

The test specimens shall be stored on the site at a place free from vibration, under damp matting, sacks or other similar materials for 24 hours + half hour from the time of adding the water to the other incidents. The temperature of the place of storage shall be within the range 22-32 Celsius. After the period of 24 hours, the specimen shall be marked for the later identification removed from the mould and unless required for testing within 24 hours store in clean water at temperature of 24 – 30 Celsius until they are transported to the testing laboratory. They shall be sent to the testing laboratory well packed in a damp sand, damp sack or other suitable materials so as to arrive there in a damp condition not less than 24 hours before the time of test.

5. Test on fresh concrete

5.1 Slump test:

The slump test is used to determine the workability of concrete mix prepared at the laboratory or construction site. The slump value was determined for the various mix to be prepared in the project. Generally concrete slump value is used to find out the workability of concrete which indicates water –cement ratio.

Procedure:

- Clean the internal surface of the mould and apply oil.
- Place the mould on smooth horizontal non –porous base plate.
- Fill the mould with the prepared concrete mix in four approximate equal layers.
- Tamp each layer with 25 stokes of the rounded end of the tamping rod in a uniform manner over the cross-section of the mould. For the subsequent layers the tamping should penetrate into the underlying layer.
- Remove the excess concrete and level the surface with a trowel.
- Clean away the mortar or water leaked out between the mould and the base plate.
- Raise the mould from the concrete immediately and slowly in vertical direction.
- Measure the slump as difference between the height of the mould and that of highest point of specimen being tested.

Slump test

6. Tests on hardened concrete

6.1 Compressive strength test

- One of the most important and useful property of concrete.
- Primarily meant to withstand compressive stress and can be used as an approximate qualitative measure for other properties of hardened concrete.
- Compressive strength test is carried out on cubes for various mixes M1, M2, M3 and M4.
- The compressive strength of cubes was tested on 3, 7 and 28 days.
- Formula for compressive strength of concrete:
  = Load applied(P)/Cross sectional area (A)= N/mm^2

Compressive strength test

6.2 Split tensile strength test

The tensile strength of concrete is one of the basic and important properties. Splitting tensile strength test on concrete cylinder is a method to determine the tensile strength of concrete.

Need: The concrete is weak in tension due to its brittle nature and is not expect to resist the direct tension. The concrete develops cracks when subjected to tensile forces. Thus it is necessary to determine the tensile strength of concrete to determine the load at which the concrete member may crack.

Procedure:

- Draw diametric lines on each end of the specimen using a suitable device that will ensure that they are in the same axial plane.
- Determine the diameter of the test specimen by averaging the three diameters and the length of the specimen by averaging at least two length measurements taken in the plane containing the lines marked on the two ends.
- Place the specimen on the plywood strip and align so that the lines marked on the ends of the specimen are vertical and centered over the plywood strip. Place a second plywood strip lengthwise on the cylinder, centered on the lines marked on the ends of the cylinder.
- Apply the load continuously and without shock at a constant rate within the range 100 to 200 psi/min [0.7 to 1.4 MPa/min] splitting tensile stress until failure of the specimen. Record the maximum applied load indicated by the testing machine at failure. Note the type of failure and the appearance of the concrete.

Calculation:

The splitting tensile strength of the specimen are given below:

$$T = 2P/\pi ld$$

Where,

T = split tensile strength in MPa

P = maximum applied load indicated by the testing machine in N

l = length in mm

d = diameter in mm

Split tensile strength test

7. TEST RESULTS

7.1 Compression test results for cube

7.1.1 M1 (Control mix)

Weight (kg)	Size (mm)	Load (KN)	Stress (N/mm²)	Average (N/mm²)
8.450	150 × 150	585.0	26.0	25.86
8.420	150 × 150	579.2	25.74	
8.400	150 × 150	581.3	25.84	

3 Days Compression test result (control mix)

Weight (kg)	Size (mm)	Load (KN)	Stress (N/mm²)	Average (N/mm²)
8.385	150✕150	742.5	33.00	32.45
8.425	150✕150	748.1	33.25	
8.405	150✕150	700.0	31.11	

7 Days compression test result (control mix)

Weight (kg)	Size (mm)	Load (KN)	Stress (N/mm²)	Average (N/mm²)
8.485	150✕150	967.5	43.0	43.18
8.500	150✕150	963.0	42.8	
8.515	150✕150	984.0	43.73	

28 Days compression test result (control mix)

7.1.2 M2 (30% replacement of coarse aggregate by recycled aggregate)

Weight (kg)	Size (mm)	Load (KN)	Stress (N/mm²)	Average (N/mm²)
8.345	150✕150	644.4	28.64	28.08
8.410	150✕150	617.4	27.44	
8.300	150✕150	633.4	28.15	

3 days compression test result

Weight (kg)	Size (mm)	Load (KN)	Stress (N/mm²)	Average (N/mm²)
8.415	150✕150	874.1	38.85	38.96
8.450	150✕150	888.1	39.50	
8.500	150✕150	866.8	38.52	

7 Days compression test result

Weight (kg)	Size (mm)	Load (KN)	Stress (N/mm²)	Average (N/mm²)
8.470	150✕150	1075.5	47.8	48.49
8.465	150✕150	1095.2	48.68	
8.485	150✕150	1102.5	49.00	

28 Days compression test result

7.1.3 M3 (50% replacement of coarse aggregate by recycled aggregate)

Weight (kg)	Size (mm)	Load (KN)	Stress (N/mm²)	Average (N/mm²)
8.405	150✕150	604.8	26.88	26.72
8.455	150✕150	601.0	26.71	
8.320	150✕150	598.1	26.58	

3 Days compression test result

Weight (kg)	Size (mm)	Load (KN)	Stress (N/mm²)	Average (N/mm²)
8.425	150✕150	831.4	36.95	37.20
8.395	150✕150	842.2	37.43	
8.510	150✕150	837.7	37.23	

7 Days compression test result

Weight (kg)	Size (mm)	Load (KN)	Stress (N/mm²)	Average (N/mm²)
8.350	150✕150	987.7	43.89	44.05
8.425	150✕150	996.0	44.26	
8.400	150✕150	990.3	44.01	

28 Days compression test result

7.1.4 M4 (70% replacement of coarse aggregate by recycled aggregate)

Weight (kg)	Size (mm)	Load (KN)	Stress (N/mm²)	Average (N/mm²)
8.415	150✕150	597.9	26.57	25.60
8.380	150✕150	570.2	25.34	
8.300	150✕150	560.0	24.89	

3 Days compression test result

Weight (kg)	Size (mm)	Load (KN)	Stress (N/mm²)	Average (N/mm²)
8.335	150✕150	771.0	34.26	34.17
8.420	150✕150	766.2	34.05	
8.425	150✕150	810.4	36.01	

7 Days compression test result

Weight (kg)	Size (mm)	Load (KN)	Stress (N/mm²)	Average (N/mm²)
8.415	150✕150	879.1	39.07	38.49
8.420	150✕150	860.5	38.24	
8.405	150✕150	858.4	38.15	

28 Days compression test result

7.2 Split tensile test results for cylinder

Weight (kg)	Size (mm)	Load (KN)	Stress (N/mm²)	Average (N/mm²)
1.675	70✕150	74.10	4.49	4.575
1.655	70✕150	76.9	4.66	

Split tensile result for control mix (M1)

Weight (kg)	Size (mm)	Load (KN)	Stress (N/mm²)	Average (N/mm²)
1.675	70✕150	85.2	5.17	4.98
1.625	70✕150	79.0	4.79	

Split tensile result for M2 (30% replacement of CA by RA)

Weight (kg)	Size (mm)	Load (KN)	Stress (N/mm²)	Average (N/mm²)
1.685	70✕150	78.3	4.75	4.68
1.670	70✕150	76.0	4.61	

Split tensile result for M3 (50% replacement of CA by RA)

Weight (kg)	Size (mm)	Load (KN)	Stress (N/mm²)	Average (N/mm²)
1.600	70✕150	69.2	4.20	4.23
1.650	70✕150	70.3	4.26	

Split tensile result for M4 (70% replacement of CA by RA)

8. DISCUSSION

This chapter deals with the discussion of results and conclusion of the project.

8.1 Compressive strength test results

S.No	Curing days	Control mix (M1) N/mm²	30% (M2) N/mm²	50% (M3) N/mm²	70% (M4) N/mm²
1	3 days	25.86	28.08	26.72	25.60
2	7 days	32.45	38.96	37.20	34.17
3	28 days	43.18	48.49	44.05	38.49

Compressive strength test results

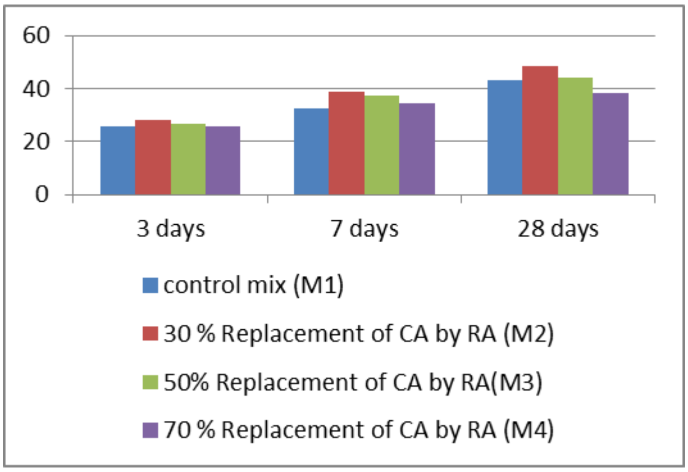

Chart showing the comparative compressive strength of various mixes at 3, 7 and 28 days

The above test result shows that the compressive strength at 3, 7 and 28 days is highest for M2 (i.e. when 30% of coarse aggregate is replaced by recycled aggregate) followed by M1, M3 and M4 except for the 7 day strength where the compressive strength of M3 and M4 is greater than M1.

8.2 Split tensile strength test results

S.No	Curing days	Control mix (M1)	30% recycled (M2)	50% recycled (M3)	70% recycled (M4)
1	28	4.575 N/mm²	4.98 N/mm²	4.68 N/mm²	4.23 N/mm²

Split tensile strength test results

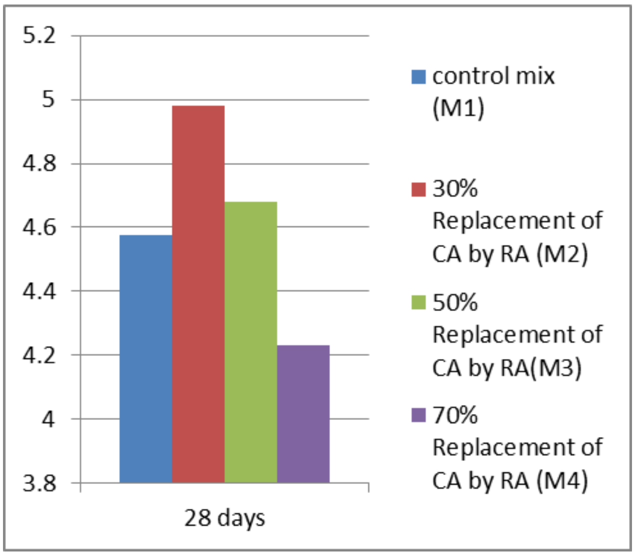

Chart showing the comparative split tensile strength of various mixes at 28 days

In case of this test, the highest split tensile strength after 28 days is observed in M2 whereas the lowest is observed in M4.Considering the strength factor, the above experimental investigation shows that it is very advisable to adopt M2 as the strength for M2 is relatively higher than other mixes. Unsurprisingly, M4 performs the poorest in terms of all the strengths mentioned above and it is not advisable to use.

9. CONCLUSION

The results indicated that the compressive strength of recycle aggregate is found to be less than the natural aggregate. With the judicious analysis done, the following conclusions were arrived:

- The compressive strength test showed that the compressive strength at 3, 7 and 28 days is highest for M2 (i.e. when 30% of coarse aggregate is replaced by recycled aggregate) followed by M1(control mix), M3(50% replacement of coarse aggregate by recycled aggregate) and M4(70% replacement of coarse aggregate by recycled aggregate) except for the 7 day strength where the compressive strength of M3 and M4 is greater than M1.
- The split tensile test showed that the highest split tensile strength after 28 days is observed in M2 whereas the lowest is observed in M4.
- Considering the strength factor, the above experimental investigation shows that it is very advisable to adopt M2 as the strength for M2 is relatively higher than other mixes.
- Unsurprisingly, M4 performs the poorest in terms of all the strengths mentioned above and it is not advisable to use.
- The optimum mix percentage is found to be 30%.
- The material can be used for all types of structures where normal concrete is used.

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BIOGRAPHIES

SABUNAM CHETTRI is a Civil Engineer from the Anna University. Her academic record is very impressive and good. She is very hard working and intelligent.

AAQIB FORDOUS is a Civil Engineer from the Anna University. His latest paper was "Design and analysis of 4 in 1 school complex" published in IRJET.