A Study on Recycling of Coarse Aggregate from Demolished Structures

R. Beaula Jasmine[1], S.Venkateswaran[2], N.Vimalraj[3], S.Prabavathi[4], V.Praveenkumar[5]

[1, 2, 3, 4] Assistant Professor, Department of Civil Engineering, Agni College of Technology, Chennai, Tamil Nadu, India

[5] P.G Student, Department of Civil Engineering, M.A.M College of Engineering, Trichy, Tamil Nadu, India

Email: [4] prabavathi905@gmail.com

Abstract

Technical journals and books of Designing Concrete mixes have been referred to get an idea to prepare the concrete mix design and planned to implement the idea in those concrete designs. M-30 grade concrete was chosen to process for the study. Generally, concrete structures get demolished due to natural and artificial calamities. Those demolished structures can be recycled to construct a new structure. Thus, it will be a very effective in saving the valuable construction materials otherwise wasted. The concrete with 25% of R.C.A. gives the maximum strength compared to other percentage of Recycled coarse aggregate but less than the concrete with Fresh coarse aggregate. Fresh coarse aggregate can be fully replaced with Recycled coarse aggregate in concrete works such as RC slabs, beams, etc., since the target strength for M-30 grade concrete is achieved. Since the compression strength achieved by M-30 grade concrete with 100% of Recycled coarse aggregate is equal to the compressive strength M-40 grade concrete, it can also be used where the M-40 grade concrete is in use.

Keywords: M-30 grade, Course Aggregate, Calamities, Recycled.

1. Introduction

Construction and demolition waste is generated whenever any construction/demolition activity takes place, such as, building roads, bridges, fly over, subway, remodeling etc. It consists mostly of inert and non-biodegradable material such as concrete, plaster, metal, wood, plastics etc.

In India it's common practice for large Construction and Demolition (C&D) projects to pile waste in the road, resulting in traffic congestion. C&D waste from individual households finds its way into nearby municipal bins and waste storage depots making the municipal waste heavy, and degrading its quality for treatments such as composting or energy recovery. Out of 48 million tonnes of solid waste generated in India, C&D waste makes up 25% annually, i.e. 12 to 14.7 million tonnes of waste annually.

Concrete is widely used for making architectural structures, foundations, brick/block walls, pavements, bridges/overpasses, motorways/roadways, runways, parking structures, dams, pools/reservoirs, pipes, footings for gates, fences and poles and even boats. Concrete has relatively high compressive strength, but much lower tensile strength. For this reason is usually reinforced with materials that are strong in tension (often steel). Structures made of

concrete can have a long service life. As concrete has a high thermal mass and very low permeability, it can make for energy efficient housing.

1.2 Scope

Construction and demolition waste in India is approximately 12 to 14.7 million tonnes per annum. So by recycling or reusing the demolition waste, we can:

i. Reduce the demand up on new resources;
ii. Cut down the cost and effort of transport and production of coarse aggregate;
iii. Use concrete waste from construction sites which would otherwise be lost to landfill sites; and Concrete wastes can be reused for laying concrete roads and construction of RC structures.

1.3 Objective

The main objectives of this project are:

i. compare properties of fresh coarse aggregate and recycled coarse aggregate;
ii. determine and compare compressive strength of concrete with partially and fully replaced recycled coarse aggregate with fresh coarse aggregate; and
iii. reduce environmental impact of concrete, as concrete is a major contributor to green house gas emissions.

1.4 Reasons for Demolishing a Structure

There are many reasons for structures being demolished; few of them are listed below:

1.4.1 Collapse of structure due to natural/artificial disasters

RC structures like buildings, bridges, etc. may get damaged due to natural disasters like earthquake, tsunami, etc. and also due to artificial disasters such as terrorist attacks, fire accidents, etc.

Violating CMDA rules

Buildings violating CMDA rules are demolished as per law. The violations may be construction of extra floors than permitted, no proper ventilation in commercial complex, and no provision of emergency exit in commercial complex, etc.

Land acquisition for government projects

The structures present in the land acquired by government for various government projects like construction of bridges, widening of roads, laying of railway lines are demolished.

Reconstruction

Now a days reconstruction is more prevalent due to emerging needs of the owner. So, the owner demolishes the old building and constructs a new one at the same site as per his/her present requirements.

Changes in plan of an ongoing construction project

Due to some unavoidable reasons if a need of changing the plan of ongoing construction project arises, structure would be demolished. This type of demolition occurs at a rare case.

1.5 Advantages of RCA

Fig. 1.1 Normal(Fresh) coarse aggregate vs Recycled coarse aggregate

i. Higher yield – recycled aggregates are lighter weight per unit of volume, which means less weight per cubic yard, resulting in reduced material costs, haul costs and overall project costs;
ii. Minimization of environmental impacts in an Urban Quarry setting;
iii. Offers a way to reduce landfill waste streams;
iv. Weighs ten to fifteen percent (10% - 15%) less than comparable virgin quarry products;
v. Provides for superior compaction and constructability;
vi. Avoid Haul-off costs; and
vii. Minimize impacts to community infrastructure.

2. Experimental Methodology

This chapter deals with the materials used in this project, concrete crushing machine to separate out coarse aggregate from concrete, test on material used, mix design, material quantity used and compression tests on concrete.

2.1 Materials Used

2.1.1. Concrete

Concrete is a composite construction material composed primarily of cement, aggregates and water.

2.1.2. Cement

Ordinary Portland cement or rapid hardening Portland cement confirming to IS: 269-1989 and IS: 8041-1990 shall be used. The initial setting time shall not be less than 30 minutes and the final setting time shall not be less than 10 hours. The average compressive strength of 1:3 cement mortar cubes after 7 days curing shall be not less than 53 MPa (53 grade).

2.1.3. Aggregate

Aggregates are inert granular materials such as sand, gravel or crushed stone that, along with water and Portland cement, are an essential ingredient in concrete. For good concrete mix, aggregates need to be clean, hard, strong particles free of absorbed chemicals or coatings of clay and other fine materials that could cause the deterioration of concrete.

Aggregates which accounts for 60% to 75% of the total volume of concrete are divided into two distinct categories:

(i) Fine aggregates

Fine aggregates generally consist of natural sand or crushed stone. Medium and fine sand are to be used in mortars. The properties of fine aggregate shall be in accordance with the requirements of IS: 383-1970.

(ii) Coarse aggregates

The aggregates to be used in reinforced cement concrete shall be for blue granite stone, machine crushed and well graded with a normal size of 20mm. The compressive strength, crushing value, etc. of the aggregate shall be in accordance with the requirements of IS: 383-1970.

Recycled concrete aggregates

Recycled concrete may also be used for partial or full replacement of coarse aggregates in concrete. Recycled concrete aggregate processing consists of crushing the demolished RC structures, screening and washing the crushed aggregate to obtain proper cleanliness and gradation. If necessary, a benefaction process such as jigging or heavy media separation can be used to upgrade the quality.

2.1.4. Water

Combining water with the cement material forms a cement paste. Water used for mixing and curing concrete shall be clean and free from injurious amounts of oil, acids, alkalis, salts, sugar, organic materials or other substances that may be deleterious to concrete or steel. Potable water may be used for mixing concrete. The suspended organic solid matter in the water shall not exceed 200mg/l and organic matter shall not exceed 3000kg/l. The pH value of water shall be not less than 6. Water used for curing should not produce any objectionable strain or unsightly deposit on the concrete surface. The presence of tannic acid or iron compounds in the water is objectionable.

2.2 MIX Design

Concrete MIX Proportioning (As per is-10262:2009)

i. Stipulations for Proportions

1.	Grade designation	:	M-30
2.	Type of cement	:	OPC-53 Grade
3.	Maximum nominal size of aggregate	:	20 mm
4.	Minimum cement content	:	320 kg/m^3
5.	Maximum water-cement ratio	:	0.5
6.	Workability	:	25 mm(slump)
7.	Degree of supervision	:	Good
8.	Type of aggregate	:	Crushed granular Aggregate
9.	Maximum cement content	:	420 kg/m^3
10.	Chemical admixture	:	Nil

ii. Test Data For Materials

1. Cement used : OPC-53 Grade confirming to IS-12269
2. Specific gravity of cement : 3.15.
3. Specific gravity of
   a) Coarse aggregate (Fresh) = 2.70.
   b) Fine aggregate = 2.65.
4. Water absorption:
   a) Coarse aggregate (Fresh) = 1.0%
   b) Fine aggregate = 1.0%
5. Free surface Moisture:
   a) Coarse aggregate (Fresh) = Nil
   b) Fine aggregate = Nil
6. Sieve Analysis:
   a) Coarse Aggregate:

Table 2.1 Grading Of Coarse Aggregate

IS Sieve Size (mm)	Analysis Of C.A. Fraction			Percentage Of Different Fractions		
	I	II	Combined	I	II	Combined
40	100	100	100	60	40	100
20	100	100	100	60	40	100
12.5	2	100	40	1.2	40	41.2
10	0	3	0	0	1.2	1.2
4.75	0	0	0	0	0	0

Thus we adopt coarse aggregate grading as 60:40(i.e. 20 mm: 12.5 mm)

   b) Fine Aggregate:

Conforming to zone-II of table 4 of IS-383.

iii. Target Strength for Mix Proportioning

$f'_{ck} = f_{ck} + 1.65\ S$ Where,

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 (S = 5).

Therefore, Target Strength = 30 + (1.65×5)

= 38.25 MPa.

[According to **MORTH** Specification (4^{th} Revision) Table 1700-1, The specified characteristic compressive strength of 150 mm cube at 28 days for M-30 grade concrete = 30 MPa But, from Table 1700-5, Target Mean strength of M30 grade concrete = **42 MPa**]

Table 2.2 Material Required for Compression Test (per cube)

S.No.	Percentage of Coarse Aggregate Replaced	Weight of Cement	Weight of Sand	Weight of Fresh Coarse Aggregate	Weight of Recycled Coarse Aggregate	Quantity of Water
	%	Kg	Kg	kg	kg	ml
1.	0	1.68	2.64	4.59	-	832
2.	25	1.68	2.64	3.4425	1.1475	844
3.	50	1.68	2.64	2.295	2.295	855
4.	75	1.68	2.64	1.1475	3.4425	867
5.	100	1.68	2.64	-	4.59	879
	TOTAL	**8.40**	**13.20**	**11.475**	**11.475**	**4277**

2.3 Observation-Compression Test

Table 2.3 Compressive Strength of M-30 Grade Concrete With 100% Fresh Coarse Aggregate

Cube No.	Period of Curing	Ultimate Load "P"	Compressive Strength "f_c = P/A"	Average Compressive Strength "f_c"	% Strength Achieved in Target Strength
-	-	N	MPa	MPa	%
1	7 days	780000	34.67	34.67	82.54
2		760000	33.78		
3		800000	35.56		
4	14 days	890000	39.56	39.85	94.88
5		900000	40.00		
6		900000	40.00		
7	28 days	1050000	46.67	46.23	>100
8		1030000	45.78		
9		1040000	46.22		

Table 2.4 Compressive Strength of M-30 Grade Concrete When Coarse Aggregate Is Replaced By 25% RCA

Cube No.	Period of Curing	Ultimate Load "P"	Compressive Strength "f_c = P/A"	Average Compressive Strength "f_c"	% Strength Achieved in Target Strength
-	-	N	MPa	MPa	%
1	7 days	770000	34.22	33.93	80.79
2		760000	33.78		
3		770000	34.22		
4	14 days	870000	38.67	38.96	92.76
5		880000	39.11		
6		880000	39.11		
7	28 days	1030000	45.78	45.48	>100
8		1020000	45.33		
9		1020000	45.33		

Table 2.5 Compressive Strength of M-30 Grade Concrete When Coarse Aggregate is Replaced by 50% RCA

Cube No.	Period of Curing	Ultimate Load "P"	Compressive Strength "f_c = P/A"	Average Compressive Strength "f_c"	% Strength Achieved in Target Strength
-	-	N	MPa	MPa	%
1	7 days	760000	33.78	33.63	80.07
2		770000	34.22		
3		740000	32.89		
4	14 days	850000	37.78	38.07	90.64
5		860000	38.22		
6		860000	38.22		
7	28 days	1020000	45.33	44.88	>100
8		1010000	44.88		
9		1000000	44.44		

Table 2.6 Compressive Strength of M-30 Grade Concrete When Coarse Aggregate is Replaced by 75% RCA

Cube No.	Period of Curing	Ultimate Load "P"	Compressive Strength "f_c = P/A"	Average Compressive Strength "f_c"	% Strength Achieved in Target Strength
-	-	N	MPa	MPa	%
1	7 days	750000	33.33	33.33	79.36
2		760000	33.78		
3		740000	32.89		
4	14 days	845000	37.56	37.85	90.12
5		855000	38.00		
6		855000	38.00		
7	28 days	1000000	44.44	44.29	>100
8		990000	44.00		
9		1000000	44.44		

Table 2.7 Compressive Strength of M-30 Grade Concrete When Coarse Aggregate is Replaced by 100% RCA

Cube No.	Period Of Curing	Ultimate Load "P"	Compressive Strength "f_c = P/A"	Average Compressive Strength "f_c"	% Strength Achieved in Target Strength
-	-	N	MPa	MPa	%
1	7 days	740000	32.89	33.18	79.00
2		750000	33.33		
3		750000	33.33		
4	14 days	840000	37.33	37.63	89.59
5		850000	37.78		
6		850000	37.78		
7	28 days	990000	44.00	43.85	>100
8		980000	43.56		
9		990000	44.00		

3. Result and Discussion

In this chapter the results for test on materials, compressive strength of concrete cube with fresh coarse aggregate and partially& fully replaced with recycled coarse aggregate were separately studied and compared.

3.1. Results of Tests on Materials

3.1.1. Tests on cement

3.1.1.1.Fineness of Cement:

The fineness of cement by dry sieving method is 99.1%

3.1.1.2.Consistency of Cement:

The amount of water as a percentage of the weight of dry cement is 31%.

3.1.1.3.Initial and Final setting time of Cement:

The Initial and Final setting time of OPC 53 Grade cement are 120minutes and 345 minutes respectively.

3.1.1.4.Specific gravity of Cement:

Specific gravity of a sample of cement = 3.15.

3.1.1.5.Compression Strength of mortar cube:

The average compression strength of mortar cubes at their respective curing period are tabulated below,

Table 3.1 Compressive strength of cement mortar cube

S. No.	Period of curing	Average comp. Strength
1.	3 DAYS	33.53 MPa
2.	7 DAYS	43.59 MPa
3.	28 DAYS	62.37 MPa

3.1.2. Tests on fine aggregate

3.1.2.1.Sieve Analysis:

The fineness modulus of fine aggregate is 3.86, on comparing the above result with Table IS-383, we confirm that the sand belongs to Zone-II.

3.1.2.2.Specific Gravity of Fine Aggregate:

The Specific gravity of Fine Aggregate sample is 2.65.

3.1.2.3.Water absorption Test:

Water absorption of given fine aggregate is 1.0%

3.1.3. Tests on coarse aggregate

3.1.3.1.Sieve Analysis:

The fineness modulus of coarse aggregate is 2.60, on comparing the above result with Table IS-383, we confirm that the coarse aggregate belongs to Zone-II.

3.1.3.2.Specific Gravity of Coarse Aggregate:

Specific gravity of a sample of Fresh C.A. = 2.70. Specific gravity of a sample of Recycled C.A. = 2.27.

3.1.3.3.Water absorption Test:

Fresh Coarse Aggregate (F.C.A.) is 1.00% Recycled Coarse Aggregate (R.C.A.) is 2.02%.

3.1.3.4.Impact & Crushing value of Coarse Aggregate: Fresh coarse aggregate is 24.43% Recycled Coarse aggregate is 27.11%

3.2. Compressive Strength of Concrete Cubes

The results below are the average Compressive Strength of M-30 grade concrete cubes at 28 days:

Table 3.2 Compressive Strength of M-30 grade concrete at 28 days

S.No.	Percentage of Fresh Coarse Aggregate Replaced with Recycled Coarse Aggregate	Compressive Strength of Concrete Cube at 28 days
1.	With 100% FCA	46.23 MPa
2.	25% RCA	45.48 MPa
3.	50% RCA	44.88 MPa
4.	75% RCA	44.29 MPa
5.	100% RCA	43.85 MPa

3.3. Comparison between FCA & RCA

3.3.1. Properties of aggregate

Table 3.3 Properties of FCA and RCA

S.No.	Properties of Coarse Aggregate	Fresh Coarse Aggregate (F.C.A.)	Recycled Coarse Aggregate (R.C.A.)
1.	Specific Gravity	2.70	2.27
2.	Water Absorption	1.00 %	2.02 %
3.	Impact Value	24.43 %	27.11 %

The figures below refer to the properties of FCA vs RCA.

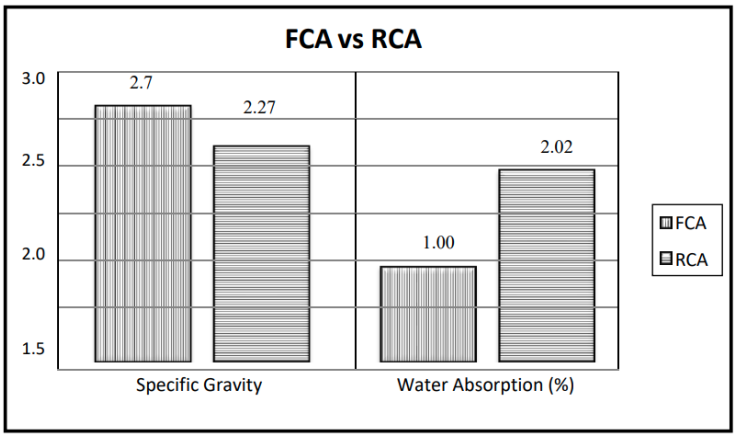

Fig. 3.1 Comparison of Specific Gravity and Water Absorption of FCA and RCA

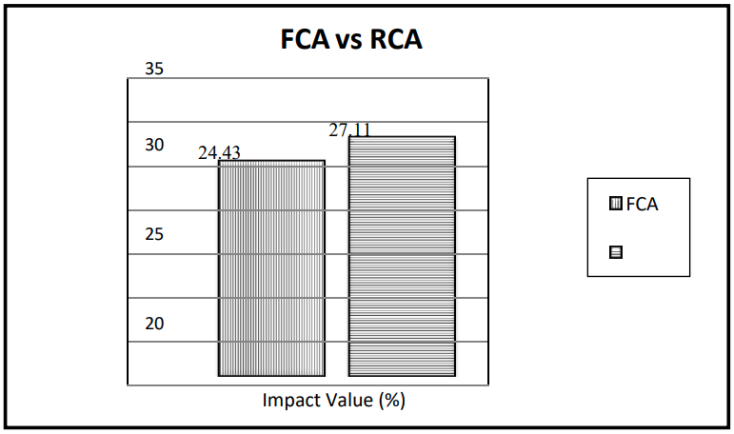

Fig. 3.2 Comparison of Impact Value of FCA and RCA

3.3.2. Compressive strength of concrete cubes with F.C.A and R.C.A.

Table 3.4 Compressive Strength of M-30 grade concrete at 7 days, 14 days and 28 days

S.No.	Percentage Of Fresh Coarse Aggregate Replaced with Recycled Coarse Aggregate	Compressive Strength Of Concrete Cube at		
		7 days	14 days	28 days
		(MPa)		
1.	With 100% FCA	34.67	39.85	46.23
2.	25% RCA	33.93	38.96	45.48
3.	50% RCA	33.63	38.07	44.88
4.	75% RCA	33.33	37.85	44.29
5.	100% RCA	33.18	37.63	43.85

The figures below refers to the comparison between compressive strength of M30 grade concrete with varying percentages of RCA (Ref. Fig. 4.3 – 4.5).

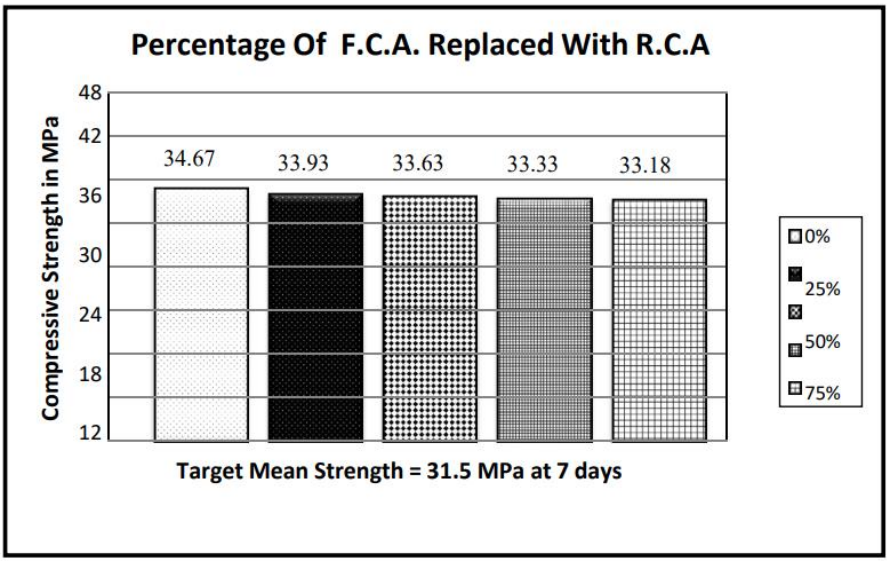

Fig. 3.3 Comparison of Compressive Strength of Concrete cube with FCA and RCA at 7 days

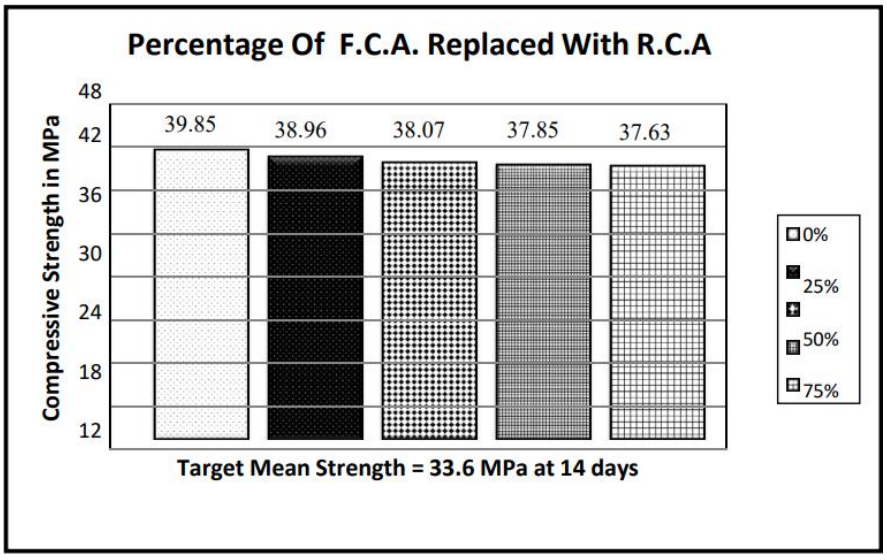

Fig. 3.4 Comparison of Compressive Strength of Concrete cube with FCA and RCA at 14 days

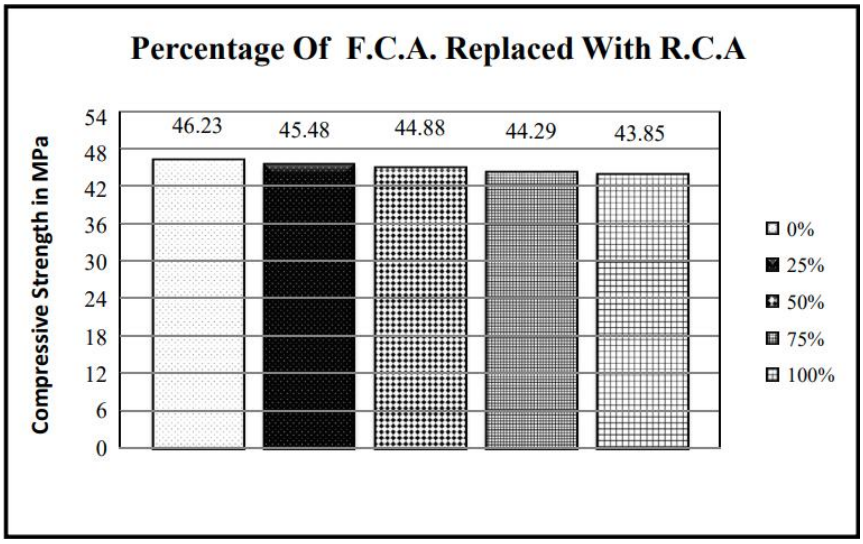

Fig. 3.5 Comparison of Compressive Strength of Concrete cube with FCA and RCA at 28 days

4. Conclusion

Based on the experimental investigation on the compressive strength of concrete, the following conclusions are arrived:

i. The concrete with 25% of R.C.A. gives the maximum strength compared to other percentage of Recycled coarse aggregate but less than the concrete with Fresh coarse aggregate.

ii. Fresh coarse aggregate can be fully replaced with Recycled coarse aggregate in concrete works such as RC slabs, beams, etc., since the target strength for M-30 grade concrete is achieved.

iii. Since the compression strength achieved by M-30 grade concrete with 100% of Recycled coarse aggregate is equal to the compressive strength M-40 grade concrete, it can also be used where the M-40 grade concrete is in use.

Reference

1. **Abdullah Yasar, Amtul Bari Tabinda.,** "Anaerobic treatment of industrial wastewater by UASB reactor integrated with chemical oxidation processes, an overview", polish J. of Environ. Stud, vol.19, No.5 (2010), 1051-1061.
2. ***Aeslina Abdul Kadar, Abbas Mohajerani (2004)*** **"Bricks**: an excellent building material for recycling wastes – a review"sludge from sewage treatment plant, sludge from paper industry, tannery sludge, iron and arsenic sludge and sludge ash.
3. **Amit Dhir., et al.,** "Design of an anaerobic digester for wastewater treatment", international journal of advanced research in engineering and applied science., vol 1., No 5 (2012)`
4. **AmmaraHaidera, Sher Jamal Khana, Muhammad Saqib Nawazb, Muhammad Usman Saleema**, Effect of intermittent operation of lab-scale upflow anaerobic sludge blanket (UASB) reactor on textile wastewater treatment, Desalination and Water Treatment, 136 (2018), pages 120–130.
5. **Anna KWARCIAK-KOZLOWASKA, et al.,** "The application of UASB reactor in meat industry wastewater treatment" (2011).

6. **British standards, 1955.** Concrete Flooring Tiles and Fittings, BSI (1197:1955), UKBureau of Indian Standard, 1979. Method of Testing for Cement Masonry Units-Hollow blocks and Solid blocks IS: 2185(part-1).BIS, New Delhi, India.
7. **Bureau of Indian Standard, 1979.** Specification for Common Burnt Clay Building Bricks, IS: 1077, BIS, New Delhi, India.
8. **Bureau of Indian Standard, 2000.** Code Practice for Plain and Cement Concrete, IS: 456. BIS, New Delhi, India.
9. **Concrete – P. Mehta,** Paulo Monteiro.
10. **Concrete Technology** – A. M. Neville, J. J. Brooks.
11. **Concrete Technology** – M. S. Shetty.
12. **Design of Concrete mixes** – N. Krishna Raju.
13. **IS 10262:1982,** "Recommended Guidelines for Concrete Mix design", Bureau of Indian Standard, New Delhi.
14. **IS 2386:1963,** "Methods of Test for Aggregates for Concrete", Bureau of Indian Standard, New Delhi.
15. **IS 383:1970,** "Specification for Coarse aggregate and Fine aggregate from Natural Sources for Concrete", Bureau of Indian Standard, New Delhi.
16. **IS 4031:1988,** "Methods of physical tests for hydraulic cement", Bureau of Indian Standard, New Delhi.
17. **Specification for road and bridge works (4th revision)** - MORTH (Ministry of Road Transport and Highways).