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AN EXPERIMENTAL STUDY ON PERFORMANCE OF RECYCLED AGGREGATE IN HIGH GRADE CONCRETRE

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ABSTRACT

Aggregate is one of the main ingredients in producing concrete .the strength of the concrete produced is dependent on the properties of aggregate used. However, the construction industry is increasingly making higher demands of the material and is feared to accommodate the many requests at one time. Hence need for an alternative coarse aggregate arises. The aim for this project was to determine the strength characteristic of high strength structural concrete by using recycled coarse aggregate and treated recycled coarse aggregate which will give a better understanding on the properties of concrete with recycled aggregates and treated recycled aggregates. The scope of this project was to investigate the possibility of using low coast recycled coarse aggregates as an alternative material to coarse aggregate high strength concrete. The experimental investigation were carried out using detailed strength and durability related tests such as compressive strength test of cubes, split tensile strength test of cylinders, modulus of elasticity tests acid resistance test, test for saturated water absorption and porosity. The experimental investigation it was found that recycled coarse aggregate and treated recycled aggregate can be used for making high strength concrete. Mix design was carried out based on IS 10262:2009. Concrete cube specimens of 150 mm x 150 mm x 150 mm were casted for testing. In this study, performance of recycled high strength of concretes are examined and a comparison is done between the conventional concrete and the concrete containing Recycled Concrete Aggregate(RCA).

1. INTRODUCTION

In the world of construction, concrete like other materials is playing an important role in development. concrete is a composite material which is a mixture of cement, fine aggregate , coarse aggregate and water .The major constituents of which is natural aggregate such as gravel, sand, Alternatively, artificial aggregates such manufactured sand furnace slag, fly ash, expanded clay, broken bricks and steel may be used where appropriate. It possesses many advantages including low cost, general availability of raw material, adaptability, low energy requirement and utilization under different environmental conditions.The goal of sustainable construction is to reduce the environmental impact of a constructed facility over its lifetime. Concrete is the main material used in construction in the world. Due to increase in Construction and Demolition activities worldwide, the waste concrete after the destruction of any infrastructure is not used for any purpose which is totally loss in the economy of the country because natural resource are depleting day by day. The debris is also a major problem for municipal authorities to dispose of at particular location. It is most common practice in all over the world that most of the materials (paper, plastic, rubber, wood, concrete, etc) are being recycled to save the natural resources and environment.

water/cement ratio while maintaining high workability, to improve mechanical and structural properties of fresh and hardened concrete so as to make structural concrete as economical.

RECYCLED CONCRETE AGGREGATE

Recycled concrete aggregate, also known as RCA, is an extremely popular replacement for natural stone aggregates. RCA is usually made up of old concrete from sidewalks, pavements, curbing and building slabs. After being compiled the concrete is processed and screened, which includes crushing the concrete into smaller pieces. The screening process sizes the crushed concrete, and any leftover steel pieces are also removed by a magnet during the process as well. The final result is recycled concrete aggregate that is composed of high quality aggregates that make it perfect for new projects

2. MATERIAL COLLECTION

RECYCLING OF CONCRETE AND USE OF RCA

Recycling of concrete is a relatively simple process. It involves breaking, removing, and crushing existing concrete into a material with a specified size and quality. The quality of concrete with RCA is very dependent on the quality of the recycled material used. Reinforcing steel and other embedded items, if any, must be removed, and care must be taken to prevent contamination by other materials that can be troublesome, such as asphalt, soil and clay balls, chlorides, glass, gypsum board, sealants, paper, plaster, wood, and roofing materials.RCA is similar to RAP (reclaimed asphalt pavement) in that it provides many benefits. RCA is commonly used as a base layer for roads and highways. Using recycled concrete aggregate provides both financial and environmental benefits to consumers and contractors alike. RCA reduces the use of landfill space and it also cuts down on the use of raw materials. Another huge benefit of RCA is that it has excellent bearing strength, which provides an ideal foundation for asphalt.

a) Many types of general bulk fills
b) Bank protection
c) Base or fill for drainage structures
d) Road construction
e) Noise barriers and embankment

RESOURCE CONSERVATION

The following factors lead to the conservation of resources in construction:

a) **Reduced land disposal and dumping:** The use of recycled concrete pavement eliminates the development of waste stockpiles of concrete. Also, since recycled material can be used within the same metropolitan area, this can lead to a decrease in energy consumption from hauling and producing aggregate, and can help improve air quality through reduced transportation source emissions.
b) **Conservation of natural aggregate:** The supply of natural aggregate in many areas is becoming limited. In such areas, the use of recycled aggregate is beginning to serve as an environmentally friendly and economically viable solution. Many European countries have placed a tax on the use of virgin aggregates. This process is being used as an incentive to recycle aggregates. It is noted that

several areas have high tipping fees for disposal of RCA, this is done to control landfill usage thus increasing the reuse of RCA.

c) **Reduce impacts to the landscape:** The reuse of concrete demolition debris reduces unsightly stockpiles of concrete rubble, animal infestation of stockpiles, and an overall environmental improvement when re-used.
d) **Metal recovery:** The removal of metal, steel reinforcement, is an important step in the recycling process and can take place in several stages. Contractors usually remove continuous reinforcement on the grade, whereas dowel and tie bar removal is typically done at the plant. Most crushing plants have an electromagnet to catch steel moving along the conveyor belt between the primary and secondary crushers. Salvaged steel usually becomes the property of the crushing plant and is sold as scrap metal. Wire mesh steel generally found in reinforced concrete pipe retains a large quantity of bonded concrete and usually becomes waste.
e) **Defined as inert material in Solid Waste Regulations:** Generally in the states that use RCA the environmental regulatory agencies have reviewed the material, where it is to be used, and have deemed it inert. After all it really is just broken up concrete pavement being reused as aggregate base or PCC aggregate

ECONOMICAL ASPECTS

Use of recycled concrete aggregate (RCA) results in saving costs in the following ways:

a) **Reduction in transportation costs:** Substitution of new aggregate with recycled concrete aggregate can provide savings in the final cost of the project. It is a common practice in many places to crush the material on site. This process eliminates the transportation costs to import natural aggregates, lessens truck traffic on already congested highways.
b) **Reduction in disposal costs:** Disposal of concrete, rubble and other waste construction materials by dumping or burial is a less attractive and more expensive option. Reconstruction of urban streets and expressways results in an enormous amount of waste concrete, creating a massive disposal problem. Recycling can therefore alleviate some of these problems by savings in terms of material acquisition and disposal costs. Places with active recycling of RCA virtually use all that is being removed. Tipping fees are also aiding in crushing operations having a good supply of material.
c) **Overall project savings:** There may be considerable projects savings by using less natural aggregate and base material. Savings are induced from decreased hauling and disposal costs. An additional benefit is the recovery of the steel from the recycling process. Usually it becomes the property of the contractor, who may sell it as scrap metal. There is also potential for cost savings in many areas where aggregates are not locally available and have to be hauled long distances.

OBJECTIVE

The following are the main objectives of the study:

a) To study the physical and mechanical properties of Recycled Aggregate Concrete (RAC) & Treated Recycled Aggregate Concrete (TRAC) and to compare these properties with conventional concrete.
b) Reuse of construction waste materials and to reduce the burden on natural resources.
c) To find the most effective method of replacement of Natural Aggregate Concrete (NAC) with either Recycled Aggregate Concrete (RAC) or Treated Recycled Aggregate Concrete (TRAC).

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SCOPE

The scope of the project includes:

a) To evaluate the strength of Natural Aggregate Concrete (NAC), Recycled Aggregate Concrete (RAC) and Treated Recycled Aggregate Concrete (TRAC).
b) To check the suitability of Recycled Aggregate Concrete (RAC) in structural members.

Applications of various recycled material

Material	Wearin g	Base	Su b	Bac k	General Fill	Drainage	Land Scapin
Reclaimed Asphalt	✓						
RCC		✓	✓	✓	✓	✓	
Bricks/Tiles		✓	✓			✓	✓
Masonry Products		✓					
Sand		✓					
Green Waste							✓

3. MATERIAL PROPERTIY

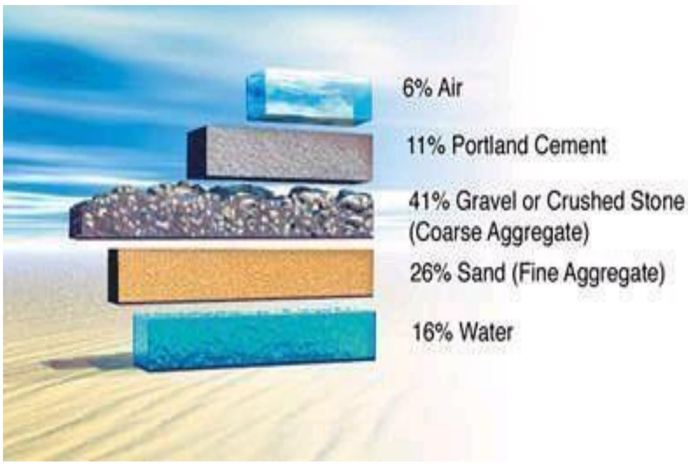

Fig.1. Basic components of concrete

MATERIALS USED IN THE PRESENT WORK

Ordinary Portland Cement (OPC):

Cement is a defined chemical entity formed from predetermined ratios of reactants at a fairly precise temperature. Ordinary Portland cement results from the calcinations of limestone and silica.

Limestone + Silica (1450 °C) = Portland Cement + Carbon dioxide

53 Grade OPC is a higher strength cement to meet the needs of the consumer for higher strength concrete. As per BIS requirements the minimum 28 days compressive strength of 53 Grade OPC should not be less than 53 MPa. For certain specialised works, such as pre-stressed concrete and certain items of precast concrete requiring consistently high strength concrete, the use of 53 grade OPC is found very useful. 53 grade OPC produces higher-grade concrete at very economical cement content. In concrete mix design, for concrete M- 20 and above grades a saving of 8 to 10 % of cement may be achieved with the use of 53 grade OPC.

Natural Fine Aggregate:

Natural or River sand are weathered and worn out particles of rocks and are of various grades or sizes depending upon the amount of wearing. Now-a-days good sand is not readily available; it is transported from a long distance. River sand generally passing the 4.75 mm IS sieve is used as natural fine aggregate in producing concrete.

Natural Coarse Aggregate:

Crushed stone/gravel of maximum 20 mm size is used as a natural coarse aggregate in producing concrete. Coarse aggregates are particles greater than 4.75mm, but generally range between 9.5mm to 37.5mm in diameter. They can either be from Primary, Secondary or Recycled sources. Primary, or 'virgin', aggregates are either Land- or Marine-Won. Gravel is a coarse marine-won aggregate; land-won coarse aggregates include gravel and crushed rock. Gravels constitute the majority of coarse aggregate used in concrete with crushed stone making up most of the remainder.

For a 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. Crushed aggregate is produced by crushing quarry rock, boulders, cobbles, or large-size gravel. After harvesting, aggregate is processed: crushed, screened, and washed to obtain proper cleanliness and gradation.

Potable Water:

Potable water available in SRM University is used for producing concrete. Almost any natural water that is drinkable and has no pronounced taste or odour may be used as mixing water for concrete. Excessive impurities in mixing water not only may affect setting time and concrete strength, but can also cause efflorescence, staining, corrosion of reinforcement, volume instability, and reduced durability. Concrete mixture specifications usually set limits on chlorides, sulphates, alkalis, and solids in mixing water unless tests can be performed to determine the effect the impurity has on the final concrete.

EXPERIMENTAL INVESTIGATION

Various tests were conducted to determine the properties of the materials used during the course of work and different experiments on fresh and hardened concrete to determine their strengths.

PRELIMINARY TESTS ON MATERIALS:

The following preliminary tests were done before using them in producing concrete:

Specific Gravity Test

The following procedure is used to determine the specific gravity of cement:

Weigh a clean and dry Le Chatelier Flask or specific gravity bottle with its stopper (W_1). Place a sample of cement up to half of the flask and weigh with its stopper (W_2). Add kerosene to cement in flask till it is about half full. Mix

Table1 Specific

$$\left(\frac{W_2 - W_1}{(W_2 - W_1) - (W_3 - W_4)}\right) X\ G_K = 3.05$$

The following procedure is adopted to calculate the specific gravity of the fine aggregate: Make and record all weight determinations to 0.1 g. Partially fill the pycnometer with water. Immediately introduce into the pycnometer 500 ± 10 g of saturated surface-dry fine aggregate prepared.

$$\left(\frac{W_2 - W_1}{(W_2 - W_1) - (W_3 - W_4)}\right) = 2.67$$

The following procedure is adopted to find the specific gravity of coarse aggregate as per IS 2386 (Part 3):

Fineness Modulus of Cement

The procedure followed to determine the fineness modulus of cement is: Weigh accurately 100g of cement and place it on a standard IS sieve of 90 micron. Breakdown any air set lumps in the sample with fingers but do not run them on the sieve. Continuously sieve the sample by holding the sieve in both hands and giving a gentle wrist motion or a mechanical sieve shaker may be used for this purpose. Weigh the residue left after 15 minutes of sieving; this residue shall not exceed the specified limits. Table shows the tabulated values for the fineness modulus of cement.

Sieve Analysis Test

The following test procedure is adopted for the sieve analysis of both fine and coarse aggregate: The sample is brought to an air- dry condition before weighing and sieving either by drying at room temperature or by heating at a temperature of 100 to 110 °C. The dried sample is weighed. The weighed sample is placed on the sieve and sieved successively on the appropriate sieves starting with the largest. Each sieve is shaken separately over a clean tray until not more than a trace passes, but in any case for a period of not less than 2 minutes. The Shaking is done with a varied motion, backward and anti-clockwise. Lumps of fine materials if present may be broken by gentle pressure with fingers against the side of the sieve. At the end of sieving, 150 microns and 75 micron sieves are cleaned from the bottom by light brushing with fine hair brush.

. MIX DESIGN FOR M30 GRADE CONCRETE

1. Design stipulation

a) Characteristic compressive strength: 30 N/mm^2

b) Max. Size of aggregates : 20 mm

c) Degree of workability : 0.90 (compacting factor)

d) Degree of quality control: good

e) Type of exposure : Moderate

2. Test data for materials

a) Cement used : OPC 53

b) Specific gravity of cement: 3.15

c) Specific gravity

i) Coarse aggregates : 2.63

ii) Fine aggregates : 2.67

d) Water absorption

i) Coarse aggregate : 0.5%

ii) Fine aggregates : 1%

3. Target mean strength of concrete $f_t = f_{ck} + 1.65S$

$= 38.25\ N/mm^2$

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Selection of water cement ratio From IS 456:2000, Table 5

Water cement ratio is 0.45

4.Selection of water and sand content

From IS 10262:1982, Table 3 for 20 mm size aggregates Volume of C.A for 0.45 w/c ratio = 0.61

Volume of F.A = 1 – 0.61 = 0.39

Required water content = 186 + (186 x 3/100) = 191.58 L

5. Determination of cement content W/C ratio = 0.45

Water = 191.58 L Cement = 425.73 kg/m^3 Say 426 > 320 kg/m^3

6. Determination of C.A and F.A For fine aggregates

= 719.17 kg/m^3

$$V = \left(W + \frac{C}{So} + \frac{1}{P}\, x \frac{fa}{Sfa}\right) x\ 1/1000$$

For coarse aggregates

$$V = \left(W + \frac{C}{So} + \frac{1}{1-P}\, x \frac{fc}{Sca}\right) x\ 1/1000 = 1124.85 \text{ kg/m}^3$$

7. Mix proportion for trial number 1 Cement = 426 kg/m^3

Water = 192 kg/m^3

F.A = 720 kg/m^3 C.A = 1125 kg/m^3 W/C Ratio = 0.45

8. Mix ratio

1 : 1.69 : 2.6

TESTS DONE ON FRESH CONCRETE

a) Slump Test

Observations of the slump test: Volume of the frustum = 0.00549 m^3 Cement content = 2.81 kg

F.A content = 4.75 kg

C.A content = 7.42 kg Water content = 1.26 L

Height of the frustum, h_1 = 30 cm

Height of the subsided concrete, h_2 = 27 cm Slump (h_1-h_2) = 3 cm

b) Compacting Factor Test

c) Procedure to determine workability of fresh concrete by compacting factor test is as follows:

d) Compacting factor = (Weight of partially compacted concrete) / (Weight of fully compacted concrete)

Observations and calculations:

Compaction Factor, C.F = $(W_2 – W_1) / (W_3 – W_1)$

= 0.85

Fig.2. Treated recycled concrete aggregate

COMPARISON OF PROPERTIES OF AGGREGATES USED

The properties of the aggregates are studied and compared in the table below:

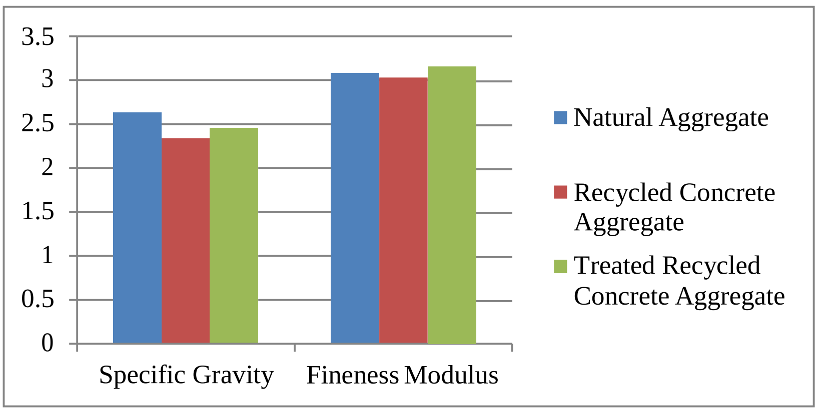

Fig.3. Comparison of specific gravity & fineness modulus of aggregates

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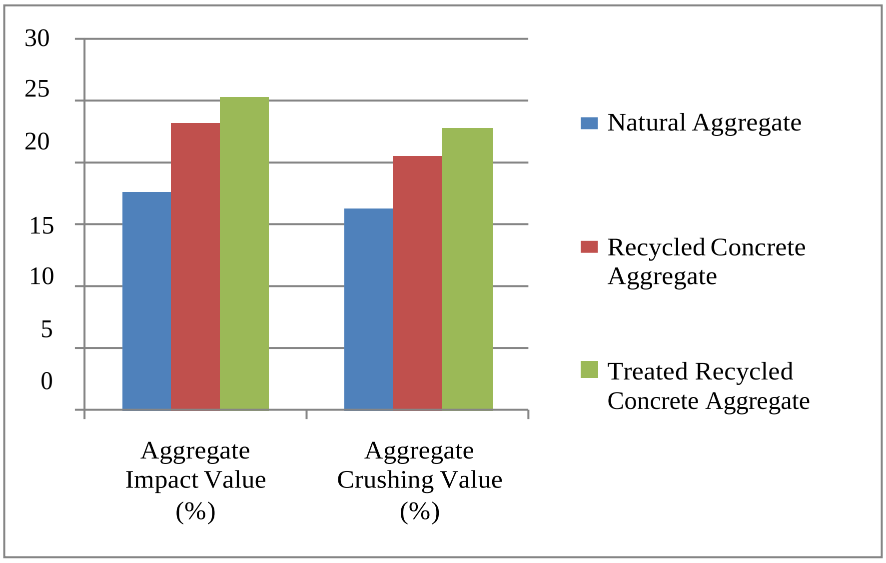

Fig.4. Comparison of aggregate impact value and aggregate crushing value of aggregates

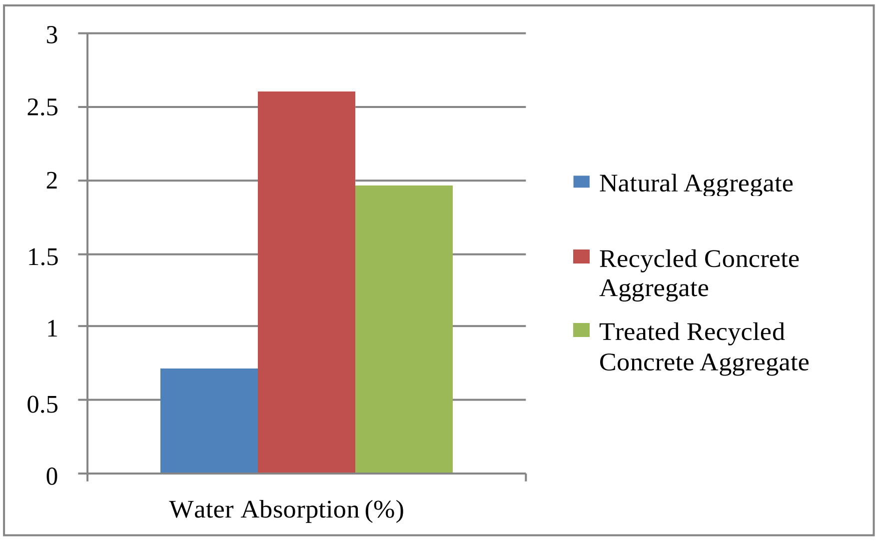

Fig.5. Comparison of water absorption of aggregates

COMPRESSION TEST ON HARDENED CONCRETE

The acceptance criteria of quality of concrete is laid down in IS:456-2000. The criteria are mandatory and various provisions of the code have to be complied before the quality of concrete is accepted. In all the cases, the 28-days compressive strength shall alone be the criterion for acceptance or rejection of the concrete. In order to get a relatively quicker idea of the quality of concrete, optional test for 7 days compressive strength of concrete be carried out. 9 Cubes of 150 x 150 x 150 mm size shall be cast, 3 for 7-days testing, 3 for 14-days testing and 3 for 28-days testing. A set of 3 cubes (specimen) average strength will be asample.

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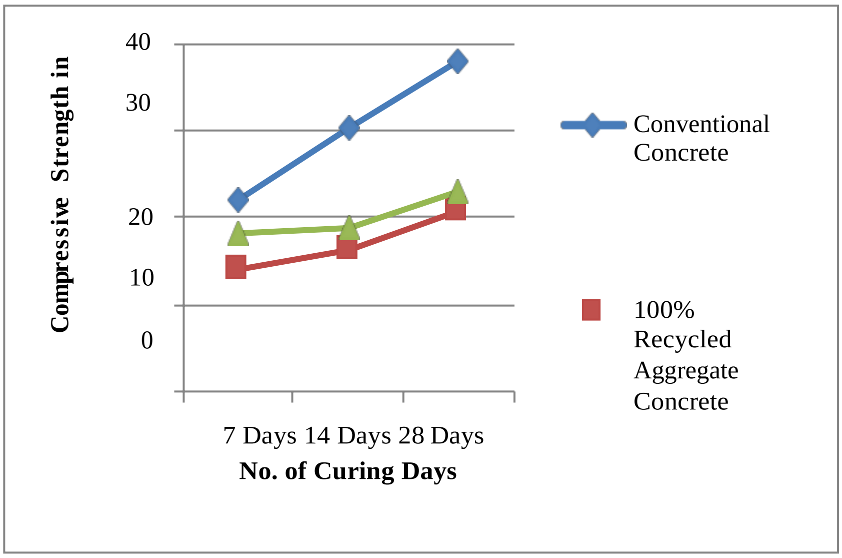
Split tensile strength of concrete cylinders of M30 grade containing 100% TRCA

Split Tensile Strength (N/m2	Curing don	Specimen			Average Val
		Cylinde	Cylinde	Cylinde	
	7	1.54	1.57	1.49	1.53
	14	2.28	2.31	2.35	2.31
	28	3.48	3.57	3.54	3.53

RESULT

The Specific gravity and Fineness modulus of cement, fine aggregate and coarse aggregate lie well within the specified range as per IS codes. The compressive strength and split tensile strength of M30 conventional concrete cubes and cylinders are recorded. RCAs are collected from a specific source and crushed to the required size before use. The RCAs are treated with a paste of fly ash and cement. The compressive strength and split tensile strength of M30 concrete cubes containing 25%, 50%, 75% & 100% Recycled Concrete Aggregate (RCA) and Treated Recycled Concrete Aggregate (TRCA) is recorded. The property tests on recycled concrete aggregate and treated recycled concrete aggregate such as specific gravity, fineness modulus, water absorption, aggregate impact value and aggregate crushing value are conducted. The test results are presented in this chapter for comparison and discussion in the following sections.



Compressive strength comparison between conventional and 100% replaced RAC & TRAC

CONCLUSION

The preliminary test results of the constituent materials confine as per the IS codes and therefore the same materials are used throughout the project. The property tests on recycled concrete aggregate and treated recycled concrete aggregate indicate that the properties of the recycled aggregate tend to improve slightly after the treatment process. A study is done on the effect of using various percentages of both recycled concrete aggregate and treated recycled concrete aggregate in the production of concrete. The replacement percentages used in the study are 25%, 50%, 75% and 100%. These results are then compared with the conventional concrete. It is noted that the compressive and split tensile strengths of concrete has a trend in reduction with increasing percentages of Recycled Concrete Aggregate (RCA) whereas after treatment of the Recycled Concrete Aggregate (RCA) the strengths seem to increase in comparison to Recycled Aggregate Concrete. It is observed that the compressive strength of 30 N/mm^2 can be achieved till a replacement percentage of 75 both with and without treatment, though higher strength is achieved in case of Treated Recycled Aggregate Concrete (TRAC). Recycling Waste Concrete Aggregates (WCAs) in concrete production may help solve a vital environmental issue apart from being a solution to the problem of inadequate natural aggregates in concrete. Recycled aggregates are the materials for the future and hence further research in this field is essential for environmental protection.

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