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TERNARY BLENDED SELF COMPACTING CONCRETE USING RECYCLED AGGREGATE

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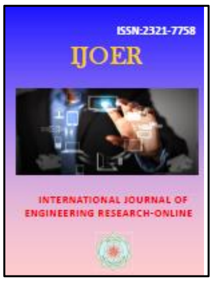

ABSTRACT
Concrete is the most widely used construction material. Inadequate compaction of concrete results in large number of voids, concrete pouring and compaction on structural element with dense reinforcement and beam column joint are difficult. Self-compacting concrete (SCC) provides a solution to these problems. SCC is new type of concrete that has flow ability, filling ability, passing ability and stability. Coarse aggregate is one of the factor that will have a significant influence on SCC. The use of recycled coarse aggregate (RCA) in any concrete is an effort of recycle waste and new development in environmental friendly concrete. Ternary blended concrete (TBC) improves strength, durability and also it is ecofriendly in nature.
In this research ternary blended SCC of 50 grade is designed by replacing natural coarse aggregate with recycled aggregate from roof slab of 25years old. The % replacements are 0, 25, 50, 75 and 100. Also, the cement is partially replaced with 10% Metakaolin by weight of binder. Super-plasticizer is added at a dosage of 1.0%, by cement weight, to achieve the flow characteristic of SCC. Tests on flow characteristics are conducted on fresh concrete for all trail mixes. The mix that has the large slump flow is tested with V-funnel and L-box and the results are presented. Further the compressive strength, split tensile strength and flexural strength are conducted at the age of 7days, 28days and 56days for SCC50 grade of concrete .The results indicated that the compressive strength of 25% and 50% replaced recycled aggregate Self compacting concrete is nearly equal to natural aggregate Self Compacting Concrete at 7, 28, 56 days age of concrete. The split tensile and flexural strength of 25% replaced recycled aggregate Self compacting concrete is nearly equal to 6 Natural aggregate Self Compacting Concrete at respective age of concrete. At all ages Flexural strength shown decrease in trends with the increase in replacement of recycled aggregate. From the research work keeping economy, eco-friendliness and compressive strength in point of view convectional aggregate can be replaced with recycle aggregate concrete by 50% in ternary blended self-compacting concrete.
The present project deals with the study and comparison of mechanical properties, permeability and durability properties of different grades of pervious concrete (M15,M20,M25).

1. INTRODUCTION

1.1 GENERAL

Concrete Technology has made a colossal step in the previous decade. Concrete is presently no more a material comprising of cement, aggregate, water and admixtures yet it is a designed material with a few new constituents performing satisfactorily under diverse conditions. Concrete today can be perfectly customized for various applications and it contains distinctive materials like metakaolin, micro silica and numerous different folios, fillers and pozzolanic materials. The improvement of deciding a concrete as indicated by its execution wants rather than the constituents and fixings has opened myriad open doors for manufacturers and shoppers to set up concrete to suit to their explicit conditions. The sort of concrete that is intended to a particular application is known as high performance concrete (HPC). HPC can be defined as "concrete that meets exceptional execution and consistency necessities that can't generally be acquired by utilizing customary ingredients, typical blending technique and curing practices."

1.2 SELF-COMPACTING CONCRETE (SCC)

Self-Compacting Concrete (SCC) because the name implies, ought to have the capacity to compact itself with no additional vibration or compaction i.e. without use of some other outside vitality. It ought to have the capacity to accept any form work shapes without depressions and entrapped air. The reinforcement ought to be adequately secured and the aggregate ought to be completely splashed with the concrete matrix. Likewise, the concrete ought to act naturally compacting type and self-distorting with no outside method of compaction.

SCC is **explicit** piece of HPC that separates itself with self – natural process properties with high flow capability. HPC finds exceptionally helpful application in the precast business in light of its prerequisites for high early strength and flow capacity. Use of plasticizers, super plasticizers and pozzolanic materials has a gigantic impact on concrete innovation and its advantages thusly sifted down to precast industry. Numerous mechanical improvements have given incremental advances in the design and placement of concrete in structures. In this, the most critical advancement is self-compacting cement (SCC). Thus, SCC will be the future of concrete technology. The principle of SCC is not new. The high contents of cement paste will lead to shrinkage and high heat generation which increases the overall cost and its applications stayed more. This prompted the improvement of admixtures, which filled the need of delivering SCC as simple one. The admixtures consists of high vary Water Reducing Agents (WRA) and consistence Modifying Agents (VMA) to enhance workability.

1.3 SUPPLEMENTARY CEMENTITIOUS MATERIAL

With the loosely utilization of cement in concrete, there has been some natural issues as way as hurt brought on by the extraction of crude material and carbonic acid gas (CO_2) emanation amid cement manufacture. This has brought pressures to diminish the concrete utilization in concrete industry. In the meanwhile, there are becoming additional wants for improvement in concrete sturdiness to manage the dynamical atmosphere that is clearly not identical because the hobbies. With the advancement in concrete technology, supplementary cementations materials, otherwise called Admixtures, have been presented as substitutes for cement in concrete. A few sorts of materials are in like manner utilize, some of which are by-items from other industrial procedures, and thus their utilization may have monetary favourable circumstances. In any case, the fundamental purpose behind their utilization is that they can give an assortment of helpful upgrades or adjustments to the concrete properties.

1.4 METAKAOLIN

Metakaolin, by and large known as "calcined dirt", is a reactive alumina-silicate pozzolan formed by warming kaolinite at a particular temperature. Metakaolin is ordinarily created by calcinations of immaculate clays at fitting temperatures. Metakaolin is a chemical stage that structures upon thermal treatment of kaolinite. Kaolinite (Al_2O_3:$2SiO_2$. $2H_2O$) as an after effect of thermal treatment between 400-500°C, the water is headed out to form an amorphous alumina silicate called "metakaolin".

Metakaolin is white in shading and goes about as a pozzolanic material. It may respond with calcium hydroxide to form calcium silicate and calcium aluminates hydrates. The reactivity of the metakaolin might likewise be influenced by crushing to a better finer particle size. The virtue of the kaolin likewise influences the general colour and reactivity. As per IS: 3812-1981[1] the base measure of SiO_2, $Al2O_3$ and Fe_2O_3 that should be available in a class N pozzolan is 70%. In this manner a impure wellspring of kaolin may be utilized to result in a pozzolanic material that meets the IS: 3812-1981[9] prerequisites. The lower measure of siliceous and aluminous material will bring about a lesser reactivity, which may be further reduced by a coarse particle size. Likewise, the colour won't be white and relying upon the impure type and level may fluctuate bringing about a conflicting item.

Metakaolin as shown in Figure 1.1 has an average particle size of about 1.5 µm which lies in between silica fume (0.1 µm to 0.12 µm) and
Portland cement (15 µm to 20 µm).

Fig.1.1 Metakaolin particles

1.5 ECO-FRIENDLY CONCRETE

- The present research Ternary blended recycle coarse aggregate SCC an eco-friendly concrete
- In this we observe that recycled aggregate can be replace 50% of natural coarse aggregate
- The cost of the materials is reducing in this process
- The wastage of building material is reduced

2. MATERIALS

2.0 INTRODUCTION

The materials utilized as a part of the present study are cement, sand, NCA and RCA. Every one of these materials are tried in the research centre to set up their physical and mechanical properties according to the determination of Indian Standards. Different properties of the materials like pulverizing worth, effect quality, and scraped area estimation of totals have been tried. Solid Mix Design was completed for SCC50 evaluation solid according to the outline rules of IS 10262-1982 and Is 456 - 2000 The crisp and solidified properties of SCC, for example, compressive quality, flexural quality and split elasticity utilizing RCA were mulled over.

2.1 Ingredients Used and Their Properties

Different ingredients used in this work are

1. Portland slag Cement
2. Fine aggregate
3. Coarse aggregate
   - Normal coarse aggregate &
   - Recycled coarse aggregate
4. Metakaolin
5. Water
6. Super Plasticizer

Table 2.1: Specific gravity of cement

	DESCRIPTION	SAMPLE
a)	Weight of bottle (W_1) g	32
b)	Weight of bottle + 1/3 of cement (W_2)g	71
c)	Weight of bottle + cement + kerosene (W_3) g	105
d)	Weight of bottle + kerosene (W_4) g	82
e)	Weight of bottle filled with water (W_5)g	88
f)	Specific gravity of kerosene,	0.79
g)	Specific gravity of cement,	3.14

2.2.1 Aggregate Crushing Value [IS 2386 – 1963][26]

- Aggregates passing through 12.5mm and retained on 10mm IS Sieve were taken and oven-dried at a temperature of 100 to 110°C for 3hrs.
- The cylinder of the apparatus was filled in 3 layers; each layer tamped with 25 strokes with tamping rod.
- The weight of the aggregates was measured .
- The surface of the aggregates was then levelled and the plunger was inserted.
- The apparatus was then placed in the compression testing machine and loaded at a uniform rate so that it has attained a load of 40t in 10 minutes.
- The sample was then sieved through a 2.36mm IS Sieve and the
- fraction passing through the sieve was weighed

Aggregate Crushing Value

Weight of surface-dry sample =2700 grams.

Weight of fraction passing the appropriate sieve =
= 725 grams.

Aggregate Crushing value = (/) x100
= (725/2700) x100 = 26.85%.

3.1.3 Metakaolin

In this paper, the cement is replaced by the proportions of 10% by weight. The workability and compressive strength of self compacted concrete for varying proportions of recycled coarse aggregate are calculated.

2.1.3 Physical Properties of Metakaolin

Metakaolin is 99.9% finer than 16 µm, and has a mean particle size of 3 µm. Some physical properties of metakaolin as per IS: 3812-1981[1] are given in below table

Table 2.2: Physical Properties of Metakaolin

Property	Result
Appearance	Off-White
P^h (10% Solids)	4.5-5.5
Bulk Density(Kg/Lit)	0.4-0.5
Specific Surface Area m^2/g	19-20
Specific Gravity	2.6

2.1.4 Chemical Properties of Metakaolin

The major constituents of metakaolin are SiO_2 and Al_2O_3. Typical chemical composition is given in Table 4.4. Metakaolin must meet the requirements of IS: 3812-1981[1], Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use as a Mineral Admixture in Concrete, Class N, with the following modifications.

Table 2.3: Chemical Properties of Metakaolin

S.No	Item	Percentage By Weight	
1	Silicon dioxide (SiO_2)	60-65%	
2	Aluminium oxide (Al_2O_3)	30-34 %	
3	Iron oxide (Fe_2O_3)	1%	
4	Calcium oxide (CaO)	0.2	–0.8 %
5	Magnesium oxide (MgO)	0.2	– 0.8 %
6	Sodium oxide (Na_2O)	0.5	– 1.2 %
7	Potassium oxide (K_2O)	0.5	– 1.2 %

2.1.5 Super-plasticizer

One of the new generations of copolymer-based super plasticizer, designed for the Production of High Performance Concrete is used i.e., SP-430. The dosage used in the mix is 1.0% by weight of cement (cementitious material).

3. Methodology

3.0 INTRODUCTION

The outline of SCC is very surprising from streaming cement. The real trouble, which was confronted being developed of SCC, was because of conflicting components that the cement ought to be completely flowable yet without draining or isolation. It is subsequently obliged that the concrete and mortar of the SCC ought to have higher consistency to guarantee flowability while non-sedimentation of greater totals. Practically speaking, three sorts of Self-Compacting Concrete are accessible to meet the solid execution necessities.

3.1 BATCHING

It is the procedure of measuring solid blend fixings either by volume or by mass and bringing them into the blend. Customarily grouping is finished by volume yet most details oblige that bunching be finished by mass as opposed to volume. Rate of precision for estimation of solid materials is as per the following:

3.2 MIXING

3.2.1 Batch Mixing: The standard kind of blender is a clump blender, which implies that one cluster of cement is blended and released before any more materials are put into the blender. There are four sorts of group blender, we used continuous blender for this particular investigation.

3.2.2 Mixing time: It is critical to know the base blending time important to deliver a cement of uniform arrangement, and of dependable quality. The blending time or period ought to be measured from time all the solidifying materials and totals are in blender drum till taking out the cement. Blending time relies on upon the sort and size of blender, on the velocity of turn, and on the nature of mixing of fixings amid charging of the blender. For the most part, a blending time of under 1 to 1.25 minutes produces considerable non-consistency in organization and a critical lower quality; blending past 2 minutes causes no noteworthy change in these properties.

Table 3.1: Recommended minimum mixing times

Capacity of mixer (yd^3)	Mixing time (Minutes)
Up to 1	1
2	1.25
3	1.5
4	1.75
5	2
6	2.25
10	3.25

3.3 CURING

Curing is the procedure in which the cement is shielded from loss of dampness and kept inside of a sensible temperature range. The consequence of this procedure is expanded quality and diminished porousness. Curing is additionally a key player in moderating splits in the cement, which extremely affects strength. In this study the time of curing is 7days, 28days and 56days

Fig.4.1 : Curing of the concrete cubes

3.4 TESTING

SCC test systems have two principle purposes. To start with is to judge whether the cement is self-perfect or not and the second is to assess deformability or consistency for evaluating legitimate blend proportionality. Ordinary workability tests, concocted for typical scope of solid blend are not sufficient for SCC, in light of the fact that they are not sufficiently delicate to recognize the inclination to isolation. Accordingly test gear were manufactured for judging the accompanying attributes are Filling Ability, Passing Ability, Segregation Resistance.

3.4.1 Filling Ability:-

1. Slump Flow Test
2. V-Funnel Test
3. T_{50} Slump Flow

3.4.2 Passing Ability:-

1. L-Box Test
2. U-Box Test

3.4.3 Segregation Resistance:

1 V-Funnel T_{5min}

3 Mechanical Strength Parameters of CVC & SCC

3.5.1Compressive strength concrete: [IS 516-1959][27]

In most basic applications, cement is utilized fundamentally to oppose compressive quality. Much of the time where the quality in pressure or in shear is of essential significance, the compressive quality is every now and again utilized as an estimation of these properties.

3.5.2 Splitting Tensile Strength: [IS 516-1959][27a]

Concrete is not usually expected to resist direct tensile forces because of low tensile strength and brittle nature. However, tension is of important with regard to cracking, which is a tensile failure. Direct tension tests of concrete ar rarely created owing to difficulties in mounting the specimens and uncertainties on thesecondary stresses iatrogenic by holding devices. An indirect test for tensile strength of concrete has developed.

4. Mix Design

Nan su method[21]

This method has been followed to find the required quantities of all the ingredients. A brief procedure is given below along with required materials of SCC

1) Basic stipulations

a) Characteristic compressive strength of concrete:50 N/mm^2

b) Maximum size of aggregate:10mm (angular)

c) Degree of workability:0.8 CF

d) Type of Exposure;Mild

e) Degree of quality control:Good

2) Test data for materials

a) Cement used -Portland Slag Cement

Specific Gravity:3.14

b) Coarse and fine aggregate Specific Gravity of Coarse Aggregate: 2.8

Specific Gravity of Fine Aggregate:2.59

c) Water Absorption

Normal Coarse Aggregate : 0.4%

Recycled Coarse Aggregate:0.5%

Fine Aggregate:0.35%

d) Free Moisture

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Coarse Aggregate: Nill
Fine Aggregate: Nill
Therefore, the mix proportions of SCC mix were
483.571:865.3:773.78:170.5
1: 1.78 :1.59 : 0.34

5.RESULTS AND DISCUSSIONS

5.0 INTRODUCTION

Modern reinforced concrete structures with clumsy reinforcement are to be eco-friendly. With the increase in the use of recycled aggregate concrete (Eco friendly), the demand on recycled aggregate is escalating. The present chapter discuss the behaviour of recycled coarse aggregate SCC need to be clearly understood. In this chapter the physical and mechanical properties of recycled aggregates and concrete are presented.

5.1 CONCRETE FLOW: The results of workability tests are shown in Table 5.1. The results obtained are within the range of acceptance criteria of Self-Compacting Concrete according to EFNARC standards.

Table 5.1: Workability Results of fresh SCC

S.No	Method	Test Results
1	Slump flow, mm	685
2	T_{50} Slump flow, sec	5
3	V-Funnel, sec T5min	10 13
4	L-Box Test (H_2/H_1) H_1 (mm) H_2 (mm) H_2/H_1	 119 97 0.81

5.2 Compressive strength:

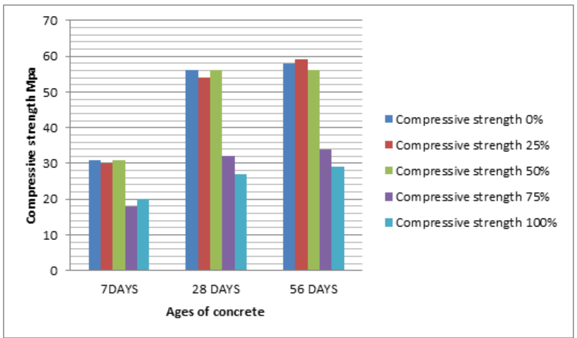

Figure 5.1 :Compressive strength of SCC50 grade concrete at all ages

Compressive strength (MPa) for SCC50 grade concrete is observed at 7, 28 & 56 days for different % replacement of RA(i.e. 0% , 25% , 50% , 75% , 100% respectively).

From the figure 5.1, at 7 days age , the compressive strength of 25% and 50% replaced recycled aggregate SCC is nearly equal to natural aggregate SCC. Strength is found to be decreased as the % replacement increased for 75% and 100% replacement. The decrease in strength is upto 50.45% for 75% replacement and 45.3% for 100% replacement.

From the figure 5.1, at 28 days age, the compressive strength of 25% and 50% replaced recycled aggregate SCC is nearly equal to natural aggregate SCC. Strength is found to be decreased as the % replacement increased for 75% and 100% replacement. The decrease in strength is upto 52.21% for 75% replacement and67.62% for 100% replacement.

From the figure 5.1, at 56 days age, the compressive strength of 25% and 50% replaced recycled aggregate SCC is nearly equal to natural aggregate SCC. Strength is found to be decreased as the % replacement increased for 75% and 100% replacement. The decrease in strength is upto 52.3% for 75% replacement and 65.57% for 100% replacement.

The strength of 75% and 100% replacement of RA decreases gradually when compare with 50% replacement at all ages. The percentage decreases in strength is within the range 50-65% at 75% and 100% replacement at all ages when compare with 0% replacement. The strength variation for 25% and 50% is very marginal (only 3%) where 50% replacement shown higher strengths at all ages . It is observed that normal aggregate can be replaced with recycled aggregate by 50% in the view of developing eco-friendly concrete.

5.3SPLIT TENSILE STRENGTH

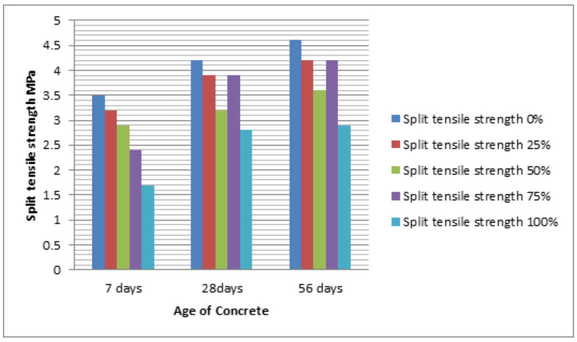

Fig.5.3: Split tensile strength of SCC50 grade

concrete at all ages with different % replacement of RA.

Split tensile strength (N/mm^2) for SCC50 grade concrete is observed at 7, 28 & 56 days for different % replacement of RA(i.e. 0% , 25% , 50% , 75% , 100% respectively).

From the figure 5.3, at 7 days age, the split tensile strength of 25% and 50% replaced recycled aggregate SCC is nearly equal to natural aggregate SCC. Strength is found to be decreased as the % replacement increased for 75% and 100% replacement. The decrease in strength is upto 35.29 % for 75% replacement and 62.2 for 100% replacement.

From the figure 5.3, at 28 days age, the split tensile strength of 25% and 50% replaced recycled aggregate SCC is nearly equal to natural aggregate SCC. Strength is found to be decreased as the % replacement increased for 75% and 100% replacement. The decrease in strength is upto 9.26 % for 75% replacement and 41% for 100% replacement.

From the figure 5.3, at 56 days age, the split tensile strength of 25% and 50% replaced recycled aggregate SCC is nearly equal to natural aggregate SCC. Strength is found to be decreased as the % replacement increased for 75% and 100% replacement. The decrease in strength is upto 10.7 % for 75% replacement and 43.4% for 100% replacement.

The strength of 75% and 100% replacement of RA decreases gradually when compare with 50% replacement at all ages. The percentage decreases in strength is within the range 45-62% at 75% and 100% replacement at all ages when compare with 0% replacement. The strength variation for25% and 50% is 15% where 75% replacement shown higher strengths at all ages.

5.4 Flexural STRENGTH OF SCC

Flexural strength (N/mm^2) for SCC50 grade concrete is observed at 7, 28 & 56 days for different % replacement of RA (i.e. 0% , 25% , 50% , 75% , 100% respectively).

From the figure 5.5, at 7 days age, the flexural strength of 25% replaced recycled aggregate SCC is nearly equal to natural aggregate SCC. Strength is found to be decreased as the % replacement increased. The decrease in strength is upto 20.82% for 75% replacement and 35.29 for 100% replacement.

From the figure 5.5, at 28 days age , the Flexural strength of 25% recycled aggregate SCC is nearly equal to natural aggregate SCC. Strength is found to be decreased as the % replacement increased. The decrease in strength is upto 17.24% for 75% replacement and 21.05% for 100% replacement.

5.5 Relation between compressive strength and split tensile strength

Table 5.2 Results of splitting tensile strength at 28days for all RA replacement percentages in TB SCC.

S.no	Percentage replacement	Split tensile strength (MPa)	Compressive Strength (MPa)	Estimated Split Tensile Strength (MPa) as per equations 1, 2 and 3		
1	0	4.19	54.2	4.12	4.94	4.67
2	25	3.76	54.6	4.13	4.96	4.70
3	50	3.30	55.7	4.18	5.01	4.79
4	75	3.95	32.3	3.18	3.72	3.01
5	100	2.32	28.4	2.98	3.46	2.71

The split tensile strength values obtained by the experimental work are lesser values when compared to theoretical values.

5.6 Relation between compressive strength and flexural strength

Table5.3: Results of flexural strength at 28days for all RA replacement percentages in TB SCC.

S.no	Percentage replacement	Flexural strength(MPa)	Compressive Strength(MPa)	Estimated flexural strength (MPa) as per equations 4 and 5	
1	0	4.78	54.2	5.15	5.92
2	25	5.04	54.6	5.17	5.97
3	50	5.09	55.7	5.22	6.09
4	75	4.02	32.3	3.97	3.52
5	100	3.69	28.4	3.73	3.09

The flexural strength values obtained by the experimental work are in between Equations 4 and 5. These values are nearly equal to CRRI equation.

6. CONCLUSIONS AND SCOPE

From the limited research work conducted the following conclusions are drawn

1. The compressive strength of 25% and 50% replaced recycled aggregate Self compacting concrete is nearly equal to natural aggregate Self Compacting Concrete at 7, 28 and 56 days age of concrete.
2. The decrease in strength is up to 50.45% for 75% replacement and 44.3% for 100% replacement for 7 days. And it is about 52.21% and 67% for 28days and 56days.
3. The compressive strength decreased beyond 50% with the increase in replacement percent of recycled coarse aggregate.
4. Up to 50% replacement of recycle coarse aggregate the compressive strength of the 7, 28, 56 days of recycled aggregate self compacting concrete achieved required compressive strength.
5. The split tensile strength of 25% replaced recycled aggregate Self compacting concrete is nearly equal to Natural aggregate Self Compacting Concrete at 7, 28, 56 days age of concrete.
6. At an age of 7, 28, 56 days split tensile strength of concrete decreased as the % replacement of recycled coarse aggregate increased.
7. The Flexural strength of 25% replaced recycled aggregate Self compacting concrete is nearly equal to Natural aggregate Self Compacting Concrete at 7, 28, 56 days age of concrete.
8. At all ages Flexural strength shown decrease in trends with the increase in replacement of recycled aggregate.
9. As the replacement of recycled aggregate increased beyond 50%, the strength improvement is not remarkable beyond 7days of age.
10. The obtained values shown slight deviations from the empirical values i.e., theoretical.
11. The split tensile and flexural strengths of Ternary blended self compacting recycled concrete is varies from conventional concrete and conventional self compacting concrete. Hence relation between the strength parameters should be established.

From the present research work, keeping economy, eco friendly and compressive strength in point of view, convectional aggregate can be replaced with recycle aggregate concrete by 50% in ternary blended self compacting concrete.

SCOPE

Scope of the thesis is followed below:

- Effect of different curing methods on mechanical properties like compressive strength, split tensile strength and flexural strength of Ternary Blended Recycle Coarse Aggregate Self Compacting Concrete can be studied.
- Durability studies like Temperature effects , Acid attacks of Ternary Blended Recycle Coarse Aggregate Self Compacting Concrete can be studied.
- Mechanical properties like compressive strength, split tensile strength and flexural strength of binary Blended Recycle Coarse Aggregate Self Compacting Concrete can be studied.
- Effect of different curing methods on mechanical properties like compressive strength, split tensile strength and flexural strength of Binary Blended Recycle Coarse Aggregate Self Compacting Concrete can be studied.
- Durability studies like Temperature effects , Acid attacks of Binary Blended Recycle Coarse Aggregate Self Compacting Concrete can be studied.

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