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Modifying Concrete Properties by Substituting Silica Fume for Portland Cement and Recycled Aggregate for Natural Aggregate

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ABSTRACT:

There are many thousands of years of tangible history. The Minoan civilization was determined to have utilized a material very close to concrete about 2000 B.C. Sometime about 300 B.C., when the Roman Empire was just getting started, its citizens discovered that by mixing sand from volcanic ash with lime mortar, they could create a durable, water-resistant substance they named concrete. The construction and demolition sectors generate a massive amount of solid waste annually. As a result, there has been a drive to increase recycling as a method of reducing construction's negative effect on the natural world. More than half of this garbage is made up of concrete. As a significant consumer of raw materials, the construction industry requires substantial inventories to sustain growth. India already generates around 23.75 million tons of construction and demolition (C & D) trash annually, and that quantity is projected to more than triple over the next seven years. Rich countries see construction and demolition debris, and concrete in particular, as a precious resource. Compressive strength of concrete of the second generation generated from recycled materials should be comparable to that of concrete of the first generation, according to studies of recyclability. The goal of this research was to analyze the effects of recycled concrete aggregates on the compressive strength of concrete using experimental means. In this piece, I perform an experimental study to determine the practicality of reusing demolition concrete in conjunction with cement as Silica fume in new construction.

I. INTRODUCTION

Depending on the specific conditions, fine and coarse particles are mixed with water to form concrete, which then hardens. Many varieties of structural elements are built using concrete. Research into alternative materials for use in concrete has increased significantly in recent years. These materials include chemicals, fibers, agricultural wastes, and construction and demolition detritus. Because of its high compression and low tension, concrete is robust in compression but fragile in stress. Cement hinders operation and causes beams and columns to crumble if the soil moisture is more than 10%. When cement is thrown away, it releases carbon dioxide and worsens the environment. This opens the door to the possibility of using silica fume as a cement substitute. A highly reactive component in pozzolanic processes, silica fume has a finer texture and a high concentration of amorphous silica. The primary advantage of adding silica fume to concrete is an increase in the material's flexural and compressive strength.

OBJECTIVES

This research set out to do two things: examine the viability of employing materials from dismantled structures, and discover the use of waste materials on concrete so that they could be compared from an economic standpoint. It is envisaged that such research would lead to a greater usage of recycled materials in the construction industry. Following are some of the goals of this study:

One way to lessen environmental damage and give old concrete a new lease on life is to include it as recycled concrete aggregate into freshly mixed batches.

The second objective is to research the possibility of using demolition and construction debris in lieu of natural coarse aggregate and silica fume in place of cement.

Third, to undertake experimental research on the mechanical and physical qualities of aggregate and cement made from destroyed and building debris as Silica Fume.

II LITERATURE REVIEW

- Khan., S. Danish., S. Arif., S. Ramzan., M. Mushtaq This paper, through experimental study and literary sources investigates the utilization of rubber waste in developing GreenConcrete (GC). The natural aggregate (sand) of Conventional Concrete (CC) is replaced as 10%, 20% and 30% with coarse and fine rubber aggregate. The samples were tested in laboratory after a specific time on various aspects including compression strength and results were compared with each other and alsowith Conventional Concrete Mix (CCM). The paper concludes that structural and non- structural rubberized concrete can bedeveloped by using specific quantity of rubber waste in placement of fine and coarse aggregates in conventional concrete. The key objective of this research is to find out an efficient solution for utilizing rubber waste for better environment and also to provide initiative for concerned governmentorganization for framing effective legislation for the use of rubberized concrete in building and construction industries. It reveals from compressive strength's tests of rubberizedconcrete (RC) that it can be produced for various use in building and construction Industries. RC will not only save the natural ingredients of concrete resulting environmentalsustainability but recycling of rubber waste will also contribute towards better environment. The replacement of 10 % of fine aggregate (sand) of Conventional Concrete (CC) with Fine Crumb Rubber (FCR) is useful for producing Structural Concrete. Therefore use of CCR concrete should be encouraged for use so that maximum consumption of waste rubber could be achieved.
- K. C. Panda, P. S. Parhi and T. Jena In this study an attempt has been made to identify the various properties necessary for the design of concrete mix with the coarse tyre rubber chips as aggregate in a systematic manner. In the present experimental investigation, the M20 grade concrete has been chosen as the reference concrete specimen. Scrap tyre rubberchips, has been used as coarse aggregate with the replacement of conventional coarse aggregate. Slump value is decreased as the percentage of replacement of scrap tyre rubber increased. So decrease in workability. The compressive strength is decreased as the percentage of replacement increased, but rubber concrete developed slightly higher compressive strength than those of without rubber concrete. The split tensile strength is increased with decreased percentage of scrap tyre rubber. Decrease in compressive strength, split tensile strength and flexural strength of the specimen. Lack of proper bonding between rubber and cement paste matrix.
- G.SenthilKumaran, NurdinMushule,M.Lakshmipathy, This study reviews the feasibility of using waste tires in the form of chips and fibers with different sizes in concreteto improve the strength as well as protecting the environment. Also it reviews the potential application in the field by exploiting its unique characteristics and properties. In this study, weoutline the use of rubberized concrete in structural and non-structural members and show how it is suitable for the concrete, its uses, barriers and benefits and way to future study. A research is underway using the grade of cement 53, to improve the strength, finesand and coarse aggregate of a combination of 10mm and 20mm. The waste tyre rubber shall be used in the form of chips and fibers bypartially replacing the coarse aggregate by 0, 5,10, 20 and 25%.Recycling technology for concrete has significantly developed in the recent years, making the material sufficiently recyclable. It is evident that from the above discussion, the reduction of compressive and tensile strength can be increased by adding some super plasticizers and industrial wastes as partial replacement of cement will definitelyincrease the strength of waste tyre rubber modified concrete. Many studies reveal thatthere will be increase in strength enhancementsas well as environmental advantages. The future NGC using waste tyre rubber could provide one of the environmental friendly and economically viable products. Though problems remain regarding the cost of production and awareness among the society the wastes can be converted into a valuable product But further research is needed to increase performance against fire.
- El-Gammal, A., A. K. Abdel-Gawad, Y. El- Sherbini, and A. Shalaby In this paper the density and compressive strength of concrete utilizing waster tire rubber has been investigated. Recycled waste tire rubber hasbeen used in this study toreplace the fine and coarse aggregate by weight using different percentages. The results of this paper shows that although, there was a significant reductionin the compressive strength of concrete utilizing waste tire rubber than normal concrete, concrete utilizing waste tire rubber demonstrated a ductile, plastic failure ratherthan brittle failure. A total of 4 main mixtures were cast. One control mixture and three

concrete mixtures. The control mixture was designed to have a water cement ratio of 0.35 with cement content of 350 kg/m3. To developthe rubberized concrete mixtures, tire rubber was used to replace the aggregate by weight. Inthe first rubberized concrete mixture, thechipped rubber totally replaced the coarse aggregate in the mixture. While, in the other two concrete mixtures, the tire rubber replaced the fine aggregate by 100% and 50% of fine aggregate weight. Concrete casted using chipped rubber as a full replacement to coarse aggregate shows a significant reduction in the concrete strength compared to the control specimen. However, significant ductility was observed before failure of the specimens. Concrete casted using chipped rubber as a full replacement to coarse aggregate shows asignificant reduction in the density of concrete compared to the control specimens. Concrete casted using crumb rubber as a full replacement to sand shows a significant reduction in the concrete strength compared to the control specimen. However, significant ductility was observed before failure of the specimens. Concrete casted using crumb rubber as a full replacement to sand shows a significant increase in the concrete strength compared to the concrete casted using chipped rubber as a replacement to coarse aggregate. There was no significant increase in theconcrete compressive strength and the concretedensity when different percentage of crumb rubber, as a replacement to sand, was used in the concrete mix. It is recommended to test concrete with different percentage of crumbrubber ranging between (10% up to 25%) to study its effect on the concrete strength.. It is recommended to use concrete in the production of curbs, roads, concrete blocks,and non-bearing concrete wall.

- T. SenthilVadivel& R. Thenmozhi In this Study, our present study aims to investigate theoptimal use of waste tyre rubber crumbs asfine aggregate in concrete composite. A total of 90 cubes, cylinders and beam specimens were cast with the replacement of fine aggregate by shredded rubber crumbs with the proportion of 2, 4, 6, 8, and 10% by weight and compared with 18 conventional specimens. Fresh and hardened properties of concrete such as workability, compressivestrength, tensile strength and flexural strength were identified and finally it is recommended that 6% replacement of waste tyre rubber aggregate with fine aggregate will gives optimal and safest replacement in concrete composites. Compressive strength decreases when the percentage of replacement of shredded fine rubber crumbs increases. Splittensile strength decreases at the maximum of 25% when rubber crumbs replaces up to 10%in fine aggregate. Flexural strength of concrete increases when rubber crumbs increases up to 6%. It is identified that the grade of concrete plays the major role in the ductility performance of rubber replaced Concrete. Slump test results show no change in workability in all the percentage of replacement of rubber crumbs. Hence no effectin consistency during rubber replaced concrete.6% replacement of waste tyre rubber proves exceptionally well in compression, tensile and flexural strength and follow the curvature of the conventional specimens all the tests in boththe grades. Hence it is recommended that 6% replacement of waste tyre rubber aggregate with fine aggregate will gives optimal and safest replacement in concrete composites. Further it is suggested to use this concrete composite for lintel beams, floor slabs, andribs where load carrying capacity not governing the design.
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III MATERIALS

In making any type of concrete, selectionand type of materials is very important as all the properties depends on them.

The following materials are being used and arelisted below.

- Cement
- Silica Fume
- Fine aggregate (sand)
- Coarse aggregate replaced with Recycledcoarse aggregate (RCA)
- Water and
- Admixture

CEMENT

The most common cement used is an Ordinary Portland Cement (OPC). The OrdinaryPortland Cement of 53 grade (OPC) conforming to IS: 8112-1989 is used. It is a powered adhesive andcohesive substance which when mixed with fine aggregate, coarse aggregate and water form a paste which on curing for certain period turns in to mass of hard stone. Proper selection of cement is utmost important as the strength of concrete mostlydepends on it. The properties of cement are shown in Table.

Table: 3.1. Properties of Cement

S.No.	CHARACTERISTICS	VALUE
1	SPECIFIC GRAVITY	3.15
2	NORMAL CONSISTENCY	31%
3	INITIAL SETTING TIME	82 minutes
4	FINAL SETTING TIME	205 minutes

Silica Fume

Silica fume is a by-product from the production of elemental silicon or alloys containing silicon in electric arc furnaces. At a temperature of approximately 2000°C the reduction of high-purity quartz to silicon produces silicon dioxide vapor,which oxidizes and condenses at low temperatures to produce silica fume

When silica fume is added to concrete, initially it remains inert. Once portland cement and water in the mix start reacting with each other (hydrating), primary chemical reactions produce two chemical compounds: Calcium Silicate Hydrate (CSH), which is the strength producing crystallization, and Calcium Hydroxide (CH), a by-product also called free lime which is responsible for nothing much other than lining available pores within concrete as a filler or leaching out of inferior concrete.

Aggregates

Aggregates are inert granular materials such as sand, gravel or crushed stone that are an end product in their own right. They are also the raw materials that are an essential ingredient in concrete. For a good concretemix, 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.

Depending upon the size the aggregates are classified into two types

- Fine Aggregate
- Coarse Aggregate

Fine Aggregate

Fine aggregate are basically sands won from the land or the marine environment. Fine aggregates generally consist of natural sand or crushed stone with most particles passing through a 9.5mm sieve. As with coarse aggregates these can be from Primary, Secondary or Recycled sources.The selection of fine aggregate is also on important factor as it directly affects the strength of concrete with the varying utilization of water.

Table: Properties of Fine Aggregate.

S.No.	CHARACTERISTICS	VALUE
1	ZONE	II
2	SPECIFIC GRAVITY	2.64
3	DENSITY	14KN/m^3

Coarse Aggregate

Coarse aggregates are particles greater than 4.75mm, but generally range between 9.5mm to37.5mm 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.

Table: Properties of Coarse Aggregate.

S.No.	CHARACTERISTICS	VALUE
1	NOMINAL SIZE	10mm
2	SPECIFIC GRAVITY	2.84
3	DENSITY	1625.83Kg/m^3

Recycled Aggregates

The waste from the demolition of concrete structures are collected, aggregates are separated as recycled aggregates. The proposed recycled aggregates are used in the concrete mix for this project. The recycled aggregates are conformed by means of grading. As per specification 20 mm angular recycled aggregates are selected for partial replacement.

PROPERTIES OF RECYCLED AGGREGATE

The use of recycled aggregate obtained from the waste concrete, as a component of the new concretemixture, implies a thorough understanding of its basic properties, considering that some of them may significantly differ from the properties of aggregates obtained from natural resources. In addition, their differences primarily depend on the quantity and quality of cement mortar, which isattached to the grains of recycled aggregate, then, on the quality of the original concrete from which the aggregate is made by recycling and also on recycling methods. Nonetheless, in cases where therecycled aggregate comes from many different sources, the uneven quality, i.e. variations in the properties of recycled aggregate are much morepronounced than as is the case with natural aggregates

Table: Physical Properties

S.No.	Physical Properties	RCA
1	Water absorption (%)	1.56
2	Specific gravity	2.63
3	Bulk Density (kg/ m 3)	1469.8

Water

Water is an important ingredient of concrete as it actually participates in the chemical reaction with cement. Since it helps to from the strength giving cement gel, the quantity and quality of water is required to be looked into very carefully. Water cement ratio used is 0.40 for M25

MIX PROPORTIONS

The concrete mix is designed as per IS: 10262 – 2009 and IS 456-2000 for the normal concrete. The grade of concrete adopted is M25 with a watercement ratio of 0.45. Replacement of NCA with RCA.

The following points should be remembered beforeproportioning a concrete mix as per IS-10262- 2009.

- This method of concrete mix proportioning is applicable only for ordinary and standard concretegrades.
- The air content in concrete is considered as nil.

The proportioning is carried out to achieve specified characteristic compressive strength at specified age, workability of fresh concrete anddurability requirements.

Table: Mix proportions values.

Mixture	A0	A1	A2	A3	A4	A5
Cement	448.6	403.8	403.8	403.8	403.8	403.8
Silica Fume	0	10% (44.8)	10% (44.8)	10% (44.8)	10% (44.8)	10% (44.8)
Coarse Aggregate (Kg/m³)	1064.65	1064.65	1064.65	1064.65	1064.65	1064.65
Replacement of coarse with recycled aggregate.	0%	20%	40%	60%	80%	100%
Fine Aggregate (Kg/m³)	752.71	752.71	752.71	752.71	752.71	752.71
Water (lit)	197.4	197.4	197.4	197.4	197.4	197.4

Table: Mix proportions details

Mix	Mix details
A0	NORMAL CONCRETE (100%)
A1	20% RCA +80% NCA
A2	40% RCA +60% NCA
A3	60% RCA +40% NCA
A4	80% RCA +20% NCA
A5	100% RCA +0% NCA

IV EXPERIMENTAL INVESTIGATION

Where P is an ultimate load in N, A is a cross sectional area of cube in mm^2

Fig. Compressive Strength Test

SPLIT TENSILE STRENGTH OFCONCRETE

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. The concrete is very weak in tension due to its brittle nature and is not expected to resist the direct tension. Theconcrete develops cracks when subjected to tensile forces. Thus, it is necessary to determine the tensilestrength of concrete to determine the load at which the concrete members may crack.

Splitting tensile strength test on concrete cylinder isa method to determine the tensile strength of concrete. Split tensile strength test was conducted by using the method prescribed by IS5816-1999. Cylinders of 150mm×300mm were used for this test. The specimens were tested for 7, 14, 28 days the cylinder specimen was placed in horizontal direction on the testing machine.

The splitting of cylinder is shown in figure. The following relation is used to find out the spilt tensile strength of cylinder

$$F_t = \frac{2P}{\pi DL}$$

COMPRESSIVE STRENGTH TEST

Concrete cubes of sizes 150mm×150mm×150mm were tested for crushing strength. Compressive strength depends on loads of factor such as w/c ratio, cement strength, excellence of concretematerial and excellence control during manufactureof concrete.

These cubes are tested by compression testing machine after 7 days, 14 days or 28 days curing. The sample is placed centrally on the base plate of machine and the load have to be apply gradually at the rate of 140 kg/cm2 per minute till the specimen fails. Load at the failure separated by area of sample gives the compressive strength of concrete. The sample to increased load breaks down and no greater load greater load can be constant. The maximum load applied to specimen shall then be recorded and any unusual value noted at the time offailure brought out in the report. The cube compressive strength, then f_c=P/A N/mm^2 Where F_t is split tensile strength,P= Ultimate load in KN

L = Length of the cylinder in mm, D = Diameter ofthe cylinder in mm

Fig.: Split Tensile Strength Testing Machine.FLEXURE STRENGTH TEST

Flexural strength test on concrete beam todetermine the strength of concrete. Flexural

strength test was conducted by using the method prescribed by IS 516 – 1959.
Beams of dimension 700mm×150mm×150mm were used for this test, the test specimen is placedin the machine at the bearing surfaces of the supporting and loading rollers. So that the loadshall be applied without shock and increasing continuously at a stress increases at approximately7 kg/sq mm that is at a rate of loading 400 kg/min for the 150 mm specimens. The load shall be increased until the specimen fails, and the maximum load applied to the specimen during the test shall be recorded.
Where, Modulus of rupture $f = PL/BD^2$P is the load in KN.
L, B is the length and breadth in mm.D is the depth in mm.
f is the flexure strength in N/mm^2

Fig.: Flexural Strength Testing Machine.

V EXPERIMENTAL RESULTS

The results completed in the present investigation are reported in the form of Tables and Graphs for various percentage of recycled aggregate as a replacement to coarse aggregate. The following arethe percentages replacement of cement i.e. 20%, 40%, 60%, 80%, 100%.

SLUMP TEST

Slump test is used to determine the workability of fresh concrete. Slump test as per IS: 1199 – 1959 isfollowed.
The apparatus used for doing slump test are Slump cone and Tamping rod.
The internal surface of the mould is thoroughlycleaned and applied with a light coat of oil. The mould is placed on a smooth, horizontal, rigid and non-absorbent surface. The mould is then filled in four layers with freshly mixed concrete, each approximately to one-fourth of the height of the mould. Each layer is tamped 25 times by the rounded end of the tamping rod (strokes are distributed evenly over the cross section). After the top layer is rodded, the concrete is struck off the level with a trowel

Table: SLUMP TEST RESULT

Table.: COMPRESSIVE STRENGTH TESTRESULT

Mix ID	% recycled aggregate	Compressive strength at Age of 7 days, MPa	Compressive strength at Age of 14 days, MPa	Compressive strength at Age of 28 days, MPa	Compressive strength at Age of 56 days, MPa
A0	0	19.2	28.4	30.2	31.8
A1	20	25.2	29.2	30.4	32.4
A2	40	19.8	26.4	29.5	33.0
A3	60	29.4	30.2	32.4	36.5
A4	80	26.5	28.8	30.8	32.5
A5	100	27.5	28.5	31.2	30.8

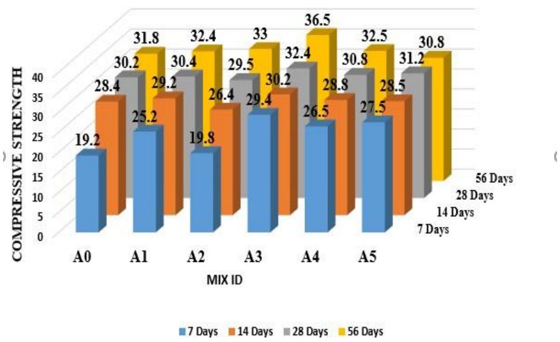

Fig.: Compressive Strength test results

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SPLIT TENSILE STRENGTH TESTRESULTS

Table.: SPLIT TENSILE STRENGTH TESTRESULT

Mix ID	% recycled aggregate	Tensile strength at Age of 7 days, MPa	Tensile strength at Age of 14 days, MPa	Tensile strength at Age of 28 days, MPa	Tensile strength at Age of 5 days, MPa
A0	0	1.98	2.02	2.58	2.85
A1	20	2.52	2.62	2.87	2.98
A2	40	2.68	2.832	2.92	3.01
A3	60	2.98	3.08	3.19	3.32
A4	80	2.71	2.78	2.89	2.98
A5	100	1.98	2.08	2.19	2.32

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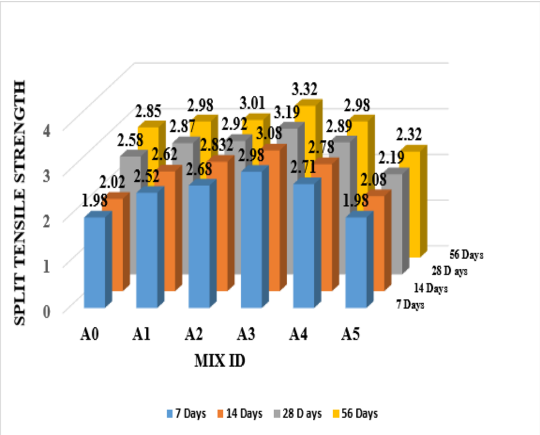

Fig.: Split Tensile Strength test results

Table.: FLEXURAL STRENGTH TESTRESULT

Mix ID	% recycled aggregate	Flexural strength at Age of 7 days, MPa	Flexural strength at Age of 14 days, MPa	Flexural strength at Age of 28 days, MPa	Flexural strength at Age of 56 days, MPa
A0	0	9.55	9.62	9.8	10.15
A1	20	9.632	9.85	9.92	10.5
A2	40	9.76	9.97	10.2	10.8
A3	60	9.8	10.4	10.8	11.2
A4	80	9.75	9.82	10.12	10.62
A5	100	9.52	9.6	9.8	10.35

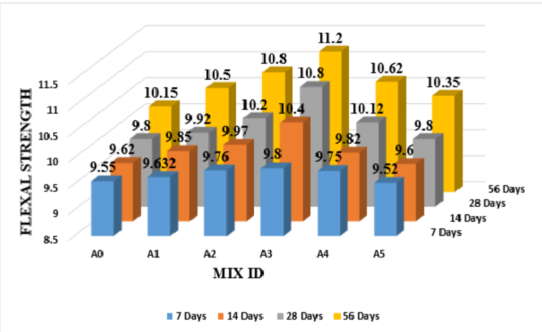

Fig.: Flexural Strength test results

NAME OF THE TEST		A0	A1	A2	A3	A4	A5
COMPRESSION STRENGTH	7 DAYS	19.2	25.2	19.8	**29.4**	26.5	27.5
	14 DAYS	28.4	29.2	26.4	**30.2**	28.8	28.5
	28 DAYS	30.2	30.4	29.5	**32.4**	30.8	31.2
	56 DAYS	31.8	32.4	33.0	**36.5**	32.5	30.8
SPLIT TENSILE STRENGTH	7 DAYS	1.98	2.52	2.68	**2.98**	2.71	1.98
	14 DAYS	2.02	2.62	2.832	**3.08**	2.78	2.08
	28 DAYS	2.58	2.87	2.92	**3.19**	2.89	2.19
	56 DAYS	2.85	2.98	3.01	**3.32**	2.98	2.32
FLEXURAL STRENGTH	7 DAYS	9.55	9.632	9.76	**9.8**	9.75	9.52
	14 DAYS	9.62	9.85	9.97	**10.4**	9.82	9.6
	28 DAYS	9.8	9.92	10.2	**10.8**	10.12	9.8
	56 DAYS	10.15	10.5	10.8	**11.2**	10.62	10.35

Table: TEST RESULTS

V CONCLUSION

Based on limited experimental investigationconcerning the strength tests i.e. compression, split tensile and flexural strength the following observations are regarding the resistance of replacement done with RCA to NCA in M25 concrete:
The following salient conclusions can be drawnbased on the findings from the review on the utilization of RCA @ percentages in concrete:

- The use of alternative material (demolished or recycled waste) for new construction which is
- beleaguered with normal waste in terms of debris, dust, rubbish etc. in place ofconventional material. Tests were conductedby using 20%, 40%,60%,80% and 100%replacement of fresh aggregate with recycled aggregate to determine the physical and mechanical properties.
- Demolished aggregate possesses relatively lower bulk crushing, density and impact standards and higher water absorption ascompared to natural aggregate. Along with Silica Fume 10%gave optimum Strength compare to normal control concrete
- Using demolished aggregate concrete as a basematerial for roadways reduce the pollution involved in trucking material.
- The compressive strength of the concrete isdecreases with increasing the percentage of
- demolished material from 0% to 60%.
- The split tensile strength of demolished concrete is also decreases with increasing
- the percentage of demolished material.
- The use of dismantled aggregate in makingfresh concrete will also help in reduction of solid waste dumping on existing landfill sites.
- The reuse of dismantled concrete will help in improvement of overall environment of the region. Firstly, by reduction in mining and

  secondly reduction in air pollution resultingfrom production of aggregates (dust pollution) and transportation of aggregate from mining toconsumption point
- The idea of reusing the waste material is very exciting and encouraging specially when it willbe helpful in minimizing destruction to earth's crust and green forest cover by virtue of reduced mining.

SCOPE OF FUTURE WORK

- ❖ Further research should be carried out to confirm the beneficial effects of RCA on several concrete properties and durability issues, and thus to encourage the use of RCA replacement of coarse aggregate in concrete.
- ❖ Additional research should be conducted to extend the use of RCA in high performance and self- consolidating concretes.
- ❖ SCC is favourably suitable especially in highly reinforced concrete members like bridge decks or abutments, tunnel linings or tubing segments,where it is difficult to vibrate the concrete, or even for normal engineering structures. So introducing RCA in SCC leads to better results.
- ❖ The improved construction practice and performance, combined with the health and safety benefits, make RCA a very attractive solution for both precast concrete and civil engineering construction.

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