A Study on The Effect of Treated Recycled Coarse Aggregate on The Strength And Durability of M40 Grade Concrete

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Abstract- *In a developing country like India, old and dilapidated structures are demolished for the purpose of building new and high rise structure to meet the population demand. As a result, considerably large amounts of debris and rubble get accumulated in cities. This waste generated during demolition is mainly in the form of aggregate and dust which are dumped into nearly empty pits or on lands, river beds, pasture lands and agriculture fields leading to wide spread environmental pollution. Development of infrastructure also increases the demand for production of concrete, which in turn increases the demand for supply of aggregates. Due to high demand for construction activities in recent years in India and all over the world, the natural aggregates resources are remarkably waning day by day and on the other hand, millions of tons of construction and demolition (C&D) residues are generated. The amount of construction and demolition waste has increased enormously over the last decade in the entire world. Construction and demolition disposal has also emerged as a problem in India.*

The research focuses on replacement of natural coarse aggregates in concrete with manually crushed recycled aggregates. In present study, five concrete mixes were used; first mix had only natural coarse aggregate and in remaining mixes natural coarse aggregate was partial replaced by 10%, 20%, 30% and 40% recycled coarse aggregate. In all the mix cement was replaced by 10% silica fume. Here an attempt is made to assess the strength and durability characteristics of M40 grade concrete made using construction and demolition waste recycled coarse aggregate.

Keywords- Recycled coarse aggregate, compressive strength, split tensile strength test and flexural test.

I. INTRODUCTION

In a developing country like India, old and dilapidated structures are demolished for the purpose of building new and high rise structure to meet the population demand. As a result, considerably large amounts of debris and rubble get accumulated in cities. This waste generated during demolition is mainly in the form of aggregate and dust which are dumped into nearly empty pits or on lands, river beds, pasture lands and agriculture fields leading to wide spread environmental pollution. Development of infrastructure also increases the demand for production of concrete, which in turn increases the demand for supply of aggregates.

The use of more and more concrete in construction not only results in scarcity of materials but also turns out to be expensive. In order to cope up with the depletion of conventional resources it would be worth to make use of suitable by-products to replace some of the conventional materials. The industrial wastes like fly ash and tile aggregates, which are produced in huge quantities that cause environmental pollution need safe disposal. But these materials possess potential characteristics, which can be tapped for various uses. Generally in design of concrete mix, cement, fine aggregates and coarse aggregates are using from a long years back. These three materials only play a crucial role in designing of a particular grade of concrete. But now a days there is a scarcity in aggregates. So, some new materials which are very near to our surroundings and some type of materials have to be introduce for replacing the fine aggregates, coarse aggregates and as well as cement to get the same strength as that these basic materials can give.

Waste arising from construction and demolition (C & D) constitutes one of the largest waste streams developed in many countries, of this a large proportion of potentially useful material disposed as landfill. The environmental and economic implications of this are no longer considered sustainable and as a result, the construction industry is experiencing more pressure than ever before to overcome this practice. On the other hand, in recent years the wisdom of continued wholesale extraction and use of aggregates from natural resources has been questioned at an international level. This is mainly because of the depletion of quality primary aggregates and greater awareness of environmental protection.

The applications of recycled aggregate in construction have done by using demolished concrete pavement as recycled aggregate in stabilizing the base course for road construction. The use of recycle aggregate concrete in construction industry is advantageous and economical. The waste from construction and demolition work is of large volume and increasing in time.

The global release of CO2 from all sources is estimated at 23 billion tons a year and the Portland cement production accounts for about 7% of total carbon emissions. The cement industry has made significant progress in reducing CO2 emissions through improvements in process and efficiency, but further improvements are limited because CO2 production is inherent to the basic process of calcinations limestone. The cement industry does not fit the contemporary picture of a sustainable industry because it uses raw materials and energy that are non-renewable; extracts its raw materials by mining and manufactures a product that cannot be recycled. Limestone mining has impact on land-use patterns, local water regimes and ambient air quality. Blasting causes problems of vibrations cracks and fly rocks. The impact of mining is especially high in ecologically sensitive areas. There is poor mine management and poor planning for rehabilitation of exhausted land. Mining is one of the reasons for the high environmental impact of the industry.

Silica fume is a byproduct in the reduce of high-purity quartz with coke in electric arc furnaces in the manufacture of silicon and ferrosilicon alloys. Micro silica consist of fine element with a surface area on the order of 20,000 m^2/kg when particular by nitrogen adsorption techniques, with particle just about one hundredth the size of the average cement Because of its excessive fineness and high silica content, micro silica is a very efficient pozzolanic material particle. Addition of silica fume also decrease the permeability of concrete to chloride ions, which protect the reinforcing steel of concrete from corrosion, especially in chloride-rich environment such as coastal region.

To overcome this issue, sustainable concrete construction is one of the strategies to be considered by the construction industry. One way of achieving these is to introduce recycled aggregates from these wastes of construction and demolition works into the production of concrete. In some countries the government encourage the use of recycled and reuse materials for construction industry. The reuse of recycled aggregate (RA) is not a common practice in construction industry. Nowadays there is depletion of natural aggregates and time will come where the sources of natural aggregate will soon decrease and will encounter a reduction in its supply.

There is a severe shortage of infrastructural facilities like houses, hospitals, roads etc. in India and large quantities of construction materials for creating those facilities are needed. The planning Commission allocated approximately 50% of capital outlay for infrastructure development in five year plans.

The research on finding out alternate materials in the concrete mainly coarse aggregate was recently started but production of these type of concretes for use in structural work would require careful and systematic processing, grading and testing of aggregate, essential for ensuring its acceptability in structural concrete. At the same time, considerable attention must be given to the control of quality. Due to a shortage in natural aggregate resources a change towards more sustainable production and consumption is urgently required. Utilization of alternative aggregate materials is one of the solutions.

The present work is aimed at assessing the suitability of percentage of recycled coarse aggregate as coarse aggregate in making of M40 grade concrete and evaluating its resistance to marine environment and durability.

The present project involves a comprehensive The present proposal involves a comprehensive laboratory study for the newer application of this waste material in the preparation of concrete. The primary objective of investigation is to study the strength behaviour i.e. compressive strength, Tensile strength and Flexural strength of concrete with different percentage replacements of coarse aggregate.

The proposed work is aimed to study the effect of silica fume and recycled coarse aggregate on:-

- Compressive Strength
- Split tensile Strength
- Flexural strength

II. REVIEW OF LITERATURE

Aggregate composed of recycled concrete generally has a lower specific gravity and a higher absorption than conventional gravel aggregate. New concrete made with recycled concrete aggregate typically has good workability, durability and resistance to saturated freeze-thaw action. Lack of widespread reliable data on aggregate substitutes can hinder its use. To design consistent, durable recycled aggregate concrete, more testing is required to account for variations in the aggregate properties. Also, recycled aggregate generally has a higher absorption and a lower specific gravity than conventional aggregate. Research has revealed that the 7-day and 28-day strengths of recycled aggregate concrete are generally lower than values for conventional concrete. Mandal et al. (2002) have found that there will be no affect on the concrete strength with the replacement of 30% of recycled aggregate. But the compressive strength was gradually decreasing when the amount of replacement of recycled aggregate increased. Hansen and Narad (1983) found that the compressive strength of recycled concrete is strongly correlated with the water-cement ratio of the original concrete if other factors are kept the same. When the water-cement ratio of the original concrete is the same or lower than that of the recycled concrete, the new strength will be as good as or better than the original strength, and vice versa. Aggregate composed of recycled concrete was reported to have a lower specific gravity and a higher absorption than conventional gravel aggregate.

Suchithra et al (2015) Performed Study on Replacement of Coarse Aggregate By E- Waste in Concrete. The replacement of coarse aggregate with E-waste in the range of 0%, 5%, 10%, 15%, and 20%, the mechanical properties and durability of the concrete mix specimens obtained from the addition of these materials is compared with control concrete mix. The test results showed that a significant improvement in compressive strength was achieved in the E-waste concrete compared to conventional concrete and can be used effectively in concrete, the reuse of E-waste results in waste reduction and resources conservation.

Prof. RoshanLal et al (2015) has done An Investigation on Strength Characteristic of Concrete Containing Recycled Aggregates of Marble Waste. The compressive strength, split tensile strength and flexural strength of specimens were tested for mixes containing marble waste recycled aggregates increased for replacement upto 30%. However for the 40%replacement of marble waste aggregate with natural aggregate a marginal decrease in compressive, split and flexural strength is recorded. Therefore it can be concluded that the production of concrete of normal strength is feasible and viable by replacing the natural aggregates by the marble waste aggregates without compromising the strength characteristics.

D.V. PrasadaRao et al (2014) have done Experimental Investigations of Coarse Aggregate Recycled Concrete. It was concluded that recycled aggregate concrete (RCA) has compressive strength comparable to the natural coarse aggregate concrete compressive strength for all grades of concrete at 3, 7, 28 and 90 days. This can be attributed to the cement mortar coat of RCA participates in hydration process and contribute additional strength. The durability property of concrete is determined using RCPT on the concrete specimens prepared with natural coarse aggregate and recycled coarse aggregate ,observed that as per ASTM C1202, the chloride penetrating rate is “high” for RCA concrete and “moderate” for NCA concrete for all grades of concrete.

Ismail Abdul Rahman et al (2009) presented a case study on Assessment of Recycled Aggregate Concrete. It was reported that 100% of RA used in concrete mix to replace the natural coarse aggregate in concrete with 100 x 100 x 100 cube mm were cast with target compressive strength is 25 MPa. The 28-day compressive strength was assess at 3, 14, 28 days reported. It was found that the usage size of 10mm and 14 mm of RA in RAC is quite similar performance with 10mm and 14mm size of natural aggregate (NA) in natural aggregate concrete (NAC).

T. Pauline et al (2015) have done Experimental Studies on Concrete by Replacing Coarse Aggregates with Recycled Aggregates. Concrete mixes with a target compressive strength of 25MPa were prepared by varying normal coarse aggregate and recycled aggregates in percentages of 10% to 100% from the total aggregate. From the experimental studies, it was found that the compressive strength and tensile strength of concrete made with RA increased upto 60% replacement. The concrete of 50% to 60% replacement by RA showed an equivalent strength and with increase in percentage of RA above 60% the strength decreased.

A.N.Dabhade et al (2012) have conducted studies on performance evaluation of recycled aggregate used in concrete. From the outcome of experiments it was found that the replacement of 100% NA by RCA can be possible. The replacement of aggregate was carried out by 0, 20,40,60,80 and 100%. The different ratios of the water-cement ratio were used. The workability of concrete had come down with the increase in %of RCA.

Ashraf M. Wagih et al (2012) have performed study on Recycled Construction and Demolition Concrete Waste as aggregate for Structural Concrete. It is reported that the results showed concrete rubble could be transformed into useful recycled aggregate and used in concrete production with properties suitable for most structural concrete applications in Egypt. A significant reduction in the properties of recycled aggregate concrete (RAC) made of 100% RCA was seen when compared to natural aggregate concrete (NAC), while the properties of RAC made of a blend of 75% NA and 25% RCA showed no significant change in concrete properties.

R. Kumutha et al (2010) performed studies on Strength of Concrete Incorporating Aggregates Recycled from

Demolition Waste. It is observed that there is a possibility to use 100% crushed concrete coarse aggregates and 60% crushed brick fine aggregate in compression elements like concrete blocks and concrete pavements since the target strength can be achieved.

Jitender Sharma et al (2014) presented a case study on Influence of Recycled Concrete Aggregates on Strength Parameters of Concrete. The tests were conducted by replacing the recycled concrete aggregates by 0,25,50,75 and 100 % replacement of natural aggregates. It was found that the compressive strength, split tensile strength and hardened density of concrete made with RCA decreases with increase in the percentage of recycled concrete aggregates.

Prof. Chetna M Vyas et al (2012) made studies on recycled aggregate concrete .Split strength had increased when natural aggregates were replaced by recycled coarse aggregates by 40% but modulus of elasticity decreases with replacement of natural aggregates.

III. MATERIALS AND METHODS

The experimental investigation work is started with various tests on the constituent materials. The constituent materials are given below.

1. Cement
2. Coarse aggregate
3. Water
4. Silica fume
5. Recycled coarse aggregate
6. Super Plasticizer

1. Cement

Ordinary Portland cement of 43 grades manufactured by Shree Ultratech Cement was used throughout the Experimental investigation. The quality of the cement was confirming to IS 8112:1989 was used in the field.

2. Fine Aggregate

Fractions from 4.75 mm to 150 microns are termed as fine aggregate. Locally available river sand passed through 4.75mm IS sieve is applied as fine aggregate conforming to the requirements of IS 383:1970.

3. Coarse Aggregate

Coarse aggregate shall be of hard broken stone of granite shall be of hard stone, free from dust, dirt and other foreign matters. The stone ballast shall be of 20mm and down and should me retained in 5mm square mesh and well graded such that the voids do not exceed 42 percent. Aggregate most of which is retained on 4.75-mmIS Sieve and containing only so much finer material as is permitted for the various types described in this standard.

4. Silica fume

Silica fume is a byproduct in the reduce of high-purity quartz with coke in electric arc furnaces in the manufacture of silicon and ferrosilicon alloys. Micro silica consist of fine element with a surface area on the order of 20,000 m²/kg when particular by nitrogen adsorption techniques, with particle just about one hundredth the size of the average cement Because of its excessive fineness and high silica content, micro silica is a very efficient pozzolanic material particle.

5. Recycled coarse aggregate

It is now widely accepted that there is a significant potential for reclaiming and recycling demolished debris for use in value added applications to maximize economic and environmental benefits. Recycling industries in many part of the world, at present converts low-value waste into secondary construction materials such as a variety of aggregate grades, road materials and aggregate fines. Often these materials are used in as road construction, backfill for retaining walls, low-grade concrete production, drainage and brickwork and block work for low-cost housing.

While accepting the need to promote the use of RCA in wider applications, it must be remembered that the aggregate for concrete applications must meet the requirements set in relevant specifications for its particular use. The gap between these interests has to be reduced in steps that are manageable and the use of RCA in structural concrete has to be promoted gradually. Similarly considerable attention is required to the control of waste processing and subsequent sorting, crushing, separating and grading the aggregate for use of the concrete construction industry. In some developed countries C & D waste is now regularly recycled and reused, albeit mainly as fill, drainage and sub-base materials, and there is considerable scope for increasing this market and the use of these materials.

IV. MIX DESIGN

The property of workability, therefore, becomes of vital importance. The mix design is done as per IS 10262-2009. Percentage dosage of super plasticizer (high range water reducers) is an additional parameter to be considered for designing an OPC mix. Percentage dosage of super plasticizer was fixed as per the mix design method described in IS 10262-2009. Mix proportion was arrived through various trial mixes. The grade of concrete prepared for the experimental study was M40.

V. RESULTS AND DISCUSSIONS

This session provides an outline of the experimental results and endeavors to draw some conclusions. The take a look at result covers the workability, mechanical properties and sturdiness properties of concrete with and while not admixtures.

5.1 REPLACEMENT DETAILS

The replacement details of silica fume and recycled coarse aggregate has been given in the table. The replacement of cement by 10% with silica fume and coarse aggregate by recycled coarse aggregate for different percentages.

5.2 COMPRESSIVE STRENGTH

Concrete specimen cubes are used to determine compressive strength of concrete and were tested as per IS 516:1959. The compressive strength is usually obtained experimentally by means of a compressive test.

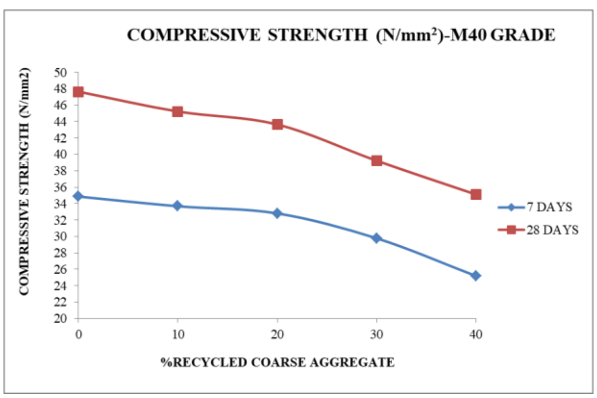

Fig 5.1 Fig 6.5 Shows Summarized Compressive strength of specimens for recycled coarse aggregates

From above Figure it is noticed that the strength of concrete at the end of 7 days decreased with the increase in the % of RCA. The decrease in % of strength in concrete mixes with RCA 10%, RCA 20%, RCA 30% and RCA 40% was 3.38%, 5.8%, 14.57% and 27.73% when compared with concrete mix having RCA 0%.

It is noticed that the strength of concrete at the end of 28 days decreased with the increase in the % of RCA. The decrease in % of strength in concrete mixes with RCA 10%, RCA 20%, RCA 30% and RCA 40% was 5.05%, 8.3%, 17.65% and 26.28% when compared with concrete mix having RCA 0%. Decrease in strength of 10% in case of concrete with 20% RCA can be used for producing conventional concrete.

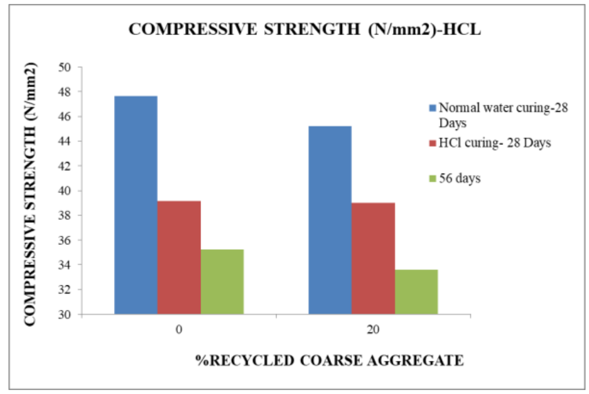

Fig 5.2Compressive strength of recycled coarse Aggregate concrete cured under HCl

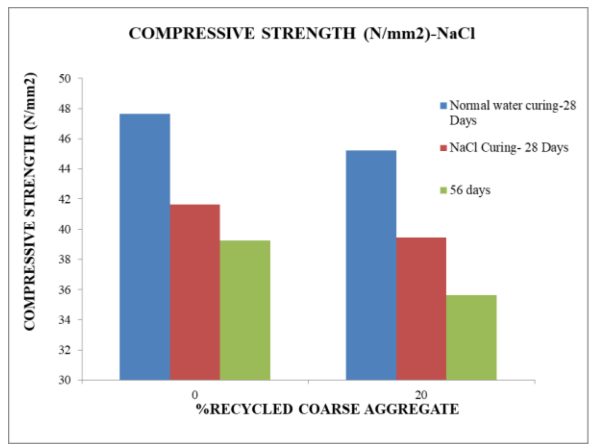

Fig 5.3 Compressive strength of recycled coarse Aggregate concrete cured under NaCl

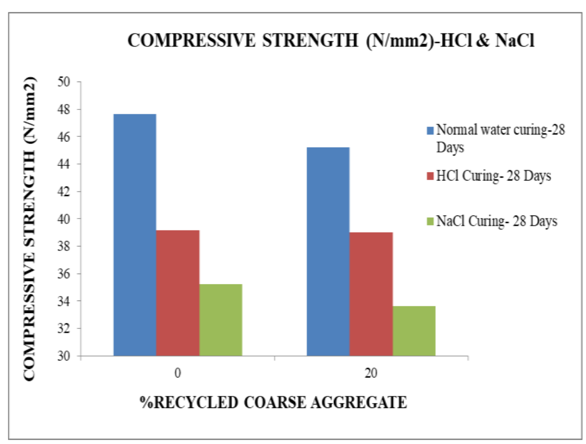

Fig 5.4 Shows summarized Compressive strength of recycled coarse Aggregate concrete cured under HCL and NaCl

The figures shows that the test results of compressive strength of specimens for HCl and NaCl curing, it is concluded that the loss of strength is more in HCl curing when compared to NaCl curing.

5.2 SPLITTING TENSILE STRENGTH

The size of specimens 150 mm dia and 300 mm length was used and the specimens were cured in normal water. Concrete specimen cubes are used to determine compressive strength of concrete and were tested as per as per IS 516 (1959) and IS 5816 (1999).

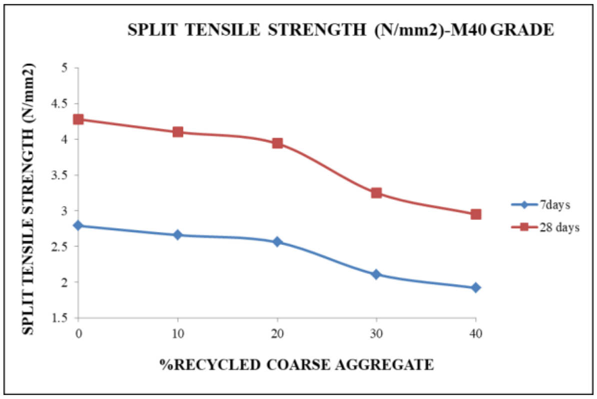

Fig 5.5 Split tensile strength of recycled Coarse Aggregate for 7 & 28 Days

The figure shows that the test results of splitting tensile strength of specimens for normal water curing, it is concluded that the loss of strength increases from 0% to 40% of replacement of RCA to compare with NCA but the maximum percentage of loss of strength was less than 8.5% and the test values was more than theoretical values.

5.4 FLEXURAL STRENGTH

The size of specimens 100 mm x 100 mm x 500 mm was used and the specimens were cured in normal water. Concrete specimen cubes are used to determine compressive strength of concrete and were tested as per as per IS 516 (1959). After 7 and 28 days curing, prismatic specimens are placed on flexural testing machine having a maximum of 100 KN and a constant rate of loading of 40 kg/m2 per minute is applied on the test specimen by placing the specimen in such a way that the two point loading should be placed at a distance of 13.3 cm from both the ends. Ultimate load at which the prismatic specimen fails is noted down from dial gauge reading.

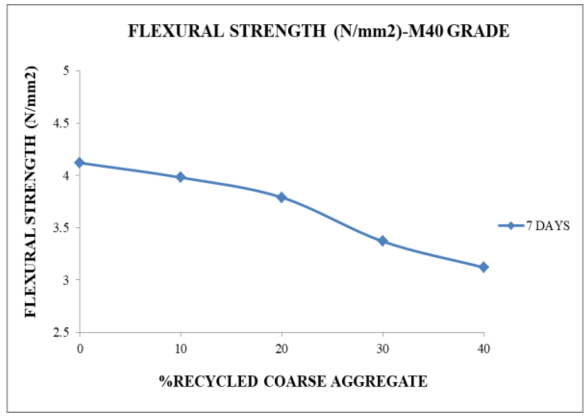

Fig 5.6 Flexural strength of recycled Coarse Aggregate for 7 days

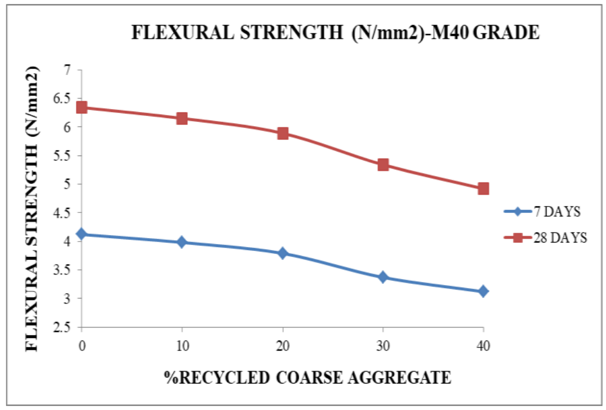

Fig 5.7 Flexural strength of specimens for recycled coarse aggregates for different curing periods

The figures shows that the test results of flexural strength of specimens for normal water curing, it is concluded that the loss of strength increases from 0% to 40% of replacement of RCA to compare with NCA but the maximum percentage of loss of strength was less than the test values was more than theoretical values.

5.5 SATURATED WATER ABSORPTION TEST

The water absorption test for concrete measures how much water penetrates concrete samples when submerged in water. It's a popular method for determining the water-tightness of concrete, and lower absorption results are better

Table 5.1: shows the percentage saturated water absorption for RCA 0% and RCA 20% after 28 days curing

Specimen No	Percentage water absorption (RCA 0%)	Percentage water absorption (RCA20%)
1	4.920	5.342
2	4.305	5.425
3	5.106	4.368
4	4.782	5.135
5	4.603	5.312
6	4.194	5.124
Average	**4.65**	**5.17**

VI. CONCLUSIONS

Based on the results of the experimental studies on M40 grade concrete with recycled and natural coarse aggregates and river sand as fine aggregate and taking the effect of curing with normal water and Hydrochloric acid and sodium chloride and the following conclusions are drawn.

- The Recycled aggregate satisfied the strength requirements for use as alternative to natural coarse aggregate in concrete making like concrete pavements.
- Recycled aggregate exhibits similar behaviour to fresh aggregate; therefore, Recycled aggregate could be incorporated into many concrete structures.
- Compressive strength of concrete with RCA 0%, 10%, 20%, 30% and 40% was 47.64, 45.23, 43.65, 39.23 and 35.12MPa respectively which show that obtained compressive strengths less than the target strength 48.25MPa. Approximately linear decrease in strength can be seen.
- The decrease in % of strength in concrete mixes with RCA 10%, RCA 20%, RCA 30% and RCA 40% was 5.05%, 8.3%, 17.65% and 26.28% when compared with concrete mix having RCA 0%. Decrease in strength of 10% in case of concrete with 20% RCA can be used for producing conventional concrete.
- Tensile strength of concrete with RCA 0%, 10%, 20%, 30% and 40% was 4.28, 4.10, 3.94, 3.25 and 2.95 respectively. The loss of split tensile strength increases from 0% to 40% of replacement of RCA concrete when compare with NCA concrete but for the 20% RCA, the maximum percentage of loss of strength was less than 7.9% in normal water curing.
- Flexural strength of concrete with RCA 0%, 10%, 20%, 30% and 40% was 6.34, 6.15, 5.89, 5.34 and 4.92 respectively. The loss of flexural strength increases from 0% to 40% of replacement of RCA concrete to compare with NCA concrete but for the 20% RCA , the maximum percentage of loss of strength was less than 7% in normal water curing
- Water absorption of recycled coarse aggregate (RCA 20%) concrete was higher than the natural aggregate (RCA 0%).
- In case of Compressive strength of recycled coarse Aggregate when subjected to HCl and NaCl. From the results it is found that loss of strength is more in HCl curing when compared to NaCl curing.

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