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An Experimental Study on Strength Properties of Concrete using Recycled Aggregate as Replacement in Coarse Aggregate

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Abstract: ***It is very important and crucial time to conserve our natural resources mainly in constructions. Concrete is second most consumable material after water compared to its volume. Concrete is mostly containing with aggregates. This report will try to observe the mechanical properties and durability properties of concrete using Recycled Aggregate (RA) in concrete specimens like cubes, cylinders and beams. So that Recycled Aggregate is taken in samples with respect to Natural Coarse Aggregate (NCA) in percentage basis like 0%, 20%, 40%, 60%, 80% and 100% replacement. Initially preliminary tests like sieve analysis, specific gravity, impact value and los angels abrasion test are performed on aggregates. And concrete strength is observed by conducting mechanical properties of concrete like compressive strength test, split tensile strength test and flexural strength test. Durability tests are conducted on concrete by treating recycled aggregate in acids like H2SO4 and HCL. Here Recycled Aggregate is submerged in 0.1 mole of H2SO4 and HCL solutions for 24 hours and then cleaned the treated recycled aggregate with potable tap water is to be used for performing the durability test. In this report, all the test specimens are prepared for M30 and M40 grade of concrete. After conducting the test it is observed and concluded that in preliminary tests, the grading zone of sand is from ZONE-II and its fineness modulus is 2.79, the recycled course aggregate strength is observed in impact and abrasion testing machines and the from the results it is concluded that in road constructions recycled course aggregate is used in all courses except in the top wearing course. In all the mechanical properties it is observed that the replacement of recycled aggregate strength is lesser than concrete with natural course aggregate but up to 40% replacement of recycled aggregate will show better results and more than that will cause lesser strength and it may affect the design mix also. And in durability tests on concrete using recycled aggregate treated with acids like H2SO4 and HCL will give better performance than untreated recycled aggregate but aggregate treated with H2SO4 will give higher strength than aggregate treated with HCL. From the overall report it is concluded that the use of recycled course aggregate up to 40% in natural course aggregate will not cause any serious strength reduction. And based on this report it is a better recommendation for makig a code of practice on recycled aggregate will be useful for future scope.***

Keywords: Recycled Aggregate, Natural Aggregate, Recycled Aggregate treated with H2SO4, Recycled Aggregate treated with HCL, compression strength, split tensile strength and flexural strength.

I. INTRODUCTION

Concrete is a construction material having the ingredients like cement, fine aggregate, coarse aggregate with water and some admixtures if any, will gave strength and durability properties. Concrete is very useful construction material since 20th century because of it is molding into any shape before setting.

About 70% to 75 % of volume is filled by coarse aggregate. We need to take care about naturally occurring coarse aggregate because of lack of availability of coarse aggregate in some countries.

Aggregate separated from construction and demolition waste will contain hardened mortar around its surface is called it as Recycled aggregate. The use of recycled aggregate will reduce the environmental losses and this type of re-usage will become an Eco-friendly construction material. To reduce large quantity of waste material it is a better step to introduce recycled aggregate. The cost of recycled aggregate concrete may be 20% to 30% less than natural aggregate concrete in some regions.

Recently Delhi Metro Rail Corporation (DMRC) takes a step to initiate towards environmental conservation and recycling of construction waste scientifically. Delhi Metro Rail Corporation commissioned at Rohini for Recycling C & DW from construction

works. This project report will try to use Recycled aggregate for constructions. And how the strength variations are obtained will be studied.

A. Literature Review

Saravanakumar el.al (2012) studied the possibility of using recycled concrete aggregate from construction and demolition waste(C&DW) and also studied the effect of admixed concrete using recycled aggregate on fresh and hardened stage. Author taken four series of concrete mixes with natural aggregate and recycled aggregate in three kinds of age of demolition like five years, ten years and fifteen years and are prepared for the experimental studies And are used with three different combinations like 0% Fly Ash, 20% Fly Ash and 25% Fly Ash with super plasticizers. The concrete grade for all this mixes are M25 grade. Author observed the maximum reduction at 15% was noticed in the case of compressive strength in all the age of Recycled Aggregate Concrete (RAC) and it shall be acceptable in practice. And it is proved to be used with the help of super plasticizers (SP) and Fly Ash (FA) to produce good quality of RAC for satisfying the strength requirements in concrete. The involvement of Super plasticizer with Fly Ash shows a reduction of 5% only in strength compared with RAC. The addition of SP reduces W/C ratio. The addition of only FA with concrete reduces the tensile strength in the range of 5 to 10% for the age of 5 to 15 years of Recycled Aggregate.

Vivian el al (2002) studied the pre-soaking approaches to clean the hardened mortar on the surface of Recycled Aggregate. The pre-soaking approaches are done with HCL, H2SO4 and H3PO solutions for removing mortar on its surface of Recycled Aggregate. Author observed from their experimental results, the water absorption of pre treated recycled aggregates significantly reduced compared to untreated RA and the mechanical properties for RA concrete are improved. Alkalinities of RAC, chloride and sulphate contents of RA have not been adversely affected. Author concluded finally that the pre-treating of RA is more effective method to improve the quality of RA for higher grade utilization and it is usable for wider application of RA for construction purpose. Revathi Purushothaman et al (2014) studied the strength characteristics and the performance of Recycled Aggregate Concrete with influence of treatment methods. Author taken six series of concrete mixes and are prepared using Natural Aggregate, Recycled Aggregate, Recycled aggregate treated with H2SO4 solution and RA treated with HCL solution. Sample of Recycled aggregate is obtained after Scrubbing treatment, heating and Scrubbing treatment. The six series of concrete mixes are prepared for determining its physical properties and mechanical properties of concrete. Using these all aggregates, the performance of Recycled Aggregate Concrete is observed. Author concluded from the results the aggregate treated with H2SO4 and heating and scrubbing yield aggregate with reduced water absorption and other desired properties of Natural Aggregate. The concrete made by treating aggregate are able to improve the strength and performance characteristics with Natural Aggregate Concrete (NAC). Saravanakumar et al(2013) studied the strength properties of High- Volume Fly Ash (FA) based concrete of M50 grade using Recycled Aggregate (RA) were studied. The replacement of Natural Aggregate (NA) with RA is performed in different percentages like 25%, 50% and 100% to study the effect of RAC on compressive strength and tensile strength characteristics. Also Author replaced the amount of cement with Fly Ash in different proportions like 40%, 50% and 60% to study the effect of Fly ash on compressive strength and tensile strength of concrete at an age of 28days. Only lesser percentage of reduction was observed to show the improvement. The reduction of compressive strength is in the range from 20 % to 37% due to replacement of NA with RA from 25%to 100% at an age of 28 days.

B. Objectives of The Study

In this study, the objectives are initially conducting the preliminary tests for aggregates. Design mix is prepared from the preliminary tests, and recycled aggregate is replaced in coarse aggregate like percentage basis in multiples of 20 from 0% to 100%. In this study, the mechanical properties of Recycled Aggregate Concrete(RAC) such as compressive strength, split tensile strength and Flexural strength is observed and durability of concrete using recycled aggregate treated with H2SO4 and HCL are performed for M30 and M40 grade of concrete. For compressive strength of cubes samples are tested at an age of 7days and 28days and for Split tensile strength and Flexural strength of concrete cylinders and beams are tested at an age of 28 days.

C. Experimental Investigation

1) *Materials used*
2) *Cement:* Ordinary Portland cement of 53 grade was used. The Cement used has been tested for various proportions as per ISIS 4031-1988 and found to be confirming to various specifications of 12269-1987.
3) *Fine Aggregate:* The material which passes through BIS test sieve number 4 (4.75mm) is termed as fine aggregate The sample of fine aggregate is taken from Godavari River. After conducting tests like specific gravity, sieve analysis it could be found that the fine aggregate is from Zone II and its Fineness modulus is around 2.79. It conforms to IS: 383 1970 comes under zone II.

4) Coarse Aggregate: Coarse aggregate crushed angular granite metal of 12 mm, 20mm size was used.

D. Recycled Aggregate

For this experimental study, recycled aggregate is collected from different age group of structural destructions like 1year, 10 years and 15 years. Sample of recycled aggregate is collected manually because of small quantity.

E. Acids

The collected recycled aggregate contains mortar all around. For durability considerations recycled aggregate is to be treated by submerging in H2SO4 and HCL with 0.1 moles for 24 hrs. Then aggregate is used for concrete mix after washing in tap water. By this treatment the surface mortar gets reduced in a certain amount. So that recycled aggregate concrete strength variations are to be observed by comparing untreated recycled aggregate.

F. Water

Concrete mix requires potable water. It doesn't contain salt so sea water is not allowed for concrete mixes. Unless until if places having lack of fresh water and full of sea water and where structures are not considered the effect of dampness and efflorescence we use sea water. Generally water user for construction having PH of 6.5 to 8.5 is the best range. For this project water is used from tap drinking water is used in concrete mix.

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Table No-1 will show the physical properties of aggregates.

S.No	Properties	Values		
		FA	NCA	RCA
1	Specific gravity	2.63	2.644	2.545
2	Water absorption	-	1.515	6.93
3	Grading zone	ZONE-II	-	-
4	Fineness Modulus	2.79	-	-
5	Size and grading of CA	-	20mm, Single size	20mm, Single size
6	Impact value	-	21.48%	30.20%
7	Abrasion value	-	16.6%	25.86%

Table No-1

II. EXPERIMENTAL PROGRAM:

A. Mix Designs

For concrete mix design based on the percentage replacement of RA in CA, twelve design mixes are prepared for M30 and M40 grade of concrete. Mix proportions were prepared as per IS-10262-2009. For this experimental program OPC 53 grade cement, Natural fine aggregate from Godavari river, Coarse aggregate of size not More than 20mm, Recycled Aggregate from local destructive structures are used. The experimental program is to observe the mechanical properties of concrete such as Compressive strength, Split tensile strength and Flexural strength and also Durability of concrete using Recycled aggregate treated with H2SO4 and HCL solutions.

Table no-2 will show the mix proportions for 12 design mixes

Mix	Concrete grade	Cement	FA	CA	Water
1	M30 0%RA	372	695	1143	186
2	M30 20%RA	372	695	1134	186
3	M30 40%RA	372	695	1125	186
4	M30 60%RA	372	695	1117	186
5	M30 80%RA	372	695	1109	186
6	M30 100%RA	372	695	1110	186
7	M40 0%RA	389	700	1169	175
8	M40 20%RA	389	700	1160	175
9	M40 40%RA	389	700	1151	175
10	M40 60%RA	389	700	1142	175
11	M40 80%RA	389	700	1134	175
12	M40 100%RA	389	700	1125	175

B. Compressive Strength of Cubes

The results of compressive strength are mainly used to determine that the mixture of concrete as delivered on site to meet the requirement of the requirement of the specified strength. The test is based on American Society for Testing Materials ASTM C31 standard practice of concrete.

Concrete compressive strength is carried on cubes and cylinders. For this project compressive strength is carried on cube of standard size 150mm in compressive testing machine. In America compressive strength is performed on Cylinders. In fact compressive strength of concrete cylinders maintains better accuracy than tested on concrete cubes. The ratio of compressive strength of cylinder and cube is 0.85. In this project, for the 12 design mixes 48 cubes are tested in compressive testing machine at n age of 7days and 28days.

Compressive strength of concrete cubes using RA replaced at 0%,20%,40%,60%,80% and 100% in CA are tested for M30 and M40 grade. The test observations are represented in the following table no 3 & 4.

Table no3 will show the Compressive Strength of concrete cubes for M30 grade of concrete

S.NO	Percentage of RCA	Compressive strength at 7days,Mpa	Compressive strength at 28days,Mpa
1	0%	28.355	41.498
2	20%	27.745	40.844
3	40%	26.71	39.195
4	60%	23.725	35.685
5	80%	19.685	34.62
6	100%	20.04	29.911

Table No-3

Table no 4 will show the Compressive Strength of concrete cubes for M40 grade of concrete

S.NO	Percentage of RCA	Compressive strength at 7days,Mpa	Compressive strength at 28days,Mpa
1	0%	33.325	49.24
2	20%	31.06	47.285
3	40%	29.91	43.685
4	60%	27.08	41.415
5	80%	25.06	38.353
6	100%	24.795	38.555

Table No-4

C. Split Tensile Strength of concrete Cylinders

Generally split tensile strength of concrete is 8 to 10 % more than direct tensile strength of concrete. This test is conducted on cylinder having 150mm diameter and 300 mm height. The application of load on cylinder is done by compressive action on periphery of cylinder in longitudinal direction. Concrete is very strong in compressive action and very week in carrying tensile strength due to brittleness of concrete. Generally concrete tensile strength is 10 to 15 % of compressive strength of concrete. In this experimental study 12 concrete cylinders are tested from 12 design mixes at an age of 28days. Split tensile strength of concrete cylinders using RA replaced at 0%,20%,40%,60%,80% and 100% in CA are tested for M30 and M40 grade. The test observations are represented in the following table no 5 & 6.

Table no 5 will show the Split tensile Strength of concrete cubes for M30 grade of concrete

S.NO	Percentage of RCA	Split tensile strength at 28days,Mpa
1	0%	1.97
2	20%	1.86
3	40%	1.67
4	60%	1.34
5	80%	1.02
6	100%	0.95

Table no 6 will show the Split tensile Strength of concrete cubes for M40 grade of concrete

S.NO	Percentage of RCA	Split tensile strength at 28days,Mpa
1	0%	2.709
2	20%	2.55
3	40%	2.389
4	60%	2.018
5	80%	1.89
6	100%	1.55

Table No - 6

D. Flexural Strength of concrete beam

Flexural strength of concrete is tested on concrete beams having their dimensions 0.1m x 0.1m x 0.5m. Third point load is applied on beam using Flexural strength Testing Machine (FTM) for determining flexural strength of concrete. The loading value of 'P' is increased from '0' to value corresponding to which first crack developed at the bottom fiber. In this project, total 12 beams from 12 design mixes are tested at an age of 28 days. Two point loading system is performed to determine Flexural strength of concrete beam. The following table no 7 & 8 will show the test results for Flexural strength.

Table no 7 will show the Flexural Strength of concrete beams for M30 grade of concrete

S.NO	Percentage of RCA	Flexural strength at 28days,Mpa
1	0%	5.1
2	20%	4.76
3	40%	4.82
4	60%	4.38
5	80%	3.88
6	100%	3.26

Table No- 7

Table no 8 will show the Flexural Strength of concrete beams for M40 grade of concrete

S.NO	Percentage of RCA	Flexural strength at 28days,Mpa
1	0%	5.82
2	20%	5.56
3	40%	5.44
4	60%	5.18
5	80%	4.76
6	100%	4.5

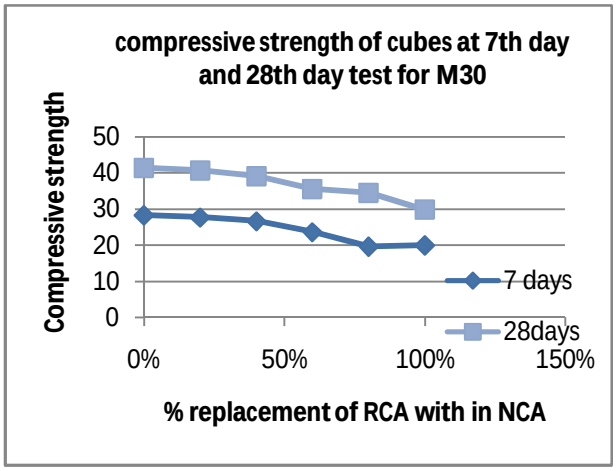
Table No-8

III. DISCUSSIONS AND RESULTS

A. Compressive Strength Of Concrete Cubes

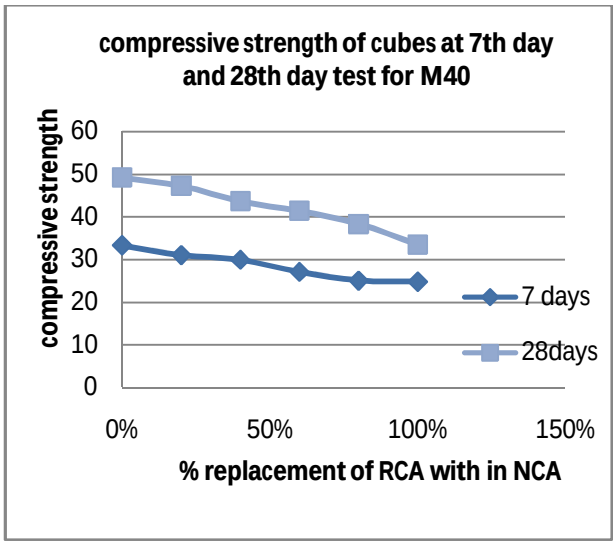
After completion of tests on concrete cubes, the graph between percentage replacement of RCA with NCA and compressive strength will show that the strength variation up to 20% replacement of RCA is satisfactory and between 20% and 40% is reasonably satisfactory but above 40% replacement of RCA till 100% will affect the strength of concrete cubes in a greater extent.

Graph No 1 will show the Compressive strength variation for M30 grade of concrete at 7days and 28days



Graph No-1

Graph No 2 will show the Compressive strength variation for M40 grade of concrete at 7days and 28days

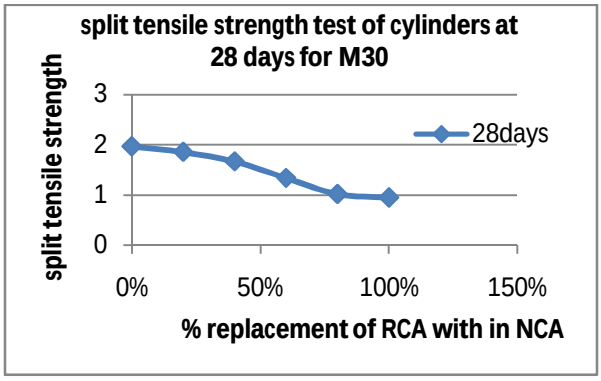


Graph No 2

B. Split Tensile Strength Of Concrete

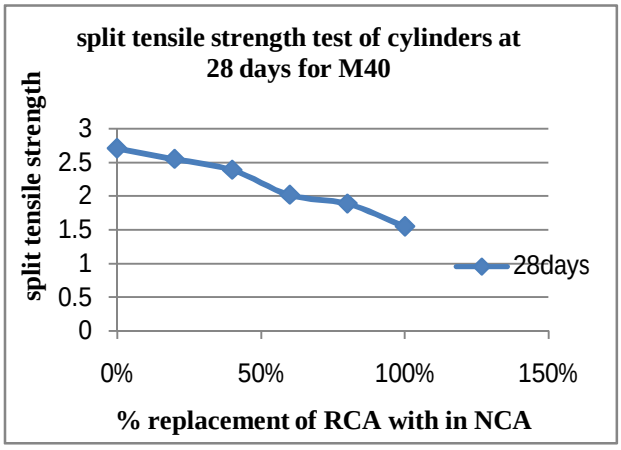
After the experimental results it is found from the graph that up to 30 % replacement of RCA will not affect the strength of concrete after that the strength gets reduced in a greater extent.

Graph No 3 will show the Split tensile strength variation for M30 grade of concrete at 28days



Graph No - 3

Graph No 4 will show the Split tensile strength variation for M40 grade of concrete at 28days

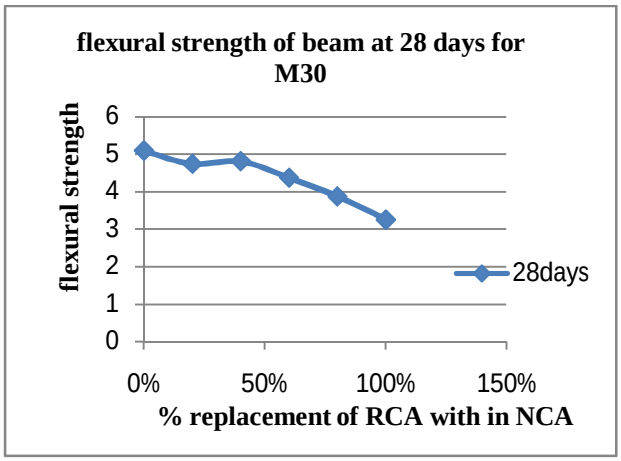


Graph No – 4

C. Flexural strength of concrete beams

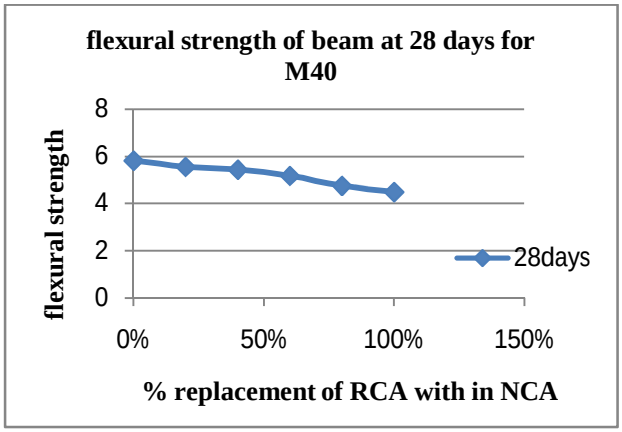
In an overall observation, by using recycled aggregate in flexural strength, after completion of test results the graphs will show that up to 40 % replacement of RCA there is no greater difference of their strength reduction. But from 40 % to 100% replacement of RCA the strength variations are much reduced.

Graph No 5 will show the Flexural strength variation for M30 grade of concrete at 28days



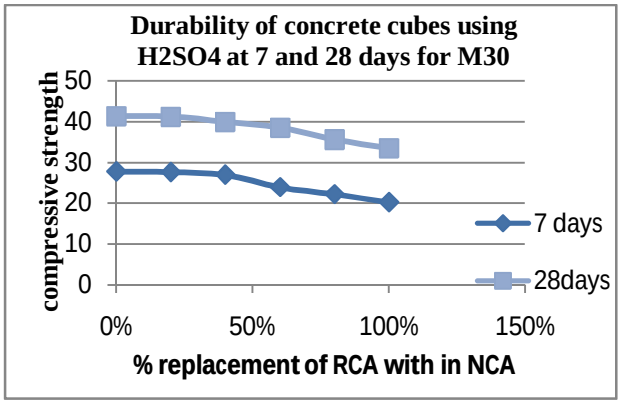
Graph No – 5

Graph No 6 will show the Flexural strength variation for M40 grade of concrete at 28days

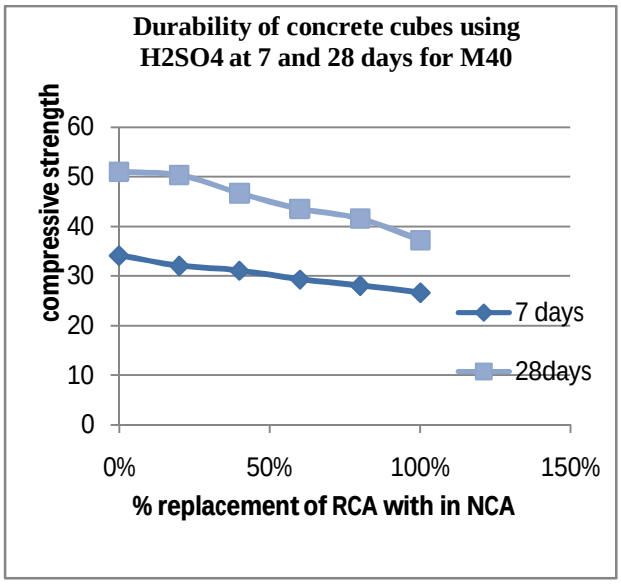


Graph No - 6

Graph No 7 will show the Durability variation of concrete using RA treated with H2SO4 for M30 grade of concrete at 7days and 28days

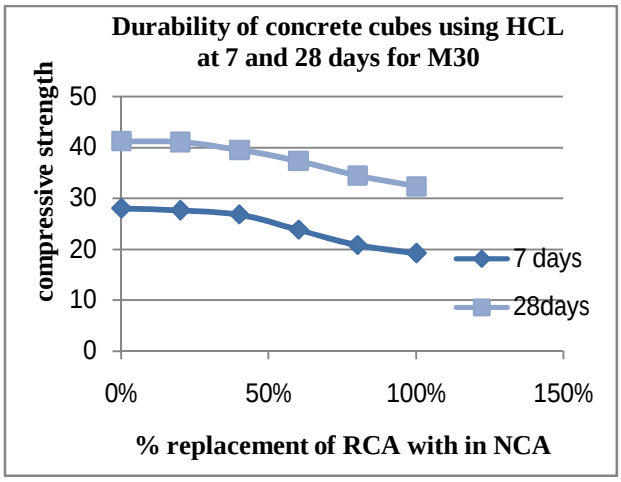


Graph No 8 will show the Durability variation of concrete using RA treated with H2SO4 for M40 grade at 7days and 28days



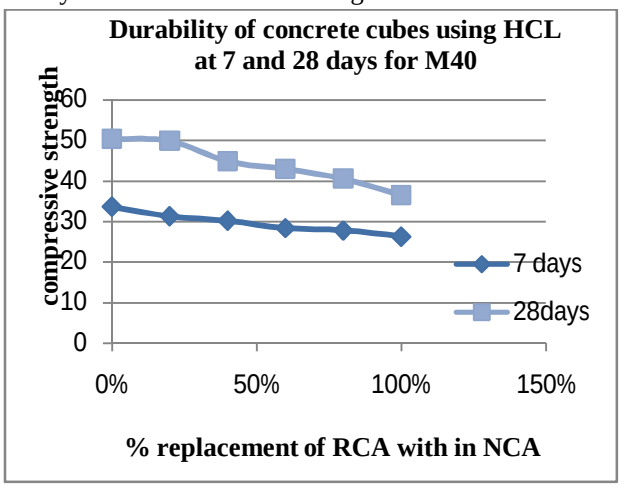
Graph No – 8

Graph No 9 will show the Durability variation of concrete using RA treated with HCL for M30 grade at 7days and 28days



Graph No – 9

Graph No 10 will show the Durability variation of concrete using RA treated with HCL for M40 grade at 7days and 28days



Graph No - 10

IV. CONCLUSIONS

From the tested results the following points are to be concluded. Hope this project report will be used for usage of recycled aggregate as a construction material again. The conclusion is based on primary properties of aggregate and mechanical properties of concrete and durability properties of concrete using acid treatment Recycled Aggregate.

A. Recycled course aggregate (RCA) is replaced with Natural course aggregate (NCA) in percentage basis like 0%, 20%, 40%, 60%, 80% and 100%. The test results will show that up to 20 to 40% replacement of RCA will give better results.
B. Durability of concrete cubes using RCA treated with H2SO4 will give more strength values than the durability of concrete using RCA treated with HCL.
C. Compared to untreated recycled aggregate in concrete, the acid treated recycled aggregate using H2SO4 and HCL will give better results but in actual practice the treatment process may increase the cost of the project so that the usage of recycled aggregate in percentage replacement will be a better choice for economic criteria.
D. In mechanical properties of concrete like compressive strength, split tensile strength, flexural strength, the strength is gradually reduced but it is lesser reduction up to 40% and grater reduction is observed in concrete by replacement of RCA more than 40%.
E. The attachment of mortar around the recycled aggregate will affect the specific gravity and water absorption. Therefore in calculation of design mix care should be taken in water cement ratio.
F. Finally, it is concluded that the usage of recycled aggregate will a better choice for constructions. And the wastage of natural resources is reduced in a little extent.

V. FUTURE SCOPE

A. From the results it is observed that by making a proper design mix and using proper percentage of recycled aggregate we can gain the strength and also reducing the usage of natural course aggregate.
B. It can be possible to reduce the waste disposal by using recycled aggregate in construction again.
C. By preparing code of practice it will be encouraging for use of recycled aggregate in a greater extent.

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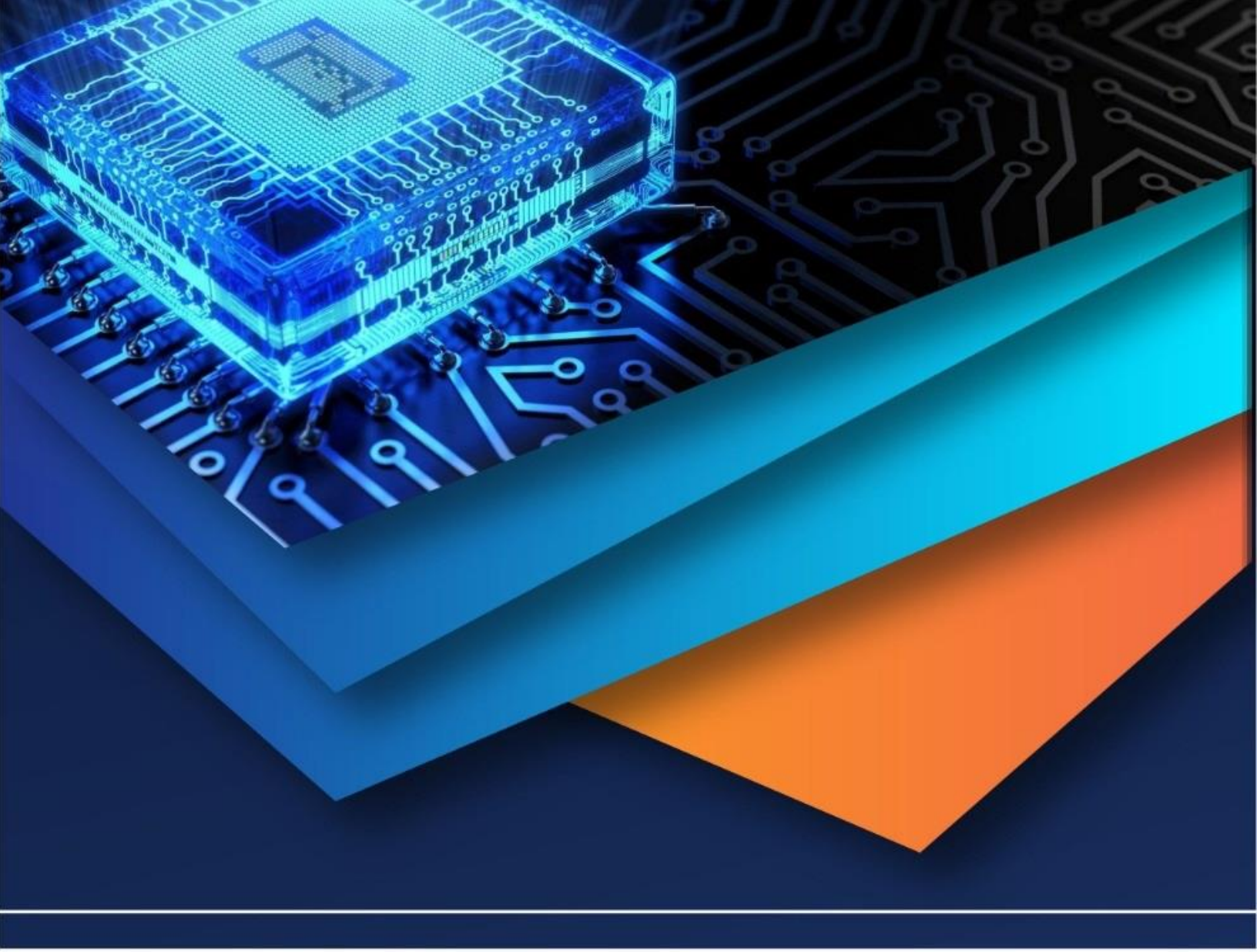

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