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STUDY OF PARTIAL REPLACEMNT OF NATURAL AGGREGATE BY RECYCLED AGGREGATE ON CONCRETE

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Abstract: In developing countries like India, the generations of Construction and Demolition waste is increasing day by day, on the other hand the reuse of construction waste is highly essential to preserve natural resources. Using the demolished concrete debris as recycled concrete aggregate which inturn conserves the natural resources, there by reduces the impact on landfills. In the present work attempts have been made to assess the effect of recycled concrete aggregates on the strength of nominal concrete mix. A study has been carried out to determine the properties of recycled aggregate which is to be used as a coarse aggregate for M_{25} grade of concrete. The percentages of recycled aggregate that partially replaced natural aggregate by weight was 0%, 10%, 20%, 30% and 40%. Concrete cubes were casted and tested in laboratory. Properties of natural aggregates and recycled aggregates were studied, Workability tests and Compressive Strength tests were performed. The results shows that upto 30% replacement of recycled aggregate with natural aggregate there is a slight decrease in strength when compared with conventional concrete. The goal of this study is to develop the economical and sustainable concrete by using the concrete waste available in the site.

Index Terms **–Compressive Strength, Conventional Concrete, Demolished Concrete, Recycled Aggregate.**

I. INTRODUCTION

Any construction activity requires several materials such as concrete, steel, brick, stone, glass, clay, mud, wood, and so on. However, the cement concrete remains the main construction material used in construction industries. For its suitability and adaptability with respect to the changing environment, the concrete must be such that it can conserve resources, protect the environment, economize and lead to proper utilization of energy. To achieve this, major emphasis must be laid on the use of wastes and byproducts in cement and concrete used for new constructions.

The utilization of recycled aggregate is particularly very promising as 75 per cent of concrete is made of aggregates. In that case, the aggregates considered are slag, power plant wastes, recycled concrete, red mud, burnt clay, saw dust and foundry sand. The enormous quantities of demolished concrete are available at various construction sites, which are now posing a serious problem of disposal in urban areas. This can easily be recycled as aggregate and used in concrete. Research & Development activities have been taken up all over the world for proving its feasibility, economic viability and cost effectiveness.

Recycled concrete aggregate (RCA) is generally produced by two-stage crushing of demolished concrete, and screening and removal of contaminants such as reinforcement, paper, wood, plastics and gypsum. Concrete made with such recycled concrete aggregate is called recycled aggregate concrete (RAC).

Recycling concrete is a viable option to decrease the demand on high quality natural resources and to limit the amount of waste that is disposed in landfills. Recycled concrete has been primarily used as a unbound material in embankments, bases, and sub-bases. Engineers have also used recycled concrete as an aggregate in the construction of new structures such as concrete pavements but with limited frequency. Recycled aggregate are produced from aged concrete that has been demolished and removed from foundations, pavements, bridges or buildings. It has been crushed and processed into various size fractions.

II. LITERATURE REVIEW

Abdulsamee M. Halahla [2019], "Utilization of demolished waste as coarse aggregate in concrete":

In this research, the old concrete was crushed and used as aggregates to obtain new concrete. Different mechanical tests were carried out to measure and characterize the new recycled aggregate concrete. All the mechanical tests showed that recycled aggregate concrete has slightly lower values than the natural aggregate concrete. The old crushed concrete can be a good alternative to be used as an aggregate in new concrete.

Mbereyaho Leopold [2018], "Reuse of construction and demolished concrete waste in producing strong and affordable concrete blocks":

The objective of this study was to assess the strength characteristics of concrete blocks made from construction and demolished (C&D) concrete waste after recycling and reusing them in fresh concrete. After laboratory testing of recycled concrete blocks, the compressive strength fell within the accepted range thereby the blocks can be used easily in building construction as per the study.

Jay Surya, Dr.I. Padmanaban, [2018], "Strength Studies on Recycled Aggregate Concrete with Partial Replacement of Cement by Using Flyash":

This paper reports the strength properties of recycled aggregate concrete with partial replacement of cement by using fly ash with various proportions (10%,20%,30%) Similarly concrete properties like compressive strength, flexural strength, etc are studied and compared with normal aggregate concrete. From the experimental work carried out on "Recycled aggregate concrete with partial replacement of cement by using fly ash". The compressive strength of recycled aggregate concrete with 20% of fly ash has higher strength when compared to normal concrete and split tensile test shows that concrete has good tensile strength when replace up to 20-30%. The water absorption of (RAC) recycled aggregate concrete is high when compared to ordinary coarse aggregate concrete, therefore usage of RAC with addition of proper admixture will reduce water content and increase strength also.

Menka, Urmil Yadav [2017], "Use of demolished concrete in construction":

In this thesis, the laboratory experiments were carried out on concrete by using natural aggregates & concrete by using partial replacement of recycled coarse aggregates - RCA (of 0%, 10%, 20%, 30%, 40%) for the construction of pavement. The test result showed that when added 10% of RCA to the newly mixed concrete, it gives more compressive strength than conventional concrete at the age of 28 days. There is a slight decline in compressive strength when added 20% and 30% of RCA, compared to the addition of 10% of RCA and again sudden increase when 40% of RCA is added to the newly mixed concrete. It is also observed that water absorption is more because RCA absorbs more water. It decreases the workability. So, super plasticizer (0.6% of cement) is used for control of excessive water absorption.

AnaghaKalpavalli [2015], "Use of demolished concrete waste as coarse aggregate in high strength concrete production":

In this research, various tests were done on concrete with replacement of natural coarse aggregates and on conventional concrete. The demolished waste was crushed to required size manually by using rammers and thoroughly washed to remove adhere present in the aggregate. Then soaked in the water for 24 hrs to reduce the water absorption in concrete. Due to this, no additional water is required while mixing. It shows that the concrete replaced with more recycled aggregates will develop the least strength compared to the lesser replacement ratio concrete. But, it can be seen that up to 30% replacement gives better results. Beyond this replacement, the strength acquired reduces gradually and does not cross the required tensile strength. Further, this also concludes that split tensile strength follows same trend.

Prof. Dharmesh K. Bhagat, Jigar P. Parmar, Yati R. Tank, Darpan H. Gadhiya, Jigar S.Goyani, [2014],"Experimental Study of Compressive Strength of Recycled Aggregate Concrete":
In the present work, attempts have been made to assess the effect of recycled concrete aggregate on the strength of ordinary concrete. The basic engineering properties of Recycled Concrete Aggregate (RCA) is evaluated and it is compared with the Normal Aggregate (NA). Similarly, the basic concrete properties like, compressive strength, workability etc. are studied for the different combinations of RCA with NA. The goal of this study is to develop the economical and sustainable concrete by using the concrete waste available on the site. The results of compressive strength shows that, the use of RCA up to 40% affect the functional requirements of concrete structure. Also the result of slump test shows there is continuous decrease in workability of concrete mix, as the cement mortar paste is attached to RCA.

Mohd Monish [2013], "Demolished waste as coarse aggregate in concrete":

This project carries out a comparison between conventional concrete and concrete with demolished waste as partial replacement of coarse aggregate. In this, demolished waste is partially replaced with coarse aggregate as 10%, 20%, 30% and compared with conventional concrete. It is observed that more water is required for producing the same workability. Water usage increases with increase in percentage of demolished waste. In conventional concrete, Up to 30% replacement of coarse aggregate with recycled aggregate is acceptable. The compressive strength retention is in the range of 86.84%-94.74% as compared to conventional concrete. The recycled aggregates have more crushing and impact value than normal aggregates.

III. MATERIALS CHARACTERIZATION

Cement: A cement is a binder, a substance used for construction that sets, hardens, and adheres to other materials to bind them together. Cement is seldom used on its own, but rather to bind sand and gravel (aggregate) together.

Fine Aggregate: Aggregates are commonly obtained by crushing naturally occurring rock. The properties of aggregates depend on the parent rock which can be igneous, sedimentary, or metamorphic. Aggregates are evaluated through tests to determine their suitability for various applications.

Natural Coarse Aggregate: Coarse aggregate are generally obtained by blasting in stone quarries or by breaking them by hand or by crushers. machine – crushed stones consist of stones of various sizes whereas hand – broken aggregates consist of only ingle size stones. To produce graded aggregates for high- class concrete, they are again mixed in specific proportions.

Recycled Coarse Aggregate: Recycled Aggregates is a term that describe crushed cement concrete from construction debris that is reused in other building projects. Recycled aggregates to be produced from aged concrete that has been demolished and removed from foundations, pavements, bridges or buildings, is crushed and processed into various size fractions.

IV. EXPERIMENTAL PROGRAM

3.1Tests on Fine Aggregate

(a) Fineness Modulus of Fine Aggregate (IS 2386 Part-I 1963)

To determine the particle size distribution of the fine aggregates and determine whether it is suitable to use in concrete mixing.

Fineness Modulus = (Sum of cumulative percentage weight retained)/100

(b) Specific Gravity of Fine Aggregate (IS 2386 Part-III 1963)

It is defined as the ratio of the weight of a given volume of aggregate to the given volume of water.

$$\text{Specific gravity of fine aggregate} = G = (W_2\text{-}W_1)/((W_2\text{-}W_1) - (W_3\text{-}W_4))$$

Where, Empty weight of pycnometer = W_1, Weight of pcynometer+ sample = W_2
Weight of pycnometer + sample + water = W_3, Weight of pycnometer+ water = W_4

3.2 Tests on Coarse Aggregate

(a) Fineness Modulus of Coarse Aggregate (IS 2386 Part-I 1963, IS: 383-2016)

The Fineness Modulus (FM) is an empirical figure obtained by adding the total percentage of the sample of an aggregate retained on each of a specified series of sieves, and dividing the sum by 100.

(b) Specific Gravity of Coarse Aggregate (IS 2386 Part-III 1963)

The coarse aggregate specific gravity test is used to calculate the specific gravity of a coarse aggregate sample by determining the ratio of the weight of a given volume of aggregate to the weight of an equal volume of water.

(c) Water Absorption Test (IS 2386 Part-III 1963)

Water absorption is defined as the amount of water absorbed by a material and is calculated as the ratio of the weight of water absorbed to the weight of the dry material.

(d) Aggregate Crushing Test (IS 2386 Part-IV 1963)

The strength of coarse aggregate is determined by using the aggregate crushing test. The resistance capacity of aggregate under gradually applied compression load is known as aggregate crushing value. The test that is performed to measure the relative resistance is called aggregate crushing value test.

$$\text{Aggregate crushing value} = (W_3 / W) \text{ or } W_3 / (W_2 - W_1)$$

Where, W_1 = Empty weight of cylindrical Measure, W_2 = Weight of Aggregate with Cylindrical Measure
$W = W_2 - W_1$ = Weight of Aggregate Sample, W_3 = Weight of crushed aggregate sample passed through 2.36 mm IS Sieve.

(e) Aggregate Impact Test (IS 2386 Part-IV 1963)

The aggregate impact value is a determining measure of resistance to sudden impact or shock, which may differ from its resistance to gradually applied compressive load.

$$\text{Aggregate Impact value} = W_2/ W_1 *100$$

Where, W_1 – Weight of oven-dried aggregate, W_2 – Weight of aggregate which passes through the IS sieve 2.36mm

(f) Bulk Density Test (IS 2386 Part-III 1963)

Bulk density is defined as ratio of mass of coarse aggregates by the total volume they occupy. Total volume means volume of coarse aggregate, volume of inter particles between them and volume of internal pores present in coarse particles.

Bulk density = Net compacted weight/Volume

Where, W_1 = Weight of empty cylindrical metal measure

W_2 = Weight of cylindrical metal measurement filled with compacted coarse aggregate.

3.3 Tests on Hardened Concrete

(a) Slump Cone Test

Workability of concrete refers to the ease with which the concrete can be mixed, transported, placed and compacted fully. This test method is used to determine the slump of freshly mixed concrete. Slump is the relative measurement of workability of concrete. The test may be done in the laboratory and in field.

(b) Compressive Strength Test

Compressive strength is the most common test conducted on hardened concrete, partly because it is an easy test to perform, and partly because most of the desirable characteristic properties of concrete are qualitatively related to its compressive strength. To evaluate the compressive strength cubes of size 150 mm x 150 mm x 150 mm were casted using C.I. mould.

$$Fcr = P/A$$

Where, Fcr = Compressive Strength P = Failure load in Compression (kN) A = Loaded area of cube (mm^2).

3.4 Mix Proportions and Properties of Materials

Table 1: Mix Proportions

Sample no.	Identification of sample	% of natural aggregate used	% of recycled aggregate used
1.	RCA_0	100	0
2.	RCA_{10}	90	10
3.	RCA_{20}	80	20
4.	RCA_{30}	70	30
5.	RCA_{40}	60	40

Table 2: Physical Properties of Cement

S.no.	Property of cement	Values obtained
1.	Standard Consistency	29%
2.	Initial Setting Time	42 minutes
3.	Final Setting Time	480 minutes
4.	Fineness	8%
5.	Specific Gravity	3.15

Table 3: Properties of Fine Aggregate

S.no.	Property of fine aggregate	Values obtained
1.	Specific Gravity	2.71
2.	Fineness Modulus	2.89
3.	Grading Zone	III
4.	Water Absorption (%)	1.5

Table 4: Properties of Coarse Aggregate

S.no.	Property of coarse aggregate	Values obtained
1.	Specific Gravity	2.75
2.	Fineness Modulus	8.79
3.	Water Absorption (%)	0.5
4.	Bulk Density (kg/m^3)	1510
5.	Aggregate Crushing Value (%)	18.4
6.	Aggregate Impact Value (%)	17.65

Table 5: Properties of Recycled Aggregate

S.NO.	Property Of Recycled Aggregate	Values obtained
1.	Specific Gravity	2.58
2.	Fineness Modulus	7.78
3.	Water Absorption (%)	0.3
4.	Bulk Density (kg/m^3)	1650
5.	Aggregate Crushing Value (%)	36.3
6.	Aggregate Impact Value (%)	35.2

IV. RESULTS AND DISCUSSION

4.1 Results of Slump Cone Test

Table 6: Slump Cone Values

S.No.	Replacement of Recycled Aggregate (%)	Slump Value Obtained (mm)
1.	0%	110
2.	10%	105
3.	20%	98
4.	30%	95
5.	40%	84

Chart 1: Slump Cone Value

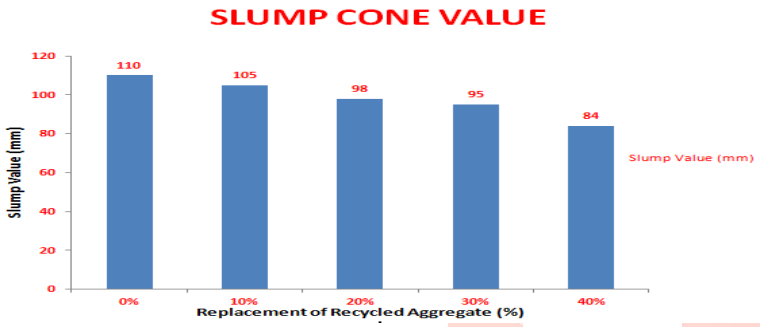
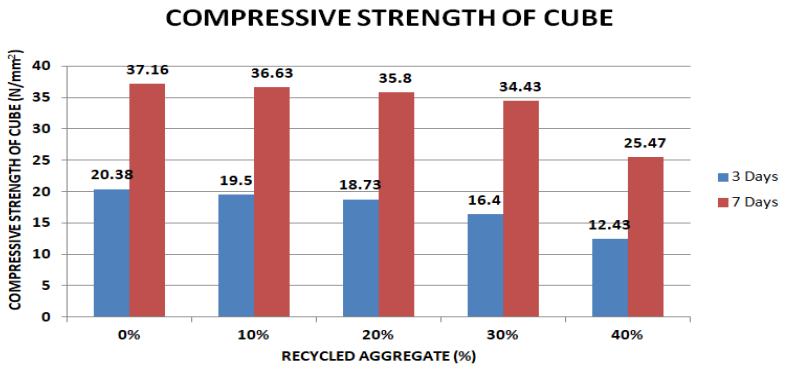


Table 7: 3 days & 7 days Compressive Strength of Cube (n/mm^2) for Varying Percentages of Replacement of Coarse Aggregate with Recycled Aggregate

S.NO.	Recycled Aggregate (%)	Compressive Strength of Cube (n/mm^2)	
		3 Days	7 Days
1.	0%	20.38	37.16
2.	10%	19.50	36.63
3.	20%	18.73	35.80
4.	30%	16.40	34.43
5.	40%	12.43	25.47

CHART 2: Compressive Strength of Cube vs % of Recycled Aggregate Used



From the table 7 and chart 2 it can be seen that, the compressive strength of M25 grade normal concrete at 7 days is 37.16 N/mm^2. At the same time, the compressive strength at 10 %, 20%, 30% replacement is found to be 36.63 N/mm^2, 35.80 N/mm^2, 34.43N/mm^2. Also, there is sudden fall in strength at 40% replacement, as the quantity of RCA increases. At 40% replacement, the compressive strength is about 25.47 N/mm^2.

V. CONCLUSIONS

From the experimental work done the following conclusions can be made:

- Recycling and reuse of building wastes have been found to be an appropriate solution to the problems of dumping hundred of thousands tons of debris accompanied with shortage of natural aggregates. The use of recycled aggregates in concrete prove to be a valuable building materials in technical, environment and economical aspect. Use of RCA in concrete save the disposal and land filling cost and produce a sustainable concrete for construction.
- From the material testing, it can be concluded that, RCA exhibits comparatively less specific gravity than NA. As the water absorption of RCA was found greater then NA, because of adhering mortar and cement paste. This need to be compensated during mix design. On the other hand, RCA is having comparatively same Bulk Density as NA. But, the impact and crushing value of RCA are comparatively less than NA.
- The Slump value showed a steep decrease when the RA percentage is increased as shown in Chart -1.
- The compressive strength showed a steep decrease when the RA percentage is increased as shown in Chart -2.
- The results of compressive strength shows that, the use of RCA up to 40% affect the functional requirements of concrete structure. Also the result of slump test shows there is continuous decrease in workability of concrete mix, as the cement mortar paste is attached to RCA.

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