Nishant Patil, al. 2023, 11:5
ISSN (Online): 2348-4098
ISSN (Print): 2395-4752

International Journal of Science, Engineering and Technology

An Open Access Journal

Properties of Self Compacting Concrete Using Recycled Coarse Aggregate

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Abstract- The study presents the mix design for M40 grade concrete. Optimum value for recycled aggregate calculated. The results of strength test (compressive) conducted on Natural coarse aggregate concrete and Recycled coarse aggregate concrete of M40 grade for Normal water curingand sea water curing respectively. The chapter also presents the effect of sea water curing on mechanical properties (compressive strength) of Recycled coarse aggregate concrete of M40 grade. The experimental investigation also presents the durability studies like acid attack, sulphateattack, and alkaline attack of recycled coarse aggregate concrete of grade M40. It is concluded that up to 40% of replacement of recycled coarse aggregate can be safe and gave similar results to compare with natural aggregates in normal water curing and sea water curing. The loss for flexural and split tensile strength is less in sea water curing to compare with normal water curing. For durability studies itis concluded that the loss of strength in acid attack is more to compare with sulphate and alkaline attack.

Keywords- Recycled aggregate, Mix Design, Concrete, Sea Water Curing & Durability Studies.

I. INTRODUCTION

Concrete is the most widely used construction material in the world with annual consumption estimated between 21 and 31 billion tonnes (Sabnis, 2012). Concrete is used more than any other man-made material (Lomborg, 2001) and is the second largest material consumed by mankind after food and water (Adegbola and Dada, 2012).

Mehwish et al., 2013 have inferred that about 7.5 billion cubic meters of concrete is produced each year, more than one cubic meter for every person on the Earth. Production of concrete requires a host of material resources in terms of cement, sand and aggregates. Most of these materials used in concrete are naturally occurring and due to their extensive use are becoming scarce. River sand sources are fast depleting and the quantity of sand required is falling short of demand. To overcome this deficit, alternative material to river sand, namely manufactured stone crushed sand is being used in the industry in making concrete. It is well known fact that even aggregates faced with issues pertaining to shortage of supply of raw materials have already switched on to recycling for meeting their requirement. As a large proportion of this requirement can be supplemented by using the demolished material, nevertheless this secondary material needs to be assessed before being used in making of second generation concrete. This work tests such demolished material as an alternative material to be used in concrete by recycling thus saving onto the natural resources and also satisfying the social and environmental objective [1].

II. BACKGROUND

International Scenario

The recycling industry had its existence in European countries way back during the Second World War. During this period a large quantity of rubble left behind was required to be disposed off. With the economy of these countries dismally shattered, acute transportation problem and shortage of equipment to work in aggregate quarries, the problem of reconstruction in these countries posed a major challenge. This paved a way in reusing of demolished concrete and building rubble as an alternate raw material. In addition to this, number of European countries notably, Germany, England, and Netherlands made systematic attempts to harness the use demolition material in the pavements [2].

Around the year 1973, fresh upsurge in research interest was seen in Western Europe and U.S.A. The objective of research this time was different: heavy urbanization and expansion had depleted the natural resources. Growth was seen consistently in the construction sector which resulted in heavy demand for these natural resources that was expected to grow further in future. As reported by Van, 2006 the construction spending has increased from 3500 billion US Dollars in 2003 to 4800 billion US Dollars in 2008 and 6200 billion US Dollars in 2013. These figures indicate an enormous growth worldwide in construction market that is predicted to almost double in 10 years time. A large demand for the natural resources must be met with to sustain the growth. KeunHyeok Yang et al., (2008) have reported that the global requirement of normal aggregates will be around 8 - 10 billion tons annually beyond 2010. Thus globally enormous need for natural non-renewal resources is required to satisfy this growth in the construction sector [3].

On account of the non-replenishing material the cost of construction is also considerably rising, thus paving way for a search of an alternative resource. Furthermore, major repair and renovation works have generated large amounts of waste adding to the burden for need of alternative method of disposal. Lauritzen (2004) has reported that the quantity of construction and demolition waste discarded every year in the USA is about 250-300 million tonnes per year, 200 to 300 million tonnes in the European economic communities, 4.5 million tons annually in Egypt (AlAnsary et al., 2004) 30 million tonnes in Japan and in the United Kingdom, and 24 million tonnes in France (Alaejos et al., 2004) [4].

It is estimated that these figures will increase nearly threefold by the turn of this century. Evidently, these countries for the above reasons took up ―Recycling Technology‖ very seriously. Significant research progress in the United States of America, the United Kingdom, Germany, France, Japan and Netherlands indicated positive and encouraging conclusions advocating utilization of recycled aggregate for construction purposes, especially for pavements of all types [5].

Owing to the extensive studies, developed countries like the Netherlands, Belgium and Denmark presently recycle more than 80 percent of its construction and demolition waste. In recent years many countries have considered the reutilization of construction and demolition waste as a new construction material as being one of the main objectives with respect to sustainable construction activities. From the mid 70’s many researchers have dedicated their work to describe the properties of these aggregates, the minimum requirement for their utilisation in concrete and the properties of concrete made with recycled aggregates. Many of the aforementioned countries have also started formulating their codes of practice/standards as guidelines for use of recycled aggregate for construction purpose [6].

Indian Perspective

Indian construction industry today is amongst the fifth largest in the world and at the current rate of growth, it is slated to be amongst the top two by the next century. It makes a significant contribution to the gross domestic product (GDP) growth and to national economy. The construction sector alone contributes around 8 percent of GDP and is the second largest economic activity after agriculture.

The contribution of construction to India’s GDP is likely to increase in the coming years with huge infrastructure projects taken up by the government in the Power and Highway sectors. As per the UN 1995 report it is believed that India will have more than 40 percent of its populace living in cities in the next 30 years.

The Planning Commission of India has proposed an investment of around US$ 1 trillion in the Twelfth five-year plan (2012-2017), which is double of that in the Eleventh five-year plan. Growth in the current scenario is indispensable for a developing country like India [7]. Construction materials in general and aggregates in particular, are important components of infrastructure requirements. Projections for building requirement in the housing sector indicate a shortage of about 55000 million cum of aggregates and another 750 million cum is required to fulfill the target of the road sector. With the shortage as likely seen today, the future seems to be in dark for the construction sector. The projected requirements of natural raw materials are not only required to fulfill the demand for the upcoming projects, but also are the needs of the extensive repairs or replacements required for the existing infrastructure and structures built few decades back [8].

Fulfilling the demand of resources at present is one part but presently the construction industry is facing with the massive waste disposal problem. Estimated waste generated during construction is 40 to 60 kg/m2 and during renovation another 40 to 50 kg/m 2 Technology Information, Forecasting and Assessment Council TIFAC, 2002. The management of construction and demolition waste is a major concern due to increase in quantity of demolition rubble, continuing shortage of dumping sites, increase in cost of disposal and transportation and above all, the concern about environment degradation. In developing countries the amount of construction and demolition waste is constantly increasing owing to the rise in living standards, change in consumption pattern and normal growth of population.

According to a survey conducted by Central Pollution Control Board, the estimated quantity of solid waste generated in India in 2007 was around 48 million tons per annum of which 25 percent was the waste from construction. The Energy and Resources Institute (TERI) has estimated that by 2047, waste generation in Indian cities will increase five-fold to touch 260 million tonne per year, implying that the current solid waste generation is over 50 million tonne per year (Kala and Kumar, 2013). They estimated the annual increase in the quantity of solid waste in Indian cities to be at the rate of 5 per cent per annum [9].

Presently in India this waste is disposed off in the landfill or used as an infill material. The poor management of solid waste has led to contamination of groundwater and surface water through leachate. Unscientific practices in processing and disposal in reclaimed areas or river banks compound the environmental hazards posed by solid waste. With landfill spaces decrease and environment being destroyed, this inert waste needs a better strategy to manage. Thus with huge demand seen in construction industry and strategies present to fulfill the demand, an integrated and holistic approach involving design and construction engineering is required which respects the construction and economic environment of the country [10]. Rapid strides are being made towards advancement of research in the field of construction material and technology. Recycle options have been tried to fulfill the growing demand which has led to the reuse of demolished waste in countries outside India. Research work on recycling of aggregates has also been carried out at Central Building Research Institute.

(CBRI), Roorkee, and Central Road Research Institute (CRRI), New Delhi, but as per the study commissioned by (TIFAC), 70 percent of the construction industry is not aware of recycling techniques. Hence creating awareness as well as promoting the use of recycled product is the need of the day to achieve the necessary goal. Thus it is seen that the problems in India are also alarming as in the west, considering the quantum of construction and demolishing waste generated. It is not far off when India may also have to seriously think of reusing demolished rubble and concrete for production of recycled construction material. Work on recycled concrete has been carried out at few places in India but waste and quality of raw material produced being site specific, tremendous inputs are necessary if India has to use the material in construction for producing concrete.

III. AIMS AND OBJECTIVE

The objective of this work is to analyse and propose technical guidelines on compressive strength, performance criteria and behaviour of concrete made with recycled aggregates. For recycled aggregates to be used in structural concrete, it is necessary to carry out an in depth study of their material properties and analyse how these properties in turn affect the quality of the second-generation concrete.

There is already very rich experience in some European countries, Japan and in the USA on quality control standards of recycled aggregates and guidance on using them in construction. Japan and other developed countries have even laid down specifications for use of recycled aggregate in concrete. Therefore it is necessary to prepare specifications for the use of this material in construction having regards to local conditions in India. Recycled aggregates are obtained from the demolished waste crushed concrete. From a quality point of view, these aggregates are heterogeneous in composition being derived from different minerals and adhered mortar. The properties of these aggregates must be determined if they are to be used in concrete, therefore an attempt is made to study the aggregate characteristics to be employed in concrete mixes. Thus the objective of present work is

1. To characterize the recycled aggregates in terms of physical and chemical properties and also to study the properties of concrete made with recycled aggregates, to study the durability properties and lay standard guidelines for using recycled aggregate in concrete.
2. To analyze the structural behaviour of concrete made with different percentages of recycled coarse aggregates.
3. To analyze the option for the use of recycled aggregate in concrete in main stream construction rather than using it as an infill material.
4. To ameliorate the reservations if any, for the use of recycled aggregates in concretes and make the industry aware of the option available on recycling and reuse.

IV. HYPOTHESIS

Hypothesis 1: Research works signify that the concrete made using recycled aggregates does not provide the desired compressive strength. A reduction in compressive strength of around 15 to 25 percent is observed when recycled aggregates are used in making concrete. This work will assess such recycled aggregates and determine whether M25 grade concrete could be prepared. The work will also try to propose a mix design procedure to be adopted if recycled aggregates are to be used in producing concrete.

Hypothesis 2: Recycled aggregates are poor in their characteristics on account of the adhered mortar content which is porous. This attached adhered mortar is the cause of higher water absorption and lower specific gravity in case of recycled aggregates. It is observed from various research reports that it is on account of this adhered mortar that concrete made with recycled aggregates compromises on compressive strength. Thus this work would try to testthe material and find out possible alternatives to improve the quality of recycled aggregates so as to prevent its detrimental effect on concrete without imposing huge capital expenditure and be feasible to be applied on site for mass production.

Hypothesis 3: Any grade of concrete not only needs to provide the desired compressive strength but also to satisfy the criteria of performance during its serviceable life. Performance is generally understood by the ability of the material to resist strain and permeation of water and other aggressive agents. Since concrete prepared with recycled aggregate is porous on account of the adhered mortar content it would be essential to evaluate whether such concrete is also durable though it may provide the necessary compressive strength. Durability in the present context will be evaluated in terms of water permeability, chloride permeation, drying shrinkage, modulus of elasticity and creep strain in concrete prepared with recycled aggregates.

V. PROPOSED METHODOLOGY

Materials And Methods

Many engineers and senior faculties have also studied and researched also before us. In same manner we also studied and researched about the recycling of concrete [3]. We collect the material and screen the coarse aggregate and conduct various experiments on it and find final results. We find that the properties or test results differ 15% from its standard results [4]. The present study investigates the effects of using RCA as a Coarse aggregate on the mechanical properties of concrete [5]. To investigate the Laboratory tests is also main object of the study.

Materials

1. **Cemen**t- Ordinary Portland cement was used because it is easily available in market. The cement was used in measuring Slump value and Compaction factor. The Specific gravity of cement was 3.2 and the fineness of cement was 4%.
2. **Coarse Aggregate:** The Coarse aggregate was used as Recycled coarse aggregate (RCA). The specific gravity of the RCA was 2.30. The Fineness modulus was 3.67
3. **Fine Aggregate:** Natural river sand was used as fine aggregate. The Specific gravity of Fine aggregate was 2.68. B. Methods
4. **Fineness Modulus:** This test was done with the help of various sieves. The aggregate was properly sieved by this test. The relative percentage of aggregate was determined by this test so we can say it like grain size distribution also. This test was done by sieve analysis in laboratory using Sieve shaker. The nominal size of the aggregate was determined by Fineness modulus test.

5. **Specific gravity-** The specific gravity of an aggregate is a measure of quality of material. According to IS Code 2386(Part III)-1963 the strength is lower with lower specific gravity value .This test was done by using wire basket.

- **Crushing value test:** The crushing value test was carried out by compression testing machine (CTM). The total load of 40 tones was applied at the rate of 4 ton per minute. The percentage crushing value was determined by divided the passing weight from total weight of aggregate.
- **Slump Test:** The Unsupported fresh concrete, flows to the sides and a sinking in height takes place. This vertical settlement is known as slump. Slump test is carried out by using RCA with Concrete mix Design CMD method and the slump was measured by using temping rod and Steel rule.
- **Compaction Factor Test:** Workability gives an idea of the capability of being worked, i.e. idea to control the quantity of water in cements concrete mix to get uniform strength. Compaction test was done by using Compaction factor test apparatus.

C. **Fineness Modulus Test** : The test was conducted as per describe as per procedure. The test was then further spread and determine results 5.67 as Fineness Modulus. The test results were accurate as normal aggregate. Hence we can easily use the RCA.

D. **Specific gravity Test :** The Specific Gravity test was conducted as per IS: 2386 (Part III) – 1963. The Specific gravity of coarse aggregate was determined as 2.309. It was 13% reduce from standard value 2.67 which is in the range from 2.5 to 3.0. The Specific gravity of fine aggregate was also accurate.

E. **Aggregate Crushing value test:** This test was performed as per IS: 2386 (Part IV) – 1963. The crushing value of RCA was 20%. It was also less than the upper limit according to IS Code which is 30%. Hence the RCA is used as road construction material also.

F. **Slump Test:** The Slump test was also conducted in laboratory according to IS: 1199 – 1959. This Test gives test results as 100 mm which is designed for 100 mm assumption by CMD.

G. **Compaction Factor Test:** This Test was performed as per IS: 1199 – 1959. The Test results were 0.93. It is observed that the workability of concrete increases with using RCA.

Cement

53 grade OPC cement is used in the present work. The properties of cement are determined from the laboratory investigations. The results of tests conducted on cement are presented in Table, along with the permissible limits for ascertaining quality of cement.

F-TEST

An ***F*-test** is any statistical test in which the test statistic has an *F*-distribution under the null hypothesis. It is most often used when comparing statistical models that have been fitted to a data set, in order to identify the model that best fits the population from which the data were sampled. Exact "*F*-tests" mainly arise when the models have been fitted to the data using least squares. The name was coined by George W. Snedecor, in honour of Ronald Fisher. Fisher initially developed the statistic as the variance ratio in the 1920s.[1]

It is a known fact that Statistics is a branch of Mathematics that deals with the collection, classification and representation of Data. The tests that use F - distribution are represented by a single word in Statistics called the F Test. F Test is usually used as a generalized Statement for comparing two variances. F Test Statistic Formula is used in various other tests such as regression analysis, the chow test and Scheffe test. F Tests can be conducted by using several technological aids. However, the manual calculation is a little complex and time-consuming. This article gives an in-detail description of the F Test Formula and its usage.

An F-test is conducted by the researcher on the basis of the F statistic. The F statistic is defined as the ratio between the two independent chi square variates that are divided by their respective degree of freedom. The F-test follows the Snedecor's F-distribution. The F-test contains some applications that are used in statistical theory. This document will detail the applications. The F-test is used by a researcher in order to carry out the test for the equality of the two population variances. If a researcher wants to test whether or not two independent samples have been drawn from a normal population with the same variability, then he generally employs the F-test. The F-test is also used by the researcher to determine whether or not the two independent estimates of the population variances are homogeneous in nature.

An example depicting the above case in which the F-test is applied is, for example, if two sets of pumpkins are grown under two different experimental conditions. In this case, the researcher would select a random sample of size 9 and 11. The standard deviations of their weights are 0.6 and 0.8 respectively. After making an assumption that the distribution of their weights is normal, the researcher conducts an F-test to test the hypothesis on whether or not the true variances are equal.

The researcher uses the F-test to test the significance of an observed multiple correlation coefficient. It is also used by the researcher to test the significance of an observed sample correlation ratio. The sample correlation ratio is defined as a measure of association as the statistical dispersion in the categories within the sample as a whole. Its significance is tested by the researcher.

The researcher should note that there is some association between the t and F distributions of the F-test. According to this association, if a statistic t follows a student's t distribution with 'n' degrees of freedom, then the square of this statistic will follow Snedecor's F distribution with 1 and n degrees of freedom. The F-test also has some other associations, like the association between the it and chi square distribution.

Due to such relationships, the F-test has many properties, like chi square. The F-values are all non negative. The F-distribution in the F-test is always non-symmetrically distributed. The mean in F-distribution in the F-test is approximately one. There are two independent degrees of freedom in F distribution, one in the numerator and the other in the denominator. There are many different F distributions in the F-test, one for every pair of degree of freedom.

General Steps for an F Test

If you're running an F Test, you should use Excel, SPSS, Minitab or some other kind of technology to run the test. Why? Calculating the F test by hand, including variances, is tedious and time-consuming. Therefore you'll probably make some errors along the way. If you're running an F Test using technology (for example, an F Test two sample for variances in Excel), the only steps you really need to do are Step 1 and 4 (dealing with the null hypothesis). Technology will calculate Steps 2 and 3 for you.

1. State the null hypothesis and the alternate hypothesis.
2. Calculate the F value. The F Value is calculated using the formula F = (SSE1 – SSE2 / m) / SSE2 / n-k, where SSE = residual sum of squares, m = number of restrictions and k = number of independent variables.
3. Find the F Statistic (the critical value for this test). The F statistic formula is: **F Statistic = variance of the group means / mean of the within group variances.** You can find the F Statistic in the F-Table.
4. **Support or Reject the Null Hypothesis**.

F test can be defined as a test that uses the f test statistic to check whether the variances of two samples (or populations) are equal to the same value. To conduct an f test, the population should follow an f distribution and the samples must be independent events. On conducting the hypothesis test, if the results of the f test are statistically significant then the null hypothesis can be rejected otherwise it cannot be rejected.

F Test Critical Value

A critical value is a point that a test statistic is compared to in order to decide whether to reject or not to reject the null hypothesis. Graphically, the critical value divides a distribution into the acceptance and rejection regions. If the test statistic falls in the rejection region then the null hypothesis can be rejected otherwise it cannot be rejected. The steps to find the f test critical value at a specific alpha level (or significance level), αα, are as follows:

- Find the degrees of freedom of the first sample. This is done by subtracting 1 from the first sample size. Thus, x = n1−1n1−1.
- Determine the degrees of freedom of the second sample by subtracting 1 from the sample size. This given y = n2−1n2−1.
- If it is a right-tailed test then αα is the significance level. For a left-tailed test 1 - αα is the alpha level. However, if it is a two-tailed test then the significance level is given by αα / 2.
- The F table is used to find the critical value at the required alpha level.
- The intersection of the x column and the y row in the f table will give the f test critical value.

F Test Statistic Formula Assumptions

F Test equation involves several assumptions. In order to use the F - test Formula, the population should be distributed normally. The samples considered for the test should be independent events. In addition to these, it is also important to consider the following points.

- Calculation of right-tailed tests is easier. To force the test into a right-tailed test, the larger variance is pushed in the numerator.
- In the case of two-tailed tests, alpha is divided by two prior to the determination of critical value.
- Variances are the squares of the standard deviations.

If the obtained degree of freedom is not listed in the F table, it is always better to use a larger critical value to decrease the probability of type 1 errors.

- In the case of Statistical calculations where the null hypothesis can be rejected, the F value can be less than 1; however, not exactly equal to zero.
- The F critical value cannot be exactly equal to zero. If the F value is exactly zero, it indicates that the mean of every sample is exactly the same, and the variance is zero.
- One of the key points to remember while working with the F Statistic is that the population variances are always considered to be equal. If this condition is not met, the obtained F value might not be correct.
- The degrees of freedom is taken as the number of samples minus one. In the case of a two-sample problem, there are two samples, and hence it becomes 2 - 1 = 1.
- When the alpha level is not mentioned in the F Test, the standard value used in most of the cases is equal to 0.05.

VI. RESULT AND ANALYSIS

The concrete mix M40 grade was designed in accordance to IS 10262 - 2009. The mix proportion for M40 concrete was designed by considering the properties of ingredients. The water cement ratio adopted in the present project is 0.45. Design mix of M40 grade for conventional aggregate without recycled aggregate forms the basic reference mix and then the recycled aggregates were replaced by different levels.

Table 1. 7-day Compressive strength of concrete.

%RCA	Compressive strength of concrete(*kn/m²*)
10	30
20	29
30	28
40	27
50	26
60	26.3
70	25
80	24.95
90	23
100	22

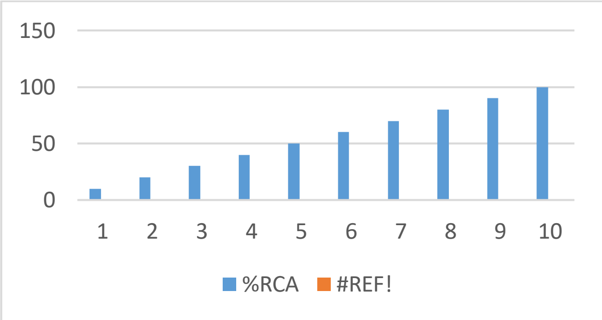

Fig.1Compressive strength of concrete.

Table 2.F-Test Two-Sample for Variances

F-Test Two-Sample Variances		
	%RCA	Compressive strength of concrete (kn/m^2)
Mean	55	26.125
Variance	916.6666667	6.337361111
Observations	10	10
df	9	9
F	144.6448531	
P(F<=f) one-tail	1.19572E-08	
F Critical one-tail	3.178893104	

Interpretation

This analysis investigation of average value of compressive strength found 26.125 for 55% of RCA. This result obtained minimum error $1.19572x10^{-8}$.

Table 3. 28-day Compressive strength of concrete.

%RCA	Compressive strength of concrete(kn/m^2)
10	45.23
20	45.2
30	45.15
40	45.5
50	44.97
60	40
70	37
80	36
90	35
100	34

Table 4.F-Test Two-Sample for Variances

F-Test Two-Sample for Variances		
	%RCA	Compressive strength of concrete (kn/m^2)
Mean	55	40.805
Variance	916.6667	23.93178
Observations	10	10
df	9	9
F	38.30332	
P(F<=f) one-tail	4.11E-06	
F Critical one-tail	3.178893	

Interpretation

This analysis investigation of average value of compressive strength found 40.805 for 55% of RCA. This result obtained minimum error 4.11×10^{-6}.

VI. CONCLUSION

It is desirable to use SCC because of its advantages like faster rate of construction and superior level of finish and also it can be used in congested reinforcement very well. Since the strength is not much reduced with recycled aggregates and flow properties were good recycled aggregatecan be effectively used in SCC. Early age strength was less in SCC compared to traditional concrete. While comparing the Split tensile strength SCC gave highest result. But with coarse aggregate replacement gives a less value. When Flexural strength was studied all concrete mixes gave similar to that of traditional concrete. The water absorption increased in SCC with recycled aggregate was due to the higher water absorption in RCA. But it is within satisfactory limits. So RCA is a good alternative of CA in SCC. SCC with more percentage of RCA is to be studied.

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