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SUSTAINABLE USE OF RECYCLED AGGREGATE IN CONCRETE

Mr. Dupargude Naveenkumar R.[1]
Mr. Patole Nikhil G[2].
Mr. Rathod Shubham L.[3]
Mr. Swami Nityanand P.[4]
[1,2,3,4] Undergraduate Students, Department of Civil Engineering/AGPIT, Solapur/
Dr. Babasaheb Ambedkar Technological University, Lonere, Raigad, Maharashtra

Prof. Miss. Mamdyal Kalyani
Asst. Prof., Department of Civil Engineering/AGPIT, Solapur
/Dr. Babasaheb Ambedkar Technological University, Lonere, Raigad, Maharashtra

ABSTRACT
The research work carried out here primarily deals with use of recycled aggregates in concrete to achieve sustainability. Slump, percentage of RCA, compressive strength and split tensile strength are among the various parameters observed during the research. Result obtained by theoretical formulation has been validated first by comparing the concrete cubes casted and cured. For M25 grade, replacement of 75% RCA shows 11.89% cost reduction for 1m^3 concrete. For M30 grade, replacement of 75% RCA shows 7.12% cost reduction for 1m^{3}concrete.

BACKGROUND
Concrete is the premier construction material across the world and the most widely used in all types of civil engineering works, including infrastructure, low and high-rise buildings, defense installations, environment protection and local/domestic developments. Concrete is a manufactured product, essentially consisting of cement, aggregates, water and admixtures. Among these aggregate i.e. inert granular materials such as sand, crushed stone or gravel form the major part. Traditionally aggregates have been readily available at economic price. However, in recent years the wisdom of our 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. In light of this, the availability of natural resources to future generations has also been realized. Given this background, the concept of sustainable development put forward almost a decade ago, at the 1992 Earth Summit in Rio de Janeiro, and it has now become a guiding principle for the construction industry worldwide.
In fact many governments throughout the world have now introduced various measures aimed at reducing the use of primary aggregates and increasing reuse and recycling, where it is technically, economically, or environmentally acceptable. For example, the UK government has introduced a number of policies to encourage wider use of secondary and recycled coarse aggregate (RCA- defined as minimum of 95% crushed concrete) as an alternative to naturally occurring primary aggregates. These include landfill and future extraction taxes to improve economic viability, support to relevant research and development work.

NEED TO USE RCA
Waste arising from Construction and Demolition constitutes one of the largest waste streams within the EU, Asian and many other countries. For example, it is estimated that core waste (described as those

types of materials which are obtained from demolished building or civil engineering infrastructure) amounts to around 180 million tons per year or 480 kg/person/year in the EU. This ranges from over 700 Kg/person/year in Germany and the Netherlands to under 200 in Sweden, Greece and Ireland. The estimates for the UK are 30 million tons/year and just over 500 Kg/person/year respectively, putting the UK in second place behind Germany. At the same time, the results of a recent study undertaken by the CSIR Building and Construction Technology have revealed that nearly a million tone of C & D waste ends up in landfills in South Africa. This is in addition to large quantities that are dumped illegally. Thus, construction demolition waste has become a global concern that requires sustainable solution. Sustainable construction rather than a fancy idea now is a necessity. It was introduced due to the growing concern about future of the planet, and it applies specifically for construction industry as, this being a huge consumer of natural resource. In addition to the 1.6 billion tons of cement used worldwide, the concrete industry is consuming 10 billion tons of sand and rock, and 1 billion tons of mixing water annually. In short the concrete industry, which uses 12.6 billion tons of raw materials each year, is the largest user of natural resources in the world. 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. As a direct result of these, recycling industries in many part of the world, including South Africa 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. In addition, there is an urgent need for legislative or regulatory measures to implement sustainable C & D waste management strategy and encourage recycling for use in value added applications.

INDIAN STATUS

There is severe shortage of infrastructural facilities like houses, hospitals; roads etc. in India, large quantities of construction materials for creating these facilities are needed. The planning Commission allocated approximately 50% of capital outlay for infrastructure development in successive 10th & 11th five-year plans. Rapid infrastructural development such highways, airports etc. and growing demand for housing has led to scarcity & rise in cost of construction materials. Most of waste materials produced by demolished structures disposed of by dumping them as landfill. Dumping of wastes on land is causing shortage of dumping place in urban areas. Therefore, it is necessary to start recycling and re-use of demolition concrete waste to save environment, cost and energy. Central Pollution Control Board has estimated current quantum of solid waste generation in India to the tune of 48 million tons per annum out of which, waste from construction industry only accounts for more than 25%, management of such high quantum of waste puts enormous pressure on solid waste management system. In view of significant role of recycled construction material and technology in the development of urban infrastructure TIFAC

(Technology Information, Forecasting & Assessment Council) has conducted a techno-market survey on 'Utilization of Waste from Construction Industry' targeting housing /building and road segment. The total quantum of waste from construction industry is estimated to be 12 to 14.7 million tons per annum out of which 7-8 million tons are concrete and brick waste. According to findings of survey, 70% of the respondent have given the reason for not adopting recycling of waste from Construction Industry is "Not aware of the recycling techniques" while remaining 30% have indicated that they are not even aware of recycling possibilities. Further, the user agencies industries pointed out that presently, the BIS and other codal provisions do not provide the specifications for use of recycled product in the construction activities.

APPLICATION OF RCA

The use of recycled concrete can be traced back to post-World War II Europe. At that time, there was a great need for the Europeans to rebuild their countries. Rubble from damaged buildings and structures was used as an aggregate in new concrete structures. Once the demand for materials no longer existed, conventional materials for new construction were utilized for a period of time. In modern day Europe, there has been an increase in the use of recycled concrete. The government has taken an active role in the disposal of building materials and has created incentives that encourage the use of materials like recycled concrete.

In general, applications without any processing include:

1. Many types of general bulk fill.
2. Bank protection
3. Base or fill for drainage structures
4. Noise barriers and embankments.

After removal of contaminants through selective demolition, screening, and /or air separation and size reduction in a crusher to aggregate sizes, crushed concrete canbe used as:

1. New concrete for pavements, shoulders, median barriers, sidewalks, curbsand gutters, and bridge foundations.
2. Structural grade concrete.
3. Soil-cement pavement bases.
4. Lean-concrete or eco-concrete bases.
5. Bituminous concrete
6. Most concrete in urban areas is recycled as fill or road base and not placed inlandfills.
7. Concrete pieces from demolished structures can also be reused to protectshorelines, for example in gabion walls or as rip rap.
8. Recycled concrete can be used as aggregate in new concrete, particularly thecoarse portion.

Smaller pieces of concrete are used as gravel for new construction projects. Sub- base gravel is laid down as the lowest layer in a road, with fresh concrete or asphalt poured over it. The highway department may use techniques such as these to build new highways from the materials from old highways. With proper quality control at the crushing facility, well graded and aesthetically pleasing materials can be provided as a substitute for landscaping stone or mulches concrete if it is free of contaminants.

MERITS OF RCA

- Produce specification sized recycled aggregates at your location
- Avoid haul-off costs and landfill disposal fees
- Eliminate the expense of aggregate material imports and exports
- Increase project efficiency and improve job cost - recycled concreteaggregates yield
- More volume by weight (up to 15%)
- Minimize impact to community infrastructure by reducing import and exporttrucking
- Keeping concrete debris out of landfills saves landfill space.
- Using recycled material as gravel reduces the need for gravel mining
- Recycling one ton of cement could save 1,360 gallons water, 900 Kg of Co2.
- Using recycled concrete as the base material for roadways reduces the pollution involved in trucking material.
- The use of recycled aggregate can save money for local governments and other purchasers create additional business opportunities, save energy when recycling is done on site, conserve diminishing resources of urban aggregates.
- Using recycled concrete for new construction projects routinely cuts costsdown by 50% over what they would be if only brand new concrete were used.

SUSTAINABILITY

Recycling concrete provides sustainability several different ways. The simple act of recycling the concrete reduces the amount of material that must be land filled. The concrete itself becomes aggregate and any embedded metals can be removed and recycled as well. As space for landfills becomes premium, this not only helps reduce the need for landfills, but also reduces the economic impact of the project. Moreover, using recycled coarse aggregates reduces the need for virgin aggregates. This in turn reduces the environmental impact of the aggregate extraction process. By removing both the waste disposal and new material production needs, transportation requirements for the project are significantly reduced. In addition to the resource management aspect, recycled coarse aggregates absorb a large amount of carbon dioxide from the surrounding environment. The natural process of carbonation occurs in all concrete from the surface inward. In the process of crushing concrete to create recycled coarse aggregates, areas of theconcrete that have not carbonated are exposed to atmospheric carbon dioxide

LITERATURE REVIEW

Yong, P.C.[1] and Teo, D.C.L.," Utilization of Recycled Aggregate as Coarse Aggregate in Concrete", UNIMAS E-Journal of Civil Engineering, Vol. 1: issue 1August 2009.

In this research, recycled concrete aggregates (RCA) from site-tested concrete specimens were used. These consist of 28-days concrete cubes after compression test obtained from a local construction site. These concrete cubes are crushed to suitable size and reused as recycled coarse aggregate. The amount of recycled concrete aggregate used in this research is approximately 200 Kg. Many researchers state that recycled aggregates are only suitable for non-structural concrete application. This research, however, shows that the recycled aggregates that are obtained from site- tested concrete specimen make good quality concrete. The compressive strength of recycled aggregate concrete (RAC) is found to be higher than the compressive strength of normal concrete. Recycled aggregate concrete is in close proximity to normal concrete in terms of split tensile strength, flexural strength and wet density. The slump of recycled aggregate concrete is low and that can be improved by using Saturated Surface Dry (SSD) coarse aggregate.

Cheolwoo Park, Ph.D., P.E. Research Professor Department of Civil and Environmental Engineering, Hanyang University, Ansan, Korea, Da Jongsung Sim, Ph.D. Professor Department of Civil and Environmental Engineering, Hanyang University: Jul. 27 2005), "Fundamental Properties of Concrete using Recycled Concrete Aggregate produced through Advanced Recycling Process"

The amount of construction waste has been dramatically increased in the last decade, and social and environmental concerns on the recycling of the waste have consequently been increased. Waste concrete is particularly crucial among the construction wastes. Recent technology has also improved the recycling process. This study aims to evaluate the fundamental characteristics of concrete using recycled concrete aggregate (RCA) that was recycled through advanced recycling process. The concrete evaluated in this study contained various amount of fine RCA with 100% of coarse RCA. Compressive strength gradually decreased as the amount of the fine RCA increased. When complete aggregate was replaced with the RCA, the strength was about 15.5% less than that of non-RCA concrete at 28 days. Greater strength reduction was observed as the amount of the fine RCA was increased over 60%. The chloride ion penetrability was shown to be moderate up to the fine RCA ratio of 60%. The carbonation resistance was shown to be sufficient and drying shrinkage of the concrete using RCA was very comparable to the estimation suggested by ACI 209 that was originally for the natural aggregate concrete. Dynamic modulus of elasticity decreased as greater amount of RCA was incorporated, and was smaller than the literature. From the experimental studies herein, it is anticipated that the coarse RCA can be successfully applied to structural concrete members. However, it is suggested that the replacement ratio of the fine RCA be limited below 60% when the coarse RCA replacement ratio is 100% due to strength development and other durability related properties including chloride ion penetration.

Andres Salas, "Recycled Concrete Aggregate for Airfield Pavements", University of Illinois

Recycling of concrete is needed for the effective utilization of construction and material resources. At the present time, utilization of recycled aggregate (RA) in pavements is primarily applied to support layers for roads and airfields. There will be a continued increase in the amount of concrete waste materials coupled with a shortage of disposal sites and depleted high quality natural resources. This paper summarizes work completed in partnership with the O'Hare Modernization Program to examine the effect of recycled concrete aggregates (RA) on the fresh and hardened concrete properties for airfield rigid pavement applications. A relative new method for batching and mixing recycled concrete aggregate called the two-stage mixing approach (TSMA) was evaluated in order determine its effect on the fresh and hardened concrete properties relative to virgin aggregate concrete. The study also included the effect of different percentages of Class C and Class F fly ashes on early age fresh and hardened properties of different recycled aggregate concrete (RAC) mixtures including coarse and fine recycled aggregates. The results of these mentioned mixtures showed that is possible to obtain recycled aggregate concretes with considerable amounts of fly ash that meet the requirements to be used on airfieldrigid pavements.

Keith W. Anderson, Jeff S. Uhlmeyer, Mark Russell, "Use of Recycled Concrete Aggregate in PCCP", June 2009.

The Washington State Department of Transportation (WSDOT) is considering recycling concrete pavements to produce aggregate for new concrete (PCC) pavements. Recycling pavements to produce new pavements conserves natural resources, reduces the impact on dwindling landfill space, reduces disposal costs, and may reduce overall projects costs. Washington pavements contain some of the highest quality aggregates in the world and this fact has been cited as the reason for the excellent performance of not only the PCC pavements, but also hot mix asphalt (HMA) pavements. Pavements made with RCA aggregates may have problems with excessive mid slab cracking, poor load transfer, and durability if proper steps are not taken to combat D-cracking, freeze-thaw and ASR susceptibility. The workability of mixes made with RCA can be improved by limiting the use of recycled fine aggregate, adding fly as a partial cement replacement and using water reducing agents. The literature suggests that the use of RCA in pavements in Western Washington is worth considering given the hard, durable nature of the virgin aggregates that were used to build the existing pavement on the west side of the state. Many of the performance issues cited in the literature and experienced by other states will not be a problem due to our excellent aggregates or will not show up because of our existing mix design and construction practices.

Nik. D. Oikonomou, "Recycled concrete aggregates", Laboratory of Building Materials, Department of Civil Engineering, Aristotle University of Thessaloniki, 54124 Thessaloniki, Greece.

The subject of concrete recycling is regarded as very important in the general attempt for sustainable development in our times. In a parallel manner, it is directly connected with (a) increase of demolition structures past out of performance time, (b) demand for new structures and (c) results—especially in Greece—of destruction by natural phenomena (earthquakes, etc.). The present paper refers to the concrete recycling subject and, more specifically, to a proposal for Greek specifications of recycled concrete aggregates (RCA) with reference to international experience and practice. The existence of Greek specifications of RCA—the European ones will come much later—will help Olympic Games 2004 to be as ‘‘green’’ as possible.

Victor Cervantes, Dr. Jeffery Roesler, and Amanda Bordelon, University of Illinois, Dept. of Civil and Environmental Engineering, "Fracture Properties of Concrete Containing Recycled Concrete Aggregate", January 9, 2007

The objective of this study was to show that using recycled concrete as a coarse aggregate with and without the addition of synthetic fibers can produce a paving concrete with similar fracture properties as those made with virgin coarse aggregate. Six different concrete mixtures were produced. Two mixtures were made completely with virgin coarse aggregate, two mixtures only used recycled coarse aggregate (RCA), and the last two were a blend of virgin and recycled coarse aggregate. For each of the mixtures three point bending, shrinkage, compression, and tensile splitting tests were conducted. Testing results demonstrated that the use of RCA alone reduced the peak load capacity of the concrete beam specimen, the total fracture energy of the concrete, and created greater drying shrinkage. However, when 0.2% volume fractions of fibers were added the total fracture energy of all the mixtures became similar. The blending of RCA and virgin course aggregate at a 50-50 volume percentage also produced a pavement concrete with similar fracture and shrinkage properties to that of the virgin coarse aggregate concrete.

NBM Media, "Use of Recycled Aggregates in Concrete –A Paradigm Shift"

This paper presents the experimental results of recycled coarse aggregate concrete and results are compared with the natural crushed aggregate concrete. The fine aggregate used in the concrete, i.e. recycled and conventional is 100 percent natural. The recycled aggregate are collected from four sources all demolished structures. For both types of concrete i.e. M-20 and M-25, w/c ratio, maximum size of aggregate and mix proportion are kept constant. The development of compressive strength of recycled aggregate concrete at the age of 1,3,7,14,28, 56, and 90 days; the development of tensile & flexural strength at the age of 1,3,7,14 and static modulus of elasticity at the age of 28 days are investigated. The results shows the compressive, tensile and flexural strengths of recycled aggregate are on average 85% to 95% of the natural aggregate concrete. The durability parameters are also investigated for recycled aggregate concrete and are found to be in good agreement with BIS specifications

Case Study O'Hare Modernization Project

Recycled concrete aggregates are being considered for use in the O'Hare Modernization Project (OMP). Laboratory testing using a two-stage mixing method showed that using RCA from Chicago O'Hare International Airport for the coarse aggregate reduces bleeding and segregation and produces similar workability, compressive strength, and shrinkage as virgin aggregates. In October of 2009, a field test of RCA was initiated in two lanes at Gate F7B. In a side-by-side comparison, a lane of concrete using virgin aggregates was placed next to a lane of concrete using RCA. The RCA was produced on-site using concrete removed at the airport. The ready mixed concrete supplier treated the RCA like lightweight aggregates and was able to produce concrete in a single-stage mixing process. Contractors placing the RCA concrete said the workability was similar to that of the virgin aggregate concrete and the placement had good finish. Within four days, the placement was in full service. Sensors were placed in the concrete at the time of placement to measure the internal relative humidity, temperature, and the lift-off of the slab from the cement- treated permeable base. Other properties were regularly monitored, such as surface appearance and joint width. After five months of monitoring, the data between the two concrete lanes are the same, showing no difference in behavior between the RCA concrete and virgin aggregate concrete.

THEORETICAL FORMULATION

The main aim of this research project is to utilize recycled concrete aggregates as coarse aggregate for the production of concrete. It is essential to know whether the replacement of RCA in concrete is inappropriate or acceptable. Three types of aggregates are used in this project, which include natural coarse aggregate, natural fine aggregate and RCA. Natural coarse aggregate used is microtonalite with maximum size of 20 mm. Natural fine aggregate used is river sand and RCA is used from demolished concrete waste on which physical test such as specific gravity, absorption, impact value and sieve analysis are carried out. Then concrete cube and cylinders prepared for 0%, 25%, 50%, 75%, 100% replacement of RCA and the same has been tested for 7 and 28 days for determination of compressive strength and tensile splitting test. The results at each testing age are reported as an average. The engineering properties of the RCA were also compared to those of the reference concrete.

TRIAL MIX FOR OPTIMUM STRENGTH

The mix design is done according to the IS design method and numerous trial mixes were conducted to obtain the optimum mix. Once the optimum mix is determined, it is used to produce concrete with 0%, 25%, 50%, 75% AND 100% replacement of RCA. The concrete is prepared to find out the compressive strength and the tensile splitting strength.

MIX DESIGN OF CONCRETE

The process of selecting suitable ingredients of concrete and determining their relative amounts with the objective of producing a concrete of required strength, durability and workability as economically as possible, is term as concrete mix design. The proportioning of ingredient of concrete is governed by the required performance of concrete in 2stages, namely the plastic and hardened states. If the plastic concrete is not workable, it cannot be properly placed and compacted. The property of workability, therefore, becomes of vital importance. The compressive strength of hardened concrete which is generally considered to be an index of its other properties depends upon many factors, e.g. quality and quantity of cement, water and aggregates, batching and mixing, placing, compaction and curing. From technical point of view the rich mixes may lead to high shrinkage and cracking in the structural concrete, and to evolution of high heat of hydration in mass concrete which may cause cracking.

REQUIREMENT OF CONCRETE MIX DESIGN

The requirement, which forms basis of selection and proportioning of mix Ingredients are:

- The minimum compressive strength required from structural consideration.
- The adequate workability necessary for full compaction with the compactingequipment available.
- Maximum water-cement ratio and/or maximum cement content to giveadequate durability for the particular site conditions.
- Maximum cement content to avoid shrinkage cracking due to temperaturecycle in mass concrete.

FACTORS TO BE CONSIDERED FOR MIX DESIGN

- The grade designation giving the characteristic strength requirement ofconcrete.
- The type of cement influences the rate of development of compressivestrength of concrete.
- Maximum size of aggregates to be used in concrete may be as large aspossible within the limits prescribed by IS 456:2000.
- The cement content is to be limited from shrinkage, cracking and creep.
- The workability of concrete for satisfactory placing and compaction is related to the size and shape of selection, quantity and spacing of reinforcement and technique used for transportation, placing and compaction.

PROCEDURE FOR MIX DESIGN

1. Determining the mean target strength f_t from the specified characteristic compressive strength at 28-days fck and the level of quality control. f_t = fck + 1.65 S

Where s is the standard deviation obtained from the table of approximate contents given after the design mix.

2. Obtained the water cement ratio for the desired mean target using the empirical relationship between compressive strength and water cement ratio so chosen is checked against the limiting water cement ratio. The water cement ratio so chosen is checked against the limiting water cement ratio for the requirements of durability given in table and adopts the lowerof the two values.
3. Estimate the amount of entrapped air for maximum normal size of aggregate from the table.
4. Select the water content, for the required workability and maximum size of aggregates (for aggregate in saturated surface dry condition) from table.
5. Determine the percentage of fine aggregate in total aggregate by absolute volume from table for the concrete using crushed course aggregate.
6. Adjust the values of water content and percentage of sand as provide in the table for any difference in workability, water cement ratio, grading of fine aggregate and for rounded aggregate the values are given in table.
7. Calculate the cement content from the water-cement ratio and the final water content as arrived after adjustment. Check the cement against the minimum cement content from the requirement of durability and greater ofthe two values is adopted.
8. From the quantities of water and cement per unit volume of concrete and the percentage of sand already determined in step 6 & 7 above, calculate the content of coarse and fine aggregates per unit volume of concrete fromthe following relations:
9. Determine the concrete mix proportions for the first trial mix.
10. Prepare the concrete using the calculated proportions and cast cubes of 150 mm size and test them after 28 days moist curing and check for the strength.
11. Prepare trial mixes with suitable adjustments till the final mix proportionsare arrived at.

TESTS PERFORMED ON CONCRETE

Slump Test:

Properties of fresh concrete were mainly judged by workability by slump test. Slump test is performed to check the workability and consistency of the fresh concrete. Slump test as per IS: 1199 – 1959 is followed.

Procedure

Slump test is performed on both the concrete mix prepared by normal water and magnetized water. The mould is dampened and placed on a flat, moist, non- absorbent (rigid) surface. It shall be held firmly in place during filling by the operator standing on the two foot pieces, and filled by the fresh concrete prepared by normal water in three layers, each approximately one third the volume of the mould. 25 strokes of the tamping rod is applied to each layer, uniformly distributing the strokes over the cross-section, and just penetrating into the under laying layer. After the top layer has been removed, the surface of the concrete is stricken off by means of a screening and rolling motion of the tamping rod. The mould is removing immediately from the concrete by raising it carefully in a vertical direction. The slump is measured immediately by determining the difference between the height of the mould and the height over the original centre of the base of the specimen.

Compressive Strength Test:

The compression test is carried out according to determine the characteristic strength of the concrete. In this test, 150 mm standard cube mound is used for concrete mix. The apparatus should be clean and free from hardened concrete and superfluous water before testing. The test is carried out for each cube. The reported compressive strength is the average of 3 measurements tested at the age of 7 and 28 days.

Figure 1:- Concrete Cube Specimens before Failure

Figure 2:- Concrete Cube specimen after Failure

Split Tensile Test:

The split cylinder test is performed to find the tensile strength of a cylindrical concrete specimen. The cylindrical specimen is placed with its axis horizontally and subjected to a line load along the length of the specimen. The diameter and length of the cylindrical concrete are 150 mm and 300 mm respectively. Two wooden-bearing strips, 3.2 mm thick, 25 mm wide and slightly longer than the length of the specimen, are placed between the steel bars and the specimen to take account of deviations in the surface of the specimen. The machine used is same as that used for compression test.

Figure 3:- Concrete Cylinder Specimen

PARAMETRIC INVESTIGATION

Preliminary Remark

Concrete mix design has been studied in chapter three. Concrete mix design M25, M30 & M35 is designed in this chapter, normal aggregates and RCA both are used for casting concrete cube. The compressive strength of various percentage of RCA in concrete cube have been tasted and compared with concrete cube casted with normalaggregates.

VALIDATION OF RESULTS

Result obtained by present theoretical formulation have been validated first by comparing the concrete cubes casted and cured with normal water for M25 mix design in Tom Lab., N B Navale Singhad College of Engineering, and Solapur with the cubes made with same mix design in NTPC, Lab. (NATIONAL THERMAL POWER CORPORATION), Solapur on Compression Testing Machine (CTM).

Table 1:- Compressive Strength of Concrete Cubes with M25 Mix Design inN/mm^2

LABORATORY	7 Days	28 Days
TOM Lab, NBNSCOE, Solapur.	19.64	30.22
NTPC Lab, Solapur.	19.90	30.77

CALCULATIONS FOR CONCRETE MIX DESIGN

Concrete Mix Design

A) Mix proportion for M25

a) Volume of concrete=1 m^3

b) Volume of cement = $\{\frac{480.87}{3.15\times1000}\}$ =0.152m^3

c) Volume of water = $\{\frac{197}{1\times1000}\}$ =0.197m^3

d) Volume of all Aggregates = {1-(b+c)} = {1-(0.152+0.197)}
=0.6503 m^3

e) Weight of fine aggregate =0.382 $\times$2.6 $\times$ 0.6503 $\times$ 1000

=645.87kg

f) Weight of coarse aggregate =0.6503$\times$ 0.618 $\times$ 2.89 $\times$ 1000
=1161.44kg

g) Water added in batching plant by water absorption of C.A. &F.A.
=197+ {{(1.83/100) $\times$ 1321.019] + [(2.04/100) $\times$ 509.34]}
= 231.56 kg/m^3

h) Mix design proportion =1:1.34:2.41

Table 2:- Mix proportion for 1m^3 M25 Concrete

W/C ratio	Water	Cement	Sand	Aggregate
0.41	231.56 kg	480.87 kg	645.87kg	1161.44kg

A) Mix Proportion for M30

a) Volume of concrete=1 m^3

b) Volume of cement = 0.156 m^3

c) Volume of water =0.197m^3

d) Volume of Coarse aggregate = 0.219m^3

e) Volume of Fine aggregate = 0.146m^3

f) Weight of coarse aggregate =1159.38 kg

g) Weight of Fine aggregate =639.23kg

h) Water added in batching plant by water absorption of C.A. &F.A. = 231.25 kg/m^3

i) Mix design proportion =**1:1.29:2.35**

Table 3:- Mix Proportion for 1m^3 M30 Concrete

W/C ratio	Water	Cement	Sand	Aggregate
0.40	231.25 kg/m^3	492.9 kg	639.23kg	1159.38 kg

B) Mix Proportion for M 35

a) Volume of concrete=1 m^3

b) Volume of cement = 0.165 m^3

c) Volume of water = 0.197m^3

d) Volume of Coarse aggregate = 0.219m^3

e) Volume of Fine aggregate = 0.146m^3

f) Weight of coarse aggregate =1152.34 kg

g) Weight of Fine aggregate =624.68 kg

h) Water added in batching plant by water absorption of C.A. & F.A. = 230.78 kg/m^3

i) Mix design proportion =**1:1.20:2.22**

Table 4:- Mix Proportion for 1m^3 M35 Concrete

W/C ratio	Water	Cement	Sand	Aggregate
0.38	230.78 kg	518.42 kg	624.68 kg	1152.34 kg

Casting and Curing of Concrete Cube.

1. Concrete cubes were caste and cure with normal aggregates as well as RCA for three mix designs M25, M30 and M35 for 7 days and 28 days and its compressive strength &split tensile strength is tested.
2. The casting and curing of concrete cubes were done in various stages
3. The casting of concrete cubes is done are as follows

i. Casting with 0% of RCA
ii. Casting with 25% of RCA
iii. Casting with 50% of RCA
iv. Casting with 75% of RCA
v. Casting with 100% of RCA

- Total 135 number of cubes & 48 number of cylinder was casted for above mix design combination
- After 7 days, 14 days and 28 days the compressive strength of all these concrete cubes & cylinders are checked and recorded

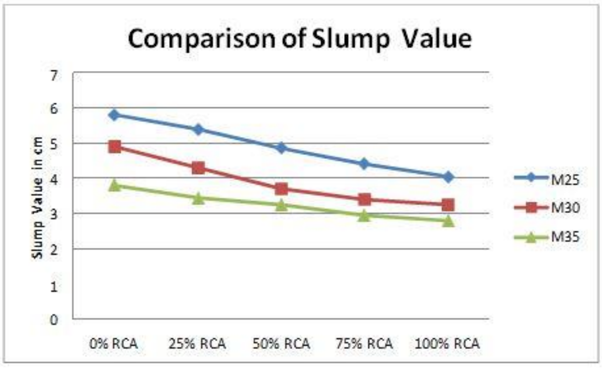
Result and Discussion

A) Slump Cone Test

The slump values of different percentage of RCA are as follows.

Table 5:- Result of Slump Cone Test

Sr. No.	Grade of Concrete	Slump Value For Various % of RCA in cm				
		0%	25%	50%	75%	100%
1	M25	5.8	5.39	4.85	4.4	4.05
2	M30	4.9	4.3	3.70	3.4	3.25
3	M35	3.8	3.45	3.25	2.95	2.8



Comparison of Slump Value

Discussion:

1. Slump of concrete mix prepared by 0% RCA (natural aggregate) is more.
2. The decrease in slump of concrete was observed as percentage of RCAincreases.

B) Compressive Strength of Concrete Cubes

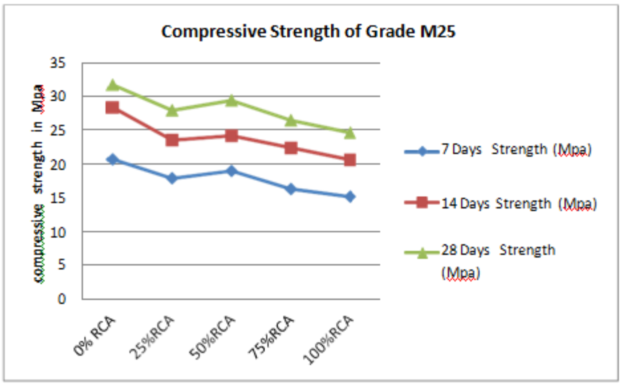
Following table shows compressive strength of 0% RCA (Natural Aggregate)

Table 6:-Test Result of Mix Designs of Concrete Grades M25, M30, M35

Concrete Grade	CubeNo.	Compressive Strength			Average Compressive Strength		
		7days	14days	28days	7days	14days	28days
M25	1	19.64	27.89	30.22	20.60	28.33	31.70
	2	20.80	28.40	32			
	3	21.37	28.7	32.89			
M30	1	23.04	31.20	36.00	22.46	30.47	34.96
	2	21.61	29.12	33.78			
	3	22.75	31.09	35.56			
M35	1	22.47	32.45	35.11	22.70	32.63	35.78
	2	23.11	32.89	36.56			
	3	22.53	32.56	35.67			

Table 7:- Test Result of Compressive Strength of Grade M25

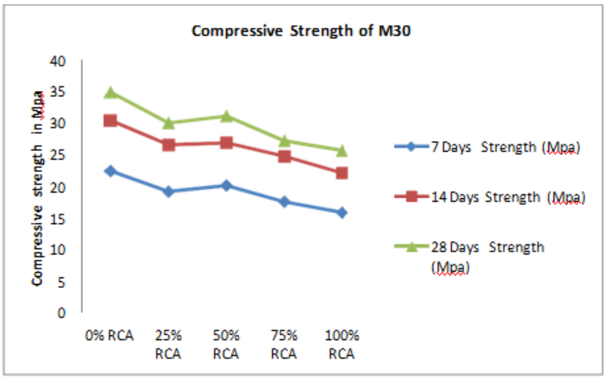
Sample	0% Replacement	25% Replacement	50% Replacement	75% Replacement	100% Replacement
7Days Cube Strength (Mpa)	20.60	17.78	18.89	16.20	15.06
14Days Cube Strength (Mpa)	28.33	23.47	24.12	22.32	20.54
28Days Cube Strength (Mpa)	31.70	27.89	29.37	26.41	24.56



Comparison of Compressive Strength of Grade M25 with DifferentPercentage of RCA

Table 8:- Test Result of Compressive Strength of Grade M30

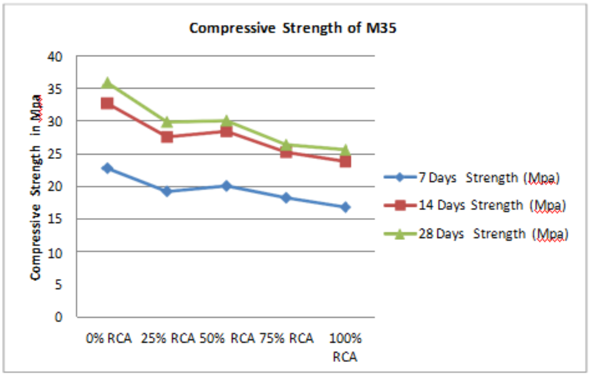
Sample	0% Replacement	25% Replacement	50% Replacement	75% Replacement	100% Replacement
7 Days Cube Strength (Mpa)	22.46	19.20	20.16	17.59	15.88
14 DaysCube Strength (Mpa)	30.47	26.6	26.94	24.78	22.13
28Days Cube Stre ngth (Mpa)	34.96	30.08	31.17	27.25	25.69



Comparison of Compressive Strength of Grade M30 with DifferentPercentage of RCA

Table 9:- Test Result of Compressive Strength of Grade M35

Sample	0% Replacement	25% Replacement	50% Replacement	75% Replacement	100% Replacement
7Days Cube Strength (Mpa)	22.70	19.17	20.02	18.21	16.77
14Days Cube Strength (Mpa)	32.63	27.49	28.36	25.16	23.76
28Days Cube Strength (Mpa)	35.78	29.78	29.98	26.32	25.54



Comparison of Compressive Strength of Grade M35 with DifferentPercentage of RCA

Discussion:

1. Decrease in compressive strength was observed as percentage of RCA increased for Grade M25, M30 and M35.
2. For M25 Grade, replacement of 100% RCA is not giving appropriate compressive strength but replacement of 25%, 50%, and 75% RCA gives required compressive strength however replacement of 50% RCA gives betterresult.
3. For M30 Grade, replacement of 75% and 100% RCA is not giving appropriate compressive strength but replacement of 25% and 50% RCA gives required compressive strength however replacement of 50% RCA gives better result.
4. For M35 Grade, replacement of 25%, 50%, 75% and 100% RCA is not giving appropriate compressive strength.

Split Tensile Strength of Concrete Cylinder

As replacement of 50% RCA gives better result than other percentage of RCA.

Table 10:- Splitting Tensile Strength of Cylinder for M25 Grade in Mpa

Sample	0%	50%
7 Days	2.30	2.14
14 Days	2.68	2.43
28 Days	3.39	3.29

Discussion:

5. Decrease in Splitting tensile strength was observed as percentage of RCAincreased for Grade M25, M30 and M35.
6. Replacement of 50% of RCA gives better result than other percentage ofRCA.

Table 11. Splitting Tensile Strength of Cylinder for M30 Grade in Mpa

Sample	0%	50%
7 Days	2.6	2.5
14 Days	2.97	2.76
28 Days	3.73	3.53

Table 12:- Splitting Tensile Strength of Cylinder for M35 Grade in Mpa

Sample	0%	50%
7 Days	3.18	2.93
14 Days	3.41	3.06
28 Days	3.95	3.58

Cost Comparison for various Grade of Concrete

For M25 Grade:-

From table 4.7 it is observed that result of 100% RCA is not showing appropriate compressive strength. Therefore cost comparison is not been considered for 100% RCA. Following table shows cost comparison between 0%, 25%, 50% and 75% RCAfor 1m^3 Concrete

Table 13:- Cost Comparison of M25 Grade for 1m^3 Concrete

Sr. No.	Materials	0% RCA		25% RCA		50% RCA		75% RCA	
		Qty kg	Amt Rs.	Qty kg	Amt Rs.	Qty kg	Amt Rs.	Qty kg	Amt Rs.
1	Cement	481	3079	481	3079	481	3079	481	3079
2	Fine Aggregates	646	8530	646	853	646	8573	646	853
3	Course Aggregates (Natural)	1162	9001	872	675	581	450	290	225
4	Course Aggregates (Recycled)	-	-	290	50	581	75	872	100
Total		-	4832	-	4657	-	4457		4257
% cost Reduction				3.62%		7.76%		11.89%	

For M30 Grade:-

From table 4.8 it is observed that result of 75% and 100% RCA is not showing appropriate compressive strength. Therefore cost comparison is not been consider for75% and 100% RCA. Following table shows cost comparison between 0%, 25% and 50%RCAfor 1m^3 concrete.

Table 14:- Cost Comparison of M30 Grade for 1m^3 Concrete

Sr. No.	Materials	0% RCA		25% RCA		50% RCA	
		Qty kg	Amt Rs.	Qty kg	Amt Rs.	Qty kg	Amt Rs.
1	Cement	493	3156	493	3156	493	3156
2	Fine Aggregates	640	845	640	845	640	845
3	Course Agg (Natural)	1160	898	870	673	580	449
4	Course Agg (Recycled)	-	-	290	50	580	100
Total		-	4899	-	4724	-	4550
% cost Reduction				3.57%		7.12%	

For M35 Grade:-

From table 4.9 it is observed that result of 25%, 50%, 75% and 100% RCA is not showing appropriate compressive strength. Therefore cost comparison is not been consider for 25%, 50%, 75% and 100% RCA. Therefore cost comparison is not donefor various percentage of RCA.

CONCLUSION

From the experimental work carried out on "Recycle of Concrete Aggregates",the following conclusion can be drawn:

1. The slump of the normal concrete is observed to be more than the recycledone.
2. The decrease in slump of concrete was observed as percentage of RCA increases as water absorption of RCA is higher than natural aggregate.
3. Decrease in compressive strength and split tensile strength was observed as percentage of RCA increased for Grade M25, M30 and M35
4. The compressive strength of concrete containing 50% RCA has strength in close proximity to that of normal concrete.
5. Tensile splitting test shows that concrete has good tensile strength whenreplace up to 25-50%.
6. The strength of concrete is high during initial stages but gradually reducesduring later stages.

Cost Comparison

1. For M25 grade, replacement of 75% RCA shows 11.89% cost reduction for1m^3 concrete.
2. For M30 grade, replacement of 75% RCA shows 7.12% cost reduction for 1m^3concrete.

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