ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

Experimental Study on Strength and Durability of High Strength Recycled Aggregate Concrete

S.Vinodh Kumar
M.Tech (Structural Engineering)
KMM College,
Tirupari, A.P.

A.Brahmini
M.Tech (Structural Engineering)
KMM College,
Tirupari, A.P.

Abstract

In developing countries like India, the generation of construction and demolition (C &D) waste is upto the tune of 23.75 million tones annually and these figures are likely to double fold in the next 7 years. On the other hand, the reuse of construction waste is highly essential from the view point of Life Cycle Assessment (LCA) and effective recycling of the construction resources. Using the demolished concrete debris as recycled concrete aggregate conserves natural aggregates, reduces the impact on landfills, decreases energy consumption and can provide cost savings. The use of recycled aggregates in concrete results in significant economical and environmental benefits. 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) are 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.

INTRODUCTION

Cement is a standout amongst the most generally utilized development material bringing on an appeal for it. As a consequence of this, there is an expansion in the interest for its constituents like the coarse totals, sand, concrete and water. This increment sought after is creating broad quarrying of normal totals as it is required as coarse totals in solid generation furthermore it frames the significant constituent by mass in cement.

Keeping in mind the end goal to possess property in development there has been store of substitution for various constituents of cement by optional building materials. as an option, counterfeit totals like manufacturing plant made sand chamber scoria, fly powder, stretched earth, broken blocks and steel might be utilized wherever fittingly. it's few advantages like low value, general accommodation of material, capacity, low vitality interest and usage underneath very surprising ecological conditions.

The point of any property development is to diminish the effect on setting of any development over its lifespan. Cement is that the primary material utilized in development all over the place the globe. as a result of expansion in Construction and Demolition exercises around the world, the solid squanders created due to pulverization conjointly will increment. in any case this waste isn't utilized for any reason that is totally misfortune inside the economy of the nation as an aftereffect of regular assets square measure draining at a quick pace. progressively the produced solid squanders cause genuine transfer issues in light of the fact that the districts don't appear to be prepared to understand the best response for it while not powerful the setting. we as a whole realize that the premier regular watch all over the place the globe just in the event of the greater part of the materials (paper, plastic, elastic, wood, concrete, and so forth.) is use to spare loads of the characteristic assets and setting. Cement is such a chic and vitality overpowering material anyway it's dazzling that solid waste is

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

seldom used by use the solid as a reused solid mix (RCA) to use for the improvement capacities. Rather it's basically discarded in landfills.

Subsequently one can reason that there is no conceivable substitution for cement in development field. Along these lines it is important to preserve the common totals and in the meantime give consistent supply of cement to development industry. This present concentrate accordingly goes for utilizing the wrecked cement in the wake of reusing as coarse totals in the new solid generation.

To accomplish supportability in development, scientists and organizations concentrate on utilizing waste cement, as another development material. It is called reused total which can be created by squashing the annihilated cement reasonably either by manual smashing or by utilizing machines. The totals are ordered by size as coarse and fine total. In the event that reused totals can be utilized viably, not just would it be able to diminish the effect on environment additionally help in being utilized as development material keeping it from turning into a waste and achieving landfills.

The crucial issue required in using devastated concrete as aggregate is related to finishing awesome workability. There has starting now been a couple of headways in this field of upgrading the execution of bond moreover to defeat issues related to workability in different courses and to continue with the change to direct imperativeness, rough materials, change of great concrete, prestressed strong, high early quality, and low possible water/security extent while keeping up high workability, to improve mechanical and helper properties of fresh and set strong so as to make fundamental concrete as mild.

As the guardian totals from various wellsprings of pulverization squanders are diverse in its temperament, the qualities of RAC will likewise subsequently fluctuate. Subsequently stand out examination can't be convincing and thus it is ideal that appropriate examinations and tests are performed on the examples before utilizing them as a part of field. For instance, the age at annihilation, total properties like water assimilation, smashing and effect values, solid evaluation and quality, and so forth influence the properties of RAC.

In the event that the solid utilized as a part of past development was of high quality, then the remaining quality after obliteration will be more contrasted with that solid which has lower quality in the past development. Consequently securing reasonable learning about the acquired obliterated solid like age at destruction, quality of cement utilized, constituents, and so on will help us to pick the destroyed waste in light of the necessity of new development.

Later on it will get the chance to be imperative to find new wellspring of aggregate for the era of bond on account of development looked for after for and lessen in supply of ordinary aggregate. As the demolition activities are alarmingly extending a result of urbanization, end of organization life of structure, forbidden nature of a structure for current necessities or due to trademark fiascoes, the issue of exchange of this strong rubble has been the colossal test. This has incited an excitement for the probability of using crushed cement as aggregate as a piece of new concrete. Revealing the way that strong is engineered composite material, which includes confining medium inside which are embedded particles. The coupling medium is for the most part a bond water paste. The mineral filler or rock particles which are suspended in paste are called aggregates. Aggregates can be of different size, either coarse or fine.

The explanation behind the paste is to fill the voids amidst the sums and to give the quality to the hardened bond. The inspiration driving the aggregate is to give unassuming filler to the bond, and to decrease the volume change of strong when it cements. In asked for to be seen as a mass of concrete, the mass must be workable when recently mixed. Exactly when bond is made, it must have the ability to be pumped to a

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

substitute region or have the ability to set in certain position. In like manner when bond sets, it needs to wind up as hard as stone. While the purpose behind bond is to give an unassuming yet strong material, strong still ought to have attractive quality. Bond is usually used for structures and clearing material, moreover has limitless diverse jobs.

Reusing cement is the best decision to lessen the enthusiasm on incredible customary resources and to oblige the measure of waste that is masterminded in landfills. Reused concrete has been generally used as an unbound material as a piece of dams, bases, and sub-bases. RAC has in like manner been used as a part of the improvement of pavements and squanders yet in less cases as the investigation in this field is almost no the most extreme limit of RAC has not yet been explored. The usage of reused concrete in weight bearing structures has not expanded wide affirmation likely in perspective of the nonattendance of accessible information on the subject, for instance, expected fresh and cemented material properties. Concrete is by all record by all account not the only reused material that has been used as a part of past advancement applications. Reused dark top, fly searing remains, and slag have been used as a part of past exercises. Reused materials add to material practicality, diminish environmental impact of demolished materials, and end up being saving. The cost of an endeavor could reduce if concrete does not should be pulled and dumped, and rather be used to supplant a touch of virgin aggregate in the new strong structure.

Recycled Aggregate

Recycling is the act of processing the used material for use in creating new product. The usage of natural aggregate is getting more and more intense with the advanced development in infrastructure area. In order to reduce the usage of natural aggregate, recycled aggregate can be used as the replacement materials. Recycled aggregate are comprised of crushed, graded inorganic particles processed from the materials that have been used in the constructions and demolition debris. These materials are generally from Buildings, roads, bridges, and sometimes even from catastrophes, such as wars and earthquakes.

Recycled Coarse Aggregate

There are many advantages through using the recycled aggregate. The advantages that occur through usage of recycled aggregate are listed below.

- Environmental Gain
- Cost
- Job Opportunities
- Sustainability
- Market is wide

High-Strength Concrete

Concrete, a composite consisting of aggregates enclosed in a matrix of cement paste including possible pozzolans, has two major components – cement paste and aggregates. The strength of concrete depends upon the strength of these components, their deformation properties, and the adhesion between the paste and aggregate surface With most natural aggregates, it is possible to make concretes up to 120 MPa compressive strength by improving the strength of the cement paste, which can be controlled through the choice of water- content ratio and type and dosage of admixtures (Mehta and Aitcin, 1990). However, with the recent advancement in concrete technology and the availability of various types of mineral and chemical admixtures, and special superplasticizer, concrete with a compressive strength of up to 100 MPa can now be produced commercially. These developments have led to increased applications of high-strength concrete (HSC) all around the globe. In spite of the rapid development in concrete technology

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

in recent years, concrete with compressive strength higher than 40 MPa is still regarded as HSC.

REQUIREMENTS OF INGREDIENTS FOR HIGH STRENGTH CONCRETE

From the preceding discussions on information found from literature, the necessary requirement of different ingredient materials required for producing HSC can be summarized as stated in Table

Material / issue	Requirements
Cement	Portland cement Higher content (8 to 10 sacks per cu. yd. of concrete)
Water	Portable quality water. w/b ratio 0.22 to 0.40
Fine aggregate	- Smaller sand content or coarser sand - Grading is not critical for concrete strength Coarse aggregate - Sand with rounded particle shape -Higher FM(around 3)
Coarse aggregate	-Smaller maximum size (10 – 12 mm) is preferred - Angular and crushed with a minimum flat and elongated particles. Higher CA/FA ratio than that for normal strength concrete. - Gradation within ASTM limits has little effect on concrete strength
Admixtures (chemical & mineral)	- Type of admixture depends on the property of the concrete to be improved - Reliable performance on previous work can be considered during selection. -optimum dosage
Overall basic considerations - Quality materials	- Improved quality of cement paste as well as aggregates - Denser packing of aggregates and cement paste - Improved bond between aggregate surface and cement paste - Minimum numbers as well as smaller sizes of voids in the paste

Properties of Recycled Concrete Aggregate

The crushing characteristics of hardened concrete are similar to those of natural rock and are not significantly affected by the grade or quality of the original concrete. Recycled concrete aggregates contain not only the original aggregates, but also hydrated cement paste. This reduces the specific gravity and increases the porosity compared to similar virgin aggregates. The concrete produced with recycled aggregate loses its workability more rapidly than the conventional concrete, because recycled aggregate is more porous than natural aggregate. Thus concrete with recycled aggregate may require more mixing water to achieve the same workability as original aggregate. Recycled aggregates produced from good quality concrete can be expected to fulfill the requirements for the Los Angeles abrasion loss percentage, crushing and impact values.

MIX DESIGN

Concrete like other engineering materials needs to be designed for properties like strength, durability, workability and cohesion. Before having any concrete mixing, the selection of mix materials and their required materials proportion must done through a process called mix design. Concrete mix design is the science of deciding relative proportions of ingredients of concrete, to achieve the desired properties in the most economical way. With advent of high-rise buildings and pre-stressed concrete, use of higher grades of concrete is becoming more common. Even the revised IS 456-2000 advocates use of higher grade of concrete for more severe conditions of exposure, for durability considerations. With advent of new generation admixtures, it is possible to achieve higher grades of concrete with high workability levels economically. Use of mineral admixtures like fly ash, slag, meta kaolin and silica fume have revolutionized the concrete technology by increasing strength and durability of concrete by many folds There are lots of methods for determine concrete mix design. In this project IS Method of Design shall be used.

Table 2 IS Method of Design for M_{40} Concrete

Cement	Water	Sand	Aggregate
367	147	726	1230
1	0.4	1.97	3.35

To obtain the desired mix design, admixture Conplaspt SP 430 was be used as per specifications. Trial mix was conducted to achieve the target strength.

Table 3 Proportion and weight of each mix material by weight

TRIAL MIX	CEMENT Kg/m^3	WATER Kg/m^3	SAND Kg/m^3	COARSE AGGREGATES Kg/m^3
1	367	147	726	1230
2	370	148	724	1227
3	372	149	722	1220
4	375	150	720	1184

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

TESTING PROCEDURE

The following test done by the concrete compressive strength of cube, flexural strength of beam & split tensile strength for cylinder

Compressive Strength Test

When a specimen of material is loaded in such a way that it extends it is said to be in tension. On the other hand if the material compresses and shortens it is said to be in compression. On an atomic level, the molecules or atoms are forced apart when in tension whereas in compression they are forced together. Since atoms in solids always try to find an equilibrium position, and distance between other atoms, forces arise throughout the entire material which oppose both tension and compression. The phenomena prevailing on an atomic level are therefore similar. The "strain" is the relative change in length under applied stress; positive strain characterises an object under tension load which tends to lengthen it, and a compressive stress that shortens an object gives negative strain. Tension tends to pull small sideways deflections back into alignment, while compression tends to amplify such deflection into buckling. Compressive strength is measured on materials, components, and structures.

At the time of testing, each specimen must keep in compressive testing machine. The maximum load at the breakage of concrete block will be noted. From the noted values, the compressive strength may calculated by using below formula.

Compressive Strength = Load / Area
Size of the test specimen=150mm x 150mm x 150mm

Figure-Compression Test

Figure-Split Tensile Test

Figure-Flexural Strength Test

Split Tensile Test

The size of cylinders 300 mm length and 150 mm diameter are placed in the machine such that load is applied on the opposite side of the cubes are casted. Align carefully and load is applied, till the specimen breaks. The formula used for calculation.

$$\text{Split tensile strength} = 2P/\ \mu dl$$

The tensile strength is one of the basic and important properties of the concrete. The concrete is not usually expected to resist the direct tension because of its low tensile strength and brittle nature. However, the determination of tensile strength of concrete is necessary to determine the load at which the concrete members may crack. The cracking is a form of tension failure.(Figure.5.2). Apart from the flexure test the other methods to determine the tensile strength of concrete can be broadly classified as (a) direct methods, and (b) indirect methods. The direct method

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

suffers from a number of difficulties related to holding the specimen properly in the testing machine without introducing stress concentration, and to the application of uniaxial tensile load which is free from eccentricity to the specimen. As the concrete is weak in tension even a small eccentricity of load will induce combined bending and axial force condition and the concrete fails at the apparent tensile stress other than the tensile strength.As there are many difficulties associated with the direct tension test, a number of indirect methods have been developed to determine the tensile strength. In these tests in general a compressive force is applied to a concrete specimen in such a way that the specimen fails due to tensile stresses developed in the specimen.. The splitting tests are well known indirect tests used for determining the tensile strength of concrete sometimes referred to as split tensile strength of concrete. The test consists of applying a compressive line load along the opposite generators of a concrete cylinder placed with its axis horizontal between the compressive platens. Due to the compression loading a fairly uniform tensile stress is developed over nearly 2/3 of the loaded diameter as obtained from an elastic analysis. The magnitude of this tensile stress Osp (acting in a direction perpendicular to the line of action of applied loading) is given by the formula (IS : 5816-1970). The ratio of the split tensile strength to cylinder strength not only varies with the grade of the concrete but is also dependent on the age of concrete. This ratio is found to decrease with time after about a month. The air-cured concrete gives lower tensile strength than that given by moist-cured concrete. The flexural strength as obtained by rupture test is found to be greater than the split tensile strength.

This test is becoming very popular because of the following advantages, viz.,

i) The test is simple to perform and gives more uniform results than that given by other tests.

ii) The strength determined is closer to the actual tensile strength of concrete than the modulus of rupture value.

iii) The same moulds and testing machine can be used for compression and tension tests

Flexural Strength Test

During the testing, the beam specimens of size 7000mmx150mmx150mm were used. Specimens were dried in open air after 7 days of curing and subjected to flexural strength test under flexural testing assembly. Apply the load at a rate that constantly increases the maximum stress until rupture occurs. The fracture indicates in the tension surface within the middle third of span length. Flexural strength, also known as modulus of rupture, bend strength, or fracture strength,[a mechanical parameter for brittle material, is defined as a material's ability to resist deformation under load. The transverse bending test is most frequently employed, in which a specimen having either a circular or rectangular cross-section is bent until fracture or yielding using a three point flexural test technique. The flexural strength represents the highest stress experienced within the material at its moment of rupture. The flexural strength would be the same as the tensile strength if the material were homogeneous. In fact, most materials have small or large defects in them which act to concentrate the stresses locally, effectively causing a localized weakness. When a material is bent only the extreme fibers are at the largest stress so, if those fibers are free from defects, the flexural strength will be controlled by the strength of those intact 'fibers'. However, if the same material was subjected to only tensile forces then all the fibers in the material are at the same stress and failure will initiate when the weakest fiber reaches its limiting tensile stress. Therefore it is common for flexural strengths to be higher than tensile strengths for the same material. Conversely, a homogeneous material with defects only on its surfaces (e.g., due to scratches) might have a higher tensile strength than flexural strength.

TEST RESULT

For M25 Grade Concrete RATIO –I

Recycled Aggregate – 100 % by replacement of Coarse Aggregate

RATIO - II

Paper Crete – 20 % by replacement of Recycled Aggregate

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

RATIO –III

Paper Crete – 40 % by replacement of Recycled Aggregate

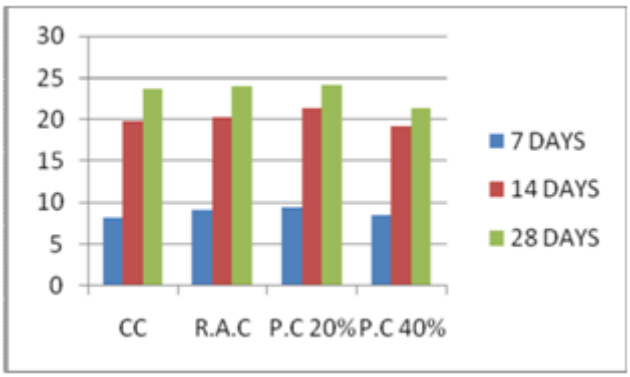

Figure.Graph Shown Compressive Test on Cube

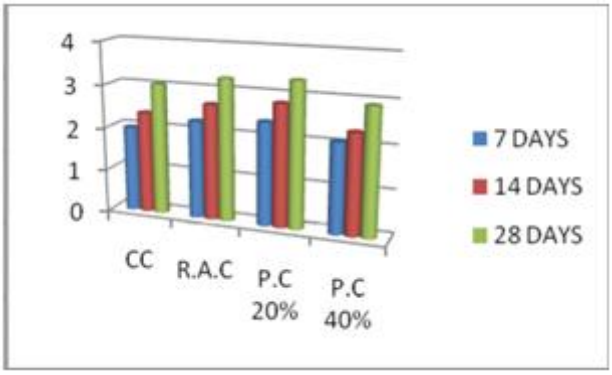

Figure.Graph Shown Split Tensile Strength of cylinder

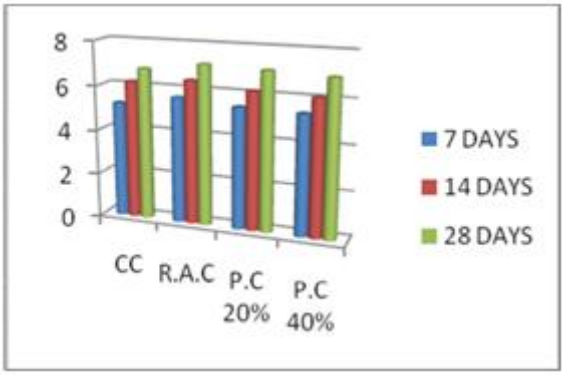

Figure.Graph Shown Flexural Strength of beam

CONCLUSIONS

- From the compressive strength results of the concrete it can be concluded that both the natural and recycled aggregate concrete gain strength with age.
- But at any instant the strength of recycled aggregate concrete is lower than the strength of natural aggregate concrete.
- The greater the replacement ratio, the lesser is the strength developed in the concrete.
- The compressive strength of 40% recycled aggregate concrete is 14.36% lower than that of natural aggregate concrete while that of 10% recycled aggregate concrete is just 0.55% lower than that of natural aggregate concrete
- From the compression test results it can be concluded that up to 30% replacement of natural aggregates with recycled aggregates there is no considerable reduction in strength of concrete and hence can be considered as optimum replacement without compromise on strength.
- The same above conclusions follow for split tensile strength and flexural strength of concrete.
- The split tensile strength of 40% RAC is 26.46% lower than that of NAC while the split tensile strength of 10% RAC is 6.75% lower than that of NAC.
- The flexural strength of 40% RAC is 27.45% lower than that of NAC while that of 10% RAC is 3.48% lower than that of NAC.
- Hence from the strength results, 30% replacement is considered as optimum and two sets of cubes- one of NAC and other of 30% replacement RAC were casted for durability tests for a period of 28 days.
- In case of water absorption, the RAC exhibit higher water absorption values as compared to NAC. This is due to the presence of attached mortar present in the aggregates. The greater is the attached mortar, the more is the water absorption in the concrete.

From the above observations it can be concluded that although the values of strength results of RAC is lower than the NAC, they are still within the useable range and by limiting the replacement ratio, the desirable

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

strength can be easily obtained using recycled aggregate concrete also.

REFERENCES

[1] Considerations in producing high strength concrete" (2009), Mohammad Abdur Rashid and Mohammad Abul Mansur,Journal of Civil Engineering (IEB).

[2] Use of recycled concrete aggregates in highstrength concrete" (2000).M.C.Limbachiya, T. Leelavat and R.K.Dhir.Materials and Structures , Vol:33

[3] Effectiveness of using coarse recycled aggregate in concrete"(2011),Neela Deshpande,S.S.Kulkarni, International Journal of Earth Science and Engineering

[4] Influence of fine stone dust on high strength concrete" August 2007,V. Syam PrakashDhanya Krishnan,G. Jeenu,32ndConference on OUR WORLD IN CONCRETE & STRUCTURES

[5] IS: 456 – 2000 (Fourth Revision) Indian Standard Plain and Reinforced Concrete Code of Practice.

[6] IS: 383-1970 (Second Revision), Specifications for Coarse and Fine Aggregates from Natural Resources for Concrete.

[7] IS: 10262-2009 (first revision), Concrete Mix Proportioning Guidelines.

[8] IS: 516-1959,Methods of test for strength of concrete, edition 1.2(1991-07)

[9] M.S Shetty "Concrete Technology", Theory and practice, S Chand 2011.

[10] Tsung-Yueh, Yuen-Yeun Chen, Chao-Lung Hwang(2006), "Properties of HPC with recycled aggregates", Cement and Concrete Research, vol:36, pp943-950.

[11] J.S.Ryu, (2002),"An experimental study on the effect of recycled aggregate on concrete properties", Mag. Concr. Res, Vol:54 (1), pp-7-12

[12] A. K. Padmimi, K. Ramamurthy, M. S. Matthews (2002), "Relative moisture movement through recycled aggregate concrete", Cement Concrete Research, vol: 54(5), pp-377-384

[13] J. M. Khatib (2005), "Properties of concrete incorporating fine recycled aggregate", Cement and Concrete Research, vol: 35, pp-763-769

[14] L. Evangelista & J.de Brito, (2007)" Mechanical behavior of concrete made with fine recycled concrete aggregates", Cement & Concrete Composites, Vol: 29, pg: 397-401.

Author Details

S.Vinodh Kumar
M.Tech (Structural Engineering)
KMM College,
Tirupari, A.P.

A.Brahmini
M.Tech (Structural Engineering)
KMM College,
Tirupari, A.P.