Research Inventy: International Journal of Engineering And Science
Vol.4, Issue 01 (January 2014), PP 27-36
Issn (e): 2278-4721, Issn (p):2319-6483, www.researchinventy.com

Experimental Studies on High Strength Concrete by using Recycled Coarse Aggregate

N.Sivakumar[1], S.Muthukumar[2], V.Sivakumar[2] D.Gowtham[2], V.Muthuraj[2]
[1]Assistant Professor, Department of Civil Engineering
Jay Shriram Group of Institutions, Tirupur-638660, TamilNadu, India.
[2]UG Students Department of Civil Engineering
Jay Shriram Group of Institutions, Tirupur-638660, TamilNadu, India.

ABSTRACT: *Aggregate is one of the main ingredients in producing concrete. It covers 75% of the total for any concrete mix. The strength of the concrete produced is dependent on the properties of aggregates used. However, the construction industry is increasingly making higher demands of this material and is feared to accommodate the many requests at one time. Hence need for an alternative coarse aggregate arises.*

The aim for this project was to determine the strength and durability characteristics of high strength structural concrete by using recycled coarse aggregates, which will give a better understanding on the properties of concrete with recycled aggregates. The scope of this project was to investigate the possibility of using low cost recycled coarse aggregates as an alternative material to coarse aggregate in high strength structural concrete.

The experimental investigation were carried out using detailed strength and durability related tests such as compressive strength test of cubes, split tensile strength test of cylinders, modulus of elasticity tests acid resistance test, test for saturated water absorption and porosity. The tests were conducted by replacing the coarse aggregates in high strength concrete mixes by 0, 10, 20, 30, 40 and 50% of recycled coarse aggregates. A 50% replaced mix with reduced w/c ratio was also tested. From the experimental investigation it was found that recycled coarse aggregates can be used for making high strength concretes by adjusting the w/c ratio and admixture contents of the mix.

KEY WORDS*: Concrete, High Strength Concrete, Recycled Aggregates, Recycled concrete aggregates*

I. INTRODUCTION

Any construction activity requires several materials such as concrete, steel, brick, stone, glass, clay, mud, wood, and so on. However, the cement concrete remains the main construction material used in construction industries. For its suitability and adaptability with respect to the changing environment, the concrete must be such that it can conserve resources, protect the environment, economize and lead to proper utilization of energy. To achieve this, major emphasis must be laid on the use of wastes and byproducts in cement and concrete used for new constructions. The utilization of recycled aggregate is particularly very promising as 75 per cent of concrete is made of aggregates. The use of recycled aggregates from construction and demolition wastes is showing prospective application in construction as alternative to primary (natural) aggregates.

Research on the usage of waste construction materials is very important since the materials waste is gradually increasing with the increase of population and increasing of urban development. The reasons that many investigations and analysis had been made on recycled aggregate are because recycled aggregate is easy to obtain and the cost is cheaper than virgin aggregate.

1.1 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

Recycled Coarse Aggregate

Buildings, roads, bridges, and sometimes even from catastrophes, such as wars and earthquakes. There are many advantages through using the recycled aggregate. The advantages that occur through usage of recycled aggregate are listed below.

a) Environmental Gain
b) Cost
c) Job Opportunities
d) Sustainability
e) Market is wide

1.2 High-Strength Concrete (HSC)

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

II. 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 1

Table 1

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

2.1 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.

III. 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

IV. DURABILITY TEST

Concrete cubes each from the HSC mix and the HSC mix with percentage replacements of RCA is to be casted and tested for its durability by conducting the following tests.

4.1 Acid Resistance Test

After 28 days curing, cubes of 150mm size is weighed and immersed in 3% sulphuric acid solution for acid resistance test for 45 days continuously. Then the cubes are taken out, surface dried and weighed. The percentage loss in weight and the percentage reduction in compressive strengths are determined.

4.2 Saturated water absorption test

Saturated Water Absorption (SWA) tests were carried out on 100 mm cube specimens at the age of 28 and 90 days curing as per ASTM C 642. The specimens were weighed before drying. The drying was carried out in a hot air oven at a temperature of 105^0C. The drying process was continued, until the difference in mass between two successive measurements at 24 hours interval agreed closely. The dried specimens were cooled at room temperature and then immersed in water. The specimens were taken out at regular intervals of time, surface dried using a clean cloth and weighed. This process was continued till the weights became constant (fully saturated). The difference between the measured water saturated mass and oven dried mass expressed as a percentage of oven dry mass gives the SWA. The water absorption was calculated as

$$\text{Percentage water absorption} = \frac{(W_s - W_d)}{W_d} \times 100 \qquad (6.1)$$

Where
Ws = weight of specimen at fully saturated condition.
W_d = weight of oven dried specimen

4.3 Porosity Test

The saturated water absorption of concrete is a measure of the pore volume or porosity in hardened concrete which is occupied by water in saturated condition. It denotes the quantity of water which can be removed on drying a saturated specimen. The porosity obtained from absorption tests is designated as effective porosity. It is determined using the following formula:

Effective porosity = (Volume of voids/ bulk volume of specimen) x 100

The volume of voids is obtained from the volume of water absorbed by an oven dried specimen or the volume of water lost on oven drying water saturated specimen at 105°C to constant mass. The bulk volume of the specimen is given by the difference in mass of the specimen in air and it's mass under submerged condition in water.

$$\text{Effective porosity, } n = \frac{(Ws - Wd)}{(Ws - Wsub)} \times 100$$

Where
Ws - Weight of specimen at fully saturated condition
Wd - weight of oven dried specimen
Wsub = weight of specimen submerged in water.

V. INTERPRETATION OF TEST RESULTS

5.1 Slump Test Result and Analysis

The slump test indicates a decreasing trend of workability when the percentage of recycled aggregate increased. Below shows the average slump recorded during the test. Figure 1 below shows a graphical representation of slump height.

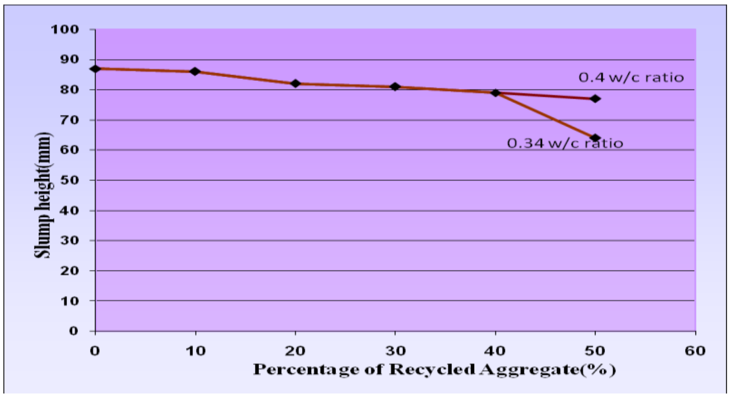

Figure 1 Graph showing the result of slump test

According to the result, the highest slump obtained was 87mm and the lowest slump was 64mm. The average slump for each batch of mix was 80mm. Therefore, target slump had been achieved, where the range is from 50mm to 100mm.The workability was good and can be satisfactorily handled for 0% recycled aggregate to 50% recycled aggregate. The slump from 0% recycled aggregate to 50% recycled aggregate were considered moderate due to the drop in the range of 5mm to 10mm.There was no problem for the placement and compaction of fresh concrete. The only problem occurred was for the batch with 50% recycled aggregate (with 0.34 water cement ratio). The workability was very low due to the slump was just 64mm. The reason was because of the high absorption capacity of recycled aggregate. From the result obtained, it shows that the workability was getting lower when more recycled aggregate were used.

5.2 Compression Test Result and Analysis

The compression test indicates an increasing trend of compressive strength in the early age of the concrete specimens. However, it shows that the strength of recycled aggregate specimens is lower than natural aggregate specimens. Figure 2 below shows a graphical representation of variation of compressive strength. The target strength for this project is 40MPa. From the obtained result, it shown that the only batch that met the target strength is the batch with 0% recycled aggregate. The compressive strength for other batches is less than 40MPa.The compressive strength of the concrete specimens for 50% recycled aggregate replacement with 0.34 water/cement ratio is 37MPa, which almost met the target strength. This shows that upto 30 to 40 % recycled aggregate replacement may achieve high strength by reducing the water/cement ratio. The results also shows that the concrete specimens with more replacement of recycled aggregate will get the lower strength when compared to the concrete specimens with less recycled aggregate.

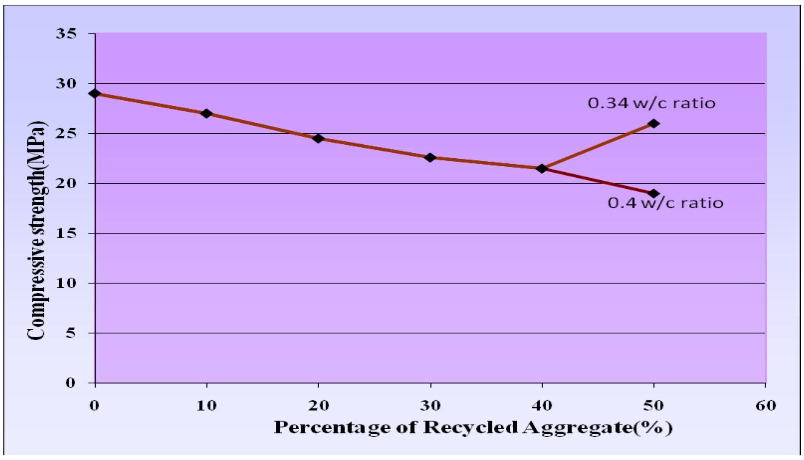

Figure 2 Variation of compressive strength after 7 days

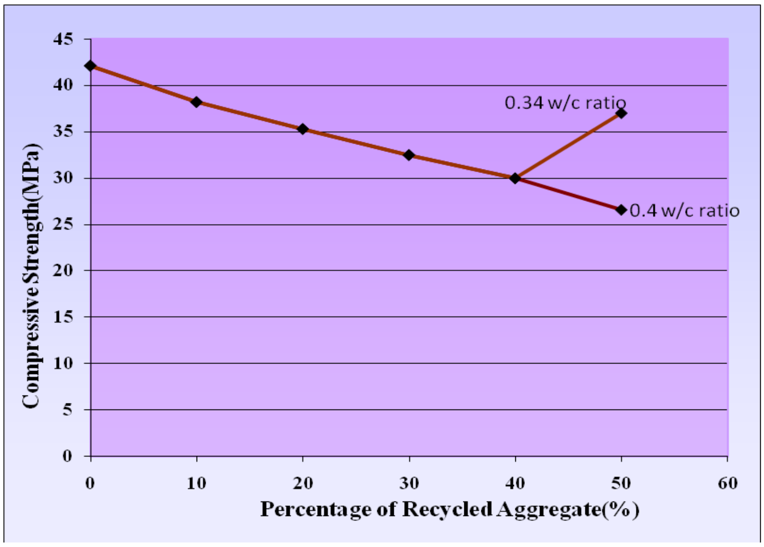

Figure 3 Variation of compressive strength after 28 days

Figure 4 shows the percentage of the compressive strength remained when percentage of recycled aggregate replacement increased. The compressive strength used from each batches were based on day 28 strength. The compressive strength of 0% recycled aggregate was taken as the 100% compressive strength. From the result, the batch of 50% recycled aggregate has the lowest compressive strength remained, which is only 63%.There is a drop of 37% when compared to 0% recycled aggregate. However the compressive strength remained for 50% recycled aggregate replacement with reduced water cement ratio is 88%.Hence the drop in compressive strength is reduced to 12%. From the obtained result, it is possible to use 30 to 40% recycled aggregate with the less water cement ratio in the high strength concrete mixes.

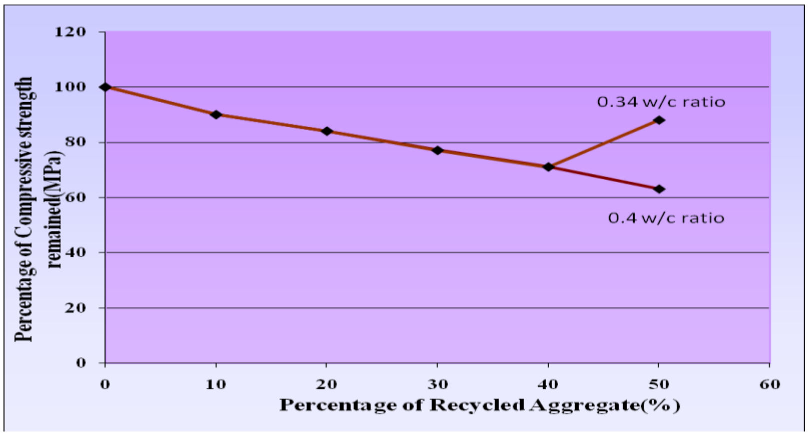

Figure 4 Graph showing percentage of Compressive Strength remained

5.3 Indirect Tensile Test Result and Analysis

The indirect tensile test indicates a decreasing trend of indirect tensile strength when the percentage of recycled aggregate increased. Figure 5 below shows a graphical representation of variation of tensile strength.

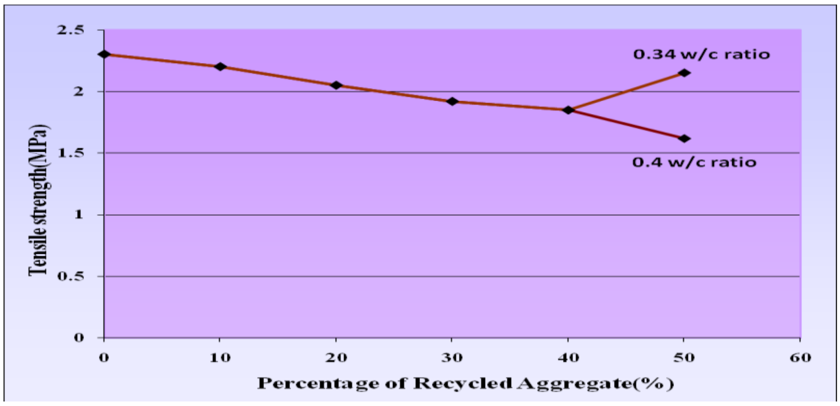

Figure 5 Variation of Tensile strength after 7 days

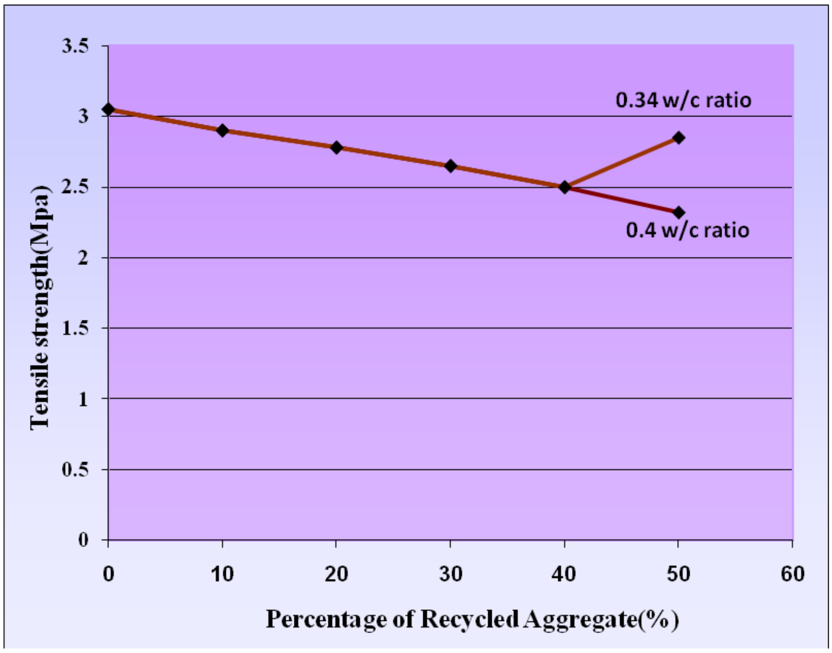

Figure 6 Variation of Tensile strength after 28 days

Figure 7 shows the percentage of tensile strength remained for the concrete specimens with the different percentage of recycled aggregate replacement. The result is almost same as the result of compressive strength. The concrete specimen of 50% recycled aggregate with 0.4w/c ratio has the lowest tensile strength remained, which is only 76%.There is a drop of 24% for the concrete specimen with 50% recycled aggregate (0.4 water/cement ratio), which is still remained 76% of tensile strength when compared to 0% recycled aggregate concrete specimen. However, the concrete specimen with the 50% recycled aggregate (0.34 water/cement ratio) has the most tensile strength remained. It just drops 7%, which is still remained 93% when compared to 0% recycled aggregate concrete specimen. The reason is because of the lower water cement ratio than other batches of concrete specimens.

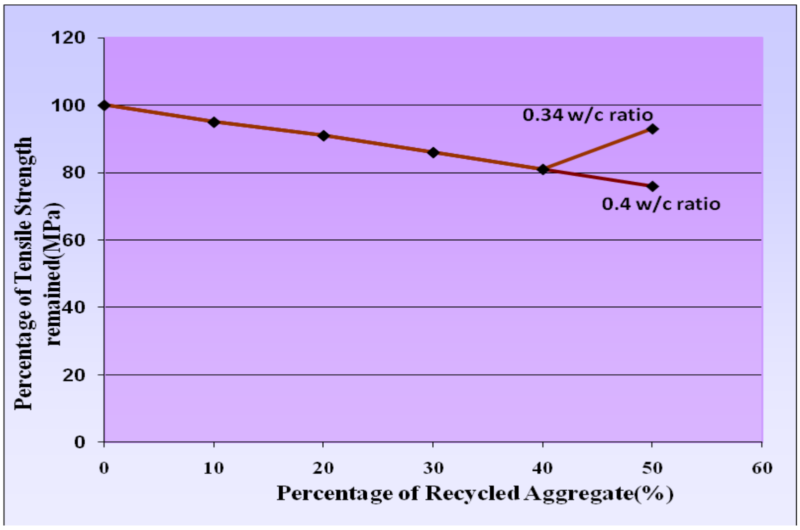

Figure 7 Graph showing percentage of Tensile Strength remained

5.4 Modulus of Elasticity Result and Analysis

The modulus of elasticity test indicates a decreasing trend of modulus of elasticity value when the percentage of recycled aggregate increased. Figure 8 below shows a graphical representation of the variation of modulus elasticity.

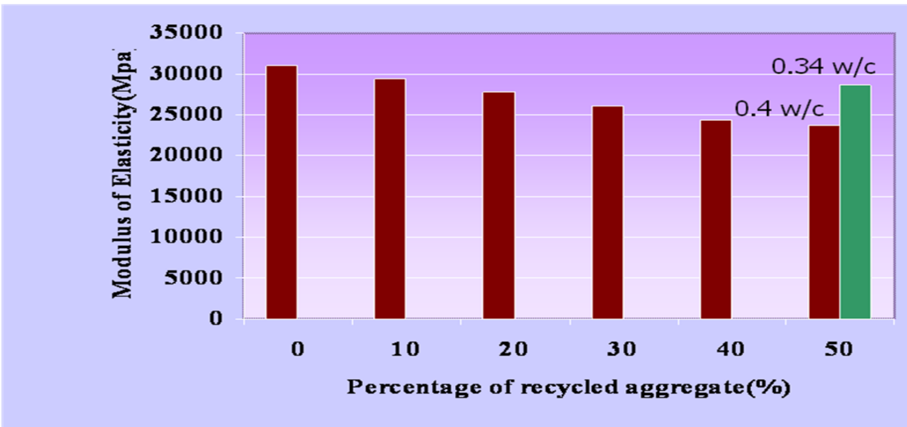

Figure 8 Graph showing variation of modulus of elasticity

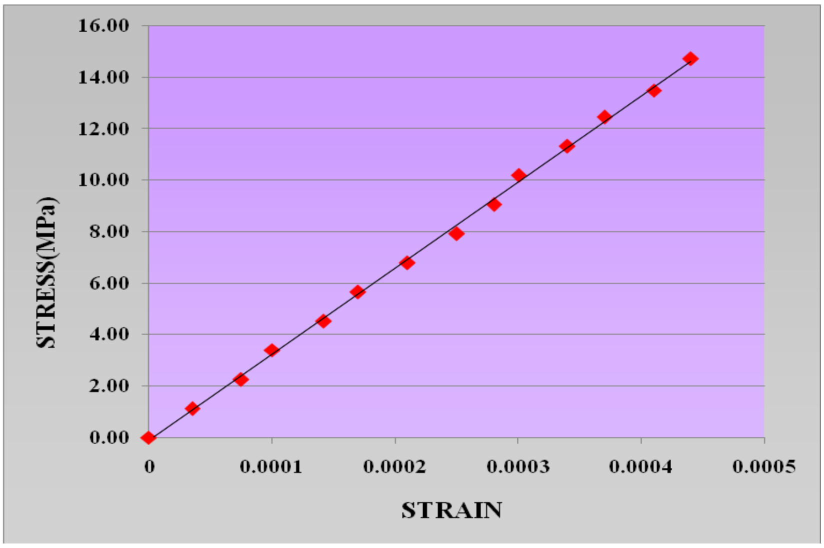

Figure 9 Stress and Strain Relationship for 0% RCA replacement

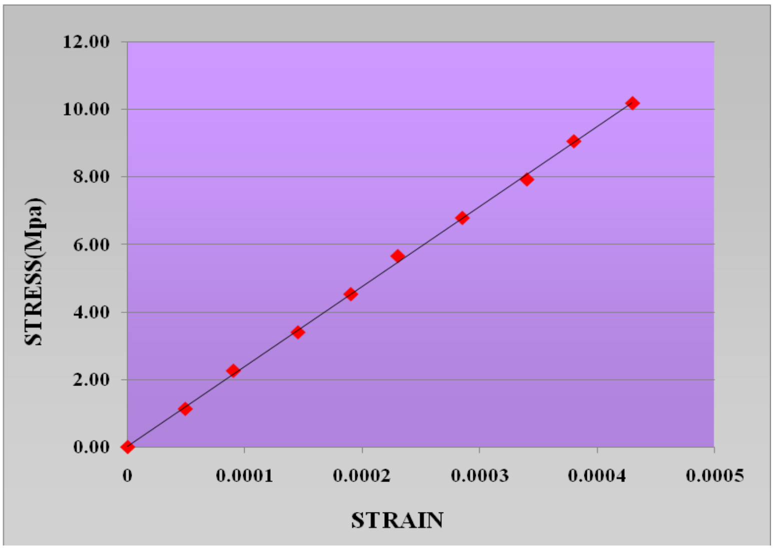

Figure 10 Stress and Strain Relationship for 50% RCA replacement

Figure 9 and 10 shows the stress / strain curve for 0% and 50% RCA replaced concrete specimens taken from modulus of elasticity tests. Figure shows that the slope is decreasing when the rate usage of recycled aggregates is increased. However, comparing all recycled aggregate specimen, it shows that the 50%RCA replaced specimen with 0.34 water/cement ratio has a rate slope higher than 50%RCA replaced specimen with 0.4 water/cement ratio.

5.5 Acid Resistance Test

The results are tabulated in Table 4. From the test results it was observed that the percentage loss in weight of concrete cubes after 45 days immersion in 3% sulphuric acid increases as the percentage of RCA replacement increases.It was observed that RCA replaced mix containing lower water cement ratio is less attacked by sulphuric acid.

Table 4 Reduction in Compressive Strength based on Acid resistance Test

Percentage Replaced	28 day compressive strength (MPa)	After 45 days immersion of cubes in Sulphuric acid solution		
		Percentage reduction in weight	Compressive strength (MPa)	Percentage reduction in compressive strength compared to 28 day strength
0	42.1	0.42	38.3	9.03
10	38.2	0.47	33.8	11.52
20	35.3	0.51	31.1	11.9
30	32.5	0.56	28.0	13.85
40	30	0.59	25.0	16.67
50	26.6	0.63	21.3	19.92
50 % with reduced w/c ratio	37	0.52	32.0	12.33

5.6 Tests for Saturated Water Absorption and Porosity

The results of water absorption tests are tabulated in Table 5. From the results it was noted that the saturated water absorption and porosity of high strength concrete mixes containing recycled aggregates are higher compared to that of high strength concrete mix without recycled aggregates.

Table 5 Test for saturated water absorption & porosity

Percetage replaced	saturated water absorption	Percentage increase in saturated water absorption	Effective Porosity	Percentage increase in Effective Porosity
0	1.10	0	3.30	0
10	1.24	12	3.51	6
20	1.38	25	3.85	16
30	1.56	41	3.90	18
40	1.66	50	3.97	20
50	1.74	57	4.05	22
50 % with reduced w/c ratio	1.37	24	3.59	9

VI. CONCLUSION

Research on the usage of waste construction materials is very important because, construction waste materials is gradually increasing with the increase in population and increasing urban developments. The reason that many investigations and analysis had been made on recycled aggregate is because, recycled aggregate is easy to obtain and the cost is cheaper than natural aggregate. Natural aggregates need to mine but recycled aggregate can ignore this process.

Aim of this research project is to determine the strength and durability characteristics of recycled aggregate for potential application in the high concrete structural concrete. The study shows that:-

1) When the percentage of RCA replacement was increased, compressive strength gets reduced. However when water/cement ratio of mix was decreased, the compressive strength increases.
2) The target compressive strength (40MPa) can be achieved for 30 to 40 % of RCA replacement by decreasing the water cement ratio and adjusting the admixture content of mix. This is classified as high strength concrete and can be applied in infrastructures, which need compressive strength up to 40MPa.
3) Another result found in this research is that when reducing the water cement ratio used in recycled aggregate mixes, tensile strength and modulus of elasticity are also improved. This will give an improvement in general strength characteristics of structural building.
4) The percentage loss in weight of concrete cubes after the conduct of acid resistance test is negligible for 30 to 40% RCA replacements. Moreover reduction in the strength is also nominal, which shows that these mixes were less attacked by acid.
5) The water absorption and porosity of RCA replaced mixes are higher than normal mix but within the permissible limits. These properties can be modified by reducing the w/c ratio and by incorporating admixtures.

6) The general trends observed indicates that coarse RCA can be used in a range of high strength concrete mixes with satisfactory engineering properties namely compressive strength, flexural strength and modulus of elasticity
7) Although recycled aggregate can be applied in the high strength structure, one issue must not be neglected that increase in recycled aggregate with reduce water content would have low workability. Whenever recycled aggregate is applied, water content in the concrete mix has to be monitored carefully as the water absorption capacity of recycled aggregate will vary.
8) It is important to recognize that there is a need to introduce new standards for recycled aggregates and demonstrate that these materials van be used successfully in practice, under arrange of exposure conditions.

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.

[1]AUTHOR PROFILE

N.Sivakumar received the B.E. degree in Civil Engineering from TamilNadu College of Engineering Coimbatore in 2006. M.E. degree in Structural Engineering from College of Engineering Guindy Campus in 2010, Anna University Chennai. He has qualified in **GATE** 2008 held on February 10, 2008. (Percentile Score: 84.84) He has more than 4 years of experience in Structural Consultancy, Construction and Academic experience also. He is an active member in some technical bodies like ISTE, LBS; He has published 5 articles in reputed journals and presented 4 papers in International conferences and 2 papers in national conferences. He now working as Assistant Professor in Department of Civil Engineering at Jay Shriram Group of Institutions,