MECHANICAL AND DURABILITY PROPERTIES OF HSC USING RHA, QUARRY DUST AND POLYPROPYLENE FIBER

N.Rishinath, S.P.Kanniyappan, A.Krishnamoorthi

Assistant Professor, Adhiparasakthi College of Engineering, Kalavai, Tamilnadu, India
rishinathnehru@gmail.com, +91 7200272439

Abstract- In the past two decades, construction sector has made a tremendous change in the dimensions of its boundaries. Because of mankind's unpredictable innovation added along with the technological advancements, unimaginable architectural designs have been made into existence only because of the advanced building materials which helped to get the required physique for the structure without adjusting any collapse and serviceability criteria. As concrete is considered as important building material, lots of variations has been made in the type of cement to be used as well concrete making technology in order to make the structure adaptable in any environmental condition as well fulfill the conditions for which it has been constructed. The most recent innovation in concrete technology is the "High Strength Concrete". As the name suggests, this type of concrete are very strong and makes the concrete structure to be highly resistant to environmental hazards.

The waste products from different sectors are considered to be harmful for disposal and hence turned to be an issue. With the innovation of using these waste by-products as a replacement of basic ingredient in concrete, an effective and efficient way of disposing them has come into act. This study examines the properties of High Strength Concrete (HSC) having Quarry dust by completely replacing natural river sand and partial replacement of cement with 5%, 10%, and 15%, of Rice Husk Ash (RHA), and 0.3% of polypropylene fiber.

Keywords

Cement, Coarse aggregate, Quarry dust, Rice Husk Ash, Polypropylene fiber, super plasticizers, High strength concrete, Fiber reinforced concrete, compression test, Split tensile test, Flexural test, Beam test, Acid attack, Sulphate attack, Alkaline attack.

INTRODUCTION

The world at the end of the 20th Century that has just been left behind was very different to the world that its people inherited at the beginning of that Century. The latter half of the last century saw unprecedented technological changes and innovations in science and technology in the fields of communications, medicine, transportation and information technology, and in the wide range and use of materials. The construction industry has been no exception to these changes when one looks at the exciting achievements in the design and construction of buildings, bridges, offshore structures, dams, and monuments, such as the channel tunnel and the millennium wheel. There is no doubt that these dramatic changes to the scientific, engineering and industrial face of the world have brought about great social benefits in terms of wealth, good living and leisure, at least to those living in the industrialized nations of the world.

Extensive research has now established, beyond a shadow of doubt that the most direct, sound and economically attractive solution to the problems of reinforced concrete durability lies in the incorporation of finely divided siliceous materials in concrete. The fact that these replacement materials, or supplementary cementing materials as they are often known and , such as Pulverized Fuel Ash (PFA), Ground Granulated Blast Furnace Slag (GGBS), Silica Fume (SF), Rice Husk Ash, Natural Pozzolana, and Volcanic Ash are all either pozzolanic or cementitious make them ideal companions to Portland Cement (PC).

CONCRETE AND ENVIRONMENT

Concrete as a construction material is still rightly perceived and identified as the provider of a nation's infrastructure and indirectly, to its economic progress and stability, and indeed, the quality of life. It is so easily and readily prepared and fabricated into all sorts of conceivable shapes and structural systems in the realms of infrastructure, habitation, transportation, work and play. Its great simplicity lies in that its constituents are most readily available anywhere in the world; the great beauty of concrete, and probably the major cause of its poor performance, on the other hand, is the fact that both the choice of the constituents, and the proportioning of its constituents are entirely in the hands of the engineer and the technologist.

The most outstanding quality of the material is its inherent alkalinity, providing a passivating mechanism and a safe, non-corroding environment for the steel reinforcement embedded in it. Long experience and a good understanding of its material properties have confirmed this view, and shown us that concrete can be a reliable and durable construction material, and plays a rightful role and large quantum of concrete is being utilized. River sand, which is one of the constituents used in the production of conventional concrete, has become highly expensive and also scarce. In the backdrop of such a bleak atmosphere, there is large demand for alternative materials from industrial waste.

ENHANCED PROPERTIES OF RHA CEMENT

Portland cement produces an excess of lime. Adding a Pozzolana, such as RHA this combines with lime in the presence of water, results in a stable and more amorphous hydrate calcium silicate. Laboratory research and field experience has shown that careful use of pozzolana is useful in countering all of these problems. The RHA is not just a "filler", but a strength and performance enhancing additive, its chemical properties are listed in the table 1.

This project present the usage of Rice Husk Ash (RHA) as a replacement along with cement, feasibility of the usage of quarry dust as hundred percent substitutes for river sand and with polypropylene fiber as admixture. Tests were conducted to ensure there mechanical strength and durability studies were done for concrete with RHA, quarry dust and polypropylene fiber and compared with conventional concrete.

Table 1 Chemical Composition of RHA

Sl.No	Parameters	Values
1	Silicon dioxide (SiO_2)	87.20%
2	Aluminum oxide (Al_2O_3)	0.15%
3	Ferric oxide (Fe_2O_3)	0.16%
4	Calcium oxide (CaO)	0.55%
5	Magnesium oxide (MgO)	0.35%
6	Sulphur trioxide (SO_3)	0.24%
7	Carbon (C)	5.91%
8	Loss on Ignition	4.94%

FIBER REINFORCED CONCRETE

Concrete is by nature a brittle material that performs well in compression, but is considerably less effective when in tension. Reinforcement is used to absorb these tensile forces so that the cracking which is inevitable in all high-strength concretes does not weaken the structure.Latest developments in concrete technology now include reinforcement in the form of fibers, notably polymeric fibers, as well as steel or glass fibers.

Fiber-reinforcement is predominantly used for crack control and not structural strengthening. Although the concept of reinforcing brittle materials with fibers is quite old, the recent interest in reinforcing cement-based materials with randomly distributed fibers is quite old; the recent interest in reinforcing cement based materials with randomly distributed fibers is based on research starting in the 1960's. Since then, there have been substantial research and development activities throughout the world. It has been established that the addition of randomly distributed polypropylene fibers to brittle cement based materials can increase their fracture toughness, ductility and impact resistance. Since fibers can be premixed in a conventional manner, the concept of polypropylene fiber concrete has added an extra dimension to concrete construction.

HIGH STRENGTH CONCRETE

Concrete is generally classified as Normal Strength Concrete (NSC), High Strength Concrete (HSC) and Ultra High Strength Concrete (UHSC). There are no Clear cut boundaries for the above classification. In the world scenario, however, in the last 15 years, concrete of very high strength entered the field of construction, in particular construction of high –rise buildings and long span bridges. Concrete strengths of 90 to 120 MPa are occasionally used.

The advent of prestressed Concrete Technology Techniques has given impetus for making concrete of higher strength. In India there are cases of using high strength concrete for prestressed concrete bridges. But strength of concrete more than 35 Mpa was not commonly used in general construction practices.

MATERIALS USED AND THEIR SPECIFICATIONS

Materials play an important role in Concrete. The materials used for preparing HSC concrete are Cement, Fine Aggregate, Coarse Aggregate, Water, RHA, polypropylene fiber and Super plasticizers which are confirming to the requirements of the Indian Standard (IS) specifications are given in table 2.

Table 2 Materials used and their specifications

Sl. No.	Material	Type	IS Specification
1	CEMENT	Ordinary Portland Cement (OPC)53 Grade	IS 12269-2013
2	COARSE AGGREGATE	Crushed Angular Aggregate(Size = 20 Mm)	IS 2386(Part I &III)-1963
3	FINE AGGREGATE	Natural Sand(Size ≤ 4.75 Mm)	IS 2386(Part I &III)-1963
		Quarry Dust(Size ≤ 4.75 Mm)	
4	WATER	Clean Potable Water(PH Value=7.0)	IS 456 – 2000
5	POZZOLANIC MATERIAL	Rice Husk Ash	IS 12269 : 2013
6	FIBER	Polypropylene	IRC:44-2008
7	SUPERPLASTICIZERS	Poly Carboxylate Ether (PCE) (Dosage=0.3% Of Total Cementitious Materials)	IS 9103

EXPERIMENTAL INVESTIGATION

The materials used for this study were initially investigated and tested. The test was carried out for different materials such as Cement, RHA, Fine aggregate, Coarse aggregates and their results were listed in tables.

Cement and RHA

Ordinary Portland cement of 53 grade confirming to 12269-2013was used in the present study. The properties of cement and RHA are shown in Table 3.

Table 3 Testing of Cement and RHA

Sl.No.	Type of Test	Values obtained for Cement	Values obtained for RHA
1	Fineness Test by Sieving	4%	1%
2	Standard Consistency Test	26%	30%
3	Initial Setting Time	35 Minutes	40 Minutes
4	Final Setting Time	9 Hours	10
5	Specific Gravity Test	3.15	2.08

Fine aggregate and Quarry Dust

Natural sand and Quarry Dust with fraction passing through 4.75mm and retained on 600 micron sieve is used and will be tested as per IS 2386(Part I& III)-1963. The properties of the fine aggregate and quarry dust are shown in Table 4.

Table 4 Testing of Fine Aggregate and Quarry Dust

Sl. No.	Type of Test	Values obtained for Sand	Values obtainedQuarry Dust
1	Fineness Modulus Test	2.541	2.529
2	Bulkiness Of Sand	6.66%	5.26%
3	Specific Gravity Test	2.59	2.57
4	Water Absorption Test	0.53%	0.91%

Coarse aggregate

Crushed aggregate confirming to IS 2386(Part I& III)-1963 was used. Aggregates of size 20mm has been selected for the study. The properties of the coarse aggregate are shown in Table 5.

Table 5 Testing of Coarse Aggregate

Sl. No.	Type of test	Values obtained
1	Fineness Modulus Test	2.28
2	Specific Gravity Test	2.27
3	Water Absorption Test	0.4%
4	Aggregate Crushing Value	12.85%
5	Aggregate Impact Value	12.18%
6	Aggregate Abrasion Value	36.55%
7	Flakiness Index	36.30%
8	Elongation Index	45.55%

MIX DESIGN

Mix design can be defined as the process of selecting suitable ingredients of concrete and determining their relative proportions with the object of producing concrete of certain minimum strength and durability as economically as possible. Mix design for each set having different combinations are carried out by using **ACI 211.4R-93** method. The mix proportion obtained for normal M60 grade concrete is **1:0.9:2.1** with a water-cement ratio of **0.31.**

FRESH CONCRETE

The fresh concrete is made with the mix ratio as per design standards for M60 grade concrete and the workability of the concrete was tested. The properties of fresh concrete are given in table 6.

Table 6 Properties of Fresh concrete

Sl.No.	Property	Result
1	Slump value	50 mm
2	Flow value	50%
3	Compaction factor value	94.70%
4	Vee-Bee Consistency value	8 seconds

EXPERIMENTAL PROCEDURE

STRENGTH TEST

The specimen of standard cube of size 15cmx15cmx15cm, standard cylinder of size 30cm height and 15cm diameter, prismof size 10cmx10cmx50cm and beam of size 2m x 15cm x 20 cm were used to determine the compressive strength, split tensile strength, flexural strength and structural strength of the concrete. These specimens were tested on 7th, 14th& 28thday'sstrength.

Experiments Conducted

The following experiments were conducted on the specimens casted.

- Compression test
- Split tensile test
- Flexural test
- Beam test

Compression Test

Compression test is the most common test conducted on hardened concrete, partly because it is an easy test to perform, and partly because most of the desirable characteristic properties of concrete are qualitatively related to its compressive strength. The cube specimen is of the size 15 x 15 x 15 cm were tested for compressive strength as per IS 516-1959 using a calibrated compression testing machine.

Split Tensile test

Split tensile strength of concrete is usually found by testing concrete cylinder of size 30cm height and 15cm diameter. The specimens were tested for its tensile strength as per IS: 516-1959 using a calibrated compression testing machine.

Flexural Strength Test

Flexural strength is the one of the measure of tensile strength of concrete. It is the ability of a prism to resist failure in bending. It is measured by loading un-reinforced slab or prism of size 10cm x 10cm x 50cm. The specimens were tested for its flexural strength as per IS: 516-1959 using a calibrated flexural testing machine.

Beam Test

The beams of size 2m x 15cm x 20 cm were tested under monotonic loading.The load was applied gradually to the beam till its failure. Dial gauge was fixed beneath the beam at its mid span. For each increment of loading dial gauge reading were recorded. First crack load was observed and recorded. And for each increment of load crack growth was observed and marked.

DURABILITY TEST

Durabilitytests is planned to evaluate chemical attack which results in volume change, cracking of concrete and the consequent deterioration of concrete becomes an important part of discussion.

Under chemical attack we shall discuss about the following tests:

1. Acid Attack
2. Sulphate Attack
3. Alkaline Attack

Acid Attack

In order to assess the weight loss, concrete cubes is exposed to chemical media. For acid test, hydrochloric acid (HCL) solution was prepared by mixing 5% of Conc.Hcl with one liter of distilled water as per ASTM G20-8 or make an Acidic solution with 1N (Normality) as per laboratory standards. After normal curing (28 days) cubes were taken out and weight of cube was noted. Than weighted cubes was immersed in the prepared hydrochloric acid for 30 and 60 days. After curing the cubes were taken out from acid and weight of cubes was noted. From this weight loss of cubes is calculated. And then compression test is done to find its compression strength.

Sulphate Attack

To assess the weight loss concrete cubes is exposed to chemical media. For Sulphate test, Magnesium Sulphate ($MgSO_4$) solution was prepared by mixing 5% of Magnesium Sulphate salt with one liter of distilled water as per ASTM G20-8 or make a solution with N/2 (Normality) as per laboratory standards. After normal curing (28 days) cubes were taken out and weight was noted. Than weighted cubes was immersed in the prepared Magnesium Sulphate solution for 30 and 60 days. After curing the cubes were taken out and weighted. From this weight loss is calculated. And then compression test is done to find its compression strength.

Alkaline Attack

To assess the weight loss concrete cubes is exposed to chemical media. For alkaline test, Sodium hydroxide (NaOH) solution was prepared by mixing 5% of sodium hydroxide pellets with one liter of distilled water as per ASTM G20-8 or make an Alkali solution with 1N (Normality) as per laboratory standards. After normal curing (28 days) cubes were taken out and weight was noted. Than weighted cubes was immersed in the prepared sodium hydroxide solution for 30 and 60 days. After curing the cubes were taken out and weighed. From this weight loss is calculated. And then compression test is done to find its compression strength.

International Journal of Engineering Research and General Science Volume 3, Issue 6, November-December, 2015
ISSN 2091-2730

EXPERIMENTAL RESULTS

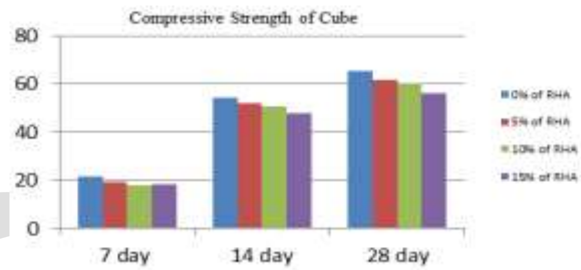
STRENGTH TEST

Compression Test

The Compressive strength test results of the hardened concrete cubes for standard, 5%, 10% & 15% RHA replaced concrete for 7, 14 and 28 days were given in table 7 with its graphical representation

Table 7 Compressive Strength for Cubes

% of RHA (Replacement for Cement)	Compressive Strength (N/mm^2)		
	7th day	14th day	28th day
0	21.63	54.42	65.30
5	19.24	52.11	61.52
10	18.00	50.63	60.13
15	18.37	47.71	56.20

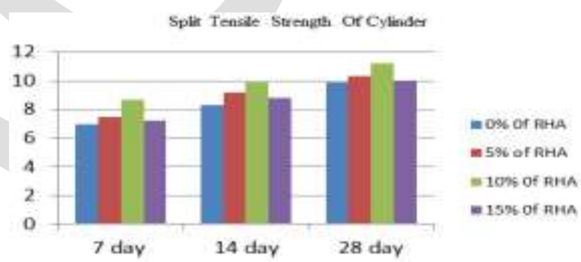


Split Tensile test

The Split tensile strength test results of the hardened concrete Cylinders for standard, 5%, 10% & 15% RHA replaced concrete for 7, 14 and 28 days were given in table 8with its graphical representation.

Table 8 Split tensile strength for Cylinders

% of RHA (Replacement for Cement)	Split tensile strength (N/mm^2)		
	7th day	14th day	28th day
0	6.98	8.30	9.90
5	7.50	9.20	10.30
10	8.70	9.90	11.20
15	7.20	8.80	10.00

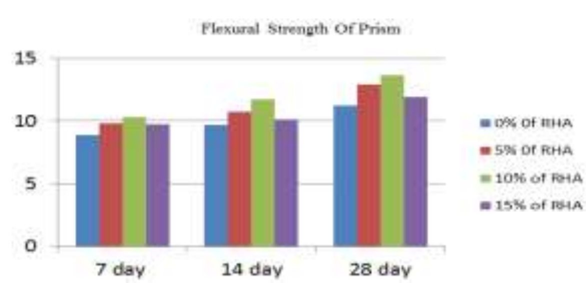


Flexural Strength Test

The Flexural strength test results of the hardened concrete Prisms for standard, 5%, 10% & 15% RHA replaced concrete for 7, 14 and 28 days were given in table 9 with its graphical representation

Table 9 Flexural strength for Cylinders

% of RHA (Replacement for Cement)	Flexural strength (N/mm^2)		
	7th day	14th day	28th day
0	8.90	9.70	11.20
5	9.80	10.70	12.90
10	10.30	11.70	13.65
15	9.75	10.10	11.90

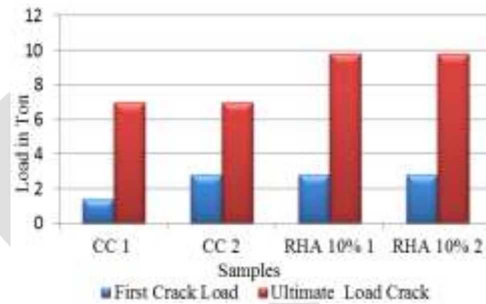


Beam Test

The table 10 gives the loads taken by conventional concrete beam and 10% RHA replaced concrete beam for two samples. From the results it was observed that 10% RHA replaced concrete beam is higher than that of normal conventional concrete beam and the graph was plotted between load and samples.

Table 10 Comparison of First and Ultimate crack Load of CC and RHA10%

Sl.No.	Beam ID	First Crack Load in (Ton)	Ultimate Load in (Ton)	Ultimate Load/ First Crack Load
1	CC 1	1.4	7	5
2	CC 2	2.8	7	2.5
3	RHA 10% 1	2.8	9.8	3.5
4	RHA 10% 2	2.8	9.8	3.5



DURABILITY TEST

Acid Test

Acid Test is carried out to obtain weight loss of different type of concrete. Acid test results are shown in table 11 & 12. From the result it will be observed that weight loss is nearly equal for conventional HSC and quarry dust HSC. Quarry dust and Rice Husk Ash has good void filling ability. So that acid test on quarry dust HSC will show the good result. From the result we can found that acid attack in quarry dust concrete will be very less after long duration.

Table 11 Percentage Loss in weight due to Acid Attack

Sl. No	Type of concrete	Percentage Loss in weight (kg)	
		30 days	60 days
1	NormalConventional concrete	1.1	1.6
2	RHA Concrete(5% Replacement)	1.05	1.58
3	RHA Concrete(10% Replacement)	1.0	1.50
4	RHA Concrete(15% Replacement)	1.18	1.8

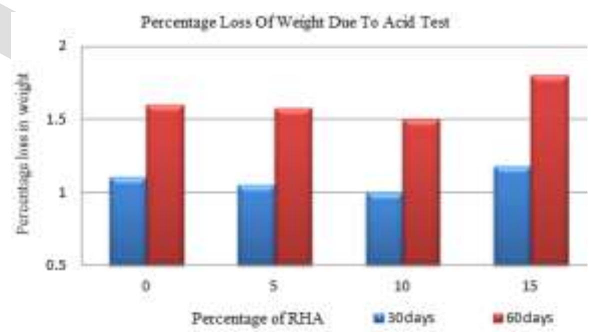
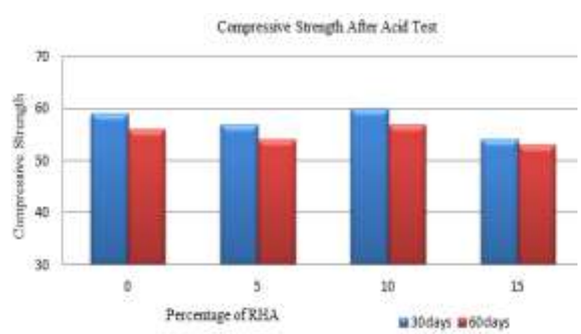


Table 12 Compressive Strength after Acid Test

% of RHA (Replacement for Cement)	Compressive strength in (N/mm^2)	
	30 days	60 days
0	59	56
5	57	54
10	60	57
15	54	53



Sulphate Test

Sulphate Resistance test was carried out to obtain weight loss of different type of concrete. Sulphate attack test results are shown in table 13 & 14. From the result it will be observed that 30 & 60 days Magnesium Sulphate attack to the RHA concrete is less when compared to normal conventional concrete.

Table 13 Percentage Loss in weight due to Sulphate Attack

Sl. No	Type of concrete	Percentage Loss in weight (kg)	
		30 days	60 days
1	Normal Conventional concrete	0.5	0.97
2	RHA Concrete (5% Replacement)	0.6	0.9
3	RHA Concrete (10% Replacement)	0.4	0.8
4	RHA Concrete (15% Replacement)	0.9	1.1

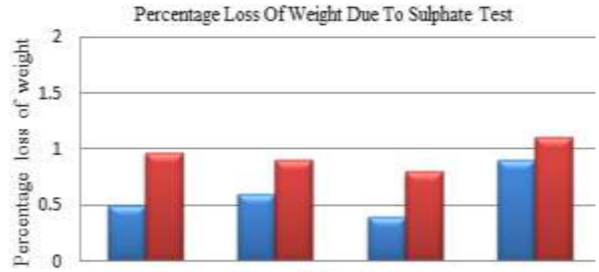
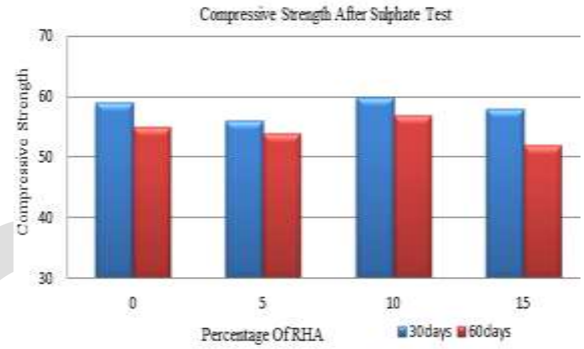


Table 14 Compressive Strength after Sulphate Test

% of RHA (Replacement for Cement)	Compressive strength in (N/mm^2)	
	30 days	60 days
0	59	55
5	56	54
10	60	57
15	58	52



Alkaline Test

Alkaline test was carried out to obtain weight loss of different type of concrete. Alkaline test results are shown in table 15 & 16. From the result it will be observed that weight loss is nearly equal for conventional HSC and quarry dust HSC. Quarry dust and RHA are the substance which has good resistance to alkaline. So that alkaline test on quarry dust HSC will show the good result. From the result we can found that alkaline attack in quarry dust concrete will be very less after long duration.

Table 15 Percentage Loss in weight due to Alkali Attack

Sl. No	Type of concrete	Percentage Loss in weight (kg)	
		30 days	60 days
1	NormalConventional concrete	0.45	0.56
2	RHA Concrete(5% Replacement)	0.53	0.6
3	RHA Concrete(10% Replacement)	0.4	0.53
4	RHA Concrete(15% Replacement)	0.7	0.81

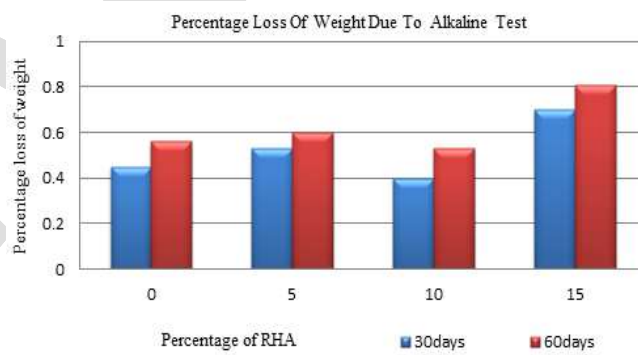
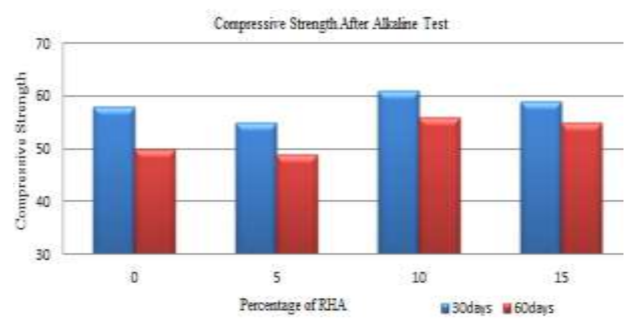


Table 11.19 Compressive Strength after Alkaline Test

% of RHA (Replacement for Cement)	Compressive strength in (N/mm^2)	
	30 days	60 days
0	58	50
5	55	49
10	61	56
15	59	55



CONCLUSION

This project work is based on the usage of the rice husk ash, an agricultural waste material used as partial replacement of cement, Quarry dust a cheap material used as complete replacement for sand and addition to that polypropylene fiber are used in the concrete mixtures. The partial substitution of cement with RHA presents better results in the improvement of compressive strength at different ages and, at the same time the reduction of cracks has been achieved due to presence of polypropylene fiber.

The experimental investigation was conducted for high strength concrete with quarry dust as fine aggregate with partial replacement of cement with rice husk ash and also with addition of polypropylenefiber. To improve the workability of the concrete mix, super plasticizer is also used. Properties of materials used in concrete were listed out. Workability, strength and durability characteristics of the of high strength concrete were compared with conventional concrete.

Quarry dust has lots of finer dust particle than sand, which reduce the workability of concrete. To compensate this problem super plasticizer was used. When quarry dust was used with super plasticizer it will show better workability and flow ability. Combination of quarry dust and rice husk ash exhibiting good performance due to efficient micro filling ability and pozzolanic action of rice husk ash. From this can conclude that 100% replacement of sand with quarry dust shows good strength and durability. From this study it was conclude quarry dust is the better alternative for natural sand.

Compressive strength of conventional concrete is higher than the quarry dust concrete, cement was partially replaced by 5%, 10% and 15% rice husk ash. When it was added with 0.3% of polypropylenefiber their flexural strength was increasing.And beam test result also show the fibrous nature of RHA and polypropylenefiber increased the load carrying capacity and reduced the micro cracks. And increase the ductility of the beam.

When adding 5%, and 10% of rice husk ash content compressive strength and tensile strength of the mix will increase. When 15% of rice husk ash was added strength will decrease because it will decrease the bonding between the materials. From the experimental investigation it was found that the optimum RHA content is 10%.

REFERENCES:

[1] AlirezaNajiGiviSuraya, Abdul Rashid, Farah Nora A. Aziz and MohamadAmranMohdSalleh"Assessment of the effects of rice husk ash particle size on strength, water permeability and workability of binary blended concrete" construction and Building Materials 24 (2010) 2145–2150.

[2] Godwin A. Akeke, Maurice E. Ephraim, Akobo, I.Z.S and Joseph O. Ukpata., "Structural Properties Of Rice Husk Ash Concrete" International Journal of Engineering and Applied Sciences, Vol. 3, Issue 3, ISSN 2305-8269, May 2013.

[3] Anithaselvasofia S.D, Gayathri R, SwathiG and Prince arulraj G, "Experimental Investigation On Quarry Dust Concrete With Chemical Admixture" International Journal of Latest Research in Science and Technology, ISSN (Online):2278-5299, Volume 2,Issue 2: Page No.91-94, March - April 2013.

[4] M. Devi, V. Rajkumar and K. Kannan 'Inhibitive Effect of Organic Inhibitors in Concrete Containing Quarry Dust As Fine Aggregate" International Journal of Advances in Engineering Sciences, Vol.2, Issue 1, Jan 2012.

[5] V.Priyadharshini and A.Krishnamoorthi, "High Performance Concrete using Quarry dust as Fine aggregate", International Science and Research Journal, Vol. 2, Issue 2, Jun 2014.

[6] G.Balamurugan and P.Perumal "Use of Quarry Dust to Replace Sand in Concrete –An Experimental Study", International Journal of Scientific and Research Publications, Vol. 3, Issue 12, December 2013.

[7] K.S. Johnsirani, A. Jagannathan and R. Dinesh Kumar "Experimental Investigation on Self Compacting Concrete Using Quarry Dust" International Journal of Scientific and Research Publications, Vol. 3, Issue 6, June 2013.

[8] Hardikkalpeshbhai Patel and Jayesh Kumar Pitroda, "A Study of Utilization Aspect of Quarry Dust" Journal of International, Vol. 1, Issue 9, October 2013.

[9] Mehul J, Patel, and M. Kulkarni, "Effect of polypropylene fiber on the high strength concrete" Journal of Information, Knowledge and Research in Civil Engineering, Vol. 2, Issue 2, Page 125, November 2012 .

[10] M. Tamil Selvi and T.S. Thandavamoorthy, "Studies on the Properties of Steel and Polypropylene Fiber Reinforced Concrete without any Admixture", International Journal of Engineering and Innovative Technology, Vol. 3, Issue 1, July 2013.

[11] IS 12269: 2013, Ordinary Portland cement 53 Grade — Specification.

[12] IS: 2386 (Part I) – 1963, Methods of Test for Aggregates for Concrete, Part I Particle Size and Shape.

[13] IS: 2386 (Part II)-1963, Methods of Test for Aggregates for Concrete, Part II Estimation of Deleterious Materials and Organic Impurities.

[14] IS:2386 (Part IV)-1963, Methods Of Test For Aggregates For Concrete, Part IV Mechanical Properties

[15] IS: 2386 (Part III) – 1963, Methods of Test for Aggregates for Concrete, Part III Specific Gravity, Density, Voids, Absorption and Bulking.

[16] IS. 456: 2000, Plain and Reinforced Concrete Code of Practice.

[17] IS 12269 : 2013, Ordinary Portland Cement, 53 Grade — Specification

[18] IS 9103: 1999, Concrete Admixtures – Specifications.

[19] IRC:44-2008, Guidelines For Cement Concrete Mix Design For Pavements (Second Revision)

[20] ACI 211.4R-93, Guide for Selecting Proportions for High-Strength Concrete with Portland Cement and Fly Ash

[21] M.S.Shetty, Concrete Technology Theory and practice, S.Chand& Company Ltd., Ram Nagar, New Delhi-110 055

[22] G.L.Ghambir, "Concrete Technology", Tata McGraw-hill Publishing company Limited, New Delhi