EXPERIMENTAL STUDY ON M50 GRADE OF HPC MIX USING HIGHLY REACTIVE METAKAOLIN AND RICE HUSK ASH WITH RECRON 3S FIBRE

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Abstract

Concrete is one of the most durable building material and versatile in nature used for making many structures worldwise. In this technological world construction industries need to plan for effective utilization of waste materials(both natural and industrial by-product) for improving production of concrete economically and aesthetically. For improving properties of concrete and to minimize use of cement which is a major component of concrete, partial replacement of cement is required as Global cement production is expected to increase from 3.27 billion metric tons in 2010 to 4.83 billion metric tons in 2030 which has a bad impact on environment .Cement production emits harmful CO_2 gas leading to global warming, health disorders and so on. Earlier studies has shown that when Rice Husk Ash(RHA) used as partial cement supplement gradual decrease in strength is seen. Here experimental investigation has been carried out with respect to strength and durability study and other mechanical properties study on performance of HPC of M50 grade of concrete using HRM and RHA as partial replacement of cement with addition of Recron 3s fibre by weight of concrete. Recron 3s fibre controls and arrest cracks in concrete. Highly Reactive Metakaolin(HRM) which is a very reactive material used in different percentage(5%,10%,15% and 20%) along with constant 5%RHA and constant 7.5% RHA with addition of 0.2%Recron 3s fibre(RF) by weight of concrete for producing better modified concrete . Various strength parameters like compressive strength, split tensile strength and flexural strength are studied. Water absorption and Porosity test are also presented experimentally in this paper.From the experimental study, it was observed that when HRM and RHA are used as partial replacement of cement with addition of recron 3s fibre to weight of concrete, it improves the mechanical properties specially the porosity and water absorption decreases and gradual increase and then decease in compressive, split tensile, flexural strength.

Keywords: *RHA, Highly Reactive Metakaolin, Recron 3s fibre, HPC mix, Durability, mechanical properties*

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1. INTRODUCTION

Concrete is a quasi-brittle material (according to modern fracture mechanics) and heterogeneous mixture of cement, fine aggregate, coarse aggregate and water. Concrete being weak in tensile strength, to make structures strong and durable there is a great need to increase and enhance the mechanical properties like strength, durability, toughness, hardness, fatigue resistance along with physical properties like density,thermal conductivity which all alone cannot be achieved using plain concrete. So HPC mix is used which can enhance performance of concrete. High degree of quality control is required for HPC mix with lower w/c ratio and use of high range water reducer. Use of Highly Reactive Metakaolin as partial replacement of cement which is produced by calcination of pure Kaolinitic clays at a temperature between (650°C-850°C) widely available in the earth`s crust. It improves the mechanical properties of concrete and ecofriendly in nature as does not produce harmful CO_2 gas. It's low overall cost due to less damage to structure,longer life service in severe environment, decreased porosity, early strength achievement, reduces maintenance, densifies concrete and reduces the thickness of the interfacial zone which improves proper mixing between cement paste and sand particles make it best material to be used as partial replacement of cement. RHA is a natural waste product about 25% by weight of rice husk when burnt in boilers contains 89% of amorphous silica. Rice husk produced annually about 20 million tones which comes from field during paddy milling from rice milling industry. RHA has high concentration of silica, generally more than 80-85% according to estimation. Recron 3s fibre used as secondary reinforcement to prevent shrinkage cracks and propagate cracks by supporting in all directions and speed up the construction work and also used for shotcrete, plastering, prestressed beams, bridges, dams etc. From previous researches we know the strength varies slightly from normal concrete when 0.1%RF and 0.3%RF are used.But best resultin strength improvement was seen using constant 0.2%RF additionso 0.2%RF by weight of concrete addition is used in concrete with HRM and RHA. When HRM and RHA both are used as partial replacement of cement with addition of recron3s fibre the results were analyzed properly. Durability test such as water absorption and porosity test at 28 days curing was also done experimentally. M50 grade of concrete is used with constant w/c ratio of 0.35

2. MATERIALS AND PROPERTIES

2.1 Cement

Cement is the basic ingredient of concrete mixture. A cement acts as a binder, to bind the fine and the coarse aggregate together and to fill the voids in between fine and coarse aggregates particles to form a compact mass. For present thesis paper, Ordinary Portland Cement (OPC) of 53 grade was used specifying all the properties from IS12269-1987. The brand of cement used was Coramendel King. The use of high grade cement saves cement requirement with high strength achievement.For various laboratory tests of cement following tests have been carried out according to IS: 8112 – 1989 and presented in table1 describing the physical properties of OPC 53 grade. From table1 we can compare properties obtained from experimental studies and actual requirement according to IS 12269:2013 specification.

Table1: Physical properties of OPC

SL. NO.	Characteristics	Value obtained experimentally	Requirement as IS 12269:2013 specification
1	Grade	53	
2	Normal Consistency	32	---------
3	Initial setting time(min)	80min	30min(minimum
4	Final setting time(min)	410min	600min(maximum)
5	Compressive strength at 3 days(MPa)	30.2 N/mm^2	27.0N/mm^2
6	Compressive strength at 7 days(MPa)	42.7 N/mm^2	37.0N/mm^2
7	Compressive strength at 28 days(MPa)	57.8 N/mm^2	53.0N/mm^2
8	Soundness:By Le chatelier method	9.8mm	10mm

2.2 Fine Aggregate and Coarse Aggregate

The sand which is used in this experimental investigation is confirming to grading zone II of Table 4 of IS 383-1970 and has been collected from locally. Most of the aggregate passes through a 4.75 mm IS sieve and contains only that much coarser material as is permitted by the specification. Sand is generally considered to have a lower size limit of about 0.07mm. According to size the fine aggregate may be described as coarse medium and fine sand. The fineness modulus may be taken as guidance for making satisfactory concrete.The object of finding the fineness modulus is to grade the given aggregate for obtaining a most economical and workable mix with minimum quantity of cement. The minimum limit of fineness modulus of fine aggregate is 2.0 and maximum limit is 3.5. The sieve analysis has been conducted to determine the FM and grading Zone. The locally available Crushed aggregate with 50% passing through 12.5mm and retained on 10mm sieve and 50% passing through 20mm and retained on 12.5mm sieve was used. The following tests have been carried out as per the procedure given in IS 383-1970 and IS.2386-1963 and the results are presented below in table2 describing properties of aggregate.

Table2: Properties of aggregates

Sl.No.	Properties of aggregate	Fine aggregate	Coarse aggregate
1	Specific Gravity	2.61	2.65
2	Fineness modulus	2.77	6.76
3	Water absorption	0.8%	0.7%

2.3 Highly Reactive Metakaolin (HRM)

The particle size of Metakaolin is significantly smaller than cement particles. Blending of Metakaolin with cement improves the mechanical properties of concrete. The pozzolanic reaction between Metakaolin and the C-H produced by the hydration of thecement enhanced the early strength. Usage of Metakaolin can be more advantageous for preparing stronger and more durable concrete mixes due to above reasons. The performance of concrete is substantially improved by using Metakaolin. Here, the physical properties of Highly Reactive Metakaolin(HRM) has been experimentally discussed. Metakaolin used for present experimental work was obtained from Navpad Sales, Pozzocrete distributor, Surat, Gujarat.Specific Gravity of HRM was found to be 2.72.

2.4 RHA

Rice husk ash is obtained by burning rice husk obtained from paddy mill at a controlled high temperature without causing environmental pollution much. When it is properly brunt it`s high SiO_2 content and can be used as a concrete admixture. Rice husk ash exhibits high pozzolanic characteristics and contributes to better strength and high impermeability of concrete.From previous experimental results we know that Rice husk ash consists of amorphous or non-crystalline silica with about 85- 90% cellular particle, 5% carbon and 2% K_2O. India produces about 122 million ton of paddy each day. Each ton of paddy produces about 40 kg of RHA. There is a good potential to make use of RHA as a valuable pozzolanic material to give almost the same properties as that of micro silica. From experimental investigation the properties of RHA is shown in table3.

Table3: shows properties of RHA

Physical state	Solid-Non Hazardous
Appearance	Very fine powder
Colour	Grey
Odour	Odourless
Specific Gravity	2.3

2.5 Recron 3s Fibre

Recron 3s fibre are manufactured by Reliance Industries limited(RIL), V.P.O.Chohal, Hoshiarpur, Punjab, India an associate company of Reliance Industries Limited(RIL)
Properties of recron 3s fibre:
Colour:- Brilliant White
Length Cut:- 12mm
Dispersion:- Excellent
Acid resistance:- Excellent

3. EXPERIMENTAL WORK AND TESTS

3.1 Mix Design

HPC of M50 grade of concrete was designed as per standard specification IS: 10262-2009 to achieve target mean strength of 58.25MPa respectively. The detailed mix design ratio and material calculation for $1m^3$of concrete are given in table 4 below:

Table4 : Mix proportion for 1 m^3 of M50 HPC mix

Material Mix	M50
Cement	444.96 kg
Fine aggregate	621 kg
Coarse aggregate	1284 kg
Water/cement ratio	0.35
Ratio	1: 1.395: 2.885

3.2 Methodology of our Study

3.2.1 Compressive Strength:-C=P/A

Where, P= load in Newton
A= area of cross section of cube in mm^2

3.2.2 Splitting Tensile Strength :-S=2P/ π× l× d

Where, P= load in Newton
l= length of cylinder in mm i.e. 300mm
d= diameter of cylinder in mm i.e 150mm

3.2.3 Flexural Strength:-F=Pl/bh^2

Where, P= load in Newton shown in dial gauge
l= length of rectangular prism in mm i.e.400mm
b= breadth of rectangular prism i.e. 100 mm

3.2.4 Durability Tests

3.2.4.1 Water absorption of Specimen

Water absorption test was determined on specimen of size $150\times150\times150mm^3$concrete cube at 28 days curing age as per ASTM C-642(1997) by drying the specimen in an oven temperature and taking weight and after cooling again keeping in water for absorption

Water absorption= (Saturated mass-Oven dry mass)/Oven dry mass × 100

3.2.4.2 Porosity

Porosity of a rock is a measure of its capacity to contain or store fluids.Water absorption of concrete is a measure of porosity in hardened concrete occupied by water in saturated condition. The porosity obtained from water absorption tests is termed as effective porosity. It is determined using the following formula:Effective Porosity = Pore Volume/Bulk volume of specimen × 100

$$\text{Effective porosity, } p = (W_s – W_d) / (W_s - W_{sub}) \times 100$$

Where, W_s = Weight of specimen at fully saturated condition
W_d = Weight of specimen at oven dried condition
W_{sub} = Weight of specimen when submerged in water.

The test for porosity was carried out on 150mm×150mm×150mm HPC cube specimen according to the above formula described above.

3.3 Slump Cone Test

Workability is the amount of work to produce full compaction. Workability is used to describe the ease or difficulty with which the concrete is transported, handled and placed between the forms. The slump test is commonly used in the field. The difference level between the height of the mould and that of the highest point of the subsided concrete is measured. The slump test values are written in Table5 and shown in figure1 below:

Table 5: Variation in slump for determining workability

% of HRM +5%RHA+0.2%RF addition	Slump(mm)
0	75
5	60
10	50
15	45
20	40

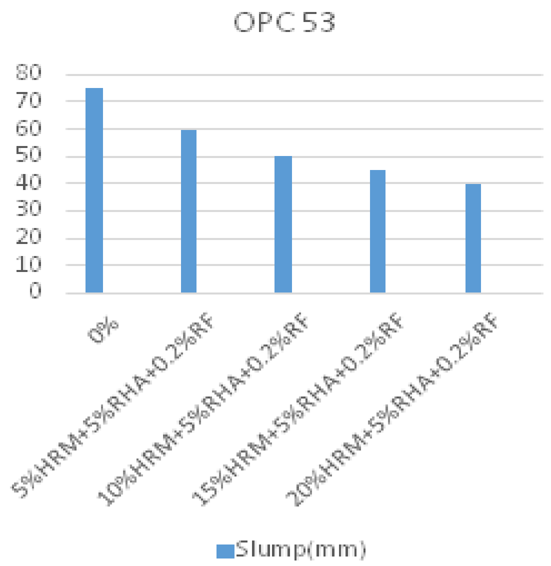

Fig 1 shows the variation of slump value

4. RESULTS WITH DISCUSSION

4.1 Compressive Strength

A set of 3 concrete cubes(150mm×150mm×150mm) casted and tested each after 7 and 28 days for each mix proportion to determine the Compressive strength and make a comparison between conventional concrete and HRM(%) and RHA(%) with recron 3s fibre as partial replacement of cement.Here cement is replaced partially by combining HRM with different percentages 5%,10%,15% and 20% and RHA with 5% only with constant addition of 0.2% RF and then HRM and 7.5%RHA with 0.2%RF addition. Here the test was carried out by keeping constant w/c ratio 0.35 and admixture of 1.2% by weight of cement was used here.The variation in compressive strength of cube mould is writteninTable6 and shown in figure2.

Table 6: Variation in Compressive strength

HRM	HRM(%) WITH 5%RHA+0.2%RF		HRM(%) WITH 7.5%RHA+0.2%RF	
	7 days Compressive strength(N/mm^2)	28 days Compressive strength N/mm^2	7 days Compressive strength N/mm^2	28 days Compressive strength N/mm^2
CC0 %	46.66	60.88	46.66	60.88
5%	47.55	63.68	47.02	62.88
10%	49.64	65.46	49.11	64.87
15%	45.54	60.44	44.84	61.32
20%	43.95	58.66	42.17	58.23

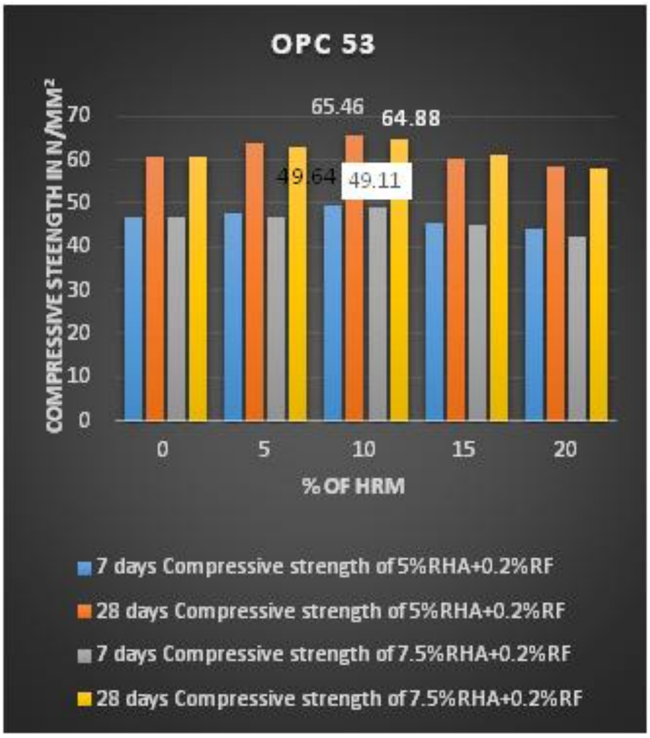

Fig 2 shows the variation in Compressive strength

4.2 Splitting Tensile Strength

Cylindrical specimens of 300mm long and 150mm diameter were tested in Compression testing machine. The results of split tensile strength test of cylinder for 7and 28 days of curing are given in the Table 5 shows the comparison of split tensile strength of Conventional concrete and partial replacement of Cement with RHA(5%) with different percentages of HRM (5%,10% , 15% and 20%) with 0.2%RF additionand partial replacement of Cement with RHA(7.5%) with different percentages of HRM (5%,10% , 15% and 20%) with 0.2%RF addition and making a comparison between them and observing the variation of splitting tensile strength from table7 and figure 3 below:

Table 7: Variation in splitting tensile strength

HRM %	HRM(%) WITH 5%RHA+0.2%RF		HRM(%) WITH 7.5%RHA+0.2%RF	
	7 days Splitting Tensile strength	28 days Splitting Tensile strength	7 days Splitting Tensile strength	28 days Splitting Tensile strength
0	4.36	6.54	4.36	6.54
5	4.796	6.106	3.924	6.976
10	5.232	6.976	4.796	6.104
15	3.488	5.232	3.488	5.232
20	3.052	4.36	2.616	3.052

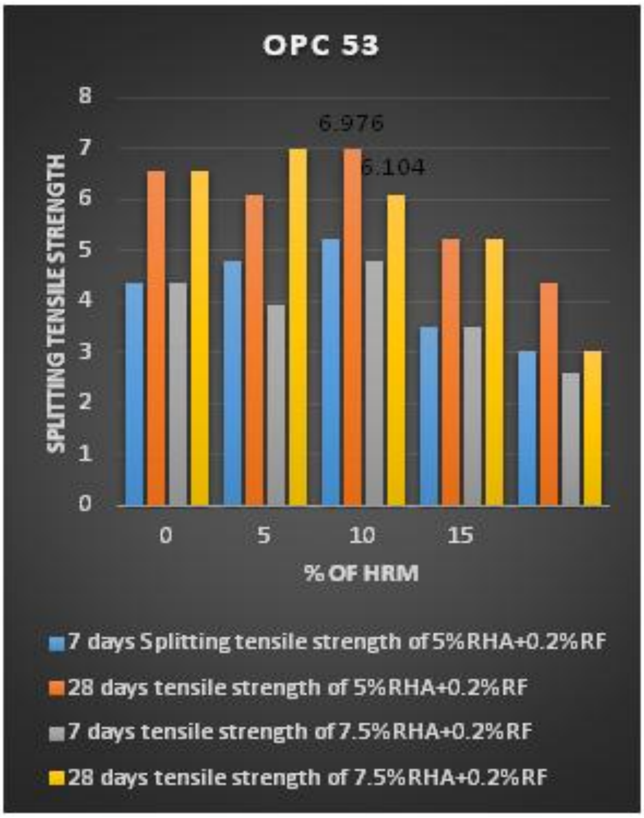

Fig 3 shows variation in Splitting tensile strength

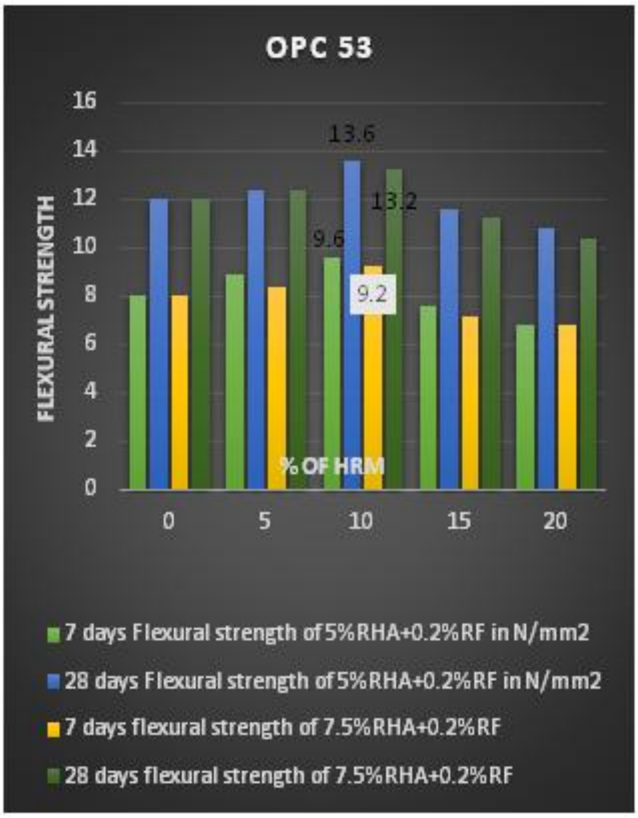

Fig 4 shows variation in Flexural strength

4.3 Flexural Strength

Prismatic specimens 100×100×500mm^3 were tested according to IS:516(1959). The results of Flexural strength of prisms for 7and 28 days of curing are given in Table8. The figure4 shows the comparisons of Flexural strength of conventional concrete and replacement of cement with RHA(5%) and HRM(%) with constant 0.2%RF addition for 7 and 28 days of curing respectively and replacement of cement with RHA(7.5%) and HRM with constant 0.2%RF addition for 7 and 28 days of curing respectively

Table 8: Variation of flexural strength

HRM	HRM(%) WITH 5%RHA+0.2%RF		HRM(%) WITH 7.5%RHA+0.2%RF	
	7 days Flexural strength (N/mm^2)	28 days Flexural strength(N/mm^2)	7 days Flexural strength(N/mm^2)	28 days Flexural strength(N/mm^2)
0%NC	8	12	8	12
5%	8.9	12.4	8.4	12.4
10%	9.6	13.6	9.2	13.2
15%	7.6	11.6	7.2	11.2
20%	6.8	10.8	6.8	10.4

4.4 Water Absorption

When HRM with different percentage and 5%RHA is used as partial replacement of cement with 0.2% recron 3s fibre addition the variation in water absorption of concrete cube moulds at 28 days is written in table9 and shown in figure5.

Table 9: Variation in water absorption after partially

Replacement by HRM+RF addition	RHA %	Wet weightkg	Dry weightkg	Water absorption(%)
0	0	2.546	2.463	3.42
5%+0.2%	5	2.483	2.434	2.01
10%+0.2%	5	2.574	2.533	1.62
15%+0.2%	5	2.600	2.502	3.91
20%+0.2%	5	2.580	2.489	3.99

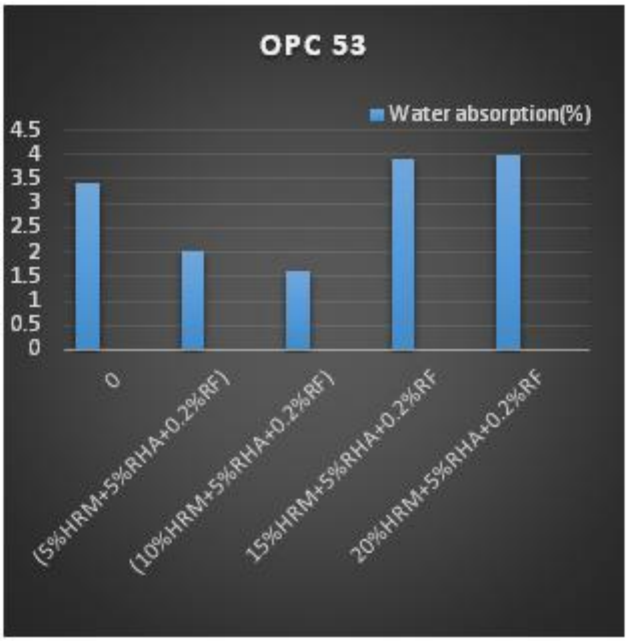

Fig 5 shows variation in water absorption at 28 days

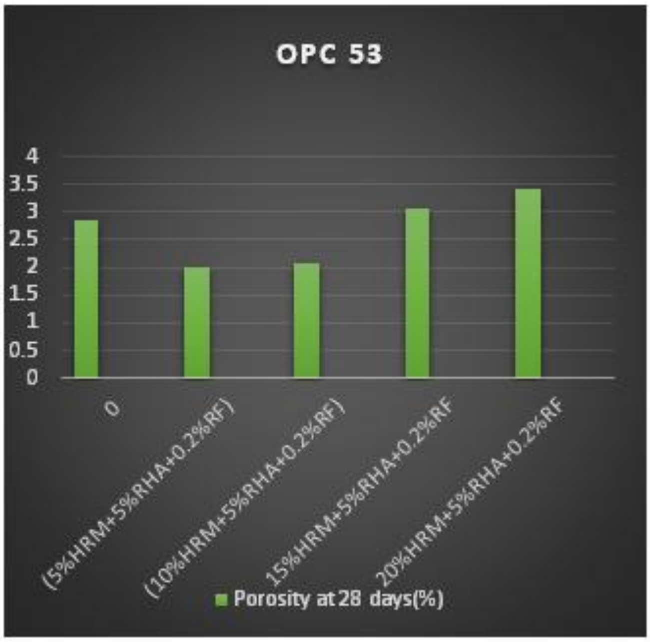

Fig 6 shows variation in porosity at 28 days

4.5 Porosity

When HRM with different percentage and 5%RHA is used as partial replacement of cement with 0.2% recron 3s fibre addition the variation in porosity of concrete cube moulds at 28 days is written in table10and shown in figure6.

Table 10: Variation of porosity of concrete

HRM+RF addition+ RHA	Dry weight in kg	Saturated weight in kg	Submerged weight (kg)	Porosity at 28 days(%)
0%	2.470	2.506	1.25	2.86
5%+0.2%+ 5%	2.560	2.587	1.25	2.02
10%+0.2% +5%	2.562	2.590	1.25	2.08
15%+0.2% +5%	2.52	2.560	1.25	3.05
20%+0.2% +5%	2.544	2.590	1.25	3.432

5. CONCLUSION

From the laboratory investigation and experimental program held in laboratory following conclusions are drawn:

1. When HRM and RHA are used as partial replacement of cement with Recron 3s fibre addition early increase in compressive strength within 7 days more than conventional concrete by about 6.38% is seen. Similarly, about 10% increase in split tensile and 11% increase in flexural strength is observed.
2. It was observed that for conventional M50 grade of HPC mix the compressive strength in 28 days was more than target mean strength(58.25N/mm^2),increasing by 4.54 i.e.60.88N/$mm^2$by using OPC 53 grade with w/c ratio 0.35
3. With the use of superplasticizer(Sika) it is possible to get a mix with low water/cement ratio (i.e0.35) to get the desired strength and durability results.
4. Using HPC mix for M50 grade there was an early gain of strength about 46.66N/mm2 for compressive strength, 4.36N/mm2 for splitting tensile strength, 8N/mm2 for Flexural strength
5. But when partial replacement of cement by HRM and constant 5%RHA with small quantity of 0.2%RF by weight of concrete addition the results were just amazing an increase of 7.5% in compressive strength to normal strength was seen till 10% partial replacement of cement then gradual decrease in strength was observed but still more than normal strength.
6. Similarly about 6.66% in splitting tensile and 13.33% in flexural strength to conventional concrete was seen till 10% replacement the after a large decrease in strength was seen in 20% replacement but more than conventional concrete
7. When partial replacement of cement done by HRM(with different percentage) and constant 7.5%

RHA with 0.2%RF addition by weight of concrete increase in strength was seen upto 10%HRM replacement then after gradual decrease in strength is observed

8. When water absorption test was done amazing results were obtained by using HRM(%),5%RHA with 0.2%RF, there was a decrease in water absorption
9. Decrease in water absorption was seen when 5% and 10%HRM was used with 5%RHA with small quantity of 0.2%RF by weight of concrete addition in it.
10. Maximum increase in compressive strength, split tensile strength and flexural strength occurred at 10%HRM and 5%RHA with small quantity of 0.2%RF by weight of concrete addition as partial replacement of cement.
11. Decrease in porosity was seen when 5% and 10%HRM was used with 5%RHA with 0.2%RF addition in it and after 10% replacement a slight increase in porosity is seen
12. Workability decreases as we increase replacement by HRM(with different percentages) and RHA(5%) and recron 3s fibre addition
13. Maximum increase in compressive strength, split tensile strength and flexural strength occurs at 10%HRM and 5%RHA with 0.2%RF addition.

REFERENCES

[1] M.L.Gambhir,"Concrete Technology",4^{th}edition,The Mc Graw-Hill Private Limited

[2] IS 456 : 2000,"Indian Standard Code of Practice for plain and Reinforced Concrete," Bureau of Indian Standard, New Delhi,2000

[3] IS 10262 : 2009,"Concrete Mix Proportioning-Guidelines,"Bureau of Indian Standard, New Delhi

[4] IS 5816 : 1999,"Splitting tensile strength of Concrete methods of test," Bureau of Indian Standard, New Delhi

[5] Rangwala," Engineering Materials[MATERIAL SCIENCE]", Charotar Publising House Private Limited

[6] IS 9103 : 1999,"Indian Standard concrete Admixture specification," Bureau of Indian Standard, New Delhi

[7] M. S. Shetty, 2002, "Concrete Technology and Practice", S. Chand company

[8] Sandeep.T.,2015,Recron Medium Strength Fibre Reinforced Concrete, International journal

PHOTO GALLERY

Casting of moulds

Compressive strength test after failure

Reron 3s fibre on weight machine

Highly Reactive Metakaolin

Vicat apparatus for initial setting time