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Utilization of Rice Husk Ash and Waste Foundry Sand as Partial Replacement f or Cement and Fine Aggregate in Concrete

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ABSTRACT

Concrete is one of the extensively used material all over the world. Increasing rate of urbanisation and industrialisation has lead to over exploitation of natural resources. Hence it is necessary to use alternate materials in concrete. This work presents the benefits from various ratios of rice husk ash (RHA) on concrete indicators with proportions of 5, 10, 15, 20, 25% RHA by the weight of cement in addition to this a constant amount of 30% waste foundry sand (WFS) by the weight of crushed stone sand has been replaced in the concrete and it has been compared with control concrete with no additives. M20 concrete with water cement ratio of 0.5 has been used. The workability of the concrete decreases as the RHA with the WFS increases. The optimum content found to be RHA10%+WFS30% for compressive strength, split tensile strength and Flexural strength test. The durability properties of the concrete have shown better results, i.e. as the 30%WFS with RHA content increases the water absorption, RCPT, sorptivity value decreases.

KeyWords: *Rice Husk Ash, Waste Foundry Sand, Replacement levels, strength characteristics.*

1. INTRODUCTION

Concrete is one of the essential building material which is widely used in construction activity all over the world. It is a composite material consisting of cement, fine aggregate, coarse aggregate bonded together with fluid called water. It is estimated that about 25 billion tons of concrete is consumed globally every year or 3.8 tonnes per person in the globe. Concrete is the 2nd largest material that is consumed after the water. Its demand in India is expected to increase in exponential rate due to the initiative taken by the government for the large infrastructure projects and mass housing schemes. The housing sector is the biggest consumer of concrete, for about 67 percent total consumption in India. Increasing rate of urbanization and industrialization has led to over exploitation of natural resources such as river sand and gravels, which is giving rise to sustainability issues. Due to increasing quantities of waste materials and industrial by-products, Solid waste management is the major concern in the world, the waste material which is dumped in landfills, will cause severe problems to the living beings. Instead of filling in land it can be effectively used in the concrete.

One of this is rice husk ash (RHA) which is used in the partial replacement of cement. RHA is one of the waste material which is produced in the rice growing region and it is obtained from burning of rice husk, which is by- product of rice milling. It is estimated that 1000kg of rice grain produce 200kg of rice husk; after rice husk is burnt, about 20 percent or 40kg would become RHA.

In order to reduce the usage of river sand, we can replace it with industrial by-product that is waste foundry sand which is obtained in metal casting process. India is third largest in the production of waste foundry sand after China and USA. In India nearly there are 5000 foundry industries and it is reported that the annual production is about 9.3 million metric tons in the year 2012-13. Waste foundry sand produced from these foundries is about 1.71MT per annum.

2. EXPERIMENTAL PROGRAMME

2.1 Materials

The cement used was ordinary Portland cement of 53 grade. The tests carried out are specific gravity 3.15, normal consistency 32, initial and final setting time are 48 and 255 minutes as per IS: 2269-2013. Fine aggregate was crushed stone sand confirming to zone II passing through 4.75 mm size sieve and having a specific gravity 2.68 with fineness modulus 2.60, bulk density of 1816 kg/m^3, water absorption 2%. Natural aggregate having 20mm down size, specific gravity 2.68, fineness modulus 4.83, water absorption 0.2%, impact value 27.01% and crushing value 25.28%was used as coarse aggregate.

2.1.2 Rice Husk Ash (RHA)

The RHA is obtained from the locally available rice mill which is one of the agricultural by –product used to replace the cement in various percentages. The RHA is sieved through 75 microns sieve to remove the larger particles with specific gravity 2.21 and fineness 1.5% (passing through 90micron sieve) as per IS:3812 part I-2003.

2.1.2 Setting Time of RHA

Initial and final setting time of cement is one of the important factors to determine the hydration and the development of strength in concrete. The incorporation of RHA by replacing cement also influences the setting time characteristics. The initial and final setting time of RHA is as shown in figure1. From the results it is observed that the initial and final setting time increases as the RHA content increases. This is due to the low heat of hydration in the paste containing RHA and also depends on the particle size of RHA.

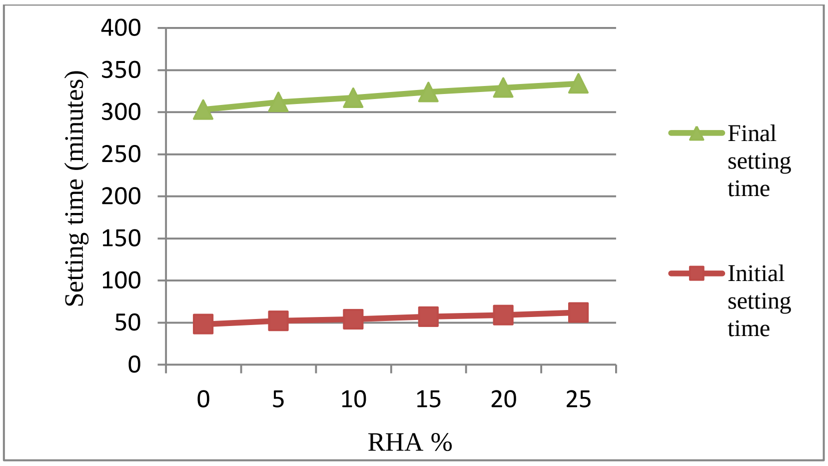

Figure1. Variation of setting with incorporation of RHA

2.1.3 Waste Foundry Sand

The locally available waste foundry sand has been used in this present work which is one of the wastes produced in foundry industries during metal casting. It is the major industrial by –product which has been used instead of river sand in the construction works. In this present work the river sand has been replaced by 30% of waste foundry sand of 4.75mm down size. The physical properties of waste foundry sand has been tabulated in table.1 as per the relevant IS code.

Table.1 Physical properties of waste foundry sand

Sl.No	Test	Results	As per
1	Specific gravity	2.50	IS:2386 part III-1963
2	Gradation	Zone IV	IS:383-1970
3	Moisture content %	3.25	IS:2720 Part II-1973
4	Fineness modulus	2.00	IS:383-1970
5	Bulk density Kg/m^3	1784	IS:2386 part III-1963

2.2 Mix Proportion

The Mix Design of concrete as per IS: 10262-2009 has to be done to know the proportions of concrete. The water-cement ratio for all the mixes is taken as 0.5. Total six different mixtures of concrete were prepared in the laboratory. First is the conventional concrete without any additives. Next with the concrete containing rice husk ash in the varying percentages of 5, 10, 15, 20, 25% and with 30% waste foundry sand were casted. The details of mix proportion of all the concrete are in table 2.

Table.2 Mix Proportions of concrete

Notation	w/c	RHA %	WFS %	Constituents kg/m^3					
				Cement	F.A	C.A	Water	RHA	WFS
CC	0.5	-	-	394	727	1090	197	-	-
R5+WFS30	0.5	5	30	374.3	508.9	1090	197	19.7	218.1
R10+WFS30	0.5	10	30	354.6	508.9	1090	197	39.4	218.1
R15+WFS30	0.5	15	30	334.9	508.9	1090	197	59.1	218.1
R20+WFS30	0.5	20	30	315.2	508.9	1090	197	78.8	218.1
R25+WFS30	0.5	25	30	295.5	508.9	1090	197	98.5	218.1

3. RESULTS AND DISCUSSION

3.1 Workability of Concrete

3.1.1 Slump Cone Test

The slump test is carried out for all the different concrete mixtures to know the workability of concrete. The slump test values for different concrete mixture are in table 3.The slump value for control concrete will be slightly higher compared to other mixtures and the degree of workability will be high. The incorporation of both RHA and WFS decreases the slump value. As the RHA content Increases the slump value decreases this reduction in slump values are due to RHA contains macro and meso- pores inside and on the surface of the particles resulting in very large specific surface area and absorbs certain amount of mixing water resulting in decrease in free water and lowers the slump value. In addition to this presence of WFS will contain some amount of clayey particles results in the reduction of slump value.

Table.3 Results of Slump Test

Concrete Mixtures	Slump (mm)	Rate of Workability
CC	120	High
RHA5+WFS30	105	High
RHA10+WFS30	95	Medium
RHA15+WFS30	90	Medium
RHA20+WFS30	85	Medium
RHA25+WFS30	70	Low

3.1.2 Compaction Factor Test

The compaction factor test is carried out to measure the degree of workability of fresh concrete. The degree of workability of control concrete will be high compared to other concrete mixtures. As the percentage of RHA increases the compaction factor value decreases. The compaction factor values are in table 4.

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Table.4 Compaction Factor Test Values

Concrete Mixtures	Compaction Factor	Degree of Workability
Control concrete (CC 0%)	0.96	High
RHA 5%+ WFS30%	0.93	High
RHA 10%+WFS 30%	0.90	Medium
RHA 15%+WFS 30%	0.86	Medium
RHA20%+WFS 30%	0.83	Medium
RHA25%+WFS 30%	0.80	Low

3.2 Hardened Concrete Properties

3.2.1 Compressive Strength Test

The compressive strength of both control concrete and the concrete which is replaced by RHA and WFS at curing period of 7, 14, 28 days is shown in the figure 6. The compressive strength of control concrete at 28 days is 30.76 Mpa and for R5FS30, R10WFS30, R15WFS30, R20WFS30 and R25WFS30 are 30.23, 34.76, 27.11, 23.56, 17.55 Mpa. From the results it is concluded that $R_{10}WFS_{30}$ will shows the highest compressive strength in compare to control concrete. As the percentage of RHA increases the strength decreases this is because increase in RHA slows down the hydration process and also delays pozzolanic activity. Foundry sand contains clay particles which influences in the reduction of strength in addition with RHA. The results are tabulated in table 5 and the figure 2 shows compressive strength of all the different concretes at 7, 14 and 28 days.

Table 5 Results of Compressive Strength Test

Sl.No	Concrete type	Percentage of RHA	Percentage of Foundry sand	Number of specimens	Compressive strength MPa		
					7 Days	14 Days	28 Days
1	CC 0%	-	-	9	25.08	26.89	30.76
2	R_5FS_{30}	5	30	9	26.79	28.26	30.23
3	$R_{10}FS_{30}$	10	30	9	28.1	30.79	34.76
4	R_{15} FS_{30}	15	30	9	23.28	25.33	27.11
5	$R_{20}FS_{30}$	20	30	9	20.89	22.13	23.56
6	$R_{25}FS_{30}$	25	30	9	14.55	15.15	17.55

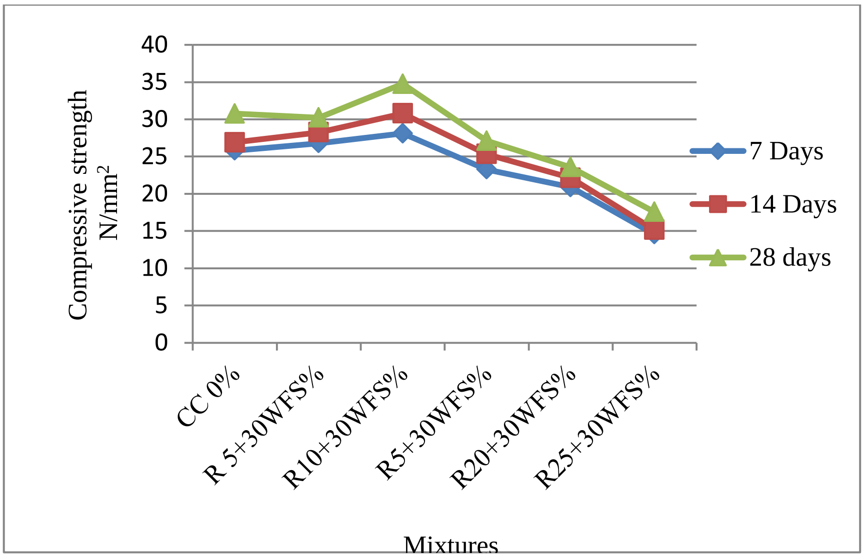

Figure.2 Compressive Strength Test Results

3.2.2 Split Tensile Strength Test and Flexural Strength Test

The tensile strength is useful to estimate the load under which cracking will develop. The figure 3 shows the split tensile strength for both types of concrete. The control concrete has the split tensile strength of 1.95MPa at the age of 28 days and RHA10+WFS30% will have 2.51 MPa and shows the higher strength compare to control concrete. As the RHA content increases the strength decreases and the flexural strength is a measure of an unreinforced concrete beam to resist failure in bending. The strength is measured at curing period of 7 and 28 days and the results are as shown in the figure 4. From the figure it shows that the sudden increase in flexural strength of concrete up to RHA 10%+WFS30% replacement and then decreases. The improvement in the strength is because of the sufficient water for the hydration process and the pozzolanic action of RHA and also the reaction of waste foundry sand which contains large amount of silica content which produces C-S-H gel. The table 6 shows the result of Split tensile strength and flexural strength of concrete.

Table 6 Results of Split Tensile Strength and Flexural Strength Test

Sl.no	Concrete type	Percentage of RHA	Percentage of foundry sand	Number of specimens	Split Tensile Strength MPa		Flexural Strength MPa	
					7 Days	28 Days	7 Days	28 Days
1	CC	-	-	6	1.6	1.95	2.85	3.15
2	R_5FS_{30}	5	30	6	1.76	2.26	4.5	5
3	$R_{10}FS_{30}$	10	30	6	2.14	2.51	4.75	5.25
4	$R_{15}FS_{30}$	15	30	6	1.9	2.15	4.5	4.75
5	$R_{20}FS_{30}$	20	30	6	1.66	1.86	3.75	4
6	$R_{25}FS_{30}$	25	30	6	1.36	1.51	3	3.5

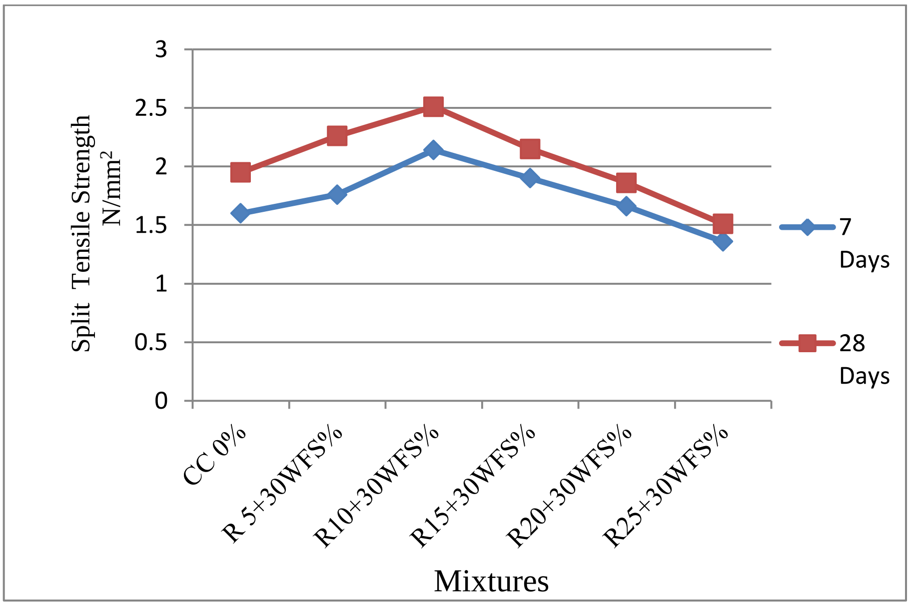

Figure.3 Results of Split Tensile Strength Test

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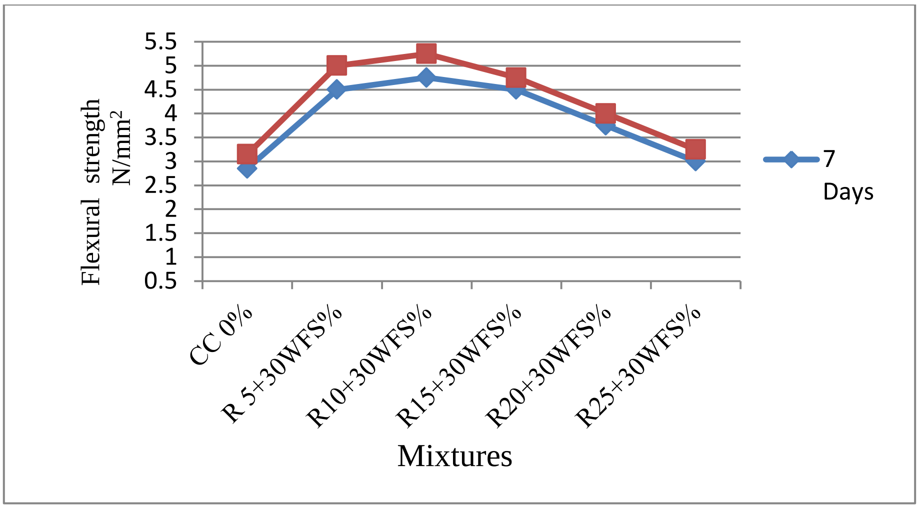

Figure.4 Results of Flexural Strength Test

3.3 Durability Properties of Concrete

3.3.1 Rapid Chloride Penetration Test

The RCPT test results of different concretes mixtures at a 28 days curing period are shown in figure.5.The rapid chloride ion permeability (RCP) of control concrete was in the "Moderate range". Whereas the incorporation of RHA and the waste Foundry sand decreased the RCP of concrete and brought down the values below 1000°C (Very Low Range). As the percentage of RHA increases the RCP decreases. It is because the presence of amorphous silica content and carbon content in RHA and in waste foundry sand has significant effect on the chloride ion permeability of concrete and due to the presence of very fine particles of both RHA and WFS reduces the pores formed in the concrete therefore it shows the less RCP values compare to control concrete. Table.7 shows the rate of chloride ion penetration.

Table.7 Rate of Chloride Ion Penetration

Mixture	Charge passing in coulombs	Chloride ion penetration rate
CC	2414	Moderate
RHA5%+FS30%	2208	Moderate
RHA10%+FS30%	1630	Low
RHA 15%+FS30%	1502	Low
RHA20%+FS30%	802	Very low
RHA25%+FS30%	727	Very low

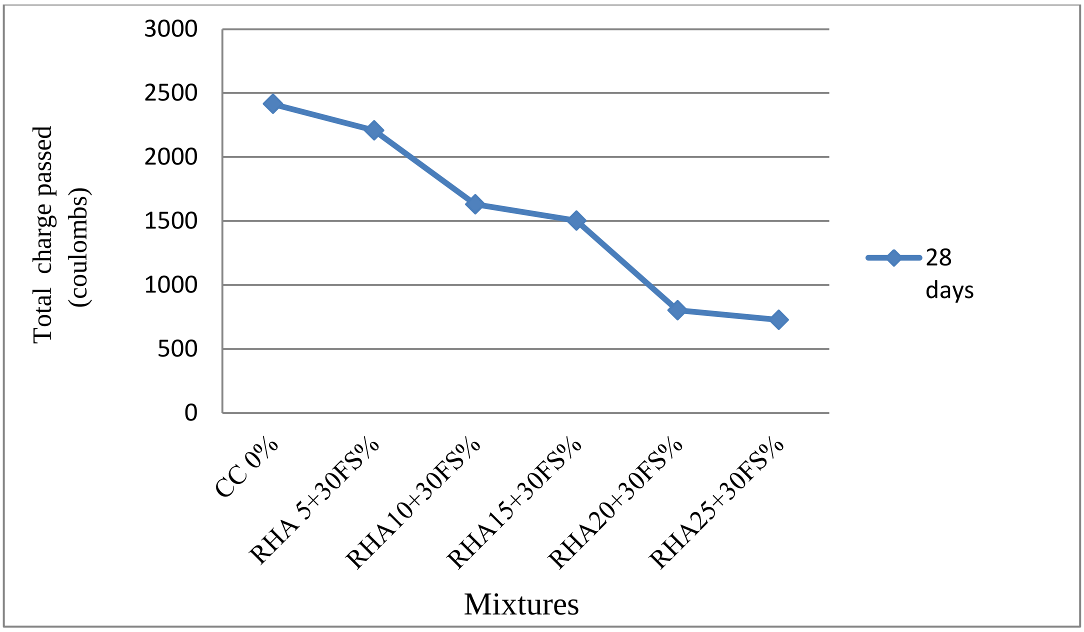

Figure.5 Results of RCPT

3.3.2 Water Absorption Test

The water absorption of different concrete mixtures is as shown in the figure.6. The water absorption of control concrete is about 2.88 %. There may be slightly higher water absorption for concrete which is replaced by RHA10%+WFS30% i.e. 2.94 and then decreases from 15% replacement of RHA. As the percentage of RHA increases the absorption decreases because the presence of finer particles of both RHA and WFS reduces the pores present in the concrete therefore the water absorption decreases.

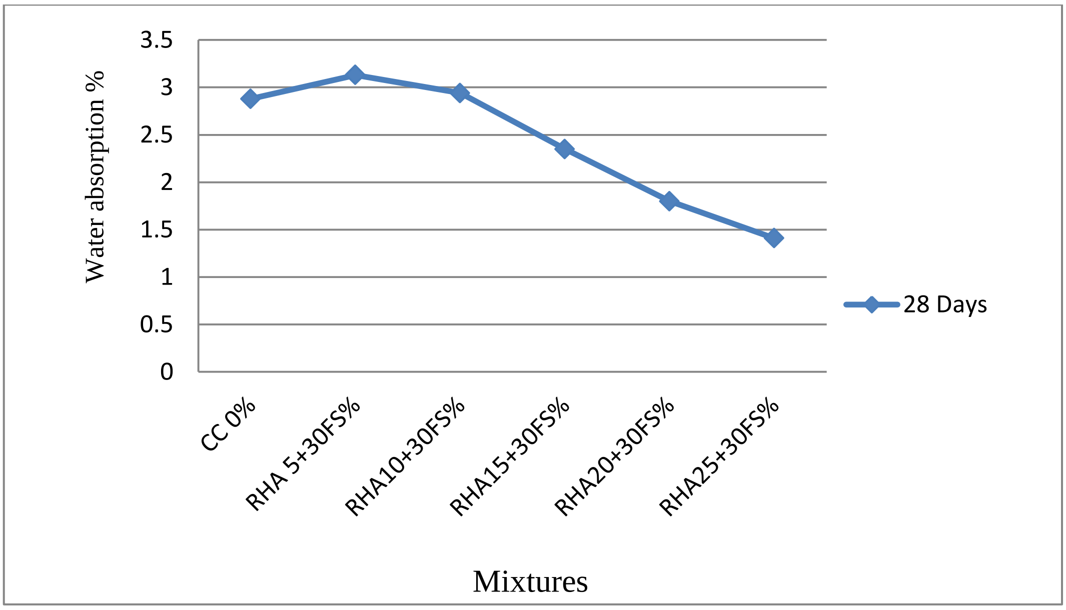

Figure.6 Results of Water Absorption Test

3.3.3 Sorptivity Test

In this test the specimens will absorb water only in vertical direction; the peripheral direction will be coated with epoxy coating such that it should not absorb any water. The sorptivity test results for different concrete mixtures are as shown in the figure.7.The sorptivity value of control concrete is 4.26×10^{-5} mm/min $^{0.5}$. For RHA25+WFS30 the sorptivity was 1.54×10^{-5} mm/min$^{0.5}$. The value decreases as the RHA in concrete increases. As the RHA content increases, the presence of finer particles also increases which helps in filling the voids present in concrete and also the finer particles of waste foundry sand will impart in the reduction of sorptivity value.

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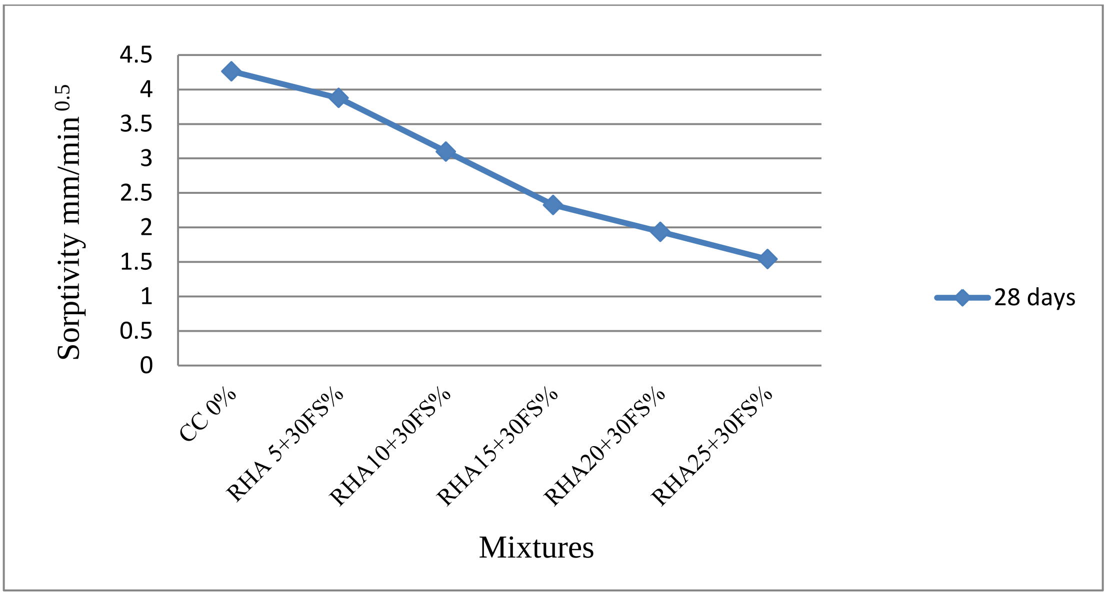

Figure.7 Results of Sorptivity Test

4. CONCULSIONS

The combined effect of foundry sand of 30% and rice husk ash with increased percentage results in the decrease of slump by 41.66% and compaction factor by 16.66% compared to ideal concrete. The decrease in slump and compaction factor is due to the presence of micro and meso pores in RHA and also due to the water absorbing capability of RHA. The increase of compressive strength by 13% is seen in the combination of RHA10% and WFS 30%. This is due to increased RHA content results in improper pozzolonic action and slows down hydration process in concrete. The combination of RHA10% and WFS30% shows the increased split tensile strength and flexural strength by 28.71% and 66.66% than the control concrete. The combination of RHA10% and WFS30% is found to be the optimum content for the compressive strength, split tensile and flexural strength test The WFS30% with increased percentage of RHA content shows the decrease in RCPT, water absorption and sorptivity value by 69.88%, 51.04% and 63.87% than the control concrete. The reduction in these values is due to presence of very fine particles in both RHA and WFS which are accountable for filling the void spaces in concrete.

SCOPE FOR FUTURE WORK

The study can be extended to determine the hydration, microstructural behaviour and morphology of this concrete.

Also, experiment's may be conducted to find the performance of the concrete in marine environment.

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