Utilization of Rice Husk Ash and Waste Paper Sludge Ash as Partial Replacement of Cement in Concrete

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Abstract* - Cement mortar and concrete are the most widely used construction materials. Due to growing environmental awareness, as well as regulations on managing industrial waste, the world is increasingly turning to researching properties of industrial wastes and finding solutions on using their valuable component parts so that those might be used as secondary raw material for other industrial applications. Paper sludge production is a by-product of paper making in the Paper Mill Industries and Rice Husk is a by-product of rice processing.In the present scenario, these by-products are being used in other industrial branches and in the field of civil constructions, such as in cement manufacturing along with clinker and in masonry work for civil works. This research work demonstrates the possibilities of using rice husk ash and waste paper sludge ash together as partial replacements of cement in concrete. This research work presents an investigation of compressive strength, and split tensile strength of concrete by adding rice husk ash and waste paper sludge ash as partial replacement of cement in various percentages.In this project Rice Husk Ash (RHA) and Waste Paper Sludge Ash (WPSA) obtained from uncontrolled combustion are used as an alternative construction material for concrete. In the present investigation, a feasibility study is made to use Rice Husk Ash and Waste Paper Sludge Ash as an admixture to Ordinary Portland Cement in Concrete, and an attempt has been made to investigate the strength parameters of concrete (Compressive and Splitting Strength). For control concrete, IS method of mix design is adopted and considering this a basis, mix design for replacement method has been made. Four differentreplacement levels namely 5%,10%, 15%and 20% are chosen for the study concern to replacement method. Large range of curing periods starting from 7days and 28days are considered in the present study. Cubes (150×150×150mm) and Cylinders (150ø×300mm) with varying ratios of RHA, WPSA and mix of both will be casted. Total no of cubes casted would be 78 and cylinder would be78. The various tests would be performed to evaluate the action of these materials will be normal consistency, setting time, compressive strength, splitting strength and water absorption. The study would be conducted in the framework of a research project aiming at improving the utilization potential of Rice Husk &Waste paper Sludge Ash.

1. INTRODUCTION

1.1GENERAL

Concrete is one of the most widely used construction products in the world. It is mixture of cement, fine aggregate, course aggregate and water. Concrete construction does not require highly skilled labour. The durability of concrete depends upon proportioning, mixing and compacting of the ingredients. The cost of construction materials is increasing day by day because of high demand, scarcity of raw materials, and high price of energy.Agricultural waste (rice husk ash) and industrial by – product (silica fume) (waste paper) have been widely used as partial replacement materials or cement replacement materials in concrete works. The advantages by incorporating these supplementary cementing materials include energy consumption saving (in cement production), low cost, engineering properties improvement, and environmental conservation through reduction of waste deposit. Durability is linked to the physical, chemical and mineralogical properties of materials and permeability. Any improvement in these properties is likely to aid durability. Addition of a pozzolanic material to concrete mix may lead a considerable improvement in the quality of the concrete and its durability. A pozzolanic material or pozzolan has been described as a siliceous and aluminous material. At ordinary temperature and with the presence of moisture it chemically reacts with calcium hydroxide (lime) to form compounds possessing cementitious properties. Rice husk ash (RHA) and silica fume (SF) waste paper sludge ash (WPSA)are considered as rich-silica materials or pozzolanic materials used to replace a portion by mass basic of Portland cement in order to modify the physical and engineering properties of cement and concrete. When these materials blended with cement and in the presence of water, they can react with Calcium Hydroxide ($Ca(OH)_2$) which forms in hydrated Portland cement to produce additional CalciumSilicate Hydrate (C-S-H). With the addition of the these pozzolanic materials, many aspects of concrete properties can be favorably influenced, some by physical effects associated with small particles which have generally a finer particle size distribution than ordinary Portland cement and others by pozzolanic and cementitious reactions resulting in certain

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desirable physical effects. Concrete mix proportion and rheological behavior of plastic concrete are caused by the physical effects associated with the particle size and morphology of pozzolans. Strength and permeability of hardened concrete are the main effects associated with the pozzolanic and cementitious reactions. Several studies in developing countries, including Guyana,Thailand, Pakistan and Brazil, have shown that rice husk ash (RHA) can be used as a partial replacement for cement in concrete. The ability to use an agricultural waste product to substitute a percentage of Portland cement would not only reduce the cost of concrete construction in these countries, but would also provide a means of disposing of this ash, which has little alternative uses. Additionally, cement manufacturing is an energy-intensive process, so in addition to reducing the cost of concrete construction and providing a means for disposing of an agricultural waste product, incorporating RHA into concrete as a partial substitute for Portland cement would also stand to reduce the amount of energy associated with concrete construction. The rapid industrialization has resulted in generation of large quantities of wastes. Most of the wastes do not find any effective use and create environmental and ecological problems apart from occupying large tracts of valuable cultivable land. It has been observed that some of these wastes have high potential and can be gainfully utilized as raw mix / blending component in cement manufacturing. The utilization of the industrial solid wastes in cement manufacture will not only help in solving the environmental pollution problems associated with the disposal of these wastes but also help in conservation of natural resources (such as limestone) which are fast depleting. The other benefits to cement industry include lower cost of cement production and lower greenhouse gas emission per ton of cement production. This may also enable cement industries to take benefits of carbon trading.

2. MATERIALS AND METHODS

2.1GENERAL

This chapter describes the properties of material used for making concrete mixes determined in laboratory as per relevant codes of practice. Different materials used in tests were OPC, coarse aggregates, fine aggregates, rice husk ash and waste paper sludge ash. The description of various tests which were used in this study is given below:

2.2 ORDINARY PORTLAND CEMENT

Ordinary Portland Cement (OPC) of 53 Grade (Ambuja cement) was used throughout the course of the investigation. The physical properties of the cement as determined from various tests conforming to Indian Standard IS: 12269:1987 are listed in Table 2.1.

Table 2.1: Properties of OPC 53 Grade

Sr. No.	Characteristics	Values Obtained Experimentally	Values Specified By IS 12269:1987
1.	Specific Gravity	3.10	3.10-3.15
2.	Standard Consistency	31%	30-35
3.	Initial Setting Time	115 minutes	30min(minimum)
4.	Final Setting Time	283 minutes	600min(maximum)
5.	Compressive Strength(N/mm^2) 7 days 28 days	 38.49 N/mm^2 52.31 N/mm^2	 37 N/mm^2 53 N/mm^2

2.3 Aggregates

Aggregates constitute the bulk of a concrete mixture and give dimensional stability to concrete. The aggregates provide about 75% of the body of the concrete and hence its influence is extremely important.

2.3.1 Fine Aggregates

The sand used for the work was locally procured and conformed to Indian Standard Specifications IS: 383-1970. The results are given below in Table 2.3.1 (A) and 2.3.1(B). The fine aggregated belonged to grading zone III.

Table 2.3.1(A): Sieve Analysis of Fine Aggregate

Weight of sample taken =1000 gm					
Sr. No	IS-Sieve (mm)	Mass Retained (gm)	Cumulative mass Retained	Cumulative %age mass Retained	Cumulative %mass passing through
1	4.74	1	1	0.1	99.9
2	2.36	22	23	2.3	97.7
3	1.18	77	100	10	90
5	600µ	153	253	25.3	74.7
6	300µ	264	517	51.7	48.3
7	150 µ	425	942	94.2	5.8
8	Below150µ	58	1000	100	0
	Total			Σ283.6	

FM of fine aggregate = 283.6/100=2.836

Table 2.3.1(B): Physical Properties of fine aggregates

Characteristics	Value
Specific gravity	2.63
Bulk density	5%
Fineness modulus	2.83

2.3.2 Coarse Aggregates

Locally available coarse aggregate having the maximum size of 20 mm was used in this work. The aggregates were tested as per IS: 383-1970. The results are shown in Table 2.3.2(A) and Table 2.3.2(B).

Table 2.3.2(A): Sieve Analysis of Coarse Aggregate (20 mm)

Weight of sample taken =2000 gm					
Sr. No	IS-Sieve (mm)	Mass Retained (gm)	Cumulative mass Retained	Cumulative %age mass Retained	Cumulative % mass passing through
1	40	0	0	0	100
2	20	145	145	7.25	92.75
3	10	1829	1974	98.7	1.3
5	4.74	124	1998	99.9	0.1
6	2.36	0	1998	99.9	0.1
7	1.18	0	1998	99.9	0.1
8	600µ	0	1998	99.9	0.1
9	300µ	0	1998	99.9	0.1
10	150 µ	0	1998	99.9	0.1
11	Below150µ	2	2000	100	0
	Total			Σ805.35	

FM of Coarse aggregate = 805.35/100=8.0535

Table 2.3.2(B): Properties of Coarse Aggregates

Characteristics	Value
Type	Crushed
Colour	Grey
Shape	Angular
Nominal Size	20 mm
Specific Gravity	2.62
Total Water Absorption	0.89
Fineness Modulus	8.05

2.4 RHA

In this work, Rice Husk was taken from the locality around Awantipora. Rice husk firstly wash with portable water then dried in the sun. After then rice husk burnt in the open atmosphere so as to convert it into ash.

Table 2.4: Physical properties of Rice Husk Ash

Appearance	Fine powder
Particle Size	Sieved through 90 micron sieve
Specific gravity	2.21
Color	Light grey

2.5 WASTE PAPER SLUDGE ASH

Waste paper sludge was taken from JML Waste Paper Corporation, Pathankot, Punjab. Waste paper was burnt in the open atmosphere so as to convert it into ash.

Table 2.5: Physical properties of Waste Paper Ash

Appearance	Fine powder
Particle Size	Sieved through 90 micron sieve
Color	Dark grey
Specific gravity	2.09

4.5 MIX DESIGN

The concrete mix design was done by using IS 10262 for M-20 grade of concrete.

Design stipulations for proportioning

Grade designation	M20
Type of cement grade	OPC 53 grade confirming to IS12269:1987
Maximum nominal size of aggregates	20 mm
Minimum cement content kg/m^3	320 kg/m^3
Maximum water cement ratio	0.55
Workability	75 mm (slump)
Exposure condition	Mild
Degree of supervision	Good
Type of aggregate	Crushed angular aggregate
Maximum cement content	450 kg/m^3
Chemical admixture	Not

Test Data for Materials

Cement used	OPC 53 grade confirming to IS 12269:1987
Specific gravity of cement	3.10
Specific gravity of Coarse aggregate Fine aggregate	 2.88 2.63
Sieve analysis Coarse aggregate Fine aggregate	Coarse aggregate : Conforming to Table 2 of IS: 383 Fine aggregate : Conforming to Zone III of IS: 383

Target Strength For Mix Proportioning

f'ck = fck + 1.65 s

Where,

f'ck = Target average compressive strength at 28 days,

fck = Characteristic compressive strength at 28 days,

s= Standard deviation

From Table 1 standard deviation, s = 4.6 N/mm^2

Therefore target strength = 20 + 1.65 x 4.6 = 27.59 N/mm^2

Selection of Water Cement Ratio

From Table 5 of IS:456-2000, maximum water cement ratio = 0.55 (Mild exposure)

Based on experience adopt water cement ratio as 0.50

0.5 < 0.55, hence ok

Selection of water and sand content From Table 4 of IS 10262:1982

Maximum Size of Aggregate(mm)	Water Content including Surface Water, Per Cubic Meter of Concrete(kg)	Sand as percent of Total Aggregate by Absolute volume
20	186	35

Adjustments from Table 6 of IS 10262:1982

Change in condition	Percent adjustment required	
	Water Content	Sand in total Aggregate
Increase or decrease in water- cement ratio that is 0.05	0	-2
Increase or decrease in value of compacting by 0.10	0	0
For Sand	0	-1.5

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Therefore, required sand content as percentage of total aggregate by absolute volume =35-3.5=31.5%

Volume of aggregate= 100-31.5=68.5%

Calculation of Cement Content

Water cement ratio = 0.50

Cement content = 186/0.5 = 372 kg/m^3 >320 kg/m^3(given)

From Table 5 of IS: 456, minimum cement content for mild exposure condition = 300 kg/m^3

Hence OK

Determination of Coarse and Fine Aggregate contents

From Table 3 of IS 10262:1982,for the specified maximum size of aggregate of 20mm,the amount of entrapped air in the wet concrete is 2 percent.Taking this into account and applying

$V= (W+C/S_C+1/P \times fa/S_{fa}) \times 1/1000$

$Ca =1-P/P \times fa \times S_{ca}/S_{fa}$

Where,

V = absolute volume of fresh concrete,which is equal to gross volume(m^3) minus the volume of entrapped air.

W = mass of water (Kg) per m^3 of concrete

C =mass of cement (Kg) per m^3 of concrete

S_c = specific gravity of cement

P =ratio of FA to total aggregate by absolute volume

F_a, C_a = total masses of FA and CA (Kg) per m^3 of concrete respectively

S_{fa}, S_{ca} = specific gravity of saturated, surface dry fine aggregate and coarse aggregate respectively.

$0.98= 186+372/3.10+1/.315 \times fa/2.63) \times 1/1000$

$980 = 306+1.20\ f_a$

f_a = 561.66 Kg/m^3

C_a=1216.74 Kg/m^3

The mix proportion then becomes:

Water:Cement:Fine Aggregate:Coarse Aggregate

186:372:561.66:1216.74

0.5:1:1.5:3.2

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Table 2.6: The mixture proportions used in laboratory for experimentation are shown in table

Mix	%	w/c ratio	Water (Kg/m^3)	Cement (Kg/m^3)	Fine Aggregate (kg/m^3)	Coarse Aggregate (Kg/m^3)	RHA (Kg/m^3)	WPSA (Kg/m^3)
Control	-	0.50	186	372	562	1217	-	-
Rice Husk Ash	5	0.50	186	353.4	562	1217	18.6	-
	10	0.50	186	334.8	562	1217	37.2	-
	15	0.50	186	316.2	562	1217	55.8	-
	20	0.50	186	297.6	562	1217	74.4	-
Waste Paper Sludge Ash	5	0.50	186	353.4	562	1217	-	18.6
	10	0.50	186	334.8	562	1217	-	37.2
	15	0.50	186	316.2	562	1217	-	55.8
	20	0.50	186	297.6	562	1217	-	74.4
Mixture of RHA and WPSA	5	0.50	186	353.4	562	1217	9.3	9.3
	10	0.50	186	334.8	562	1217	18.6	18.6
	15	0.50	186	316.2	562	1217	27.9	27.9
	20	0.50	186	297.6	562	1217	37.2	37.2

3. RESULTS AND DISCUSSION

GENERAL

This chapter presents a summary of the results obtained from laboratory tests that have been done on the specimen. Tests were done on materials (cement, fine aggregates, coarse aggregates, RHA and WPSA), fresh and hardened concrete.

3.1 FRESH CONCRETE

3.1.1 Slump Test

The slump value of all the mixture are represented in Table 5.1.1

Table 3.1.1: Slump Tests Results

Mix	Percentage	SlumpValue
Control	0%	90mm
RHA	5%	65mm
	10%	55mm
	15%	25mm
	20%	20mm
WPSA	5%	60mm
	10%	55mm
	15%	50mm
	20%	20mm
Mix (RHA+WPSA)	5%	30mm
	10%	20mm
	15%	15mm
	20%	7mm

The slump value v/s percentage of replacement was shown in Fig 5.1.1. The slump decreased when a higher amount of RHA, WPSA and combination of both (RHA+WPSA) was mix was added in concrete.

3.1.2 Compaction Factor Test

The Compaction factor values of all the mixture are represented in Table 5.1.2

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Table 3.1.2: Compaction Factor Results

Mix	Percentage	Compaction Factor
CONTROL	0%	0.93
RHA	5%	0.90
	10%	0.87
	15%	0.83
	20%	0.82
WPSA	5%	0.92
	10%	0.90
	15%	0.85
	20%	0.81
MIX (RHA+WPSA)	5%	0.84
	10%	0.83
	15%	0.80
	20%	0.78

The compaction factor value of control concrete is 0.93. As we go on increasing the % replacement of cement with the RHA from 5 to 20% the compaction factor value decreases from 0.92 to 0.82. In the case of WPSA the compaction factor value decreases gradually from 0.92 to 0.81. And same as in case of Mix (RHA+WPSA) the compaction factor value decreases gradually from 0.84 to 0.78.

3.2Hardened Concrete

3.2.1: Effect of Age on Compressive Strength

The 28 days strength obtained for M20 Grade Control concrete is 30.93 N/mm^2.The strength results reported in table no 5.2.1 are presented in the form of graphical variations, where the compressive strength is plotted against the % of cement replacement.

Table 3.2.1: Compressive Strength of Control concrete in N/mm^2

Grade of concrete	7Days	28Days
M20	20.4	30.93

The strength achieved at different ages namely, 7 and 28 for Control concrete.

It is clear that as the age advances, the strength of Control concrete increases. The rate of increase of strength is higher at curing period up to 28 days. However the strength gain continues at a slower rate after 28 days.

3.2.2 Effect of Age on Split Tensile Strength of Control Concrete

The 28 days tensile strength obtained for M20 Grade Control concrete is 2.71 N/mm^2.The strength results reported in table no 5.2.2 are presented in the form of graphical variations, where the compressive strength is plotted against the % of cement replacement.

Table 3.2.2: Split Tensile Strength of Control concrete in N/mm^2

Grade of concrete	7Days	28Days
M20	1.94	2.71

It is clear that as the age advances, the split tensile strength of Control concrete increases. The rate of increase of strength is higher at curing period up to 28 days. However the strength gain continues at a slower rate after 28 days.

3.2.3: Effect on Compressive Strength of Concrete Containing various percentages of RHA.

Table 3.2.3: Compressive Strength of RHA Concrete

Mix	Percentage of Cement Replacement	Cube Compressive Strength (N/mm^2)	
		7 days	28 Days
CONTROL	0%	20.4	30.93
RHA	5%	19.67	29.26
	10%	19.63	28.85
	15%	18.66	24.74
	20%	15.22	21.48

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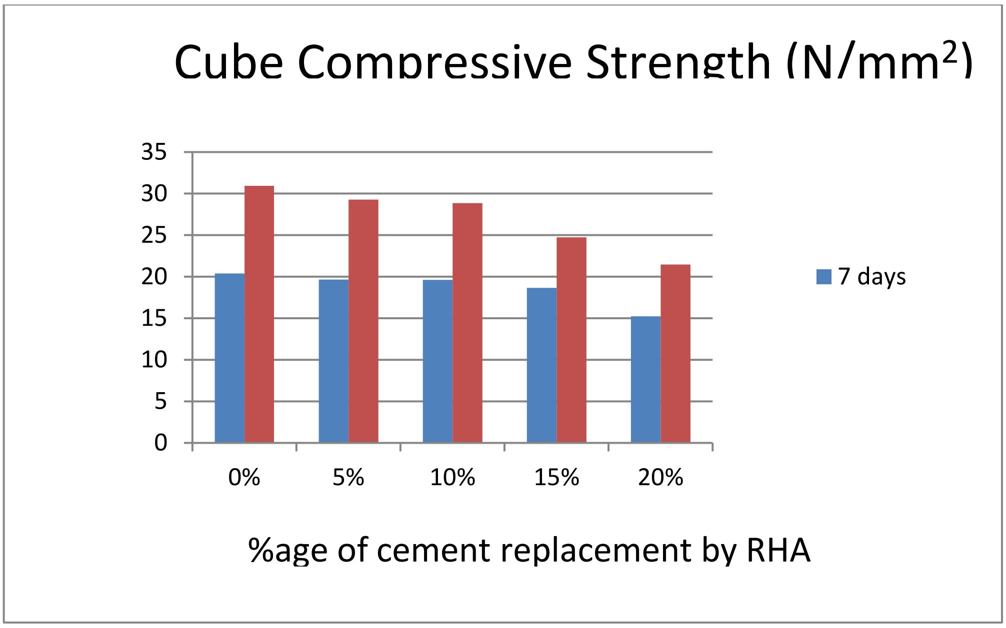
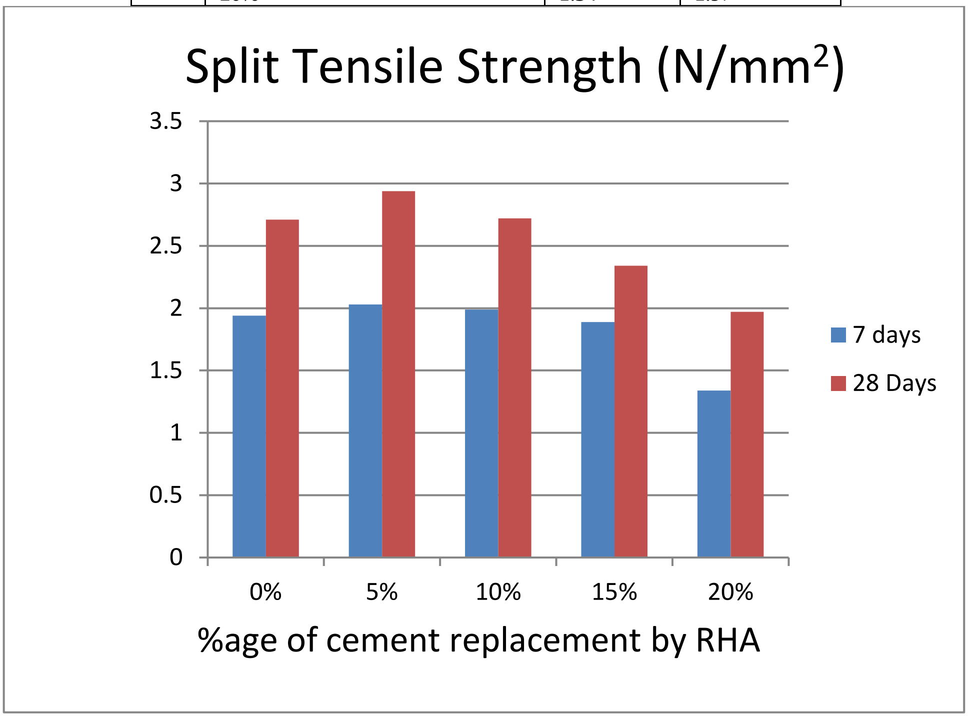


As per experimental program and results shown in table no. 3.2.3. We can replace cement by RHA up to 10%. Because the compressive strength up to 10% replacement of cement is comparatively equal to control mix design. If cement is replaced by RHA more than 10% the loss in compressive strength is comparatively greater than the replacement up to 10%.

3.2.4:Effect on Split Tensile Strength of Concrete Containing various percentages of RHA.

Table 3.2.4: Split Tensile Strength of RHA Concrete

Mix	Percentage of Cement Replacement	Split Tensile Strength (N/mm^2)	
		7 days	28 Days
M20	0%	1.94	2.71
RHA	5%	2.03	2.94
	10%	1.99	2.72
	15%	1.89	2.34
	20%	1.34	1.97



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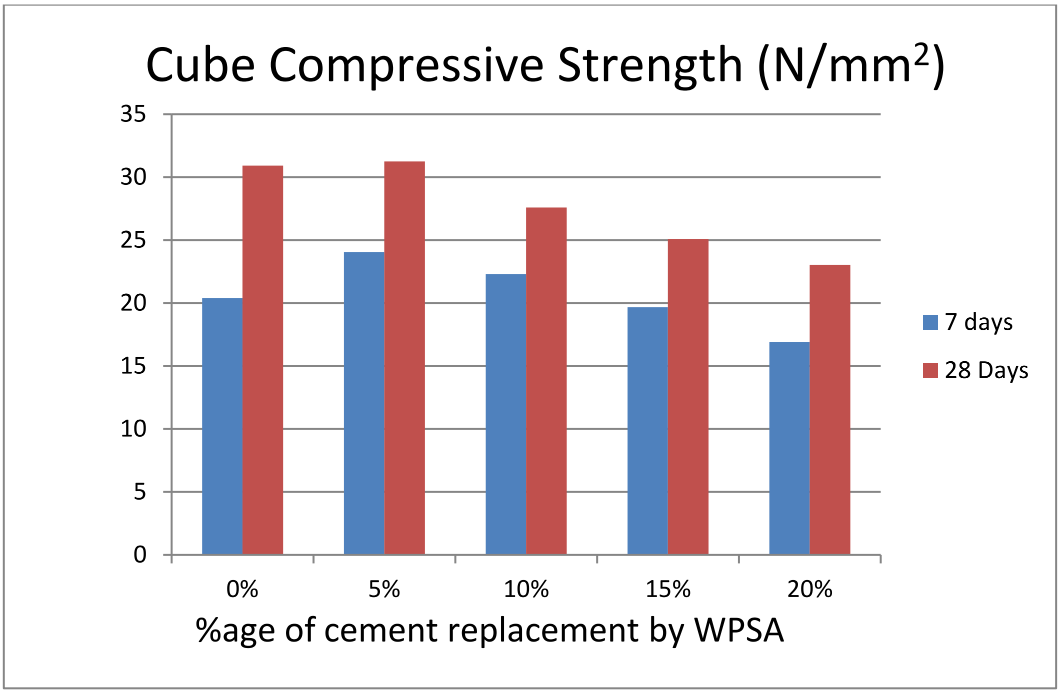
As per table no.3.2.4 the split tensile strength for replacement of 5% is higher than control mix design and decreases with further increase in RHA but up to 10% of replacement the split tensile strength is still more than the split tensile strength of control mix design.

3.2.5: Effect on Compressive Strength of Concrete Containing various percentages of WPSA

Table 3.2.5: Compressive Strength of WPSA Concrete

Mix	Percentage of Cement Replacement	Cube Compressive Strength (N/mm^2)	
		7 days	28 Days
CONTROL	0%	20.4	30.93
WPSA	5%	24.07	31.26
	10%	22.3	27.59
	15%	19.67	25.1
	20%	16.89	23.04



As per the results shown in table no.3.2.5 the compressive strength at 7 days for 5% and 10% replacement of cement by WPSA are higher than Control Mix, further increases in % replacement the compressive strength goes on decreases.The compressive strength at 28 Days for 5% replacement is found out to be 31.26 N/mm^{2}which is higher than the compressive strength of 30.93N/mm^2 of control mix. For 10% replacement the compressive strength is comparatively nearer to the control mix and for further increases in % replacement the compressive strength decreases.

3.2.6: Effect on Split Tensile Strength of Concrete Containing various percentages of WPSA

Table 3.2.6: Split Tensile Strength of WPSA Concrete

Mix	Percentage of Cement Replacement	Split Tensile Strength (N/mm^2)	
		7 days	28 Days
M20	0%	1.94	2.71
WPSA	5%	2.34	3.11
	10%	2.1	2.92
	15%	1.82	2.78
	20%	1.69	2.02

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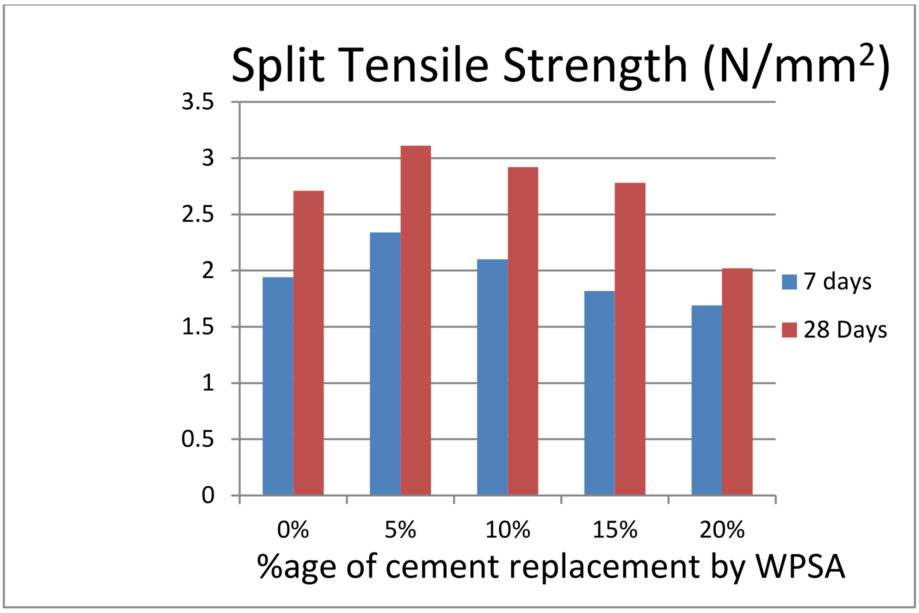
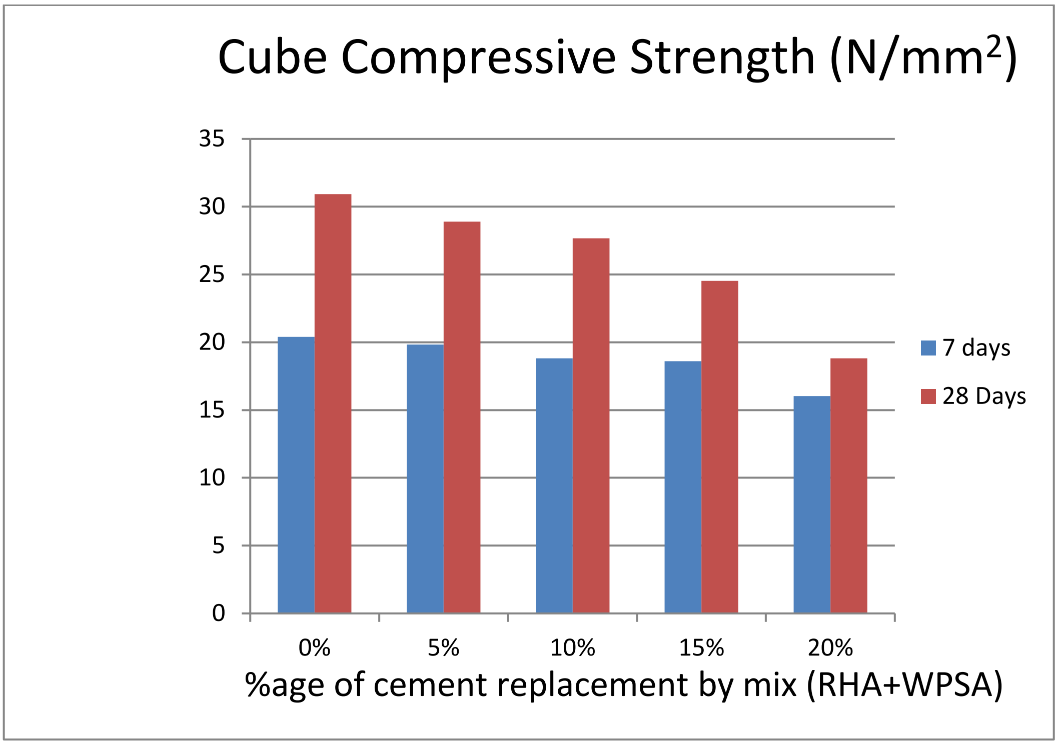


From the results shown in table no 3.2.6 the split tensile strength at 7 Days and 28 Days for 5% and 10% replacement by WPSA is found to be higher than the Control Mix. For 15% the split tensile strength is comparatively equal to the control Mix and for further increase in % replacement of cement the split tensile strength decreases.

3.2.7: Effect of Compressive Strength of Concrete Containing various percentages of Mix(RHA+ WPSA)

Table 3.3.7: Compressive Strength of Mix (RHA+ WPSA)Concrete

Mix	Percentage of Cement Replacement	Cube Compressive Strength (N/mm^2)	
		7 days	28 Days
CONTROL	0%	20.4	30.93
MIX (RHA+WPSA)	5%	19.84	28.89
	10%	18.82	27.66
	15%	18.6	24.52
	20%	16.03	18.82

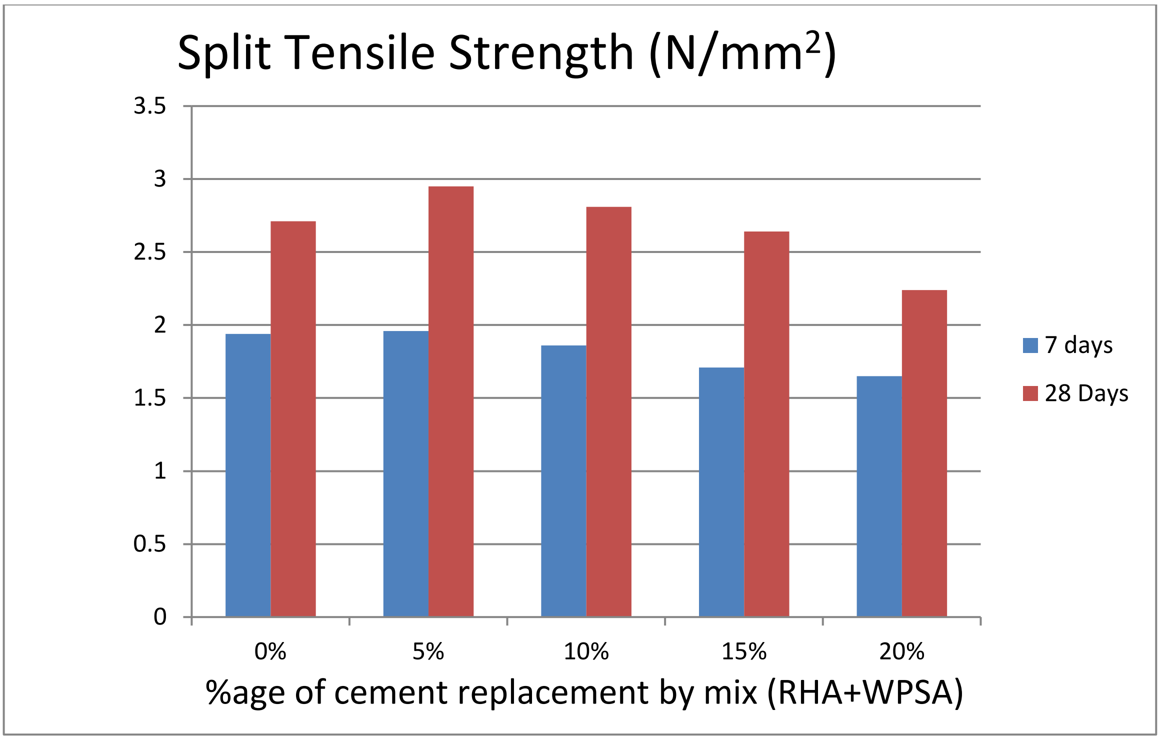


The results from table no 3.3.7 represents that 10% replacement with Mix(RHA+WPSA) the compressive strength are comparatively equal to Control Mix strength, and further increase in % replacement the strength decreases.

3.2.8: Effect of Split Tensile Strength of Concrete Containing various percentages of Mix(RHA+ WPSA)

Table 3.2.8: Split TensileStrength of Mix (RHA+ WPSA)Concrete

Mix	Percentage of Cement Replacement	Splitting Tensile Strength (N/mm^2)	
		7 days	28 Days
M20	0%	1.94	2.71
MIX (RHA+WPSA)	5%	1.96	2.95
	10%	1.86	2.81
	15%	1.71	2.64
	20%	1.65	2.24



As per the results from table no.3.2.8. The split tensile strength of 5% replacement of cement with Mix(RHA+WPSA) has higher value than the control mix and 10% replacement has comparatively equal split tensile strength to Control Mix. For the 15% and 20 % the split tensile structure decreases gradually.

4. CONCLUSIONS

4.1 GENERAL

The objective of this experimentation has been to evaluate the possibility of successful replacement of cement with RHA, WPSA and MIX (RHA+WPSA) in concrete.

The conclusion drawn during the experimentations are as follows:

4.2: Split Tensile Strength of Control Concrete, RHA Concrete, WPSA Concrete & Mix(RHA+WPSA) at 28 Days

The compressive strength and split tensile strength increased up to 20% with 5% replacement of WPSA. Further increase in WPSA decreases the strength gradually and up to 10% replacement it can be used as a supplementary material in M20 grade of Concrete.

The above results shows that it is possible to design M20 grade of concrete incorporating with RHA content up to 10%.

As test results shows the Mix (RHA+WPSA) can also be used as a replacement of cement.

Control mix with 5% WPSA showed higher Compressive Strength than Control mix, RHA concrete and Mix(RHA+WPSA) concrete.

The study showed that the early strength of RHA, WPSA and Mix (RHA+WPSA) concrete was found to be less and the strength increased with age.

The workability of RHA,WPSA and Mix(RHA+WPSA) concrete has been found to decrease with the increase in replacements.

Based on the results of Split Tensile Strength test,it is convenient to state that there is substantial increase in Tensile Strength due to the addition of RHA, WPSA and Mix (RHA+WPSA).

Use of Waste Paper Sludge Ash, Rice Husk Ash and Mix (RHA+WPSA) in concrete can prove to be economical as it is non useful waste and free of cost.

Use of waste paper sludge ash in concrete will preserve natural resources that are used for cement manufacture and thus make concrete construction industry sustainable and waste paper sludge can be used as fuel before using its ash in concrete for partial cement replacement and also the disposal problem for paper industries for this waste material is fully solved.

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