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Strength and Durability Properties of Kota Stone Slurry and Rice Husk ASH Added Concrete

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Abstract: *The Portland cement represents the most expansive component of a concrete mixture. Furthermore, mining large quantities of raw materials to produce cement, such as limestone, clay, and fuel such as coal, often results in extensive deforestation and top-soil loss. The cement industry has made significant progress in reducing CO_2 emissions through improvements in process and efficiency, but further improvements are limited because CO2 production is inherent to the basic process oflimestone calcinations. The environmental impact of the concrete industry can be reduced through resource productivity by conserving materials (cement, aggregate) and energy for concrete-making and by improving the durability of concrete products. Also concretes with cement as most expansive material often fail to prevent the ingress of moisture and aggressive ions adequately. Concrete needs to be modifying using pozzolanic and cementitious materials. Most of the pozzolanic and cementitious materials in use today are industrial by products, which require relatively little or no expenditure of energy for use as mineral admixtures. Use of these materials, result into substantial energy and cost savings. Kota Stone Slurry and Rice Husk Ash were used as admixture to study the effect of these mineral admixtures on Strength and Durability properties of concrete. Kota Stone Slurry and Rice Husk Ash on strength and permeability properties of twelve concrete mixes of M30 grade with two different w/c ratios (0.40, and 0.50) and varying Kota Stone Slurry and Rice Husk Ash content (0 to 25%) were designed. Various tests on concrete namely, compaction factor test, compressive, flexural and pull-off strength test, Carbonation, chloride migration, abrasion and DIN 1048 Water permeability test were conducted on these concrete mixes. Results indicated that compressive, flexural and pull-off strength of concrete composite mixes decreases with incorporation of Kota Stone Slurry and Rice Husk Ash content. 15% Kota Stone Slurry + 10% Rice Husk Ash, This indicates that cover zone properties of concrete are not affected due to replacement of cement by Kota Stone Slurry and Rice Husk Ash.*

Key Words: *Concrete, Durability, Strength, Composite Mixes, Kota stone slurry, Rice Husk Ash, Carbonation, and Water permeability.*

I. Introduction:

Rajasthan is the major centre of the marble, Kota stone industry in the country. More than 1,500 marble mines are operating in the Aravallis in Rajasthan, Rajasthan boasts almost two-thirds of India's mineable marble reserves, and it is responsible for around 85% of the country's total marble production. Indeed, the entire stretch of the Aravallis in lower Rajasthan is a vast depository of marble. Rajasamand, RamganjMandi, Jhalawar, Udaipur, Kota and Banswara districts contribute over half the state's marble output. The marble reserves in India are estimated at 1,200 million tons, with Rajasthan accounting for 91% of the reserves.

Marble slurry is a processing and polishing waste of mining industry. Its huge quantity is dumped on any empty land, agricultural fields, pasture lands, river beds and roadsides. The present dumping practices have been creating a number of nuisances and problems, including environmental and human health. Scientific disposal systems but with more emphasis on engineering utilization have to be developed simultaneously and as fast as possible. Construction industries can be the main user of marble slurry whether in bulk or minor quantities. The utilization of marble slurry in the manufacturing of bricks, includes full replacement of conventional fine aggregates with marble slurry content.

II. Literature Review:

In the recent years, the construction industry has faced the challenge of incorporating sustainable production processes, either by searching for new raw materials which are more environmental friendly and contribute to reduction of CO_2emission. The possibility of incorporating waste from other industrial activities in their production processes can help with this goal **(Pereira et al., 2013).**The use of replacement material offer cost reduction, energy savings, arguably superior products, and fewer hazards in the environment.

There are several type of by product (waste) materials, also called mineral admixtures, that are industrially produced such as fly ash, iron blast-furnace slag, silica fume, rice husk ash, glass powder, cutting stone and tile wastes, wheat straw ash, olive waste, etc. It was found that using some of these waste materials result in certain positive sides

India is well known for its natural stone production, these stones after their excavation are cut into desired shape. These cutting and sawing operations generate stone waste and slurry as by product. This waste is of various shape viz. powder, aggregates and large stone blocks. Stone slurry is a semi-liquid substance consisting of particles originated from the sawing and polishing processes and water used to cool and lubricate the sawing and polishing machines **(N. Almeida et al, 2007)**. When this slurry is disposed to nearby landfills, it loses most of its water content. This deposited stone waste affects the soil morphology and hydrology of nearby area by reducing the porosity and permeability of soil. This stone slurry poses a severe threat to flora and fertility of topsoil. It is unpleasant to look upon fine air suspended dust of this waste can even cause respiratory, visual or skin disorders **(Pareek, 2003).**

Researchers have tried to utilize stone wastes in various types of industries specially building materials. Due to continuous depletion of natural resources, construction industry is thriving to use stone waste and other similar materialsin cement, mortars, concrete, tiles and self-compacting concrete (SCC), agglomerate marble, pavement, embankment, glues and paints. Stone that is inappropriate as a structural or finish material can be used to construct gabion retaining walls**(ElhamKhalilzadehShirazi, 2011)**Stone waste has been frequently used by researchers as filler material for self-compacting concrete, fines in conventional and asphaltic concrete. Past investigations suggest that use of stone waste in concrete help in improving mechanical and durability properties of concrete.

India is also a major rice producing country, and the husk generated during milling is mostly used as a fuel in the boilers for processing paddy, producing energy through direct combustion and / or by gasification. About 20 million tons of Rice Husk Ash (RHA) is produced annually. This RHA is a great environment threat causing damage to the land and the surrounding area in which it is dumped. Lots of ways are being thought of for disposing them by making commercial use of this RHA. RHA can be used as a replacement for cement (15 to 25%)**(Nagrale et al., 2012)**.

RHA is a very fine pozzolanic material **(Mehta, 1992,Cook, 1986)** and its particle size and specific surface depend upon the burning conditions under which it is produced. In general, the average particle size ranges from 5 to 10 µrn, and the specific surface area ranges from 20 to 50m^2/g. A previous investigation by**Zhang et al.** indicated that the rice-husk ash used in this study ishighly pozzolanic and can be used as a supplementary cementing material to producehighperformance concrete. The concrete incorporating 10% of the RHA as a cementreplacement had high compressive strength and resistance to chloride-ion penetration compared with the control OrdinaryPortland cement concrete of the same water-to-cementitious materials ratio.RHA contains a carbon content of 5.9l%, and is black in colour. Chemical analysis in previous report indicates that the material is principally composed of SiO_2, (87.2%), and also has loss on ignition (8.55%). The ash contains a relatively high potassium content which originates mainly from the soil or due to the use of fertilizers.

III. Materials

a) Cement - Ordinary Portland cement-43 (December, 2013) procured locally, confirming IS-12269 was used.
b) Kota-Stone Slurry Waste – kota-stone slurry waste was procured from Ram Gang Mandi Kota, Rajasthan.
c) Rice Husk Ash – Rice Husk Ash was procured from a N K Enterprises, Jharsuguda, Odisha.
d) Coarse and Fine aggregates– Coarse and fine aggregates of size 20 mm, 10 mm and sand (< 2.36 mm) were procured locally.
e) Water and Super plasticizer- Natural potable water as per IS-456 along with — superplasticizer named conplast (phosrock); procured locally was used.

IV. Experimental Programme

For the durability studies on kota stone slurry and rice husk ash added concrete, the material used for its making including cement, sand and aggregate was examined as per relevant standards. Physical properties such as sieve analysis, specific gravity, crushing strength, impact value, flakiness and elongation index and free surface moisture content test were conducted. Concrete mix was designed using above tested material. After fixing the proportions of different ingredients of the concrete mix, trial mixes were prepared at two different w/c ratios, 0.45 and 0.50 to determine the quantity of plasticizer required to achieve a desired workability between 0.82 and 0.9 at varying cement replacement. Concrete mixes were prepared using a pan type mixer; total eleven concrete mixes were prepared replacing cement by equal weight of kota stone slurry –rice husk ash combination. Properties of mixes including compressive, flexural, pull off strength, abrasion, permeability, resistance to carbonation, chloride migration evaluated. The experimental program was outlined in such a way that variation of the attributes such as strength, permeability, and durability of concrete composites with respect to cement replacement (cement + kota stone slurry/ kota stone slurry - rice husk ash), water/binder ratio (w/b) could be examined.

Table 4.1: Standards for Physical properties of component materials

S.No.	Test	IS Specification.
1	Sieve Analysis	IS 383- 1970
2	Specific Gravity	IS 1727- 1967 & IS 2386 Part 3 - 1963
3	Crushing strength and impact value	IS 2386 Part 4 - 1963
4	Flakiness Index and Elongation Index	IS 2386 Part 1 - 1963

Table 4.2: Sieve analysis of coarse aggregate (20 mm)

S.No.	IS Sieve Size (mm)	Weight Retained (gm)	Cumulative Weight Retained (gm)	Cumulative percentage retained	Cumulative percentage passing	Grading Zone	Result
1.	40	0	0	0	100	100	Confirming to IS:383 – 1970
2.	20	354	354	11.8	88.2	85-100	
3.	10	2571	2925	96.5	3.5	0-20	
4.	4.75	63	2988	99.6	0.4	0-5	
5.	2.36	0	2988	100	0	-	
6.	Pan	12	3000	100	0	-	

Table 4.3: Sieve analysis of coarse aggregate (10mm)

S.No.	IS Sieve Size (mm)	Weight Retained (gm)	Cumulative Weight Retained(gm)	Cumulative percentage retained	Cumulative percentage passing	Grading Zone	Result
1.	12.5	0	0	0	100	100	Confirming to IS:383 – 1970
2.	10	330	330	11.0	89	85-100	
3.	4.75	2355	2685	89.5	10.5	0-20	
4.	2.36	300	2985	99.5	0.5	0-5	
5.	Pan	15	3000	100	0		

Table 4.4: Sieve analysis of fine aggregate

S.No.	IS Sieve Size (mm)	Weight Retained (gm)	Cumulative Weight Retained(gm)	Cumulative percentage retained	Cumulative percentage passing	Grading Zone	Result
1.	10 mm	0	0	0	100	100	Fine aggregate conforming to Grading Zone – II of IS:383-1970
2.	4.75 mm	64	64	6.4	93.6	90-100	
3.	2.36 mm	48.4	112.4	11.24	88.76	75-100	
4.	1.18 mm	185.5	297.9	29.79	70.21	55-90	
5.	600 micron	296.5	594.4	59.44	40.56	35-59	
6.	300 micron	320	914.4	91.44	8.56	008-30	
7.	150 micron	69	983.4	98.34	1.66	0-10	
8.	Pan	16.6	1000	100	0		
		1000		296.65			
			Fineness Modulus	2.97			

Table 4.5: Physical properties of materials

Materials	Specific gravity	Free Surface Moisture Content	Crushing Strength value	Impact value	Flakiness and Elongation Index
Cement	3.15	_	_	_	_
Kota stone slurry	2.88	_	_	_	_
Rice Husk Ash	2.14	_	_	_	_
Coarse Aggregates	2.62	0.10%	24.67 %	23.32%	25.6%
Fine Aggregates	2.6	1.00%	_	_	_

Table 4.6: Physical properties of cement

S. No.	Physical Properties of Cement Used	Result	Requirements as per IS 8112 – 1989 & IS 4031 – 1088 (Part – 1)
1.	Specific Gravity	3.15	3.10 – 3.15
2.	Standard Consistency	30.5 %	30 - 35
3.	Initial Setting Time	100 minutes	30 minutes minimum
4.	Final Setting Time	211 minutes	600 minutes maximum.
5.	Soundness (by Le-Chatelier's Apparatus)	2 mm	10 mm maximum

Table 4.7: Fineness modulus of cement

S. No.	Wt. retained on 90 mm IS sieve	Wt. retained on pan	Total	% Wt. retained	Fineness modulus	Avg. FM
1.	15.0	433.5	448.5	3.34	0.0334	0.04
2.	8.0	200.0	208.0	3.84	0.0384	

Table 4.8: Fineness modulus of Kota-stone slurry

S. No.	Wt. retained on 90 mm IS sieve	Wt. retained on pan	Total	% Wt. retained	Fineness modulus	Avg. FM
1.	12.5	81.0	93.5	13.36	0.1336	0.13
2.	12.0	82.0	93.0	12.90	0.1290	

Table 4.9: Compressive strength of cement mortar (7 days)

S. No.	P (in KN)	Size (in mm)	f = P/A (in N/mm^2)	Avg. compressive str.
1.	140	70.7	28.57	29.93
2.	155	70.7	31.63	
3.	145	70.7	29.59	

Table 4.10: Compressive strength of cement mortar (28 days)

S. No.	P (in KN)	Size (in mm)	f = P/A (in N/mm^2)	Avg. compressive str.
1.	240	70.7	48.98	51.36
2.	260	70.7	53.06	
3.	255	70.7	52.04	

Hence, grade of cement = **OPC- 43**

V. Mix Design

After verification of physical properties of the materials used and deciding the variables of the mix design, concrete mix design was done.Following are the mixes with 0Kota-stone slurry & Rice husk ash for each of the three water contents

a) 0.40:1 : 1:1.958:2.845 (Water: Cement: Sand: 20mm: 10mm)

b) 0.50: 1: 1:1.958:2.845 (…..Do….)

Table 5.1: Mix Parameters

Mix No.	W/C ratio	Kota-stone slurry %	Rice Husk Ash %	Cement (kgs)	KSS (kgs)	RHA (kgs)	Sand (kgs)	CA (20mm)	CA (10mm)
C1	0.40	0	0	24.987	00	00	48.924	35.54	35.54
S0	0.40	25	0	18.741	6.246	00	48.924	35.54	35.54
S1	0.40	20	5	18.741	4.997	1.249	48.924	35.54	35.54
S2	0.40	15	10	18.741	3.758	2.498	48.924	35.54	35.54
S3	0.40	10	15	18.741	2.498	3.758	48.924	35.54	35.54
C2	0.50	0	0	24.987	00	00	48.924	35.54	35.54
S4	0.50	25	0	18.741	6.246	00	48.924	35.54	35.54
S5	0.50	20	5	18.741	4.997	1.249	48.924	35.54	35.54
S6	0.50	15	10	18.741	3.758	2.498	48.924	35.54	35.54
S7	0.50	10	15	18.741	2.498	3.758	48.924	35.54	35.54
S8	0.50	5	20	18.741	1.249	4.997	48.924	35.54	35.54
S9	0.50	0	25	18.741	00	6.246	48.924	35.54	35.54

VI. Results And Discussion

Results of various tests on concrete, which have been conducted as a part of methodology for the present study, are being presented here.

6.1Compaction Factor

Results of compaction factor, on twelve concrete mixes with two different w/c ratios and varying Kota-stone slurry & Rice husk ash content into concrete mixes are shown in table.

Table 6.1: Compaction Factor

Mix No.	W/C ratio	Kota-stone slurry %	Rice Husk Ash %	% of Plasticizer used (by weight of cement)	Compaction Factor
C1	0.40	0	0	1.25	0.89
S0	0.40	25	0	1.5	0.85
S1	0.40	20	5	2.0	0.83
S2	0.40	15	10	2.0	0.82
S3	0.40	10	15	2.0	0.81

C2	0.50	0	0	1.0	0.90
S4	0.50	25	0	1.25	0.89
S5	0.50	20	5	1.5	0.85
S6	0.50	15	10	1.5	0.80
S7	0.50	10	15	2.0	0.81
S8	0.50	5	20	2.0	0.82
S9	0.50	0	25	2.0	0.82

These results indicate thatincorporation of KSS+RHA reduced the workability and high quantity of superplasticizer was required to attain the desired workability (0.81-0.90) .The mix was too dry, when the combination of 15%RHA and10 % KSS wasused at 0.40 w/c ratio. Moreover, at 20% RHA and 5% KSS combination mix was unable to form at the same w/c ratio.

6.2 Compressive Strength

The compressive strength test was performed taking three cubes from each mix, after curing them in water for 7, 28, 90 days. Results of compressive strength test as shown in Figure 4.1 and Figure 4.2 at two different w/c ratios of concrete with Kota-stone slurry & Rice husk ash composite mix, indicate that with incorporation of KSS&RHA in concrete, at 7, 28,90 days compressive strength decreases. Results show significant drop in compressive strength of KSS&RHA added concrete mix. This decrease in strength is lower for higher w/c ratios when compared with control mix.

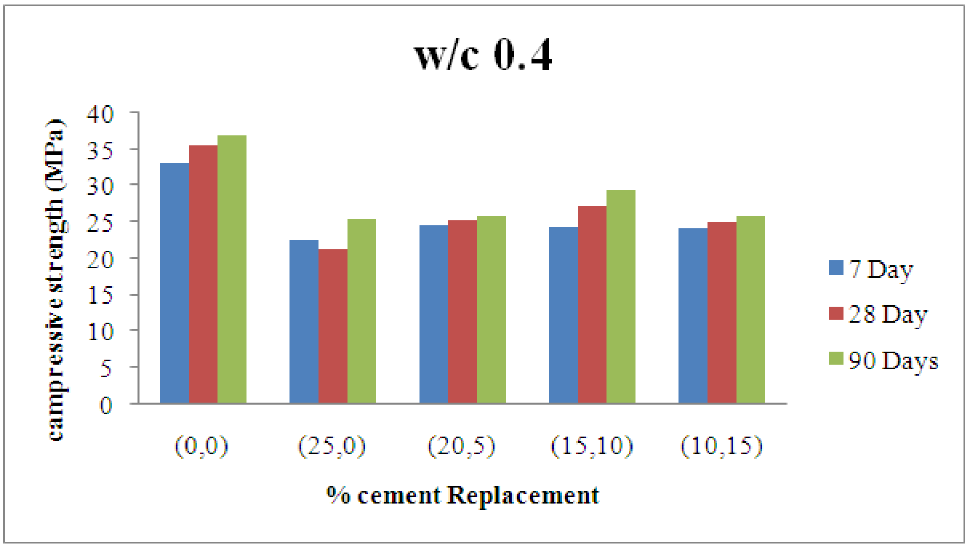

Figure 6.1: compressive strength at 7, 28, and 90 days for w/c 0.40

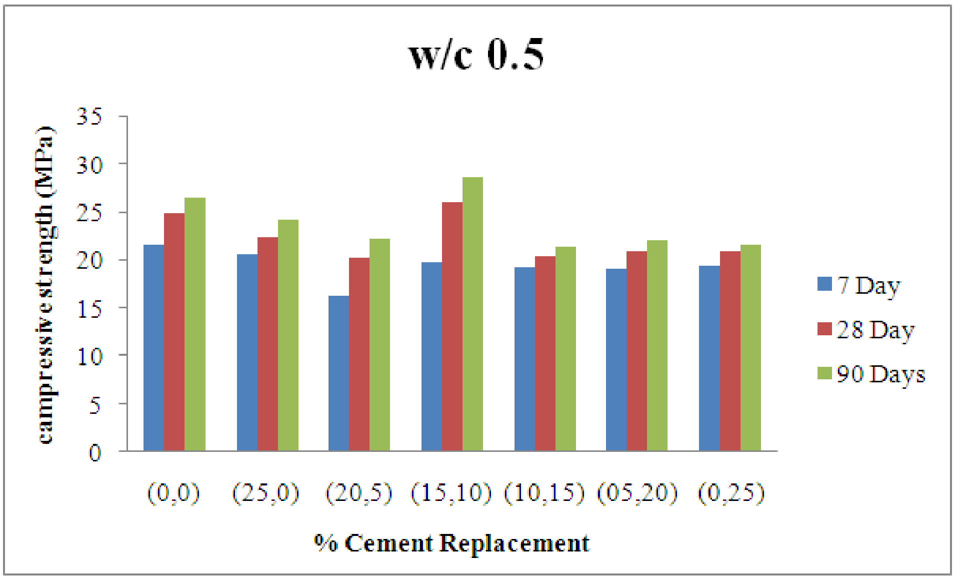

Figure 6.2: compressive strength at 7, 28, and 90 days for w/c 0.50

6.3 Flexural Strength

Results of flexural strength test as shown in Figure 4.3 and Figure 4.4 at two different w/c ratios of concrete with KSS&RHA composite mixes indicates that with increase in KSS&RHA content into concrete flexural strength decreases.

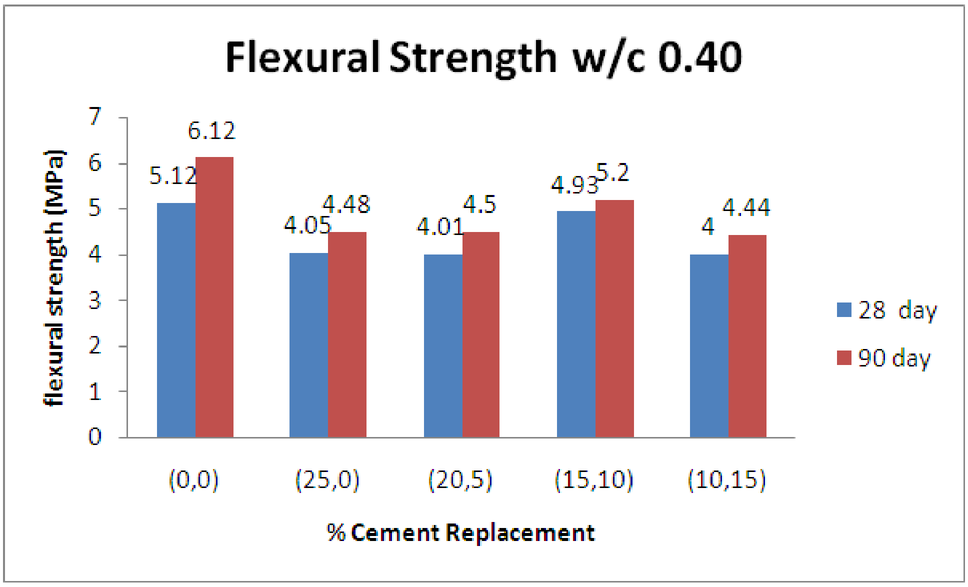

Figure 6.3: Flexural Strength at 28 and 90 days for w/c 0.40

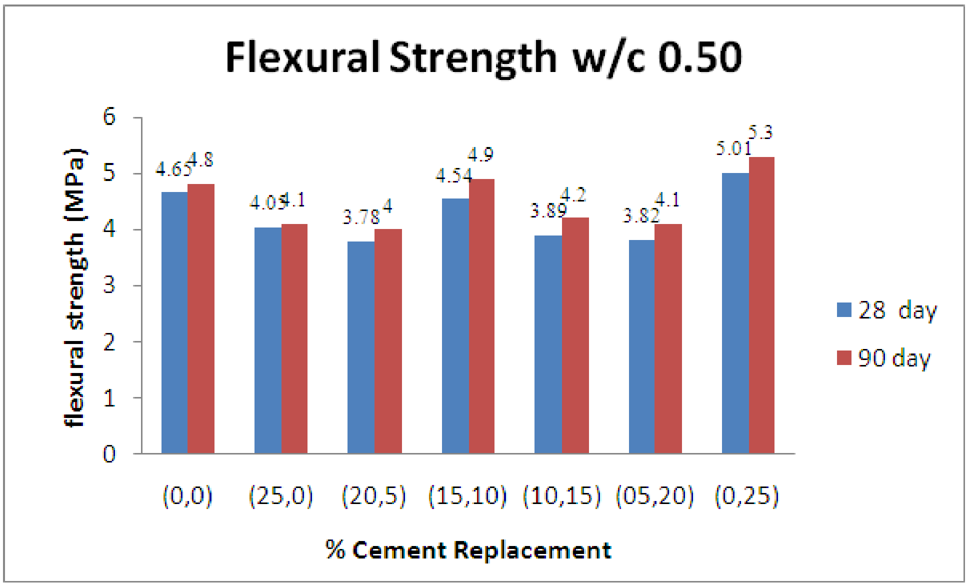

Figure 6.4: Flexural Strength at 28 and 90 days for w/c 0.50

6.4 Pull off Strength

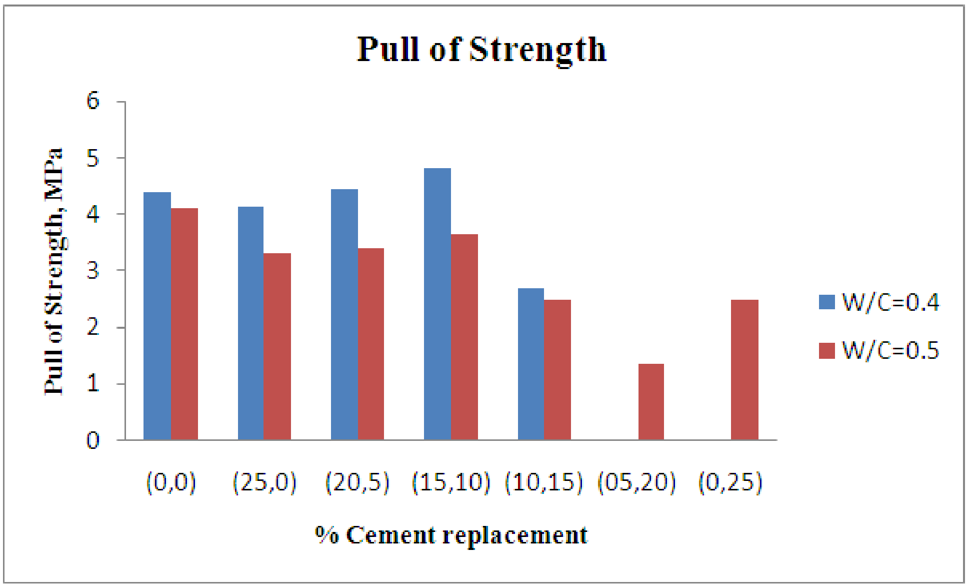

Figure 6.5: Pull off Strength at 28 days for w/c 0.40 &0.50

Pull off strength was evaluated after 28 days. Figure 4.5depicts the results of 28 days pull off strength. Strength decreasedwithincreasingRHA and decreasing KSS content. Strength of mix with 15% KSSand10% RHA is high,after that pull off strength decreases with the increase in rice husk ash percentage.Pull off strength also decreases with the increase in w/c ratio.

6.5 DIN 1048 Permeability Test

Results of DIN 1048 permeability test varied from penetration depth of 60 mm to 49 mm and 55 mm to 40 mm at 0.4 and 0.5 w/c ratios respectively. Concrete with lower w/c ratio showed higher permeability and when mix containing 25% KSS & 0%RHA depth of water penetration is high. Minimum depth of water penetration observed in the mix containing 25% RHA only is 40 mm at w/c 0.50. Figure 4.6 shows depth of water permeability in mm at 28 days.

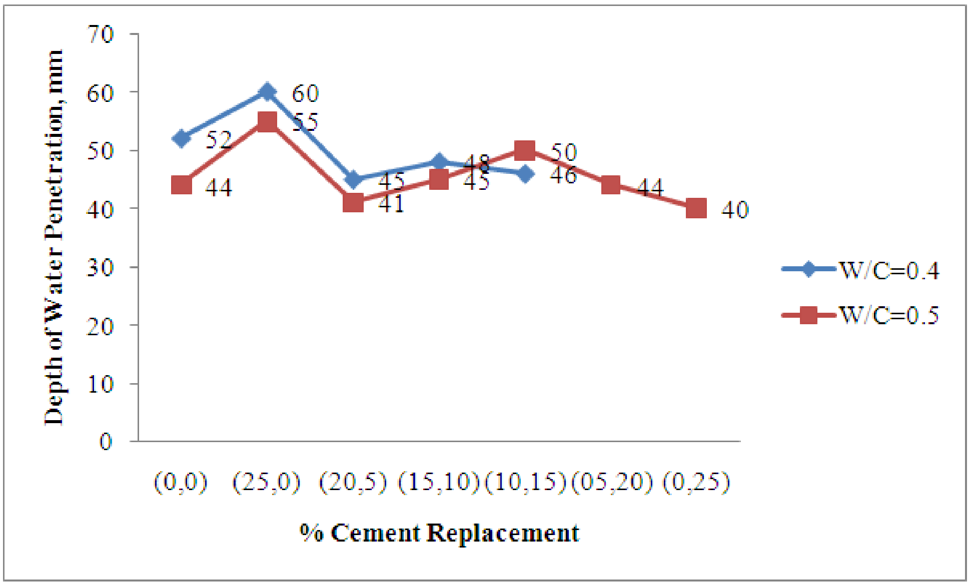

Figure 6.6 Depth of water penetration in mm at 28 days

6.6 Carbonation Test

The depth of concrete carbonation is measured at an interval of 7,14, 21 and 28 days and the results are shown in Figure 4.**7** and Figure 4.8. Three cubes of size 50mm×100mm prepared for carbonation test were taken out of carbonation chamber. These cubes were split in two parts to measure the carbonation depth after spraying phenolphthalein indicator. At 7 and 14 days, no carbonation is observed. But the result of 21 and 28 days indicates that carbonation increases with incorporation of KSS & RHA and with age.

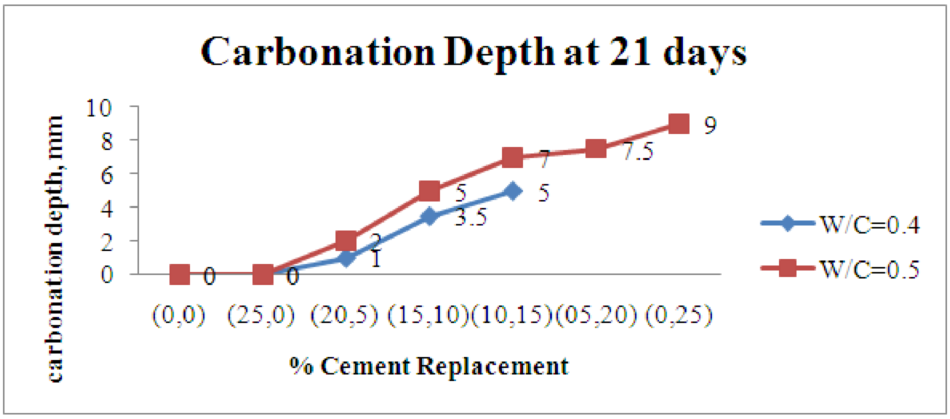

Figure 6.7: Carbonation depth at 21 days

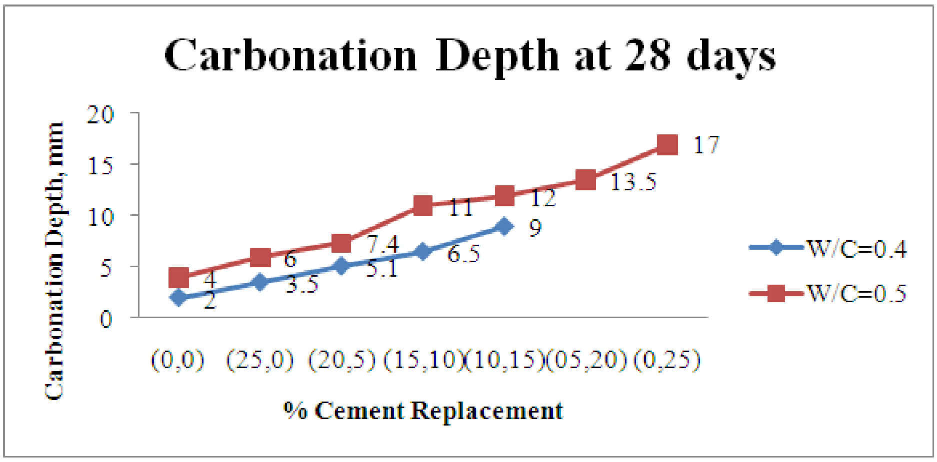

Figure 6.8: Carbonation depth at 28 days

6.7 Abrasion Test

Results of abrasion test are shown in Figure 4.9. The combination upto 15% KSS & 10% RHA mixes were found more susceptible to abrasion. Weight loss after abrasion was lesser than the initial mixes as compared to later mixes. This was similar in both the water cement ratio.

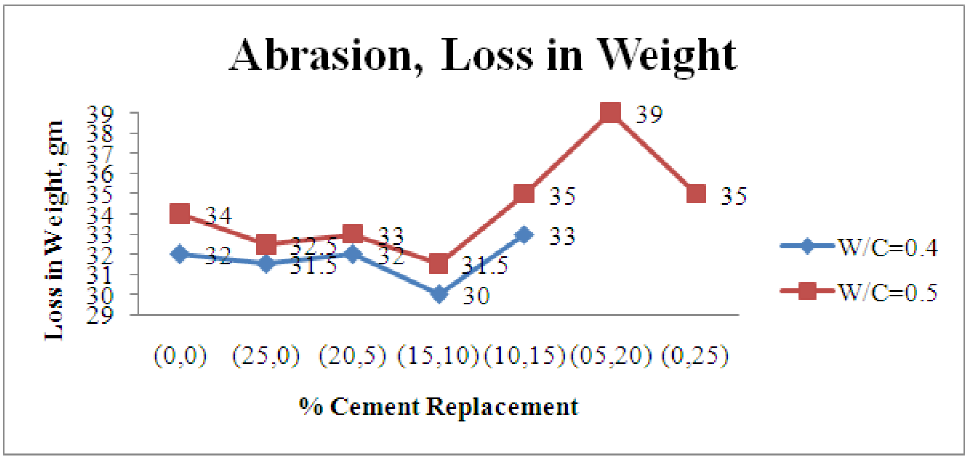

Figure 6.9: Loss in weight due to Abrasion at 28 days

VII. Conclusions

Following are the conclusions and recommendations based on the results of the present study:

- Compressive, flexural and pull-off strength of concrete composite mixes decreases with incorporation of KSS & RHA. This decrease in strength was more at higher w/c ratios.
- Addition of Kota Stone Slurry & Rice Husk Ash performed better in abrasion.Weight loss after abrasion was lesser than the initial mixes as compared to later mixes.
- The variation of permeability with addition of KSS & RHA indicates that at 25% RHA containing concrete mix is least permeable at water cement ratio of 0.5. While mix containing 25% KSS & 0% RHA depth of water penetration is high.
- The durability is affected due to addition of KSS & RHA. The depth of carbonation is observed to increase with increasing percentage of RHA and age.

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