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Experimental Studies on Blended Concrete with Chemically Cured Coarse Aggregate

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ABSTRACT: *The research describes the feasibility of using industrial wastages like Marble Sludge Powder (MSP) and Rice Husk Ash (RHA) as a partial replacement i.e.,(2.5% MSP+2.5% RHA), (5% MSP+5% RHA), (7.5% MSP+7.5% RHA) of cement in the conventional concrete. To the extended of this research, the coarse aggregate (CA) were cured chemically by immerse it in 1Molar NaOH solution for 7 and 14 days which leads to reduction in water absorption. Finally the mechanical properties and durability properties (sorptivity & weight loss measurement) were compared among Blended Concrete with MSP, RHA (BCMR), Concrete with Chemically cured CA (CCCA) and the Conventional Concrete (CC) with M40 grade and curing period of 7, 28 and 56 days. The overall conclusion is that 10% (5% MSP + 5% RHA) cement replaced blended concrete (BCMR10) and CCCA had shown the better performance in mechanical and durability point of view as compared to CC and also it was found that chemically cured CA showed better performance in strength and water absorption as compared to water curing CA and without curing CA.*

KEYWORDS: Marble Sludge Powder, Rice Husk Ash, 1Molar NaOH solution, sorptivity, corrosion resistance test by weight loss measurement.

1. INTRODUCTION

The advancement of study of concrete technology is to reduce the consumption of natural resources and energy sources and lessen the burden of pollutants on environment. The demand for cement in the construction industry has consequently increased which has resulted in the environmental effect. India is the 2nd largest cement producer in world after the China. It is estimated that by the end of 2017 India going to produce 421 million tons of cement annually (http://www.ibef.org/industry/cement-india.aspx), if it happens only India will release 421 million tons of CO_2 by the end of 2017 because 1kg of cement production will releases approximately 1kg of CO_2 (http://blogs.ei.columbia.edu/2012/05/09/ emissions-from-the-cement industry/) so to reduce the environmental degradation (emission of CO_2) due to the manufacturing of cement, several cementing supplementary and pozzolonic materials are introduced to partial replacement of cement in concrete.

The main objective of the research is utilization of cement supplementary materials like MSP and RHA in conventional concrete. Presently 7 million tons of MSP is generated annually in natural stone processing plants in India out of this contribution from Rajasthan state itself is approximately 85% of the total accounting to 6 million tons per year (http://www.tara.in/marble_sludge.aspx). In India marble dust is settled by sedimentation and then dumped away in open land which results in environmental pollution, addition to this forming dust in summer and threatening both agriculture and public health. Similarly rice millings producing annually 20 million tons (http://www.ricehuskash.com/ details.htm) of RHA in India out of which West Bengal, Andhra Pradesh, Uttar Pradesh, Punjab, Orissa, Tamil Nadu, Chattisgarh, Bihar, Karnataka and Haryana are the top 10 rice producer states in India. RHA has high pozzolanic reactivity. Silica content of RHA is increases with increasing the burning temperature. As per study of *Ramezanianpour et al. (2009, 2010)* burning rice husk between 600 to 700°C temperatures contains 90 to 95% of SiO_2 and shows high pozzolanic action and *Malhotra and Mehta (2004)* reported that RHA with fine particle size than OPC improves concrete properties, including higher substitution amounts in lower water absorption values and the addition of RHA caused an increment in the compressive strength. So use of RHA with cement improves workability and stability, reduces heat evolution, thermal cracking and plastic shrinkage. This increases strength development, impermeability and durability by blocking the large voids in the hydrated cement paste through pozzolanic reaction. RHA minimizes alkali-aggregate reaction, reduces expansion.

In addition to this, chemical curing technique with Sodium hydroxide (NaOH) solution is used to CA by immersion of CA in 1Molar NaOH solution results the formation of NaOH layer on the surface of CA which is responsible for reduction in water absorption so, the concrete prepared by using chemically cured CA had less permeability and more susceptible for environmental threatening like penetration of moisture and aggressive chemicals, sulphate attack, chloride ingress, carbonation, leaching, freezing and thawing, alkali-silica reaction, corrosion resistance etc. In this project, the CA are cured in 1M NaOH solution for 14 days then removed from the curing bucket and dried in open atmosphere for 24 hrs and then used it in concrete.

Preparation of NaOH Solution:

Molarity = moles of solute / liter of solution

Mol = molecular weight of solute

For NaOH, molecular weight = 40

Therefore, 1M solution of NaOH will contain 40gm of NaOH chemical.

i.e. (40gm of NaOH pellets + 1lit. of water = 1M of NaOH solution)

(http://environmentalchemistry.com/yogi/chemistry/MolarityMolalityNormality.html)

2. METHODOLOGY

Indian Standard code of practice for plain and reinforced concrete, IS 456- 2000, recommends the use of supplementary materials in concrete but does not specified the quantities, so the optimum usage of MSP and RHA are determined by using pH meter analysis and it showed that 5% of RHA and 5% of MSP as partial replacement of cement will gives the acceptable results, and the pH meter analysis had also compared with the many literature reviews that had showed the optimum usage of MSP and RHA used in concrete. The quantities used in concrete were nearly same.

In pH meter test, the samples were prepared as 10gm of solute dissolved in 100ml of distilled water, after stirring it for 1hr the pH meter test is conducted for different samples in different percentages and finally the test results were observed as mentioned below.

Table1: pH values for corresponding solute prepared

Solute Prepared	pH Value
100% Rice Husk Ash (RHA)	9.74
100% marble sludge powder (MSP)	11.29
100% cement	12.04
2.5% MSP + 2.5% RHA + 95% cement	12.05
5% MSP +5% RHA + 90% cement	**12.06**
7.5% MSP + 7.5% RHA + 85% cement	12.05
10% MSP + 10% RHA + 80% cement	12.05

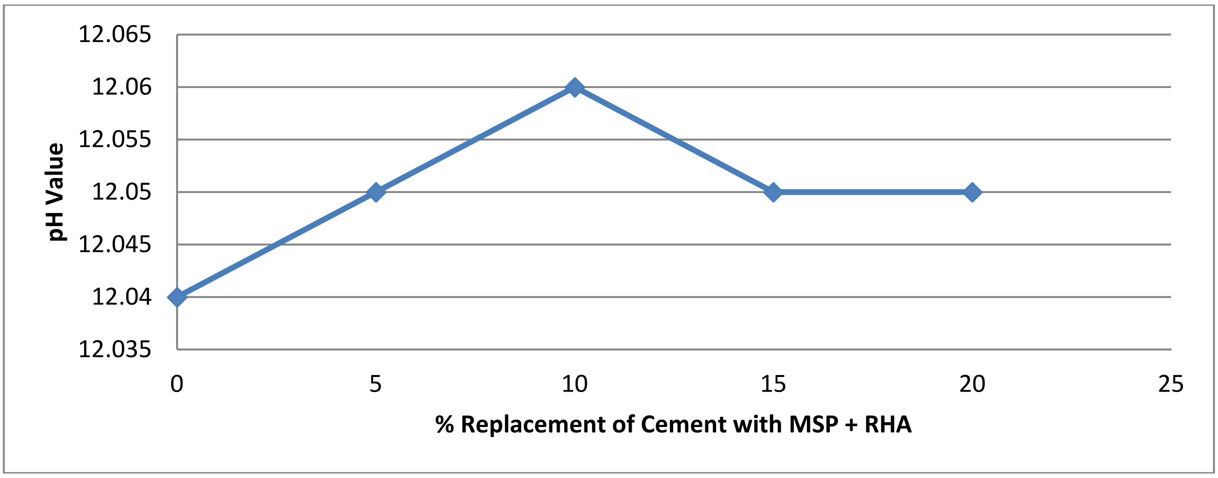

Fig 1: pH Value VS % Replacement of Cement

3. LITURATURE REVIEW

Vaidevi C. studied the possibilities of using waste materials from different manufacturing activities in the preparation of mortar and concrete. The concrete (M20) was prepared containing 5, 10, 15 and 20% waste of marble dust with cement. The compressive strength and tensile strength of concrete were calculated with and without partial replacement with marble dust at 14 and 28 days. Test result indicated that 10% of marble dust in cement concrete give best result and increase in curing days will increased the strength when compared from 14 to 28 days.

Prof. VeenaG. Pathan and Prof. Md Gulfam Pathan studied the need to use waste marble powder in concrete production. The investigation revealed that replacing cement with marble waste powder up to 20% reduces the slump of concrete mixes. In concrete production, replacement of 5% cement by marble waste powder gives comparable compressive and flexural strength as of marble free concrete specimens; but increasing the replacement range beyond 5% that leads to strength reduction.

Abdullah Anwar et.al in this research work, marble dust powder as replaced the (OPC & PPC) cement accordingly in the reach of 0%, 5% , 10% , 15% , 20% , 25% , by weight of M-20 grade concrete. Concrete mixtures were developed, tested and compared in terms of compressive strength to the conventional concrete. The result obtained for 28-days compressive strength confirms that the optimal percentage for replacement of cement with marble dust powder was about 10%.

Jashandeep Singh and Er. R S BansaL, studied the compressive strength of concrete by partial replacement of cement with WMP and M25 grade is used for which marble powder is replaced by (0% , 4% , 8% , 12% , 16% , 20%). The standard cubic specimens of size 150mm and cylindrical moulds for size 150 x 300mm were casted. Concrete cubes were casted and compressive strength of concrete was tested at 7, 14, & 28 days of age. Slump values were taken which decreased with increased percentage of marble powder. It was concluded that replacement of nearly 12% of cement with waste marble powder attains maximum compressive strength.

Baboo Rai et.al studied the effect of waste marble powder as partial replacement of cement by varying percentage of waste marble powder. It was observed that with the increase of WMP (replacing cement) the strength falls remarkably upto 10 N/mm2 when the WMP is 15% or 20%. The rate of fall being uniform upto 15%. When marble waste granules were partially replaced in fine aggregate by weight then there was increase in compressive strength at each curing age on increasing the percentage replacement beyond 10%, there was a slight reduction in the compressive strength value.

V. M. Sounthararajan et.al (2013), have done their research on Effect of the Lime Content in Marble Powder for Producing High Strength Concrete. They found that the waste marble powder up to 10% by weight of cement was investigated for hardened concrete properties. Furthermore, the effect of different percentage replacement of marble dust on the compressive strength, splitting tensile strength and flexural strength was evaluated. It can be noted that the influence of fine to coarse aggregate ratio and cement-to-total aggregate ratio had a higher influence on the improvement in strength properties. A phenomenal increase in the compressive strength of 46.80 MPa at 7 days for 10% replacement of marble powder in cement content was noted and also showed an improved mechanical property compared to controlled concrete.

Ramezanianpour et al. (2009, 2010) Concluded that burning rice husks at temperature below 700°C produces rice husk ashes with high pozzolanic activity.

Malhotra and Mehta (2004) reported that ground RHA with fine particle size than OPC improves concrete properties, including higher substitution amounts in lower water absorption values and the addition of RHA caused an increment in the compressive strength.

Ismail and Waliuddin (1996) had worked on effect of rise husk ash on high strength concrete. They studied the effect the rise husk ash (RHA) passing 200 and 325 micron sieves with 10- 30 % replacement of cement on strength of HSC. Test result indicated that strength of HSC decreased when cement was partially replaced by RHA for maintaining same value of workability. They observed that optimum replacement of cement by RHA was 10 – 20 %.

Mehta and Pirth (2000) investigated the use of RHA (Rice Husk Ash) to reduce temperature in high strength mass concrete and concluded that RHA is very effective in reducing temperature of mass concrete compared to OPC concrete.RHA which is an agricultural by-product has been reported to be a good pozzolanic material by numerous researchers.RHA is obtained after burning of rice husk at a very high temperature.

G. Venkata Suresh and J. Karthikeyan (Nov 2016) had researched on ‘Influence of chemical curing technique on the properties of fly ash aggregates prepared without conventional binders’ and they are concluded that the strength of Chemical Cured Aggregates (CCA) was found to be 64.93% and 49.03% higher after 7 days and 28 days respectively, when compared to that of Water Cured Aggregates (WCA). The percentage of water absorption of CCA is 4.0% at 7days and 4.2 % at 28 days.

4. MATERIALS USED

CEMENT: Cement is a binding material which posses pozzolanic reaction in concrete. 53 grade of Ordinary Portland Cement confirming to IS12269:1987 is used in this study.

Table 2: Physical properties of Cement

Property		Result
Fineness of cement		5%
Normal consistency		30%
Initial setting time		60 min
Soundness		3mm
Specific gravity		3.131
Compressive Strength	7 days	36.87 N/mm^2
	28 days	53.72 N/mm^2

FINE AGGREGATES: Fine aggregates generally consist of natural sand or crushed stone with most particles size less than 9.5mm. In this research locally available sand is used confirming it to IS383:1970.

Table 3: Physical properties of Sand

Property	Result
Fineness modulus	2.735
Zone	II
Specific gravity	2.678

COARSE AGGREGATES: Coarse aggregates generally range between 9.5mm to 37.5mm in diameter are used in bulk quantity in concrete constructions. In this study maximum 20mm size CA are used with confirming to IS383:1970.

Table 4: Physical Properties of CA

Property	Result
Specific gravity	2.75
Water absorption	1.98%
Impact value	14.50%
Crushing value	16.33%

MARBLE SLUDGE POWDER: MSP used in this research is collected from the stone processing plant near Bethamcherla, Kurnool (Dist), AP. It is confirmed to IS1760.

RICE HUSK ASH: The source for RHA used in this study is 'Sree Rayalaseema Green Energy Limited' Lakshmipuram, near Kurnool, AP. It is confirmed to IS1355.

Table 5: Chemical composition of MSP and RHA

Test	MSP Result	RHA Result
Silica as SiO_2	13.64%	88.52%
Iron as $Fe2O_3$	0.48%	0.63%
Alumina as $Al2O_3$	0.89%	2.37%
Calcium as CaO	46.93%	1.53%
Magnesium as MgO	0.41%	0.52%
Sodium as Na_2O	-	0.47%
Pottasium as K_2O	-	2.35%
Titanium as TiO_2	-	1.67%
Specific Gravity	2.72	2.01

Table 6: Consistency and Initial Setting Time of cement with MSP and RHA

Sample	Consistency	Initial Setting Time
100% Cement	30%	60min
2.5% MSP + 2.5% RHA + 95% Cement	32%	54min
5% MSP + 5% RHA + 90% Cement	34%	55min
7.5% MSP + 7.5% RHA + 85% Cement	36%	57min

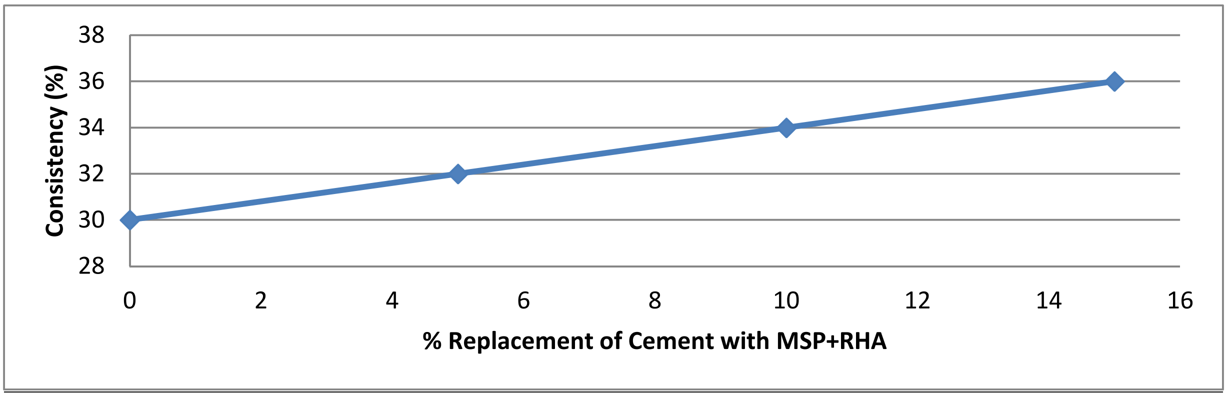

Fig 2: Consistency VS % Replacement of cement

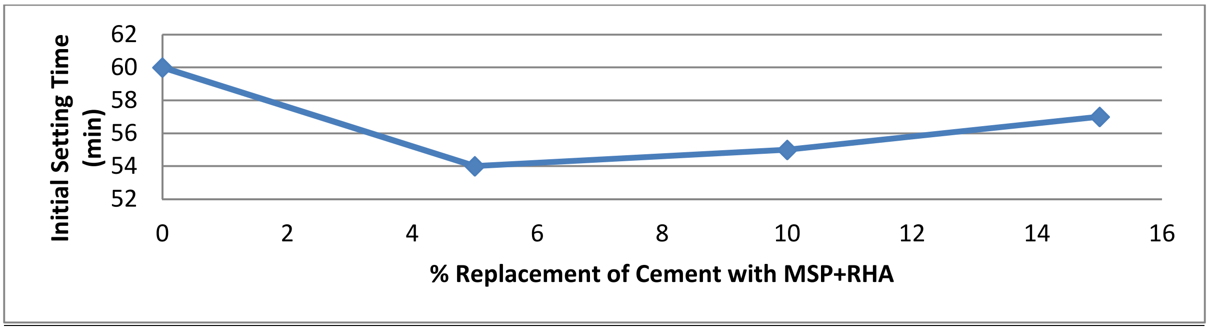

Fig 3: Initial Setting Time VS % Replacement of cement

SODIUM HYDROXIDE (NAOH): Generally 3 grades of NaOH pellets are available in market they are commercial grade, LR grade and AR grade depending on their concentration. AR grade of NaOH pellets are used in this study.

Table 7: Properties of NaOH Pellets

Test	Result	Specification
Description	White deliquescent pellets	White deliquescent pellets
Solubility	Passes	10% Solution in water should be clear
Assay (acidimetric)	98.82%	Min 97.00%
Carbonate as Na2CO3	0.93%	2.00% Max
Sulphate (SO4)	NMT 0.01%	0.01% Max
Chloride (Cl)	NMT 0.01%	0.01% Max
Phospate (PO4)	NMT 0.001%	0.001% Max
Iron (Fe)	0.0019%	0.005% Max
Heavy metal as Pb	0.0008%	0.001% Max

5. MIX DESIGN OF M40 GRADE CONCRETE

A concrete mix of M_{40} grade was designed as per IS 10262:2009 for the workability of 50mm to 100mm. From the designed concrete, cubes, cylinders and beams were casted for 7, 28 and 56 days curing tests. The mix proportions, water/cement ratio, slump and compaction factor for corresponding concrete mixes are mentioned below.

Table 8: M40 Concrete Designed Mix Proportions

Concrete Mix	Mix proportion	w/c ratio	Slump	Compaction Factor
CC	1:1.470:2.091	0.4	68mm	0.843
CCCA	1:1.512:2.121	0.4	65mm	0.839
2.5% MSP + 2.5% RHA of BCMR (BCMR-5)	1:1.293:1.762	0.4	62mm	0.835
5% MSP + 5% RHA of BCMR (BCMR-10)	1:1.284:1.748	0.4	59mm	0.829
7.5% MSP + 7.5% RHA of BCMR (BCMR-15)	1:1.279:1.742	0.4	56mm	0.823

6. DURABILITY TESTS

WEIGHT LOSS MEASUREMENT TEST:

Cubes specimens of size 150*150*150 mm were cast using OPC and OPC content is replaced with marble sludge powder and rice husk ash. In every specimen placed three rods with 10 mm diameter and 110mm long. Before introducing the rods in specimens, the rods were clean with the HCL solution thoroughly by immersing the rod in solution for 15min and gentle clean it to avoid initial rust on rebar and then weights of rods were taken say W_1. And then final weight W_2 was taken after the test carried out on CCCA, BCMR-10 and CC after 56 days of curing by breaking the specimens. The following formula for percentage weight loss will gives the corrosion rate of specimens.

$$\% \text{ weight loss} = (W_1-W_2)*100/W_1$$

POROSITY:

Porosity test is used to determine on 70.6*70.6*70.6mm cube specimens according to principle related to the weight of saturated in air and water and dry weight. The porosity was calculated by the following equation

$$P = (W_{sat} - W_{dry})*100/ (W_{sat} - W_{water})$$

SORPTIVITY:

After determining the porosity, these specimens are also used for sorptivity test. The specimens are placed to the oven at 40°C- 50°C. After removing the specimens from oven dry, cooled at room temperature. The test was conducted on pan. The water level in the pan maintained about 3cm and specimens are kept over the surface of the water in such a way that the specimens are slightly touchable to the water surface so that the capillary rise of water into the specimens will takes place. The amount of water absorbed by specimen at various times were noted say 0, 10, 20, 30, 60 min etc. The sorptivity coefficient was obtained by using the following equation

$$Q/A = K\sqrt{t}$$

Q = the amount of water absorbed *in* (cm^3)

A = the cross section of specimen was contact with water (cm^2)

K = sorptivity coefficient

t = time (s)

7. RESULTS AND DISCUSSION

Throughout the project, the tests conducted and results obtained for corresponding types of concrete were mentioned below tables.

Table 9: Compressive strength of cubes

Mix (Cubes)	7 days compressive strength (N/mm^2)	28 days compressive strength (N/mm^2)	56 days compressive strength (N/mm^2)
CC	30.39	48.18	60.44
BCMR-5	31.79	50.89	61.57
BCMR-10	33.32	53.92	63.28
BCMR-15	29.72	48.28	58.72
CCCA	30.83	48.67	60.48

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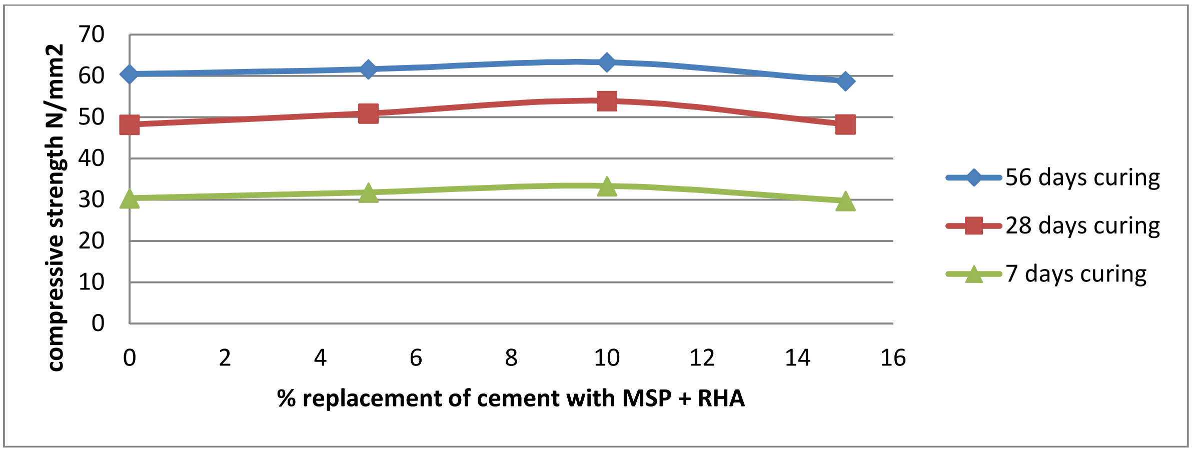

Fig 4: compressive strength VS % replacement of cement

The results in Table 9: shows that the compressive strength of all types of concrete is increasing with increasing the curing period in which BCMR-10 shown maximum compressive strengths of 33.32N/mm^2, 53.92N/mm^2 and 63.28N/mm^2 for the curing period of 7, 28 and 56 days respectively. Similarly CCCA had shown the more compressive strength than the CC.

Table 10: Split tensile strength of cylinders

Mix (Cylinders)	7 days split tensile strength (N/mm^2)	28 days split tensile strength (N/mm^2)	56 days split tensile strength (N/mm^2)
CC	2.72	3.87	5.86
BCMR-5	2.87	4.02	6.09
BCMR-10	2.98	4.31	6.33
BCMR-15	2.69	3.83	5.79
CCCA	2.83	3.92	5.84

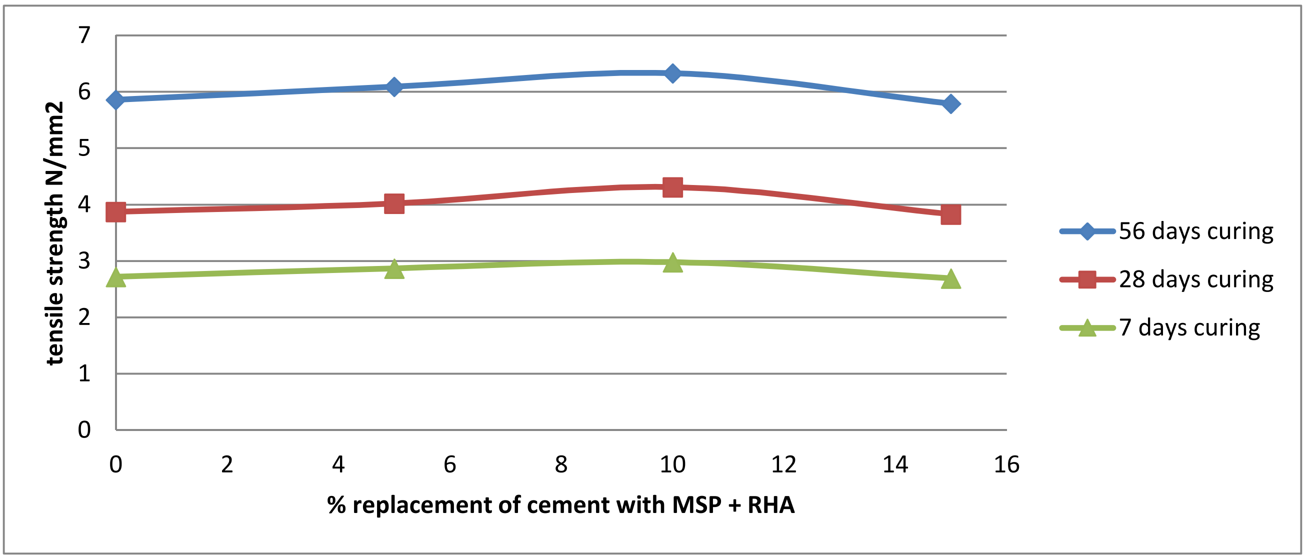

Fig 5: Tensile strength VS % replacement of cement

The BCMR-10 shown comparatively high tensile strength of 2.98N/mm^2, 4.31N/mm^2 and 6.33N/mm^2 for the curing periods of 7, 28 and 56 days respectively The increasing rate of split tensile strength of CCCA can observed with increasing curing period compare to CC.

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Table 11: Flexural strength of beams

Mix (Beams)	7 days flexural strength (N/mm^2)	28 days flexural strength (N/mm^2)	56 days flexural strength (N/mm^2)
CC	3.98	5.32	7.38
BCMR-5	4.42	6.04	7.92
BCMR-10	4.83	6.69	8.51
BCMR-15	3.94	5.29	7.34
CCCA	4.32	5.41	7.39

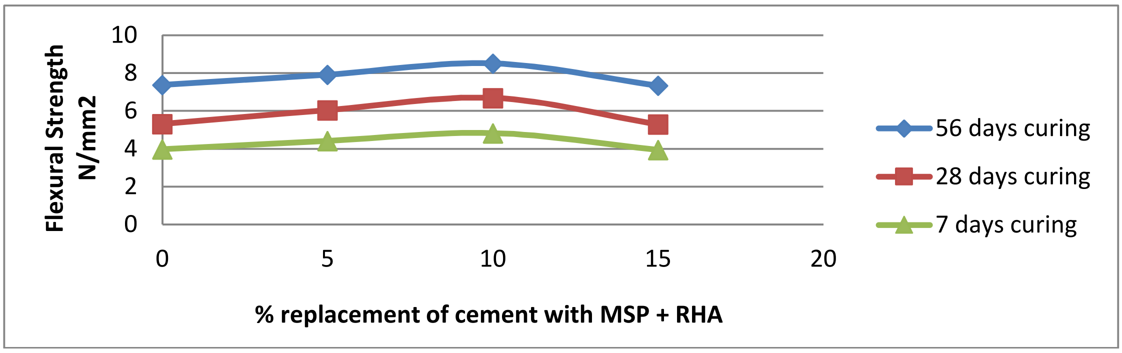

Fig 6: Flexural strength VS % replacement of cement

The flexural strength of BCMR-10 found to be comparatively maximum with the values of 4.83N/mm^2, 6.69N/mm^2, and 8.51N/mm^2 for the curing periods of 7, 28 and 56 days respectively. And weight density found to be maximum for CCCA with 2586N/mm2 and minimum for BCMR-15 with 2438N/mm2 for beam samples. And the CCCA has shown better performance in flexural strength comparing to CC but the rate of increase were decreases with increasing the time.

Table 12: % weight loss for corresponding concrete samples

Mix	Weight loss (%)
CC	0.320
BCMR-5	0.298
BCMR-10	0.259
BCMR-15	0.317
CCCA	0.266

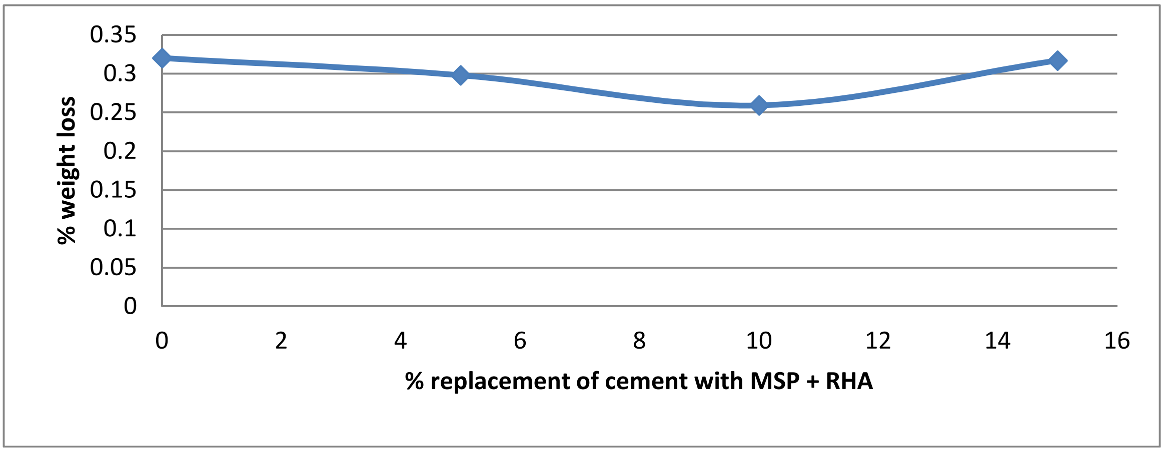

Fig 7: % weight loss VS % replacement of cement

Among 5 types of concrete BCMR-10 shows the comparatively least percentage weight loss with 0.259 for 56 days curing periods which means that relatively 0.061% weight is reduced comparing to CC for just 56 days. And CCCA was found to be 0.054% weight is reduced comparing to CC. So we can conclude that BCMR-10 and CCCA had shown the better durability performance in point of corrosion rate comparing to CC.

Table 13: The porosity and sorptivity for corresponding concrete samples

Mix	Porosity (%)	Sorptivity Cm/s ½
CC	7.125	1.321
BCMR-5	6.965	1.193
BCMR-10	6.643	1.148
BCMR-15	7.042	1.213
CCCA	6.732	1.172

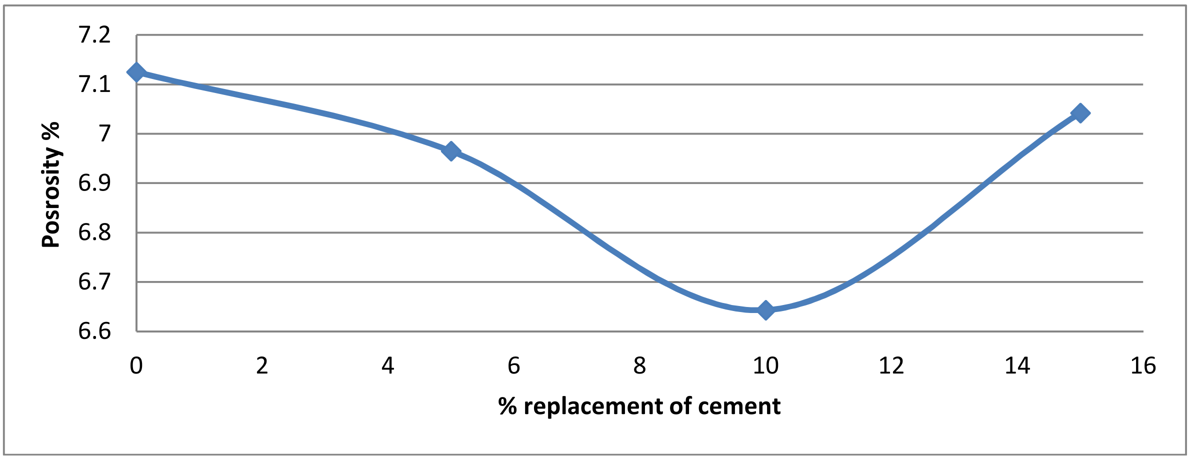

Fig 8: Porosity % VS % replacement of cement

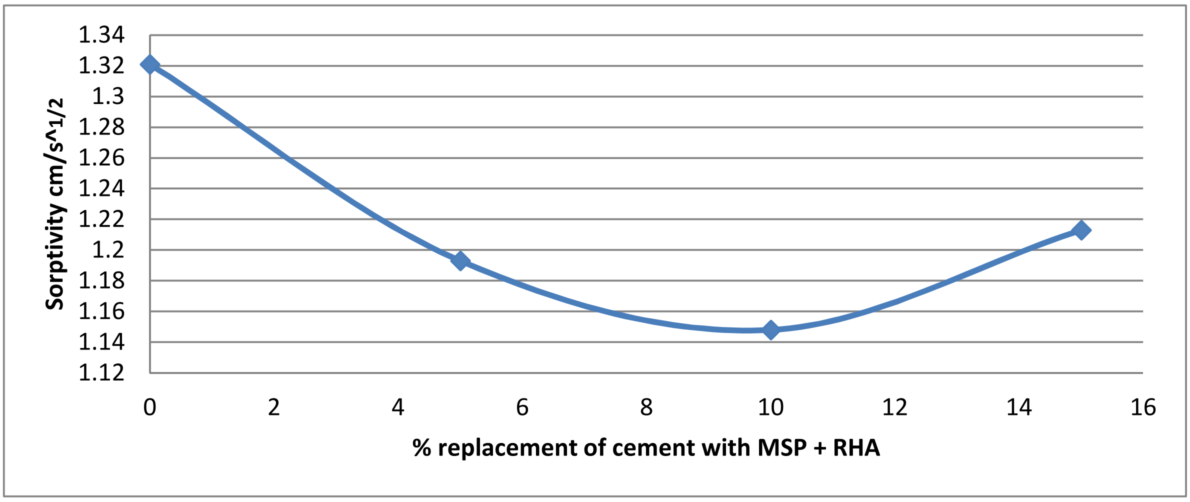

Fig 9: Sorptivity VS % replacement of cement

Table 15 results shows that the porosity and the sorpitivity for BCMR-10 and CCCA is reduced by 0.482%, 0.173 cm/s$^{1/2}$ and 0.393%, 0.149 cm/s$^{1/2}$ respectively comparing to CC which means that the permeability of water is reduced for BCMR-10 and CCCA for 56 days curing samples results that these concrete will have the long term durability among all types of concrete.

Table 14: Specific gravity, water absorption and mechanical properties of different types of CA

Sample Tested / Test	Chemically Cured CA		Water Cured CA		Without Curing CA
	7 days	14 days	7 days	14 days	
Water Absorption	1.02%	0.79%	1.69%	1.51%	1.98%
Crushing Value	10.76	9.60	13.62	12.29	16.33
Impact Value	9.89	9.26	12.36	11.79	14.50
Specific Gravity	2.824	2.843	2.780	2.799	2.750

Among 3 types of CA the chemically cured CA found to be maximum water absorption reduction of 1.19% and increasing the maximum crushing and impact strength of 6.73 and 5.24 respectively and specific gravity is also increasing from 2.75 to 2.843 for 14 days of chemical curing.

8. CONCLUSION

1. BCMR-10 had shown the significantly large compressive, tensile and flexural strength with 2.93N/mm^2, 5.74N/mm^2, 2.84N/mm^2, and 0.26N/mm^2, 0.44N/mm^2, 0.47N/mm^2 and 0.85N/mm^2, 1.37N/mm^2, 1.13N/mm^2 increment than the CC for 7, 28 and 56 days respectively.
2. BCMR-15 showed the less weight density comparing to all types of concrete prepared because the replacement of MSP and RHA to cement has the least particle size than the cement particle so the particles of MSP and RHA occupies the large volume compare to cement so the volume is indirectly proportional to the weight density which leads to volume increases weight density decreases.
3. CCCA had shown little increment in compressive, tensile and flexural strength for 7, 28 and 56 days than CC.
4. The corrosion rate by weight loss measurement found to be least in case of BCMR-10 and CCCA compared to CC.
5. An addition of RHA and MSP in CC will makes concrete as less porous and less permeable because of its least particle size compare to cement particle. Table 13 shows that the porosity and sorpitivity were least in BCMR-10 and CCCA comparing to CC.
6. Increasing in cement replacement with MSP and RHA there is increasing in consistency and decreasing the initial setting time in binding material.
7. Slump values of concrete were decreases with increasing the cement replacement with MSP and RHA.
8. The compaction factor is reduces with increasing the percentage replacement of cement with MSP and RHA which means that the time of vibration is relatively more than the conventional concrete.
9. Concrete prepared with MSP and RHA partial replacement to cement will leads to cost effective because, they are industrial wastages so freely available materials and meanwhile lessening the burden of pollutants (emission of CO_2) due to reducing the usage of cement.
10. The pH meter analysis can be effectively used to find out the maximum percentage of replacement to cement with alternative materials in conventional concrete.

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