RESISTANCE OF CHLORIDE INGRESS IN CEMENT MORTAR USING RICE STRAW ASH AS SUPPLEMENTARY CEMENTITIOUS MATERIAL

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ABSTRACT. On account of environmental hazard, the cementitious material got chemically affected which decreases the durability of construction. One of the most damaging chemical is the chloride salt, the presence of which is mainly responsible for corrosion of reinforcement. Due to the porous nature of the cementitious materials the ingress of soluble salt in the structure is a natural phenomenon. However, the ingress of the aggressive chemicals can be controlled upto certain extent by suitably modifying the porous structure. In this context, use of supplementary cementitious materials (SCM) got prominence in the recent past, further, use of SCM is important for sustainable development. In our previous research it is found that Rice Straw Ash (RSA) contains very high silica content, thus it can also act as pozzolanic material. In this paper an experimental study is made on cement mortar sample with different percentage replacement of cement with RSA. One dimensional flow of soluble chloride is allowed in the sample made with RSA as well as control specimen. Experimental results show that there is a substantial decrease of ingress of chloride with incorporation of RSA in the mortar sample. Further, drying shrinkage of the materials are also studied which also confirm the improvement of durability property.

Keywords: Rice Straw Ash, Chloride Ingress. Drying Shrinkage, Cement mortar

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INTRODUCTION

At the early age, concrete was considered to be a very durable material which required no maintenance and only strength of the concrete considered. But in later, series of failure of various concrete structures, the earlier opinion was proved wrong. To improve the durability i.e. to protect the concrete from weather action, abrasion, chemical action etc. various type of admixture are being used. The widely used admixtures are pozzolanic materials which are used as supplementary cementitious materials and considerably improve strength and durability of concrete and mortar [1-5].

As per ASTM [6] if in a materials sum of Iron Oxide (Fe_2O_3), Silicon Oxide (SiO_2) and Aluminium Oxide (Al_2O_3) is more than 70% then the materials is called pozzolanic materials.

Two types of pozzolanic materials are there and they are natural and artificial. Clays, Opals and Volcanic tuffs, Sedimentary schist and pumicite stones are natural pozzolana. Chemical composition of natural pozzolana varies as per their locations. Artificial pozzolanic are industrial waste like fly ash, slag and silica fume and agricultural waste are rice husk ash, hazel nut shell and wheat straw. Natural pozzolana is calcined in order to decompose carbonates to oxides [7].

In production of ordinary Portland cement the energy consumption as well as emission of CO_2 is very high. CO_2 is one of the major concern of environmental pollution and this can be minimize with the application of partial replacement of Ordinary Portland cement by reasonable amount of pozzolanic materials. During hydration of cement calcium hydroxide produce and it reacts with pozzolan and generate additional calcium silicate hydrate(C-S-H) gel. Many pozzolanic materials are by product materials like fly ash (FA), rice husk ash (RHA), and palm oil fuel ash (POFA). The cement produced with the help of these waste materials not only reduced the cost but also reduced the emission of CO_2 which reduce environmental pollution.
A number of relatively new supplementary cementitious materials, such as rice husk ash, sewage sludge ash, and oil shale ash, have undergone extensive research [8–12].

Many literatures indicate that there was reduction in drying shrinkage when RHA is used as partial replacement of cement in concrete, when compared with specimens without RHA [13-16].

Free chloride in concrete is one of the prime causes of corrosion of embedded rebar in Reinforced Cement Concrete structures [17-20]. Due to increase of corrosion swelling pressure form around the rebar and ultimately cracking of concrete take place [21].

Asian countries produce maximum rice in the world. According to the study conducted by the Food and Agricultural Policy Research Institute (FAPRI), the worlds demand for rice can be expected to rise to 496 million tons in 2020. India is one of the largest rice producing country in the world and its yearly production is more than 155.682 million tons. So rice straw is abundant in India and using this we can reduce the cost of cement and also the environmental pollution in large extent. Rice straw, rice husk and rice bran are found from the rice as a byproduct and these are used for cattle , poultry, fish etc. as a feed and in village people use these in cooking and other purposes [22]. By and large, farmers burn the rice straw ash in the field which emits air pollutants and these are toxic in nature [23].

Rice straw ash has varying percentage of organic like cellulose, lignin, protein, vitamin etc and major percentage of inorganic matter i.e. silica. It is a fibrous cellulose materials containing large amount of silica (about 62% to 82%) [24, 25]. Proportion of the morphological parts varies depending on the ecological condition, type of paddy etc. [26]. It is seen that after burning of RSA we get 15% ash [27].

The prime objectives of these studies are

i. To investigate the shrinkage effect on cement mortar with partial replacement of cement by rice straw ash.
ii. Chloride ingression test on cylindrical (25mm and 80mm length) cement mortar sample made with RSA by replace cement of different percentage.

EXPERIMENTAL PROGRAMME

Materials

Cement

In this experiment 43 grade Ordinary Portland Cement conforming to IS: 8112-2013 was used for preparation of all mortar samples. Chemical composition of OPC and RSA are given in Table 1.

Table 1 Chemical composition of Cement (OPC) and RSA

CHEMICAL COMPOSITION	CEMENT (OPC)	RICE STRAW ASH (RSA)
SiO_2	21.5	76.00
Al_2O_3	5.2	0.69
Fe_2O_3	3.5	0.63
CaO	65.4	4.96
MgO	1.2	2.65
SO_3	2.7	1.90
Na_2O	0.2	1.36
K_2O	0.2	9.89

Aggregates

Locally available sand of local stream which is main source of fine aggregate of construction work has been used for preparation of all type of cement mortar. From the sieve analysis as per IS: 383-1970 it is seen that the grading of sand is Zone-IV The specific gravity and fineness modulus of the fine aggregate were 2.43 and 2 respectively.

Rice Straw Ash

Rice straw ash is readily available agricultural by product in India. It was collected from Belonia, South Tripura district, Tripura, the North East State of India and type of paddy was Naveen, (Boro). At first the collected sample was thoroughly washed and properly burnt in open air at uncontrolled temperature till all the sample become ashes. Then ashes were again burnt in a muffle furnace to remove all the organic components at a temperature of 600^0C. After collecting the sample from muffle furnace, the sample was properly ground.

Water

Purified tap water has been used for mortar sample preparation.

Mortar Mixtures

Various type of cement mortar samples were prepared with partial replacement of cement by rice straw ash at 0%, 5%, 10% and 15% by weight with a water cement ratio of 0.50. Three samples were made for every mix, result calculated on the average of three sample tested. Mix proportions of mortar are excerpted in table 2.

Table 2 Mix proportion of mortar

NOTATION	RSA (%)	(OPC+RSA) : SAND	OPC (KG)	RSA (KG)	SAND (KG)
C	0	1:3	0.854	0	1.977
RSA1	5	1:3	0.8112	0.0428	1.977
RSA2	10	1:3	0.7685	0.0855	1.977
RSA3	15	1:3	0.7257	0.1283	1.977

TESTING

Shrinkage test

This test has been performed as per IS: 4031 (part 10)-1988. The mortar bars were proportioned and mixed according to is: 4031 (part 10)-1988. The mortar bars (25x25 x 280 mm) were casted with partial replacement of cement by rice straw ash at 0%, 5%, 10% and 15% by weight and Sand to cementitious material in the proportion of 1:3 with water cement ratio 0.50. After 24 hours of casting the specimens were removed from the moulds and immediately immerse in lime water at room temperature for curing. At the age of 7 days and 35 days the specimens were removed from water and measure the length using comparator. Three samples were made for every mix and result calculated on the average of three sample tested.

Chloride attack

Four types of cylindrical specimens having diameter of 25mm and height of 80mm with partial replacement of OPC (0%,5%,10% and 15%) by RSA were made. Specimens were cured in lime water for 28 days. After curing period, the samples were sealed with chemical on curved surface leaving two opposite plane surfaces for one dimensional flow. Then the samples were placed in contact with 3% NaCl solution in a box in such a way that only one plane surface of the samples were remain contact with the solution and entered into the specimens in one dimension as shown in the Figure-1. The specimens were removed from the box at the age of 28days. To measure the chloride penetration depth at 4 locations, the samples were symmetrically cut in the various locations of sample depth (20, 40, 60 and 80 mm) and details are shown in Figure 2. The tests were done as per RILEM TC 178-TMC: ‘Testing and modeling chloride penetration in concrete’.

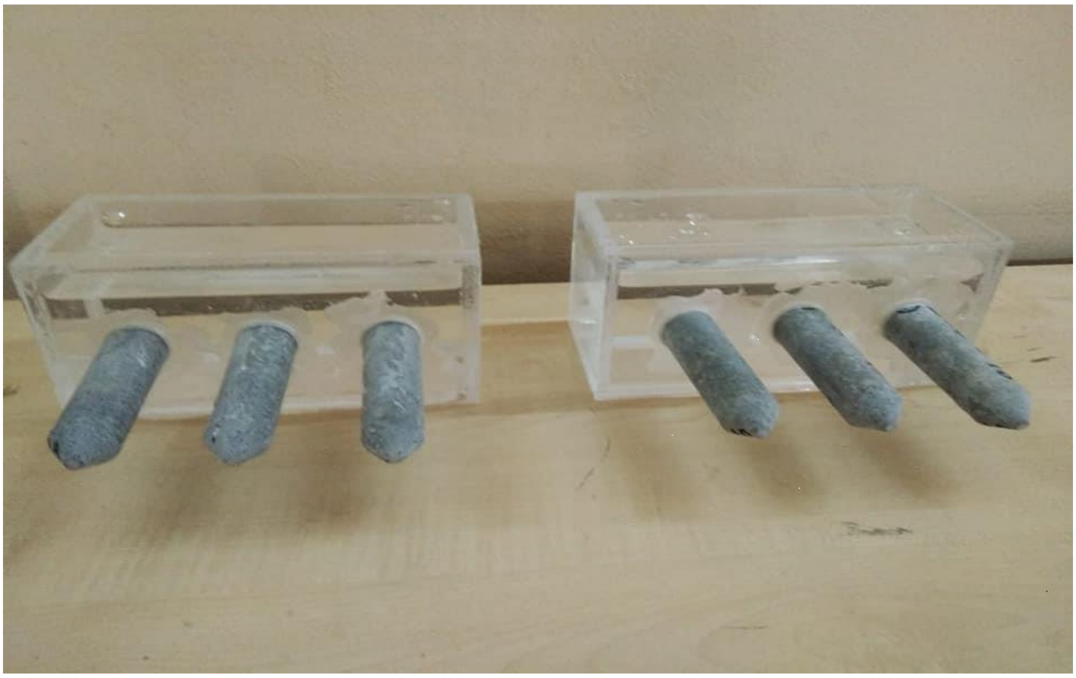

Figure 1 Sample kept in NaCl solution in a box for one dimensional flow

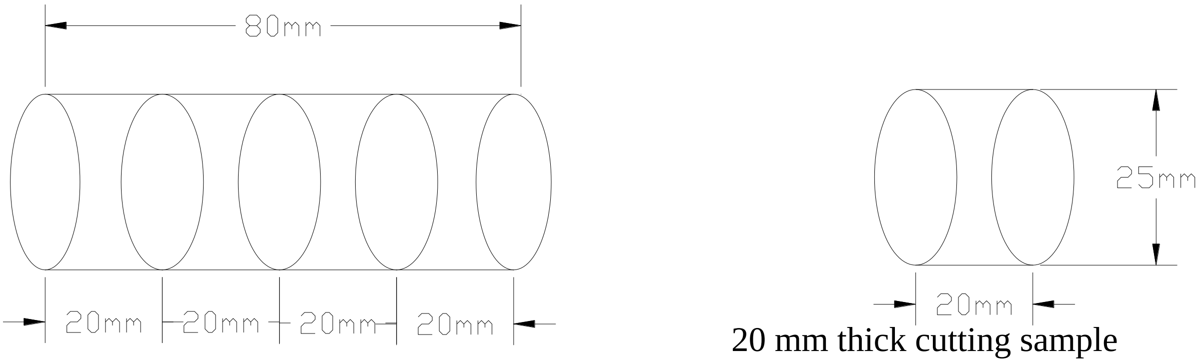

Fig. 2 Schematic view of sample cutting for chloride depth measurement

RESULT AND DISCUSSION

Shrinkage test

The shrinkage value of different samples is given in Table-3. Variation of average shrinkage values are shown in Figure 3.It is seen that percentage of shrinkage increase with increase of

Table 3 Shrinkage (%) of different sample with partial replacement of cement by RSA

SL NO	PARTIAL REPLACEMENT OF RSA	AVERAGE SHRINKAGE (%)
1	0%	.0177
2	5%	.007
3	10%	.011
4	15%	.012

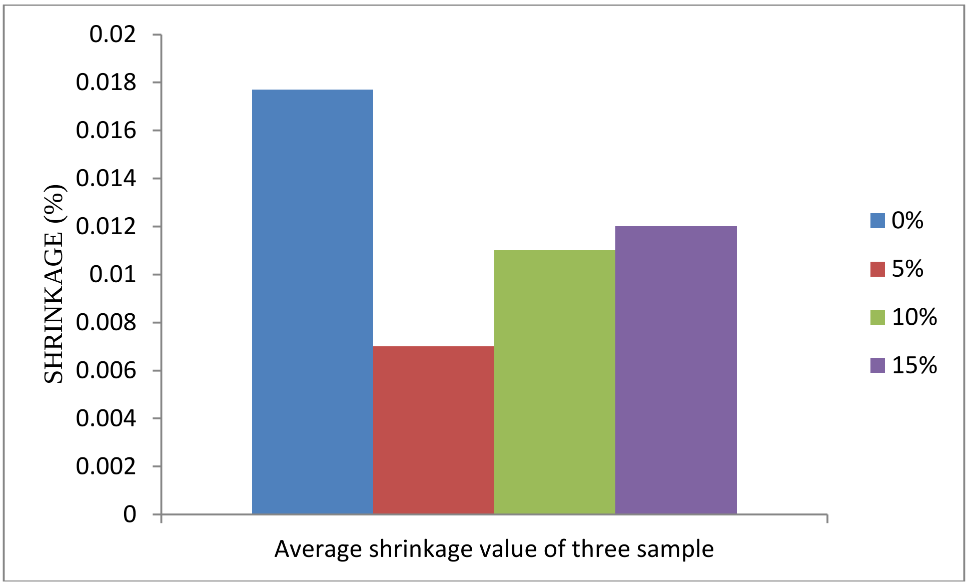

Figure 3 Shrinkage (%) of different sample with partial replacement of cement by RSA

partial replacement of cement by RSA. For 5% replacement of OPC by RSA the percentage of shrinkage is minimum. If replacement of OPC by RSA is increase then the percentage of shrinkage also increase.

Chloride attack

The chloride ingression test result of different samples are excerpted in details in figure 4. It is seen that the percentage of chloride penetration is decreases with the increases of partial replacement of OPC by RSA at various depths of a sample after 28 days immersion. The percentage of chloride penetration is minimum at 15% replacement of OPC with RSA.

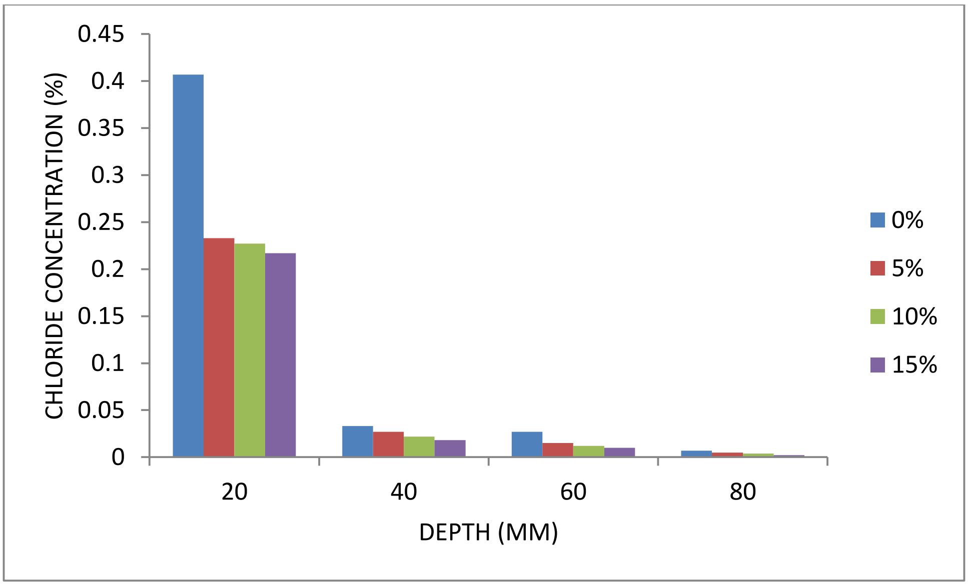

Figure 4 Chloride penetration (%) at various depths of a sample after 28 days immersion

CONCLUDING REMARKS

From various experimental results on mortar with partial replacement of various percentage of cement with RSA, the following conclusion can be drawn.
i. At 5% replacement of OPC by RSA, the shrinkage effect on mortar is minimum i.e. the decrease of percentage of shrinkage is maximum.
ii. The effect of chloride penetration in mortar depends on replacement of OPC by RSA and decrease with increase of replacement of OPC by RSA. Chloride ingression is minimum at 15% replacement of OPC by RSA.

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REFERENCES

1. KING A, Brief Introduction to Pozzolans. in: Alternative Construction - Contemporary Natural Building Methods, John Wiley & Sons, London, 2000.
2. FAN Y, YIN S, WEN Z, ZHONG J, Activation of fly ash and its effects on cement properties, Cem. Concr. Res. 29 (10) (1999) 467– 472.
3. ZELIC J, KRSTULOVIC TKALCEC R E, KROLO P, The properties of Portland cement limestone silica fume mortars, Cem. Concr. Res. 30 (3) (2000) 145–152.
4. MARCH B, DAY R, BONNER D, Pore structure characteristics affecting the permeability of cement paste containing fly ash, Cem. Concr. Res. 15 (6) (1985) 1027–1038.
5. B. MARCH, R. DAY, AND D. BONNR, Pore structure characteristics affecting the permeability of cement paste containing fly ash, Cem. Concr. Res. pp. 1027– 1038, 1985.
6. SPECIFICATION for Fly Ash and Raw or Calcium Natural Pozzolona for Use as a Material Admixture in Portland Cement Concrete, ASTM C 618-78, American Standard for Testing Materials, 1978.
7. NEVILLE A M, Properties of Concrete, Pitman Publishing, Great Britain,1990, pp. 77–81.
8. AL-KHAJA W, Effect of sludge ash on the mechanical properties of concrete, Modell., Meas. Control 63 (1) (1997) 9 – 14.
9. ZHANG M, MALHOTRA V, High-performance concrete incorporating rice husk ash as a supplementary cementing material, ACI Mater. J. 93 (6) (1996) 629– 636.
10. YU Q, SAWAYAMA K, SUGITA S, SHOYA M, ISOJIMA Y, The reaction between rice husk ash and $Ca(OH)_2$ solution and the nature of its product, Cem. Concr. Res. 29 (1) (1999) 37–43.
11. SHI C, DAY R, Pozzolanic reaction in the presence of chemical activators: Part I. Reaction kinetics, Cem. Concr. Res. 30 (1) (2000) 51– 58.
12. S. WILD J, KHATIB A JONES, Relative strength, pozzolanic activity and cement hydration in superplasticized metakaolin concrete, Cem. Concr. Res. 26 (10) (1996) 1537–1544.
13. CHATVEERA B, LERTWATTANARUK P, 2011. Durability of conventional concretes containing black rice husk ash. J. Environ. Manage. 92 (1), 59–66.

14. WU D S, PENG Y, 2003. The macro and micro properties of cement pastes with silica rich materials cured by wet mixed steaming injection. Cem. Concr. Res. 33, 1331–1345.
15. KHASSAF S.I, JASIM A.T, MAHDI F.K, 2014a. Investigation the properties of concrete containing rice husk ash to reduction the seepage in canals. Int. J. Sci. Technol. Res. 3 (4), 348–354.
16. HABEEB G.A, FAYYADH M.M, Rice husk ash concrete: the effect of RHA average particle size on mechanical properties and drying shrinkage. Aust. J. Basic Appl. Sci. 2009. 3 (3), 1616–1622.
17. ANGST U, ELSENER B, LARSEN C K, VENNESLAND O, Critical chloride content in reinforced concrete – A review, Cem. Concr. Res. 39 (12) (2009) 1122–1138.
18. BASHEER L, KROPP J, CLELAND D J, Assessment of the durability of concrete from its permeation properties: a review, Constr. Build. Mater. 15 (2–3) (2001) 93–103.
19. SHI X, XIE N, FORTUNE K, GONG J, Durability of steel reinforced concrete in chloride environments: an overview, Constr. Build. Mater. 30 (2012) 125–138.
20. STEWART, M G, ROSOWSKY D V, Rosowsky, Time-dependent reliability of deteriorating reinforced concrete bridge decks, Struct. Saf. 20 (1) (1998) 91–109.
21. CAO C, CHEUNG M M S, Non-uniform rust expansion for chloride-induced pitting corrosion in RC structures, Constr. Build. Mater. 51 (2014) 75–81.
22. RASHID MD H, MOLLA MD K A, AND AHMED T U, "Mortar incorporating rice husk ash: strength and porosity," European Journal of Scientific Research, vol.40, no. 3, pp. 471-477, 2010.
23. OANH N T K, LY B. T, TIPAYAROM D, MANANDHAR B R, PRAPAT P, SIMPSON C D, AND LIU L J S, Characterization of particulate matter emission from open burning of rice straw; Atmos. Environ. 45, 493 (2011).
24. MUNSHI S AND SHARMA R P, Sulfate and carbonation reactivity in cement mortar incorporate with rice straw ash; Res. J. Chem. Environ. 21 (2017).
25. KADAM K L, FORREST L H, AND W. A. JACOBSON; Rice straw as a lignocellulosic resource: Collection, processing, transportation, and environmental aspects; Biomass Bioenergy 18, 369 (2000).
26. GOVINDARAO V M H, Utilization of rice husk- A preliminary analysis, J. Sci & Ind. Res., vol. 39, pp. 495-515, 1980.
27. E1-SAYED MD A EL-SAMNI AND T M, "Physical and chemical properties of rice straw ash and its effect on the cement paste produced from different cement types," J. King Saud Univ., vol. 19, Eng. Sci. (1), pp. 21-30, Riyadh, 2006.