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EFFECTS OF BIO-MASS BASED POZZOLANIC MATERIAL ON CHLORIDE ION PENETRATION IN CONCRETE

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Introduction

In this paper, the results of an experimental investigation on the effect of including Rice Husk Ash (RHA) on chloride ion diffusivity of concrete are presented. The objective of the study is to obtain the maximum level of RHA replacement to gain the maximum reduction of chloride ion diffusivity. Chloride diffusivity is a material parameter that is associated with the resistance of a certain material against the ingress of chloride ions into the concrete. Greater chloride diffusivity coefficients indicate lesser resistance towards chloride ion penetration and vice versa. Therefore by modifying the pore structure the capacity of the concrete to resist chloride penetration can be changed.

Materials and Methods

Rice husks burnt under controlled temperature produce a white ash containing amorphous silica. When activated by finely grinding the ash facilitates reaction with calcium hydroxide produced in the hydration of cement to form calcium silicate hydrates in the gel pores of the cement paste reducing the size of the pores therein (Newman and Choo, 2003). Out of all chloride ingress mechanisms the most appropriate for a non-water retaining structure and that considered in this study is the diffusion. Diffusion is driven by concentration gradients and requires a continuous liquid phase.

The scope of the investigation covers six water-cementitious material ratio (*w/cm*) ranging from 0.40 to 0.65 in steps of 0.05 and Ordinary Portland Cement (OPC) replacement in five RHA replacement levels from 0 to 20% in steps of 5%. Samples were cast using a mould 100mm Ø x200mm and two samples were cast for each *w/cm* ratio and RHA Replacement level. After 28 days of submerged curing, a 50mm thick slice was obtained from the middle portion of each cylinder. Then, the cylindrical surface of each specimen was coated twice with epoxy. The specimens were then vacuum saturated. Afterwards the samples were mounted on the Rapid Chloride Penetration Test(RCPT) apparatus and sealed with silicone. RCPT apparatus has two reservoirs with one filled with 3.0 % NaCl solution and in the other with 0.3M NaOH solution where a 60V DC potential was applied across each for 6 hours. The test originally developed by Whiting [1981], is commonly (though inaccurately) referred to as RCPT (Stanish et al., 1997). The name is inaccurate as it is not the permeability that is measured but ionic movement, and also, not only the movement of chloride ions but all ions. Since the RCPT test is widely accepted in the concrete industry, this test was used to evaluate the performance of the concrete.

Results

Average chloride penetration depths and average temperature of the two chambers were used to calculate the diffusivity coefficients of the test samples using a simplified equation provided in the Nord Test (Hooton et al., 1999) and Fick's 2nd law (Stanish et al., 1997) was used to evaluate the required concrete cover for 50 and 100 year service life of each of the test mixes.

$$Dnssm = \frac{\begin{array}{c}0.0239(273+T)L\times \\ \left\{Xd - 0.0238\sqrt{(273+T)L\left\{\frac{xd}{U-2}\right\}}\right\}\end{array}}{(U-2)t} \quad \text{eq1}$$

D_{nssm} - diffusivity coefficient(non-steady-state migration coefficient) / 10^{-12} *m²/s*;

U - applied potential, *V*;

T - temperature of solution, ^0C;

L - specimen thickness, *mm*;

x_d - average penetration depth, *mm*;

t - test duration, *h*.

Fick's 2nd law

$$C_x = C_s\left[1 - \text{erf}\left\{\frac{x}{2\sqrt{Dt}}\right\}\right] \text{ - eq 2}$$

Cx -chloride concentration at distance x, *kg/m³*;

x -distance from the exposed surface, *mm*;

Cs -surface chloride concentration, *kg/m³*;

D -chloride diffusion coefficient, x10^{-12} *m²/s*;

t -exposure time, *h*;

erf -error function.

Minimum values of Chloride threshold level (C_x) of 0.6 *kg/m³* and maximum value of 1.435 *kg/m³* was used for surface chloride concentration (C_s) to have maximum safety of recommended values.(Ghods et al.,2007)

Table 1. Chloride ion penetrability rating based on the charge passed(*C*)

w/cm	RHA%	Charge (*C*)	Permeability rating
0.40	0	5985	high
0.50	0	7434	high
0.60	0	4761	high
0.45	5	5188	high
0.55	5	6306	high
0.65	5	8757	high
0.40	10	2926	moderate
0.50	10	4274	high
0.60	10	5320	high
0.45	15	2683	moderate
0.55	15	4798	high
0.65	15	5352	high
0.40	20	823	very low
0.50	20	1508	low
0.60	20	1554	low

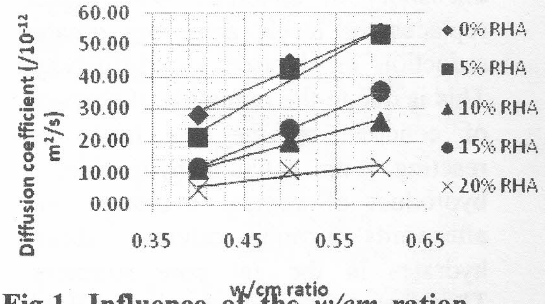

Fig.1. Influence of the *w/cm* ration and RHA replacement level on chloride ion diffusivity

Table 2. Concrete cover depth for concrete mixes for service life of 50 & 100 years

	for 50 year Service Life (*mm*)				
w/cm	**RHA Replacement**				
	0%	5%	10%	15%	20%
0.40	43	-	27	-	17
0.45	-	37	-	28	-
0.50	54	-	36	-	27
0.55	-	53	-	39	-
0.60	59	-	42	-	28
0.65	-	59	-	48	-
w/cm	**Cover for 100 year Service Life (*mm*)**				
0.40	61	-	38	-	25
0.45	-	52	-	39	-
0.50	76	-	51	-	38
0.55	-	75	-	56	-
0.60	84	-	59	-	39
0.65	-	84	-	68	-

Discussion

The results confirmed that the addition of RHA reduces the chloride ion diffusivity of concrete. With higher replacement levels achieving greater reduction in chloride ion diffusivity. This is due to the reduction of porosity of concrete by the rice husk ash reacting with calcium hydroxide, a byproduct of cement hydration and afterwards forming calcium silicate hydrates in the gel pore structure. Therefore, by the introduction of RHA the resistance of concrete against chloride attack can be enhanced, thereby reducing the required cover depth of concrete cover to steel reinforcement.

Conclusions

Low *w/cm* ratios indicate high strength concretes which naturally have a fine pore structure and are less permeable. Even in high *w/cm* ratio concretes, "low chloride ion permeability" rating is achieved at 20% RHA replacement. The lowest diffusivity coefficient was observed within the scope of the investigation at 20% RHA replacement. This reflects in the reduced amount of concrete cover depth.

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