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Study on Chloride Ion Penetration Resistance of Rubberized Concrete Under Steady State Condition

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Abstract. Foamed concrete is a controlled low density ranging from 400kg/m^3 to 1800kg/m^3, and hence suitable for the construction of buildings and infrastructures. The uniqueness of foamed concrete is does not use aggregates in order to retain low density. Foamed concrete contains only cement, sand, water and foam agent. Therefore, the consumption of cement is higher in producing a good quality and strength of foamed concrete. Without the present of aggregates, the compressive strength of foamed concrete can only achieve as high as 15MPa. Therefore, this study aims to introduce the pelletized coconut fibre aggregate to reduce the consumption of cement but able to enhance the compressive strength. In the experimental study, forty-five (45) cube samples of foamed concrete with density 1600kg/m^3 were prepared with different volume fractions of pelletized coconut fibre aggregate. All cube samples were tested using the compression test to obtain compressive strength. The results showed that the compressive strength of foamed concrete containing 5%, 10%, 15% and 20% of pelletized coconut fibre aggregate are 9.6MPa, 11.4MPa, 14.6MPa and 13.4MPa respectively. It is in fact higher than the controlled foamed concrete that only achieves 9MPa. It is found that the pelletized coconut fibre aggregate indicates a good potential to enhance the compressive strength of foamed concrete.

1 Introduction

Concrete structure exposed to aggressive environment such as marine environment and structure exposed to cold weather has tendency to received high penetration of chloride ion into concrete pores which leads to the corrosion of steel reinforcement. Corroded steel reinforcement tends to distress the concrete and high cost of repair and maintenance are required to overcome this problems. In this research, chloride transportation characteristics into concrete was studied on concrete with crumb rubber, CR as a fine aggregate in order to provide good resistance against chloride ion penetration. Study on used tire in concrete namely rubberized concrete started in early 1990's both on strength characteristics and durability performance. With the increasing of population and traffic, the utilization of used tire is important to controlled negative impact to the environment. Thus, this research was conducted to study the effectiveness of crumb rubber as constituent for concrete in providing good resistance against chloride ion penetration.

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2 Materials Preparation

2.1 Mix design

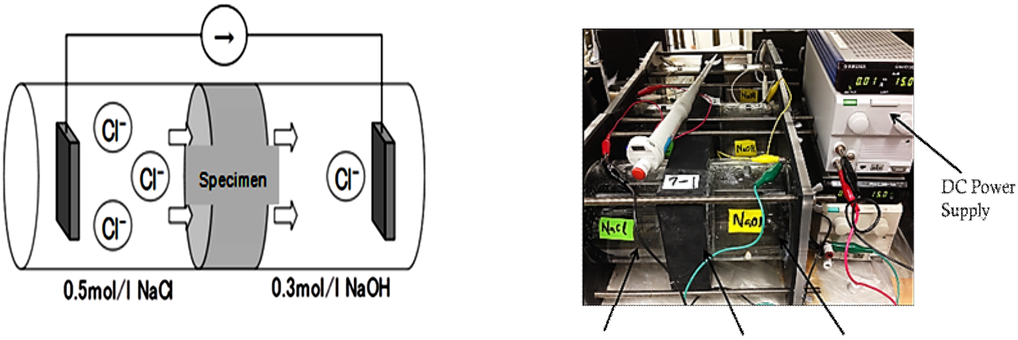
The mix design was divided into three main group of water to cement ratio, w/c as shown in Table 1. Each group contains CR at 0%, 10%, 15% and 20% and it was added in the concrete as sand replacement by volume. SF was substituted in the mixture with w/c = 35% in order to study the effectiveness of mineral admixture on strength and chloride ion diffusion. Mixing process was done in the controlled temperature room at 20^{o}C. Coarse aggregate was firstly added in the mixer, followed by binder and sand. CR and sand were mixed sufficiently until all CR completely added. All these materials was dry mixed and after 30 seconds, water was added and mixing was continued for an about 90 seconds. Then, mixer was stopped to allow hand mixing to ensure all materials in the mixer were homogeneously mixed. Mixing was finally continued for 60 seconds and stop, which makes total mixing time, became 3 minutes.

Table 1. Mix proportion of rubberized concrete.

				Water	Cement	Silica Fume	Sand	Crumb Rubber	Coarse Aggregates		Chemical Admixture		
Group	CR/(S+CR)	SF/C	w/c	W	C	SF	S	CR	G1	G2	Ether-based polycarboxylate superplasticizers	Air-entrained agent	Air-modifying agent
	(Vol %)	(%)					kg/m^3				%	%	%
Control	0	0	0.50	165	330	0	790	0	636	329	0.5	0.8	
10CR-0SF	10						711	35			0.5	0.8	
15CR-0SF	15						671	53			0.5	0.8	
Control	0	0	0.35	160	457	0	741	0	608	405	0.5	0.8	
10CR-0SF	10						667	34			0.5	0.8	
15CR-0SF	15						629	50			0.7	0.8	
20CR-0SF	20						594	67			0.7	0.7	
10CR-10SF	10	10	0.35	160	457	46	613	34	608	405	0.7		1.5
15CR-10SF	15						575	50			0.7		2.2
20CR-10SF	20						540	67			0.7		2.8

2.2 Steady state condition

Steady state condition is a process where chloride ion is allowed to migrate constantly into the pore solution of concrete under 15V voltage [2]. Figure 1 shows the migration cell in order to measure chloride, Cl^- ion that migrate from cathode towards anode and it achieved steady state condition when increment rate of Cl^- in anode side becomes constant in time as described in Figure 2. The starting sodium hydroxide, NaOH solution in the anode side is 0.5mol/L and 0.3mol/L of sodium chloride, NaCl in the cathode side. Along the testing process, the chloride ion concentration in the anode shall be less than 0.05mol/l, meanwhile as for cathode; the chloride ion concentration shall be more than 0.45mol/l. Solution was completely renewed if any side of anode or cathode solution did not meet this limitation. Test was carried out on Ø100 x 50mm thickness rubberized concrete, cut from cylindrical concrete of size Ø100 x 200mm length.



(b) Schematic diagram (a) Experimental setup

Figure 1. Migration cell.

Samples from the solution was taken to determine effective diffusion coefficient, D_e by using Nernst-Planck equation,

$$D_e = \frac{J_{Cl} RTL}{|Z_{cl}| FC(\Delta E - \Delta E_C)} .100 \tag{1}$$

where, D_e is effective diffusion coefficient in cm^2/year, R is gas constant = 8.31J/mol K, T is absolute temperature in K units, Z_{Cl} is charge of chloride ion = -1, F is the Faraday constant = 96,500 C/mol, C_{Cl} is measured chloride ion concentration in cathode side in mol/l, ΔE-ΔE_c is electrical potential difference between specimen surfaces in V and L is specimen length in mm.

3 Results and Discussion

Results of D_e are shown in Figure 2 to Figure 5. It was clearly seen that when CR is added in all mixture, resistance against chloride ion migration into the pore solution of concrete was improved. Even though, the effect in each group was slightly reduce due to small amount of CR replacement by volume, but the ability of CR in improving chloride transport characteristics cannot be neglected.

More than 50% of D_e reduction was observed in w/c = 0.50 when 10% CR was added compared to control mixture as shown in Figure 3. When w/c was reduced from 50% to 35%, the resistance against chloride penetration was much improved from 1.538cm^2/year to 0.434cm^2/year due to the increasing of binder in concrete that leads to dense concrete. The D_e in 35% w/c mix kept decreasing slightly with the increasing of CR as shown in Figure 4.

The highest resistance was observed when 10% SF was used as additional binder and the reduction was about 60% to 65% in comparison to control mix as shown in Figure 5. The ultrafine particles of SF allowed voids between cement particles and aggregate to be filled by SF [3]. This led to the porosity reduction and provides denser concrete. In addition, results on compressive strength were presented together with the D_e and according to the literature, relationship between chloride ion migration through pore solution of concrete and compressive strength is linked to the pore structure of the rubberized concrete [4]. From this relationship, it indicates that the pore structure of the rubberized concrete was still under accepted level; where positive improvement in chloride ion transport was observed even though compressive strength was reduced.

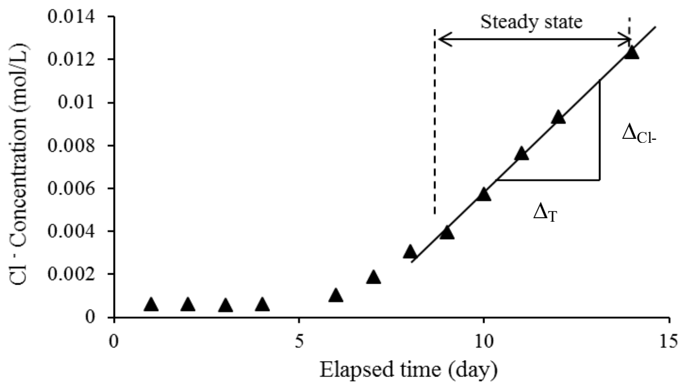


Figure 2. Steady state condition of chloride ion migration test.

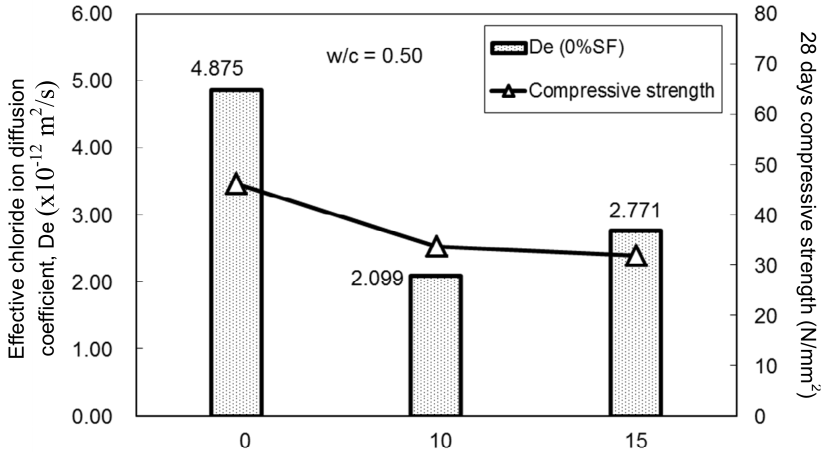


Figure 3. Effective diffusion coefficient and 28 days compressive strength of rubberized concrete with w/c = 0.50 (without SF).

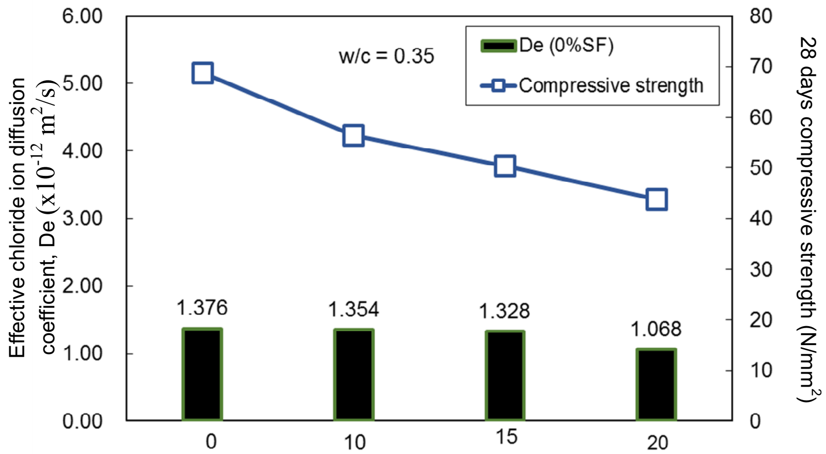


Figure 4. Effective diffusion coefficient and 28 days compressive strength of rubberized concrete with w/c = 0.35 (without SF).

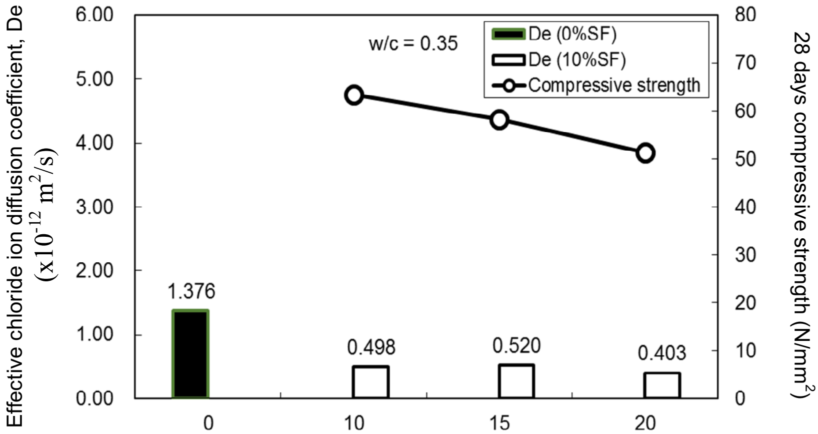


Figure 5. Effective diffusion coefficient and 28 days compressive strength of rubberized concrete with w/c = 0.35 (with 10% SF).

4 Conclusions

Several conclusions can be drawn from this research as follows,

i) Effect of the CR in rubberized concrete was clearly seen in w/c=0.50 and mix with SF in w/c=0.35.
ii) Chloride transport characteristics were improved by increasing amount of CR due to the fact that CR has the ability to repel water.
iii) Resistance of rubberized concrete against chloride ion was much improved when 10% SF was added as a binder.
iv) It was observed that compressive strength was reduce to 43% in 20% CR replacement without SF but it increasing slightly with the present of SF.

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