



## Research Article

# Observation of chloride permeability between normal aggregates concrete and recycled aggregates concrete containing fly ash and clay

Md. Shafiqul Islam, Pronab Kanti Baul\*, Oarda Haque

Department of Civil Engineering, Rajshahi University of Engineering & Technology, 6402 Rajshahi, Bangladesh

## ABSTRACT

Recycling of concrete is needed based on environmental preservation and effective utilization of resources point of view. Chloride attack has become a major concern in modern construction. Chloride ion is very dangerous for concrete structures because it leads to corrosion of the reinforcements in concrete. Many researchers have carried out numerous investigations on the chloride permeability of normal aggregates concrete. The purpose of this paper is to compare the chloride permeability between normal aggregates concrete and recycled aggregates concrete containing fly ash and clay. Water absorption in recycled aggregates concrete is also shown. The cylindrical concrete specimens made with recycled aggregates were subjected to high chloride permeability. Clay and ash were mixed in separate specimens in different proportions to reduce the porosity of concrete and hence to decrease the chloride permeability. The objective of this paper is to show the decrease chloride permeability in recycled aggregates concrete which is almost same for normal aggregates concrete and to make a relationship between water absorption and chloride permeability.

## ARTICLE INFO

### Article history:

Received 1 November 2018

Accepted 15 December 2018

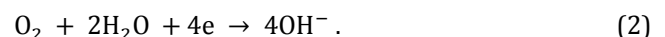
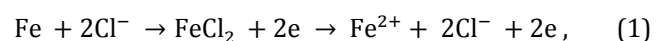
### Keywords:

Normal aggregates concrete  
Recycled aggregates concrete  
Short time absorption  
Long time absorption  
Chloride permeability

## 1. Introduction

Nowadays recycling of demolition concrete is beneficial and necessary from the viewpoint of environmental preservation and effective utilization of resources. Although it has proved that some properties of recycled aggregates concrete may be generally lower than those of normal concrete, they are still sufficient for practical application in some constructions and buildings. To make this technology feasible, a significant amount of experimental works has been conducted on mechanical properties of recycled concrete with the focus on the compressive, the tensile and the flexural strengths, the bond strength, and elastic modulus of recycled concrete.

As the research of recycled concrete proceeds, some have paid attention to its durability and found that one of the key factors determining the durability of recycled concrete is the free chloride ion, for it lowers the compressive strength and accelerates the corrosion of rebar in recycled aggregates concrete. When free chloride ion, oxygen and water all exist at the surface of rebar, the chemical reaction occurs as:



$\text{Fe}^{2+}$  could combine with  $\text{OH}^-$  in the water to produce  $\text{Fe}(\text{OH})_2$  which would expand and destroy the concrete.

## 2. Experimental Description

### 2.1. Materials

The materials required for performing the project were procured. About 10 kg of coarse aggregates (20 mm passing and 4.75 mm retained), 5 kg of fine aggregates (passing 4.75 mm) and about 5 kg of 53 grade cement and 10 kg of recycled aggregates were procured. Preliminary tests on properties of these ingredients were done as per ACI procedures and the results are as follows:

Table 1 shows the properties of the used cement. Table 2 shows the properties of coarse aggregates, fine aggregates, recycled aggregates used.

\* Corresponding author. Tel.: +880-17-38932954; E-mail address: pronabkantibaul@gmail.com (P. K. Baul)

**Table 1.** Properties of cement.

Cement grade	Cement grade : 53 grade OPC [ACI 318:21.10.3.4]
Fineness	7.33% [ACI 211.1-91]
Specific gravity	3.04 [ACI 318:1904.2.2]

**Table 2.** Properties of coarse aggregates, recycled aggregates and fine aggregates.

Coarse aggregates	Fineness modulus	8.73 [ACI 211.1-91]
	Specific gravity	2.79 (20 mm) [ACI 211.1-91]
	Water absorption value	0.5% [ASTM C 128]
Recycled aggregates	Fineness modulus	9.3 [ACI 211.1-91]
	Specific gravity	2.85 (20 mm) [ACI 211.1-91]
	Water absorption value	12.59% [ASTM C 128]
Fine aggregates	Fineness modulus	2.585 [ACI 211.1-91]
	Specific gravity	2.71 [ACI 211.1-91]
	Water absorption value	NIL [ASTM C 128]

## 2.2. Mixture proportions

A normal mix ratio of 1:2:4 (Cement: Fine Aggregates: Coarse Aggregates) was adopted for the purpose of this work and a water-cement ratio of 0.5 was used. A cylindrical mould of 4 inch diameter and 8 inch height was used. Volume of cylindrical mould was calculated and then dry volume of mould was calculated. Weights

of aggregates were calculated from the mixing ratio. Three specimens were made, two of them containing recycled aggregates (20% of normal aggregates by weight) with normal aggregates and one containing normal aggregates. Between the two specimens, one of them containing clay (25% of sand by weight) and one of them containing clay (25% of sand by weight). Table 3 shows the mix proportions of concrete used in this study.

**Table 3.** Mix proportions of concrete.

Sample	Cement (kg)	Sand (kg)	Brick khoa (kg)	Recycled aggregates (kg)	Clay (kg)	Fly ash (kg)
01	0.85	1.275	2.55	0.85	0.425	0
02	0.85	1.275	2.55	0.85	0	0.425
03	0.85	1.7	3.4	0	0	0

## 2.3. Short and long term absorption

Coating was applied on all the surfaces except one surface in samples 01, 02 and 03, respectively. So, water was forced to pass along the non-coated surface only. For short term absorption, weight of specimen was taken for 24 hours in interval of one hour. For long term absorption, weight of specimen was taken for 30 days in interval of one day. Fig. 1 shows the specimens immersed in water tank.

## 2.4. Cutting of specimen for chloride permeability test

Two inch circular disks from samples 01, 02 and 03 were made for chloride permeability test as shown in Fig. 2.

**Fig. 1.** Specimen in water.



Fig. 1. Making the circular disk.

2.5. Chloride permeability test

For chloride permeability test, a device was made which consists of two containers as shown in Fig. 3(a).

One container was filled with 3% NaCl solution and other container was filled up with 0.3 N NaOH solution. The device was connected with multimeter and voltmeter as shown in Fig. 3(b). M seal was used for making the whole system water proof. Each specimen took 6 hours to complete this test. To calculate the charge passed in coulomb, the following formula was used.

$$Q = I \times t, \tag{3}$$

where  $Q$  is charge flowing through one cell (coulombs),  $I$  is current reading in amperes immediately after voltage is applied, and  $t$  is time in seconds.

Table 4 shows chloride permeability rating as per ASTM C 1202.

Table 4. Chloride Permeability Rating as per ASTM C 1202.

Charge passed (coulombs)	Chloride permeability
>4000	High
2000-4000	Moderate
1000-2000	Low
100-1000	Very low
<100	Negligible

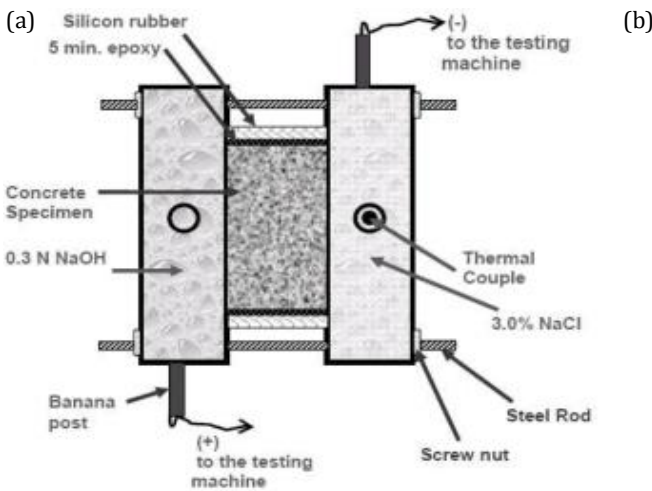


Fig. 3. (a) Experimental setup of chloride permeability test; (b) Practical set up of chloride permeability test.

3. Results and Discussions

3.1. Short term absorption

Table 5 shows the short term absorption test results for Recycled Aggregates Concrete (RAC) with clay, Recycled Aggregates Concrete (RAC) with fly ash and Normal Aggregates Concrete (NAC).

From Fig. 4, it is clear that short term water absorption of RAC (clay) is more than that of NAC but short term water absorption of RAC (fly ash) is very near to that of NAC.

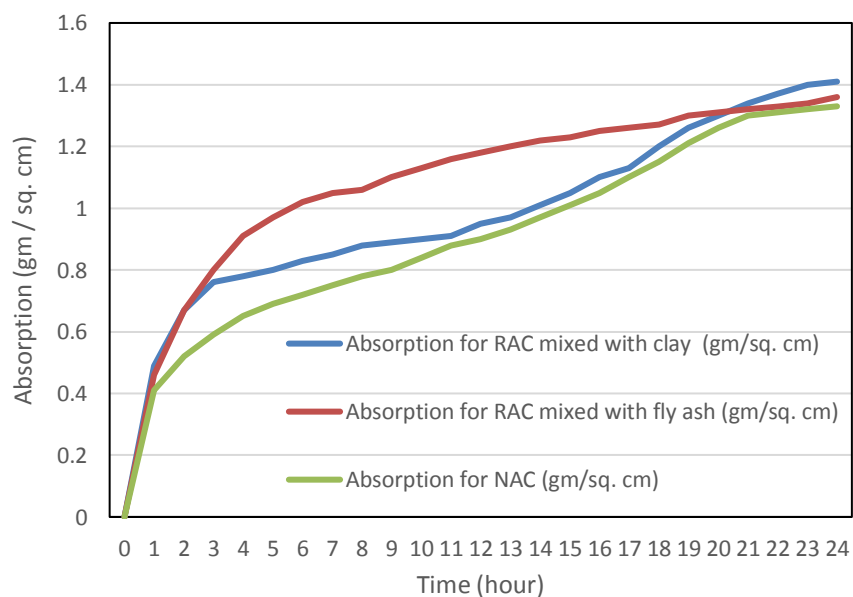
3.2. Long term absorption

Table 6 shows long term absorption test results for Recycled Aggregates Concrete (RAC) with clay, Recycled Aggregates Concrete (RAC) with fly ash and Normal Aggregates Concrete (NAC).

From Fig. 5, it is clear that long term water absorption of RAC (clay) is more than that of NAC but short term water absorption of RAC (fly ash) is very near to that of NAC.

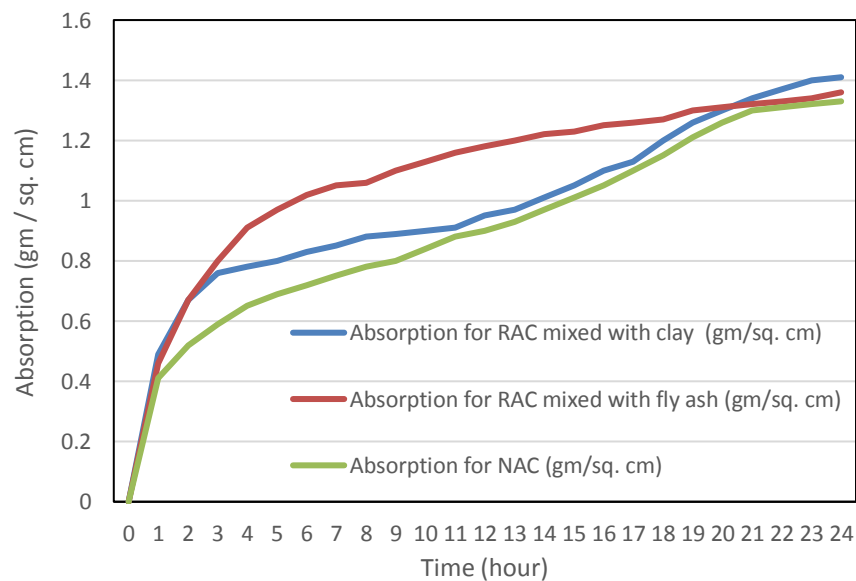
**Table 5.** Short term absorption test results.

Time (hour)	Absorption for RAC mixed with clay (gm/sq. cm)	Absorption for RAC mixed with fly ash (gm/sq. cm)	Absorption for NAC (gm/sq. cm)
0	0	0	0
01	0.49	0.46	0.41
02	0.67	0.67	0.52
03	0.76	0.80	0.59
04	0.78	0.91	0.65
05	0.80	0.97	0.69
06	0.83	1.02	0.72
07	0.85	1.05	0.75
08	0.88	1.06	0.78
09	0.89	1.10	0.80
10	0.90	1.13	0.84
11	0.91	1.16	0.88
12	0.95	1.18	0.90
13	0.97	1.20	0.93
14	1.01	1.22	0.97
15	1.05	1.23	1.01
16	1.10	1.25	1.05
17	1.13	1.26	1.10
18	1.20	1.27	1.15
19	1.26	1.30	1.21
20	1.30	1.31	1.26
21	1.34	1.32	1.30
22	1.37	1.33	1.31
23	1.40	1.34	1.32
24	1.41	1.36	1.33

**Fig. 4.** Variation of short term water absorption of RAC (clay) and RAC (fly ash) with NAC.

**Table 6.** Long term absorption test results.

Time (day)	Absorption for RAC mixed with clay (gm/sq. cm)	Absorption for RAC mixed with fly ash (gm/sq. cm)	Absorption for NAC (gm/sq. cm)
0	0	0	0
01	0.9	1.23	0.85
02	1.26	1.81	1.16
03	1.71	1.85	1.65
04	1.89	1.89	1.73
05	1.97	1.92	1.80
06	2.01	1.96	1.85
07	2.06	1.99	1.89
08	2.07	2.00	1.92
09	2.08	2.02	1.94
10	2.11	2.04	1.96
11	2.15	2.05	1.98
12	2.16	2.06	2.00
13	2.17	2.07	2.01
14	2.19	2.08	2.02
15	2.20	2.09	2.03
16	2.21	2.10	2.04
17	2.22	2.11	2.05
18	2.23	2.12	2.06
19	2.24	2.13	2.07
20	2.26	2.15	2.09
21	2.27	2.16	2.10
22	2.28	2.17	2.11
23	2.29	2.18	2.13
24	2.30	2.19	2.14
25	2.31	2.20	2.15
26	2.32	2.21	2.16
27	2.33	2.22	2.17
28	2.34	2.23	2.18
29	2.35	2.24	2.19
30	2.36	2.25	2.20

**Fig. 5.** Variation of long term water absorption of RAC (clay) and RAC (fly ash) with NAC.

**3.3. Chloride permeability**

Table 7 shows chloride permeability test data. Fig. 6 shows the Variation of chloride permeability for RAC (clay) and RAC (fly ash) with NAC.

From Chloride Permeability Rating as per ASTM C 1202, chloride permeability of NAC is low and chloride permeability of RAC (clay), RAC (fly ash) is moderate (Fig. 6).

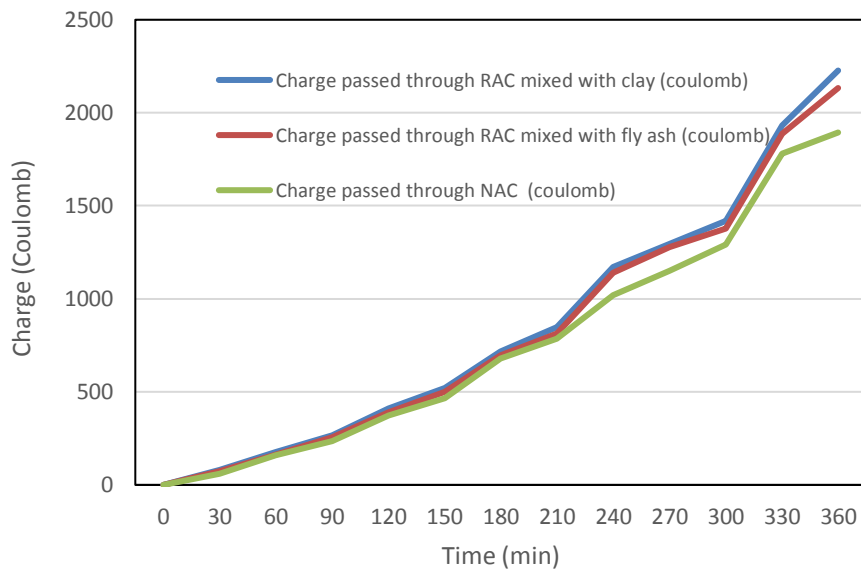
**3.4. Relation between water absorption and chloride permeability**

Relation between chloride permeability and water absorption due to admixture effect follows the equation:

$$y = 4309.6 \ln(x) - 1446.4 \quad (3)$$

**Table 7.** Chloride permeability test results.

Time (min)	Charge passed through RAC mixed with clay (coulomb)	Charge passed through RAC mixed with fly ash (coulomb)	Charge passed through NAC (coulomb)
0	0	0	0
30	81	75	61
60	177	164	159
90	265	255	236
120	411	389	374
150	521	501	466
180	716	695	679
210	849	813	786
240	1172	1139	1020
270	1295	1277	1150
300	1418	1378	1290
330	1933	1888	1781
360	2227	2133	1894



**Fig. 6.** Variation of chloride permeability for RAC (clay) and RAC (fly ash) with NAC.

**4. Conclusions**

The objective of this paper is to reduce the chloride permeability of RAC which is almost same for chloride permeability of NAC by mixing clay and fly ash separately. Chloride permeability of NAC is 1894 coulombs and chloride permeability of RAC (clay) and RAC (fly ash) is 2227

coulombs and 2133 coulombs respectively. From Chloride Permeability Rating as per ASTM C 1202, chloride permeability of NAC is low and chloride permeability of RAC (clay) and RAC (fly ash) is moderate. From results it is clear that absorption is almost constant after some time but chloride permeability increases with time and chloride permeability varies with water absorption logarithmically.

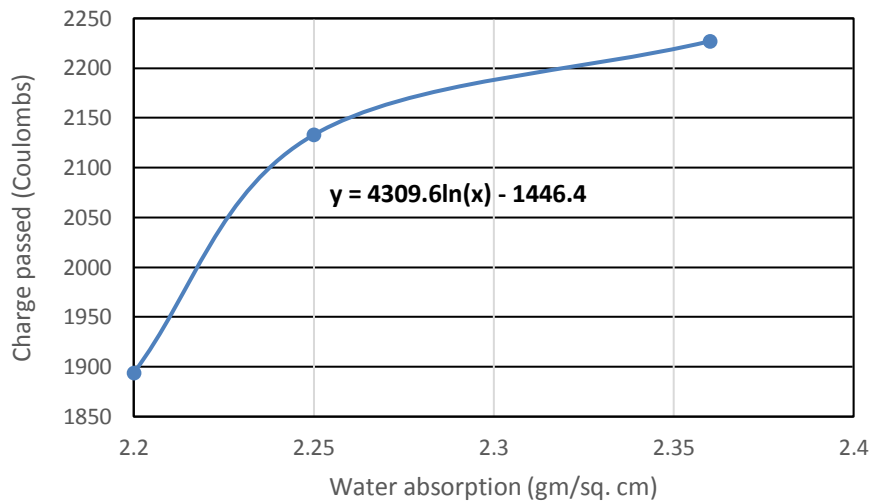


Fig. 7. Relation between chloride permeability and water absorption due to admixture effect.

### Acknowledgements

We want to express our gratitude to those who supported and helped vigorously to complete the research. We would never have been able to finish our thesis without the guidelines of our research supervisor, Md. Shafiqul Islam, Professor, Department of Civil Engineering, Rajshahi University of Engineering & Technology (RUET), 6204 Rajshahi, Bangladesh. We would like to express our gratitude to our research supervisor for his constructive suggestion, persistent encouragement, valuable advice, inspiration, constant guidance, patience and commendable guidance through the time.

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