Journal of Marine Science and Technology

Volume 20 | Issue 3 Article 6

THE RELATIONSHIP BETWEEN MIGRATION TIME IN ACMT AND PONDING TIME IN PONDING TEST FOR CEMENTITIOUS MATERIALS

Chung-Chia Yang
Institute of Materials Engineering, National Taiwan Ocean University, Keelung, Taiwan, R.O.C., ccyang@mail.ntou.edu.tw

Yu-Ming Tsai
Institute of Materials Engineering, National Taiwan Ocean University, Keelung, Taiwan, R.O.C.

Kuo-Cheng Yang
Department of Mechanical and Mechatronic Engineering, National Taiwan Ocean University, Keelung, Taiwan, R.O.C.

Recommended Citation
Yang, Chung-Chia; Tsai, Yu-Ming; and Yang, Kuo-Cheng (2012) "THE RELATIONSHIP BETWEEN MIGRATION TIME IN ACMT AND PONDING TIME IN PONDING TEST FOR CEMENTITIOUS MATERIALS," *Journal of Marine Science and Technology*: Vol. 20: Iss. 3, Article 6.
DOI: 10.51400/2709-6998.1805
Available at: https://jmstt.ntou.edu.tw/journal/vol20/iss3/6

Journal of Marine Science and Technology, Vol. 20, No. 3, pp. 281-289 (2012)

THE RELATIONSHIP BETWEEN MIGRATION TIME IN ACMT AND PONDING TIME IN PONDING TEST FOR CEMENTITIOUS MATERIALS

Chung-Chia Yang[1], Yu-Ming Tsai[1], and Kuo-Cheng Yang[2]

Key words: ACMT, Ponding test, Migration time.

ABSTRACT

The objective of this study is to investigate the relationship between the diffusion behaviors of chloride ions and the migration of chloride ions in the cementitious materials. Different kinds of mortars with different binder combination (fly ash, slag and fly ash plus slag) and w/b ratios (w/b = 0.35, 0.45, 0.55, and 0.65) were used. In this study, the diffusion test and the migration test were carried out with the ponding test (AASHTO T259) and the accelerated chloride migration test (ACMT), respectively. The chloride profiles were obtained under different ponding time with ponding test and different migration time with ACMT. The penetration depth of chloride ions was obtained from the chloride profile. The testing time relation between ponding and ACMT was determined, when they were the same penetration depth. The experimental result shows a good linear relationship between the ponding time from ponding test and migration time from ACMT.

I. INTRODUCTION

Reinforced concrete structure is constructed by steel and concrete, and the steel is embedded in concrete, then the chloride ions will not easily penetrate into the structure and result in the corrosion reaction with steel. The oxide compound generated in the corrosion reaction will expand the volume of steel, and then the cracks will be found in or on the structure. Especially under the extremity circumstances, like the marine environment. There has higher chloride concentration in the air than other place, that makes the chloride diffuse faster, decreases the service life a lot, and the cracks show up very early, the cost needed to rehabilitate deteriorated concrete structure is tremendous [10].

In 1999, the “International conference on ion and mass transport in cement-based materials”, Cickley [5] indicated that the following questions should be able to answer:

1. How to make concretes that are immune to these interlopers (ionic species), (durability).
2. How to calculate our structures will last (service life prediction).
3. How to determine the service life in the field at early age so could accept or reject structure (testing).

Salt ponding test (AASHTO T259-80 [1]) and rapid chloride penetration test (RCPT, ASTM C1202-00 [4]) are widely used to evaluate the quality of concrete. Salt ponding test is the simulation of nature diffusion, and has longer test period [8]; RCPT accelerates the transport ions by an external electrical field, and record the total amount of charge passed in 6 hours. However, some defects have been point out by many researchers [3, 7, 9, 12], and Hooton [7] and Andrade [3] indicated that the higher electrical potential (60 volts) applied in RCPT generating the heat which may affect the flow speed, it’s so-called as Joule effect. McCarter *et al*. [9] announced that the conductivity of the free pore fluid increases with temperature raised. Wee [12] also reported that the concrete containing mineral admixture such as silica fume or Ground Granulated Blast-furnace Slag (GGBS) affect the charge passed in RCPT because of the depletion of hydroxide ions in pozzolanic reaction. To avoid the problems have mentioned, modifying the test became as the accelerated chloride migration test (ACMT), decreasing the electrical potential from 60 volts to 24 volts; the NaOH and NaCl solution were compartmented and were filled with 4500 ml solution, both adjustment reducing the Joule effect and several studies [6, 11, 13] had used the electrical migration method.

The objective of this study is to analyze the time relationship between the ponding time in ponding test and migration time in ACMT by testing the non-steady state diffusion result for the mortars contenting three kinds of mineral admixture

Paper submitted 03/25/11; revised 10/04/11; accepted 12/13/11. Author for correspondence: Chung-Chia Yang (e-mail: ccyang@mail.ntou.edu.tw)
[1] Institute of Materials Engineering, National Taiwan Ocean University, Keelung, Taiwan, R.O.C.
[2] Department of Mechanical and Mechatronic Engineering, National Taiwan Ocean University, Keelung, Taiwan, R.O.C.

Table 1. Mix design (Kg/m^3).

Mix	w/b	water	cement	Fly ash	Slag	Fine aggregate	S. P.
MF35	0.35	222.6	547.8	137.0	0	1380.5	3.4
MF45	0.45	258.5	475.4	118.9	0	1369.7	3.0
MF55	0.55	288.6	419.8	104.9	0	1360.7	0
MF65	0.65	306.9	377.7	94.4	0	1360.7	0
MS35	0.35	227.3	419.7	0	279.8	1380.9	3.5
MS45	0.45	261.8	365.2	0	243.5	1377.6	0
MS55	0.55	293.3	319.9	0	213.3	1360.7	0
MS65	0.65	311.4	287.4	0	191.6	1360.7	0
MSF35	0.35	225.3	485.2	62.4	145.6	1380.8	3.5
MSF45	0.45	261.3	420.4	54.1	126.1	1369.7	3.0
MSF55	0.55	291.3	370.7	47.7	111.2	1360.7	0
MSF65	0.65	309.5	33.3	42.8	100.0	1360.7	0

(fly ash, slag and fly ash plus slag) and four different w/b ratios. The experimental results can be charted as exponential form equation, and comparing the penetration depth in ACMT and ponding test, then there would come out a time relationship between two test procedures.

II. EXPERIMENTAL PROGRAM

1. Materials and Mix Proportions

ASTM Type I Portland cement (specific gravity: 3.15), class F fly ash (specific gravity: 2.12), and slag (specific gravity: 2.79) were used as binder. River sand was used as fine aggregate (fineness modulus: 3.05) in this study. The first letter "M" means mortar specimen; the second-three letters "S, F, SF" stand for the mineral additives, slag, fly ash and slag plus fly ash, respectively; and the numbers represent the w/b ratios. For F series, the mix is 20% fly ash to replace Portland cement by weight, 40% of slag replaced cement by weight for S series, 21% of slag and 9% of fly ash replaced cement by weight for SF series mix. The proportions of the mortars are listed in Table 1. For each cylindrical specimen (ø100 × 200 mm) was cast and cured. After demolding, the specimens were cured in water (23 degree) for 365 days.

2. Experimental Procedure

1) Accelerated Chloride Migration Test (ACMT)

The specimens of 50 mm-thick slices were sawn out from the mid-portion of the cylinders and vacuum saturated according to ASTM C1202 [4]. A schematic diagram of the test set-up is illustrated in Fig. 1. The specimen was placed between two solution cells. The anode and the cathode cell were filled with 4.5 liter of 0.3 mole/L NaOH solution and 4.5 liter of 0.52 mole/L (3%) of NaCl solution respectively. Two brass meshes were placed beside the specimen as the electrodes (10 cm diameter, #20 mesh). 24 volts of electrical field was applied to accelerate chloride ion migrate from cathode to anode.

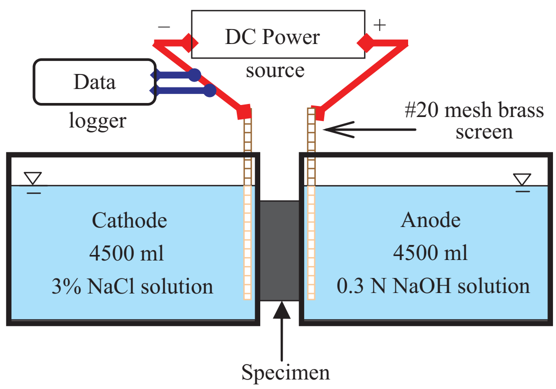

Fig. 1. The diagram of ACMT.

In this investigation, two experimental procedures were carried out for chloride analysis. One of the procedures is to measure the quantity of chloride ions passing through the specimen in anode cell and determined periodically using potentiometric titration. The breakthrough time was determined from the chloride concentration-time curve. The other experimental procedure is to measure the chloride penetration profile of mortar specimen in non-steady-state. Different accelerated migration times less than the breakthrough time (t_b) were used. After completion of the migration test of ACMT, the specimen was taken out from the acrylic cells and allowed to dry. In order to avoid the adhesion of salt crystal on the exposed chloride surface, the surface of each specimen was wire brushed until all salt crystal buildup completely removed. Fig. 2 shows that three cuboid specimens (2 cm × 2 cm × 5 cm) were obtained by cutting from the ACMT specimen (ø100 × 50 mm), and each cuboid specimen was dry cut from the exposed to chloride surface for every 5-mm. The slices specimen were then dried at 105°C to constant mass and grounded to pass through a 300-μm sieve.

The total chloride content of the powder sample was analyzed according to the specification in AASHTO T260-97 [2].

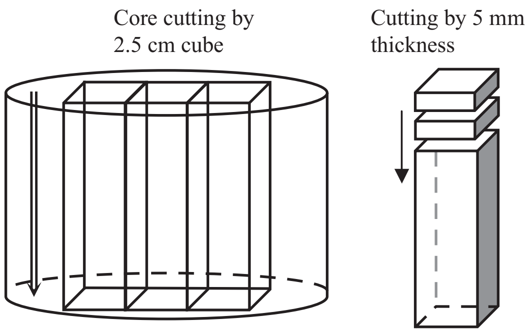

Fig. 2. The illustrated of slice cutting from ACMT specimen.

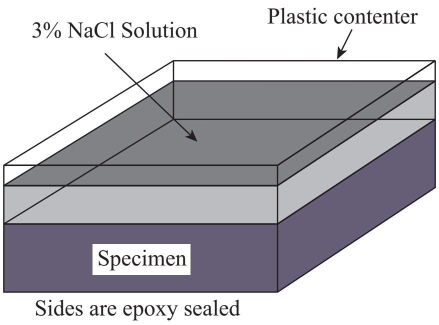

Fig. 3. The diagram of ponding test.

2) Ponding Test

According to Salt Ponding test (AASHTO T259-80 [1]), the sketch of the test apparatus are shown in Fig. 3. Specimen was required at least 75 mm thickness and a surface area was over 300 mm exposed to NaCl solution. The sides of the specimen are sealed with epoxy except the bottom and top area that ensures one-dimensional chloride diffusion. Four ponding time, 60 days, 90 days, 120 days, and 180 days, are used in this study. After exposure, the test procedure to obtain the chloride penetration profile is the same as the ACMT.

III. RESULT AND DISCUSSION

1. Accelerated Chloride Migration Test

1) Transmission Steps in ACMT

In the process of ACMT, chloride ion gradual penetrate through specimen, and reach to the cathode cell, Fig. 4 shows the variation of concentration in the cathode cell, which could separate into four steps during the process:

(1) Non-steady state: Chloride ions were not penetrated through specimen, still migrate in specimen, the time-span in this step depends on the specimen thickness, admixture, and migration field. This study focus on the observation of non-steady state.

(2) Transition period: It begins when chloride ion show up in the cathode cell, the relation between time and chloride concentration is non-linear.

Table 2. Breakthrough time and migration time in ACMT.

Breakthrough time and migration time in ACMT (hour)					
Mix	t_b	0.05 t_b	0.1 t_b	0.2 t_b	0.3 t_b
MS35	407.9	20.4	40.8	81.6	122.4
MS45	324.8	16.2	32.5	65.0	97.4
MS55	217.2	10.9	21.7	43.4	65.2
MS65	154.3	7.7	15.4	30.9	46.3
MF35	344.4	17.2	34.4	68.9	103.3
MF45	318.6	15.9	31.9	63.7	95.6
MF55	230.3	11.5	23.0	46.1	69.1
MF65	185.1	9.3	18.5	37.0	55.5
MSF35	450.8	22.5	45.1	90.2	135.2
MSF45	313.6	15.7	31.4	62.7	94.1
MSF55	234.3	11.7	23.4	46.9	70.3
MSF65	176.4	8.8	17.6	35.3	52.9

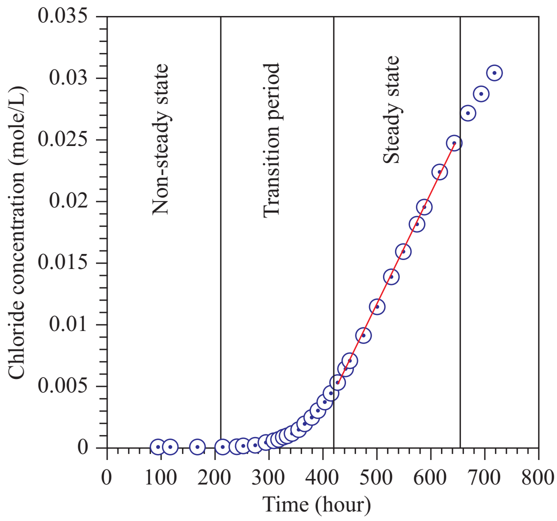

Fig. 4. Four steps of ACMT procedure.

(3) Steady state: Chloride ion passing through specimen steadily, the relation between time and chloride concentration become constant.

(4) Attenuate stage: Chloride ion transmission is retarded, the difference of chloride concentration in two cells becomes approach.

2) Define the Penetration Time and Migration Time in ACMT

When chloride ion penetrates through 5 cm specimen, chloride ion can be measured in the cathode cell. The chloride concentration in anode cell of C_0/C_0 = 0.01% (C is the concentration in cathode cell, C_0 is the initial chloride concentration in anode cell) was used as the average chloride front reached the surface of specimen in side of anode-cell to determine the breakthrough time (t_b) in this study.

After define each breakthrough time for different mixes, multiplied the value by 0.05, 0.1, 0.2, and 0.3 as the migration time in ACMT. Table 2 shows all migration time for different mixes.

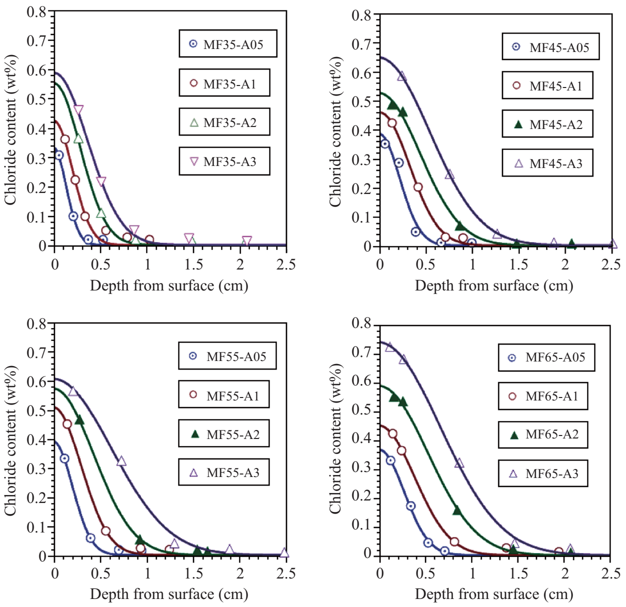

Fig. 5. F serials for different migration time.

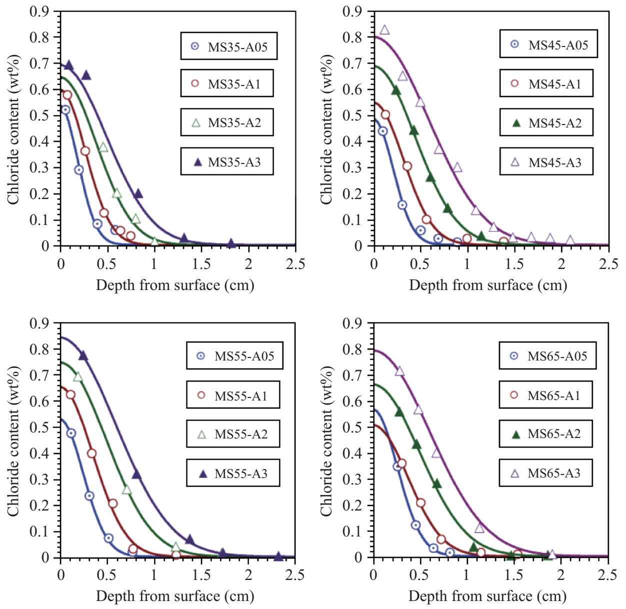

Fig. 6. S serials for different migration time.

3) Chloride Migration Depth vs. Concentration for Different Migration Time

After processed different migration time in ACMT, the non-steady result can be charted as chloride concentration vs. penetration depth (Figs. 5, 6, and 7). The chloride penetration profile was determined by collecting the powder samples at selected depth from exposed chloride surface to inner of specimen, and the total chloride content was analyzed in accordance with AASHTO T260. Since the chloride concentration at selected depth in specimen was not continually measured, and in order to obtain two parameters of surface

Table 3. Coefficients from curve fitting in ACMT.

Specimen No.	C_s (%)	A ($\times 10^{-6}$ s/cm^2)	Specimen No.	C_s (%)	A ($\times 10^{-6}$ s/cm^2)
MF35-A05	0.332	0.608	MS35-A05	0.533	1.08
MF35-A1	0.422	0.646	MS35-A1	0.595	0.995
MF35-A2	0.550	0.641	MS35-A2	0.643	1.02
MF35-A3	0.585	0.706	MS35-A3	0.689	1.09
MF45-A05	0.385	1.72	MS45-A05	0.482	1.53
MF45-A1	0.458	1.74	MS45-A1	0.546	1.73
MF45-A2	0.525	1.69	MS45-A2	0.686	1.69
MF45-A3	0.646	1.74	MS45-A3	0.797	1.96
MF55-A05	0.390	2.03	MS55-A05	0.528	3.29
MF55-A1	0.507	2.15	MS55-A1	0.651	3.13
MF55-A2	0.571	2.25	MS55-A2	0.745	3.08
MF55-A3	0.604	2.26	MS55-A3	0.841	3.01
MF65-A05	0.366	4.41	MS65-A05	0.564	4.96
MF65-A1	0.450	4.44	MS65-A1	0.504	4.99
MF65-A2	0.587	4.21	MS65-A2	0.660	4.49
MF65-A3	0.738	4.40	MS65-A3	0.791	4.41
MSF35-A05	0.533	0.885	MSF55-A05	0.435	3.18
MSF35-A1	0.581	0.903	MSF55-A1	0.464	3.08
MSF35-A2	0.751	0.834	MSF55-A2	0.688	2.91
MSF35-A3	0.827	0.903	MSF55-A3	0.846	2.93
MSF45-A05	0.614	1.56	MSF65-A05	0.588	4.48
MSF45-A1	0.696	1.51	MSF65-A1	0.631	4.44
MSF45-A2	0.620	1.49	MSF65-A2	0.690	4.16
MSF45-A3	0.756	1.52	MSF65-A3	0.682	4.31

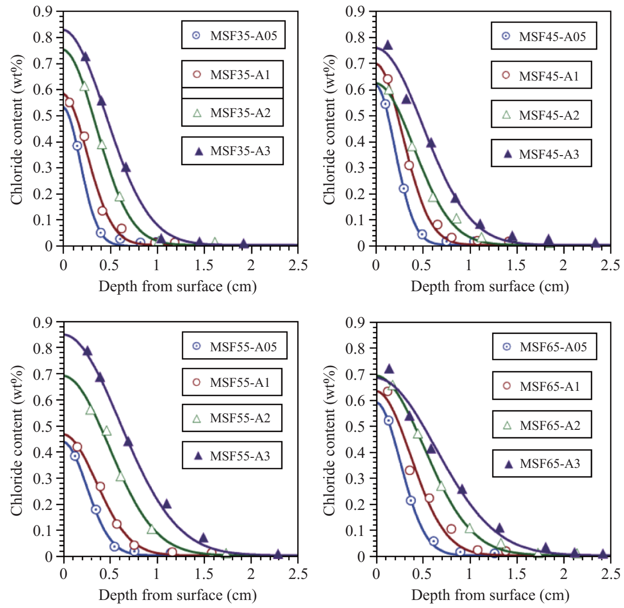

Fig. 7. SF serials for different migration time.

chloride content and the ability of resist chloride penetration of specimen, the experimental data in Figs. 5, 6, and 7 is fitted by using a non-linear regression analysis as:

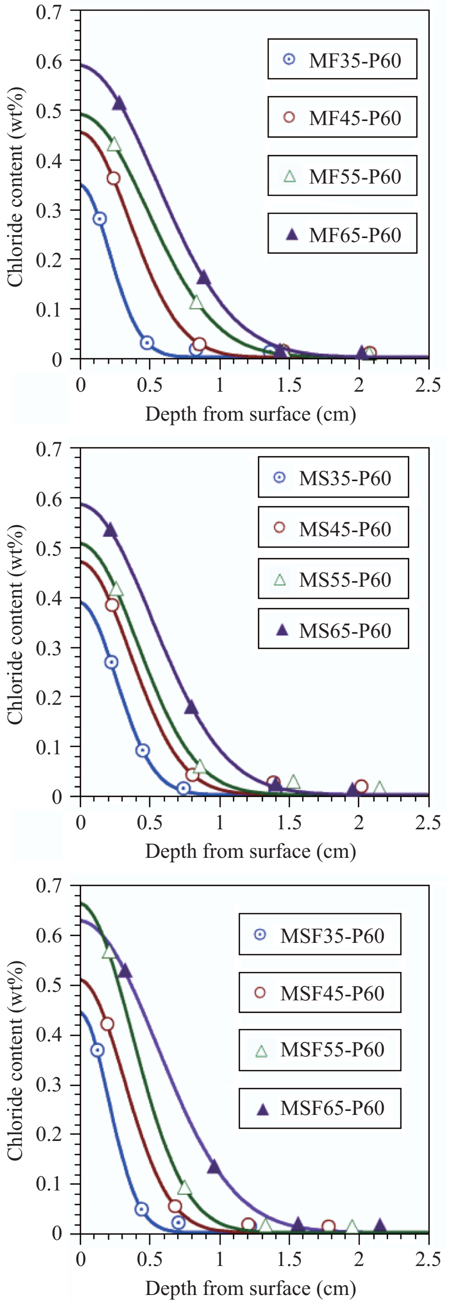

Fig. 8. All mixes ponding for 60 days.

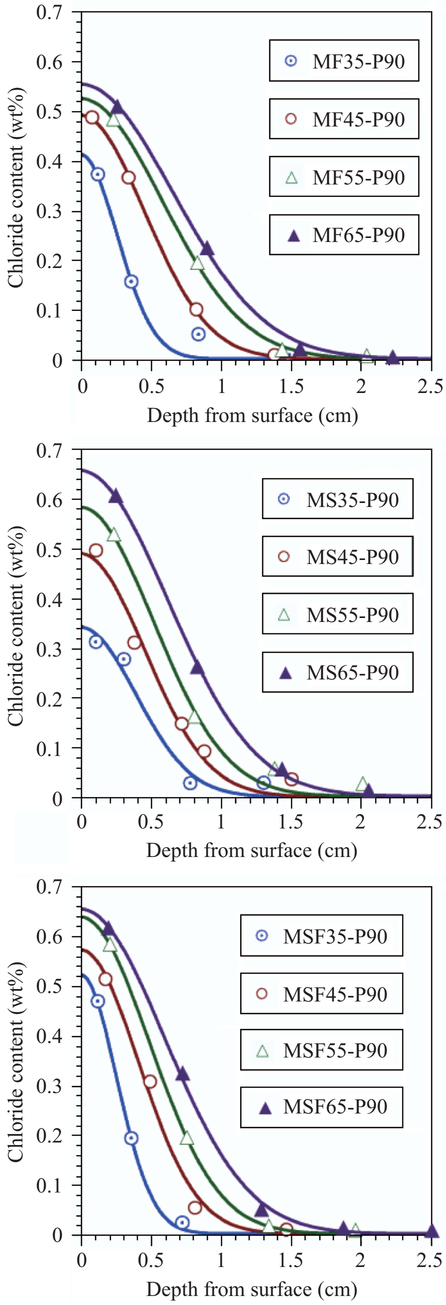

Fig. 9. All mixes ponding for 90 days.

$$C = C_s \, \mathbf{exp}\left(\frac{-x^2}{At}\right), \tag{1}$$

where C is chloride content as a function of distant, x is the sampling depth, the surface chloride content C_s was derived from Eq. (1) as $x = 0$, A is the chloride transport ability, and t is the testing time. Table 3 list the coefficients from the curve fitting, in which, the first to fourth letter represent specimen mix, and the following letters means different migration time in ACMT, A05, A1, A2, and A3 are represent 0.05, 0.1, 0.2, and 0.3 times breakthrough time.

2. Ponding Test

The chloride content vs. penetration depth result from four ponding time (60 day, 90 day, 120 day, and 180 day) are listed in Figs. 8-11, and curve fitting by Eq. (1). Table 4 shows coefficients from the curve fitting, in which, the first to fourth letter represent specimen mix, and the following letters means different ponding time.

3. The Time Relationship between ACMT and Ponding Test

In order to determine the testing time relation between ponding and ACMT from chloride penetration profile, the

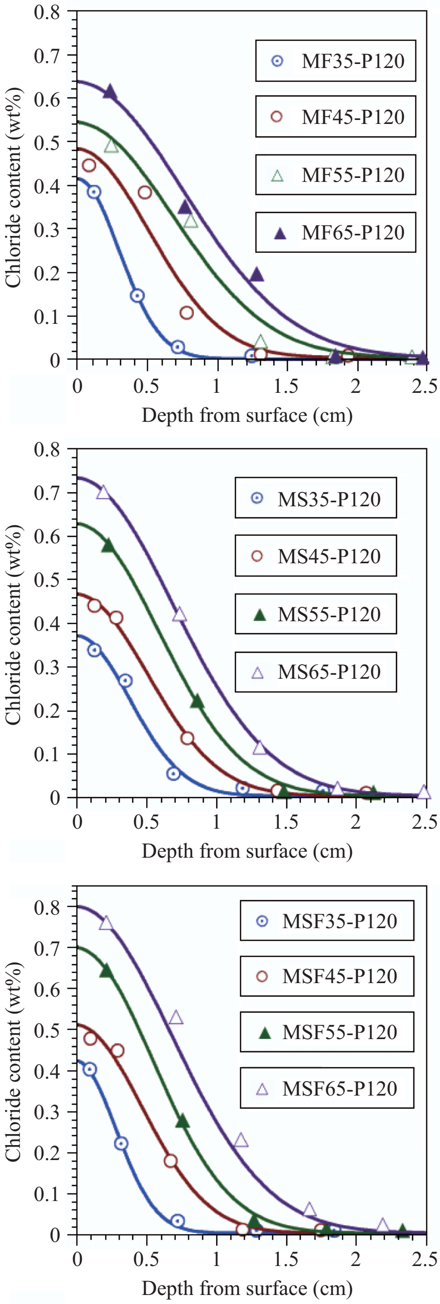

Fig. 10. All mixes ponding for 120 days.

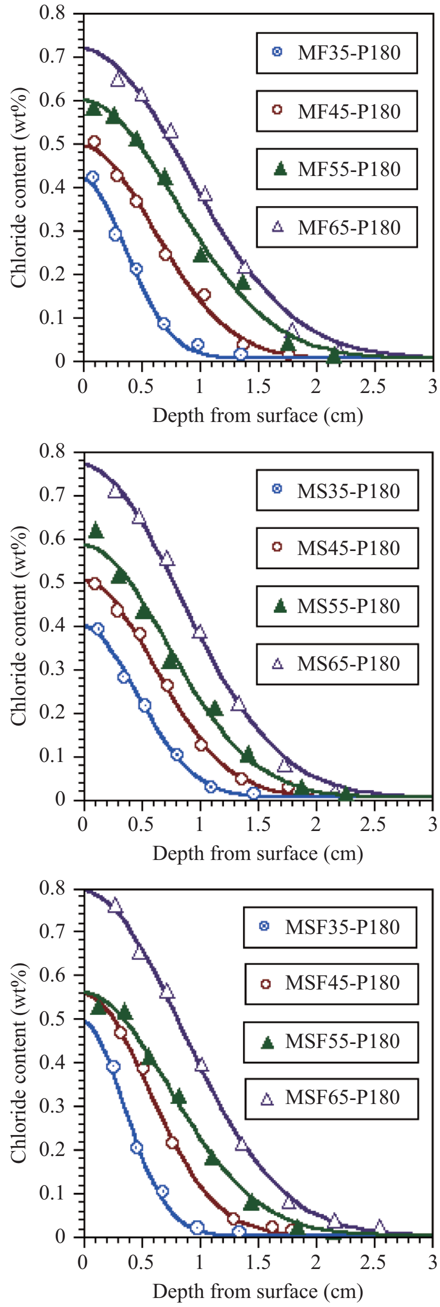

Fig. 11. All mixes ponding for 180 days.

chloride penetration depth is calculated from the chloride penetration profile. Using the chloride transport ability (A) and the surface chloride content (C_s) from the chloride penetration profile in Tables 3 and 4. The chloride penetration depth in ACMT (X_a) and Ponding test (X_p) correspond to the chloride content C = 0.01% for each specimen that is calculated from Eq. (1). The chloride penetration depth ratios (X_a/X_p) for series S, F, and SF are listed in Tables 5, 6, and 7, respectively. In Tables 5, 6, and 7, the X_{p60}, X_{p90}, X_{p120}, and X_{p180} are the chloride penetration depth with ponding test for 60 days, 90 days, 120 days, and 180 days.

The relation of the chloride penetration depth ratio (X_a/X_{p60}) and the different migration time in ACMT is plotted in Fig. 12. The X_{p60} is chloride penetration depth with ponding test for 60 days, and the X_a is chloride penetration depth with ACMT for different migration time. The data in Fig. 12 is analyzed with linear regression analysis, and the regression result is listed in Table 8. The results in Fig. 12 indicate that there is a linear correlation between the X_a/X_{p60} and the migration time in ACMT. When the 40th hour ponding time in ponding test and the migration time T_a (as shown in Fig. 12) in ACMT were used, the chloride ion reached the

Table 4. The coefficients from the curve fitting in ponding test.

Specimen No.	C_s (%)	A ($\times 10^{-6}$ s/cm^2)	Specimen No.	C_s (%)	A ($\times 10^{-6}$ s/cm^2)
MS35-P60	0.255	0.326	MS35-P120	0.369	0.285
MS45-P60	0.462	0.523	MS45-P120	0.464	0.507
MS55-P60	0.542	0.819	MS55-P120	0.626	0.679
MS65-P60	0.627	1.074	MS65-P120	0.812	0.919
MS35-P90	0.413	0.333	MS35-P180	0.393	0.300
MS45-P90	0.466	0.473	MS45-P180	0.499	0.511
MS55-P90	0.581	0.707	MS55-P180	0.580	0.710
MS65-P90	0.654	1.003	MS65-P180	0.764	0.933
MF35-P60	0.334	0.228	MF35-P120	0.414	0.171
MF45-P60	0.507	0.492	MF45-P120	0.480	0.531
MF55-P60	0.524	0.895	MF55-P120	0.540	0.926
MF65-P60	0.649	1.592	MF65-P120	0.634	1.148
MF35-P90	0.411	0.178	MF35-P180	0.413	0.194
MF45-P90	0.484	0.605	MF45-P180	0.489	0.512
MF55-P90	0.521	1.017	MF55-P180	0.593	0.964
MF65-P90	0.594	1.224	MF65-P180	0.711	1.266
MSF35-P60	0.443	0.175	MSF35-P120	0.421	0.159
MSF45-P60	0.508	0.407	MSF45-P120	0.508	0.434
MSF55-P60	0.661	0.658	MSF55-P120	0.697	0.687
MSF65-P60	0.761	1.058	MSF65-P120	0.777	1.085
MSF35-P90	0.438	0.152	MSF35-P180	0.489	0.179
MSF45-P90	0.571	0.444	MSF45-P180	0.552	0.418
MSF55-P90	0.577	0.707	MSF55-P180	0.556	0.739
MSF65-P90	0.653	0.926	MSF65-P180	0.789	0.941

Table 5. Chloride penetration depth ratio for S series.

Specimen No.	$\frac{X_a}{X_{p60}}$	$\frac{X_a}{X_{p90}}$	$\frac{X_a}{X_{p120}}$	$\frac{X_a}{X_{p180}}$
MS35-A05	0.705	0.617	0.544	0.456
MS35-A1	1.067	0.849	0.748	0.639
MS35-A2	1.543	1.228	1.082	0.935
MS35-A3	1.969	1.568	1.381	1.206
MS45-A05	0.623	0.527	0.417	0.331
MS45-A1	0.954	0.824	0.652	0.518
MS45-A2	1.371	1.227	0.971	0.772
MS45-A3	1.841	1.681	1.331	1.058
MS55-A05	0.608	0.470	0.406	0.332
MS55-A1	0.862	0.688	0.595	0.486
MS55-A2	1.228	1.00	0.865	0.706
MS55-A3	1.508	1.247	1.791	0.880
MS65-A05	0.489	0.403	0.366	0.284
MS65-A1	0.685	0.553	0.503	0.390
MS65-A2	0.951	0.801	0.728	0.565
MS65-A3	1.178	1.018	0.924	0.717

Table 6. Chloride penetration depth ratio for F series.

Specimen No.	$\frac{X_a}{X_{p60}}$	$\frac{X_a}{X_{p90}}$	$\frac{X_a}{X_{p120}}$	$\frac{X_a}{X_{p180}}$
MF35-A05	0.563	0.480	0.423	0.325
MF35-A1	0.901	0.767	0.676	0.519
MF35-A2	1.381	1.118	1.037	0.796
MF35-A3	1.807	1.539	1.357	1.042
MF45-A05	0.566	0.423	0.392	0.324
MF45-A1	0.856	0.638	0.592	0.490
MF45-A2	1.247	0.931	0.863	0.713
MF45-A3	1.640	1.225	1.135	0.938
MF55-A05	0.404	0.297	0.265	0.218
MF55-A1	0.613	0.472	0.423	0.347
MF55-A2	0.920	0.709	0.634	0.521
MF55-A3	1.106	0.883	0.789	0.649
MF65-A05	0.474	0.336	0.295	0.242
MF65-A1	0.692	0.513	0.451	0.371
MF65-A2	0.986	0.767	0.673	0.554
MF65-A3	1.268	1.021	0.896	0.736

Table 7. Chloride penetration depth ratio for SF series.

Specimen No.	$\frac{X_a}{X_{p60}}$	$\frac{X_a}{X_{p90}}$	$\frac{X_a}{X_{p120}}$	$\frac{X_a}{X_{p180}}$
MSF35-A05	0.943	0.829	0.712	0.521
MSF35-A1	1.377	1.211	1.040	0.762
MSF35-A2	2.009	1.767	1.517	1.112
MSF35-A3	2.622	2.305	1.980	1.451
MSF45-A05	0.683	0.515	0.467	0.379
MSF45-A1	0.981	0.741	0.672	0.545
MSF45-A2	1.337	1.010	0.916	0.743
MSF45-A3	1.740	1.314	1.192	0.967
MSF55-A05	0.600	0.452	0.408	0.316
MSF55-A1	0.854	0.642	0.580	0.449
MSF55-A2	1.317	0.991	0.895	0.693
MSF55-A3	1.702	1.281	1.156	0.895
MSF65-A05	0.478	0.431	0.331	0.288
MSF65-A1	0.686	0.620	0.475	0.414
MSF65-A2	0.962	0.869	0.666	0.581
MSF65-A3	1.196	1.079	0.828	0.721

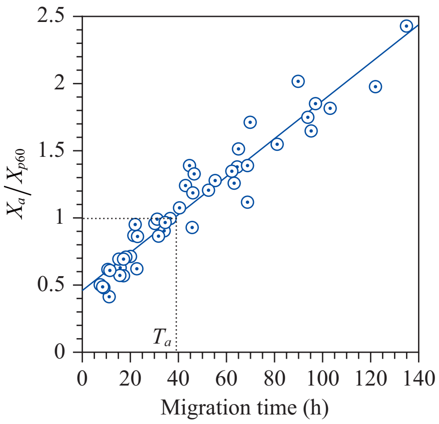

Fig. 12. The relationship between X_a/X_{p60} and migration time.

same penetration depth (X_a/X_{p60} = 1). The value of T_a is listed in Table 8. The relations of the chloride penetration depth ratios (X_a/X_{p90}, X_a/X_{p120}, and X_a/X_{p180}) and the ACMT for different migration time are shown in Figs. 13, 14, and 15. The data in Figs. 13, 14, and 15 is analyzed with linear regression analysis, and the regression results are listed in Table 8.

Fig. 16 shows the relationship between the ponding time in ponding test and the migration time in ACMT obtained from Figs. 12-15. Through linear regression analysis, the empirical relationship between ponding time (T_p) and migration time (T_a) is statistically derived as:

$$T_a = 0.0204T_p + 11.8, \tag{2}$$

where T_p and T_a are expressed in hour. The result shows that a

Table 8. Linear curve fitting result.

Relation	Curve fitting result		T_a
	Eqs.	R^2	(hour)
$\frac{X_a}{X_{p60}}$ *vs.* migration time	y = 0.01341x + 0.4671	0.921	39.74
$\frac{X_a}{X_{p90}}$ *vs.* migration time	y = 0.01075x + 0.3758	0.927	58.06
$\frac{X_a}{X_{p120}}$ *vs.* migration time	y = 0.00974x + 0.3186	0.914	69.96
$\frac{X_a}{X_{p180}}$ *vs.* migration time	Y = 0.00733x + 0.2703	0.919	99.55

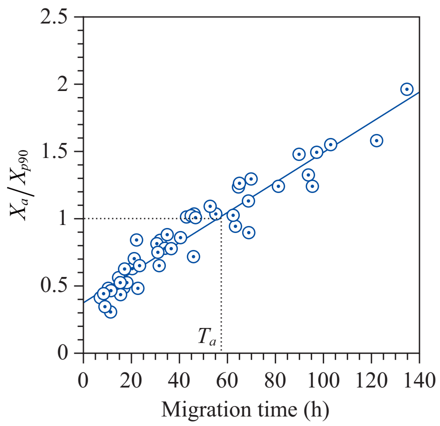

Fig. 13. The relationship between X_a/X_{p90} and migration time.

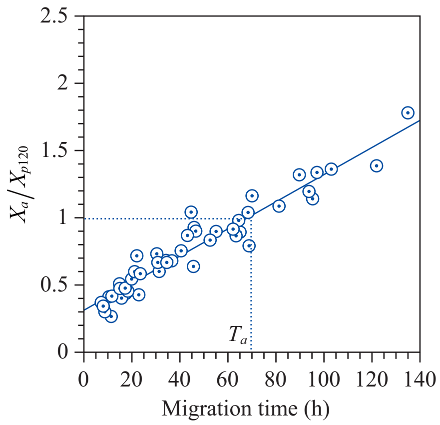

Fig. 14. The relationship between X_a/X_{p120} and migration time.

linear correlation exists between the ponding time used in ponding test and migration time in ACMT. The 90-day salt ponding test is a long-term test for measuring the penetration of chloride into specimen. Using the good experimental correlation in Eq. (2), the ACMT provide a time saving to obtain the transport property of cementitious materials.

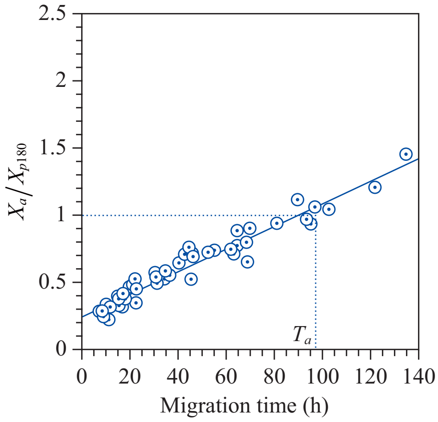

Fig. 15. The relationship between X_a/X_{p180} and migration time.

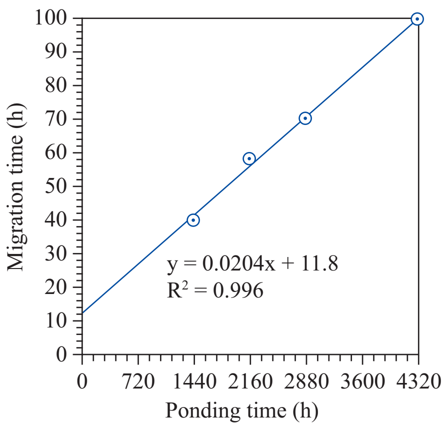

Fig. 16. The relationship between the ponding time in ponding test and the migration time in ACMT.

IV. CONCLUSION AND RECOMMENDATION

(1) In both test results, the ability of resisting chloride penetration to specimen (*A*) becomes higher as the w/b ratio decrease, when the value higher, represent that there's a better durability.

(2) The relationship between the ponding time and migration time would not be affected by the difference mixes which include w/b ratio and mineral content.

(3) The 90-day salt ponding test is a long-term test for measure-ing the penetration of chloride into specimen. Using the good experimental correlation in Eq. (2), the ACMT provide a time saving method to obtain the transport property of cementitious materials.

REFERENCE

1. AASHTO T259-80, "Standard method of test for resistance of concrete to chloride ion penetration," American Association of States Highway and Transportation Official, Washington, D.C., U.S.A. (1980).
2. AASHTO T260-97, "Standard method of test for sampling and testing for chloride ion in concrete and concrete raw materials," American Association of States Highway and Transportation Officials, Washington, D.C., U.S.A. (1997).
3. Andrade, C., "Calculation of chloride diffusion coefficients in concrete from ionic migration measurements," *Cement and Concrete Research*, Vol. 23, No. 3, pp. 724-742 (1993).
4. ASTM 1202-00, "Electrical indication of concrete's ability to resist chloride ion penetration," American Society for Testing and Materials (2000).
5. Bickley, J. A., "The mass transport of all those nasty little b..g..rs," *International Conference on Ion and Mass Transport in Cement Based Materials*, Toronto (1999).
6. Castellote, M., Andrade, C., and Alonso, C., "Modeling of the processes during steady-state migration test: quantification of transference numbers," *Materials and Structures*, Vol. 32, No. 217, pp. 180-186 (1999).
7. Hooton, R. D., "What is need in a permeability test for evaluation of concrete quality, pore structure and permeability of cementitious materials," *Materials Research Society Symposium Proceedings*, Boston, USA, pp. 1459-1475 (1987).
8. Li, Z., Peng, J., and Ma, B., "Investigation of chloride diffusion for high performance concrete containing fly ash, microsilica and the mineral admixtures," *ACI Materials Journal*, Vol. 96, No. 3, pp. 391-396 (1999).
9. McCarter, W. J., Starrs, G., and Chrisp, T. M., "Electrical conductivity, diffusion, and permeability of Portland cement-based mortars," *Cement and Concrete Research*, Vol. 30, No. 9, pp. 1395-1400 (2000).
10. Stanish, K. D., Hooton, R. D., and Thomas, M. D. A., "Testing the chloride penetration resistance of concrete: a literature review," *FHWA Report*, Toronto, Ontario, Canada, pp. 1-33 (1997).
11. Tong, L. and Gjorv, O. E., "Chloride diffusivity based on migration testing," *Cement and Concrete Research*, Vol. 31, No. 7, pp. 973-982 (2001).
12. Wee, T. H., Arvind, K. S., and Tin, S. S., "The influence of aggregate fraction in the mix on the reliability of rapid chloride permeability test," *Cement and Concrete Research*, Vol. 21, No. 1, pp. 59-72 (1999).
13. Yang, C. C., Cho, S.W., Chi, Jack. M., and Huang, R., "An electrochemical method for accelerated chloride migration test in cement-based materials," *Materials Chemistry and Physics*, Vol. 77, No. 2, pp. 463-471 (2002).