Experimental Study on Diffusion Behaviour of Chloride ION in Cement Mortar

B. Bhaskar, T. Raghavendra

Abstract*: A Chloride ion is a key factor affecting durability of concrete structures. In order to investigate chloride migration in behavior of mortar cubes, mesoscopic heterogeneity of mortar should be considered. This investigation presents comparison of cement mortar cube with and without using of Hydrochloric acid (HCL) and Sodium Chloride (NaCl). For this purpose, standard cement mortar specimens 70.6 mm x 70.6 mm x 70.6 mm were prepared and tested to find the compressive strength and volume change. The prepared specimens were allowed for 28 days curing and tested by Non-Steady State Chloride Migration setup (NSSCM) at different voltages of 25V, 30V, 35V, 40V. The volume change at these voltages is 4.05%, 6.43%, 3.25%, 7.99% and change in the compressive strength is 64%, 60%, 48%, 56% respectively.

Index Terms*: Cement Mortar, Hydrochloric Acid, Non-Steady State Chloride Migration Test, Sodium Chloride Solutions.

I. INTRODUCTION

The most reason for disintegration of structures is the distress of mortar because of its exposure to unsafe combinations that might be available in the climate and debased water. It is discovered the most forceful synthetic compounds that influence the sturdiness of structure are chloride, sulfate and acids. Solidness is an essential building property of concrete, which decides the life of the structures [1]. Due to interactions of concrete with external influences (industrial process, free acids in natural water etc.) The mechanical and physical properties of concrete are changed and cause the cement deterioration Ex: Deterioration mechanisms involving chemical processes is acid attack (concrete exposed to agricultural or industrial environments) [2]. The chloride assault emerges as a rule when chloride particles enter from outside of the structures by transport of water containing the chloride and by dispersion of the ions in the water by ingestion. Reaction related to chloride ion is:

$$Ca(OH)_2 + 2HCl \rightarrow CaCl_2 + 2H_2O$$

The impacts of compound on quality attributes of mortar have been assessed on the essential of tests performed in research facility. Loss of weight and compressive quality test were executed for examination of the impacts of individual ions on mortar cubes.

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II. DESCRIPTION OF NON-STEADY STATE CHLORIDE MIGRATION TEST SET-UP

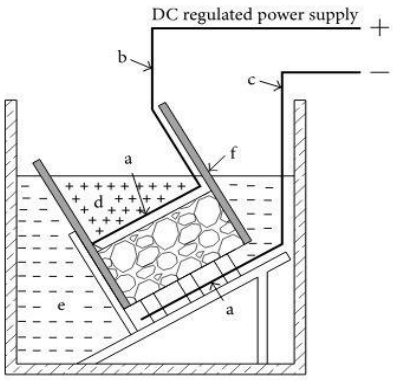
a) In this test mortar cubes of size 70.6mm x 70.6mm x 70.6mm were prepared and cured for 28 days. The test conducted for the prepared specimens is Non-Steady State Chloride Migration test.

b) The two solutions which were used are NaCl and HCL.

c) The electric flow of various voltages is passed through the electrodes and due to this sodium gets discharged which passes through mortar cubes and get scattered with HCL releasing chloride ions.

d) Released Chloride ions effect the cement mortar behavior which results decrease in the size of the mortar cube.

e) Generally cement mortar is used for different construction purposes. If the concentration of Chloride is more at the place of construction, on reacting with the atmosphere, deterioration of the structure takes place.



(a) Anode and cathode metal plate
(b) Anode
(c) Cathode
(d) Anolyte (HCL solution)
(e) Catholyte (NaCl solution)
(f) Rubber drum

Fig.1: NSSCM Test Set-up

III. PREPARATION OF SOLUTIONS

A. NACL Solution for 2N (Normality)

Sodium chloride is one of the most well-known and widely used chemicals.

Formula and structure: The compound is NaCl and its molar mass is 58.44g/mol.

$$Na^+ Cl^-$$

Physical properties: Sodium chloride is a white crystalline solid with a density of 2.16g/ml, and a melting point of 801^0C.

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It is also available as aqueous solutions of different concentrations, called saline solutions.

Chemical properties: Sodium Chloride (NaCl) is promptly dissolvable in water and other polar solvents.

- ❖ To prepare 2N of NaCl, 81gm of NaCl is added to one liter of distilled water.

B. HCL Solution for 2N (Normality)

Hydrochloric acid is the aqueous solution of hydrogen chloride. It is a strong mineral acid with many industrial uses.

Formula and structure: The compound equation for hydrochloric acid (HCl) and its atomic weight is 36.47 g/mol.

H^+ Cl^-

Physical properties: Hydrochloric acid has a very impactful smell. It is accessible in various forms in water.

Chemical properties: HCl is a solid, monoprotic corrosive, which implies it can discharge just a single H+ particle (proton). Concentrated HCl breaks up numerous metals and structures oxidized metal chlorides and hydrogen gas.

- 2N HCL - add 165.6ml of HCL in 1Litre of water.

IV. MATERIALS AND MIX DESIGN

Cement: Ordinary Portland cement (OPC) of Ultra Tech brand and 53 grade.

Table.1 Physical properties of cement

SI. NO	Name of test	Result
1	Fineness of cement	2%
2	Specific gravity	3.04
3	Standard consistency	30%
4	Initial and final setting time	155min & 9hr
5	Soundness of cement	2mm

Sand: Zone of sand is II

Table.2 Physical properties of Sand

SI. NO	Name of test	Result
1	Fineness modulus	2.67
2	Specific gravity	2.52

Mix Design:

- The material for each cube shall be mixed separately and the quantity of cement, standard sand and water shall be as follows:
- Cement 200gms, Standard sand 600g. Mix proportion is 1:3.

Water content =($\frac{P}{4}$+3%) of total weight of cement and sand

V. PREPARATION OF NSSCM SET-UP

a) In this experiment stainless steel is used as both anode and cathode.

b) NaCl solution is placed in the plastic tub where steel roll is inserted in the tub which acts as cathode.

c) HCL solution is placed in the plastic vessel where another steel roll is inserted which act as anode and a cube is placed in that plastic vessel to react with HCL.

d) These two anode and cathode is connected to variac, where current is supplied to these electrodes.

e) Wooden table is used to maintain some height in the setup to make reaction easy.

Fig.2: NSSCM test setup

VI. TEST RESULTS

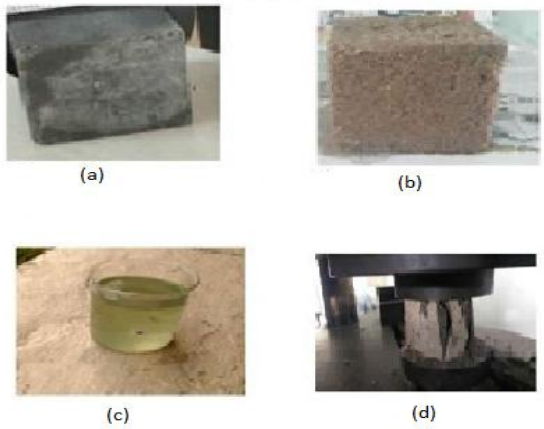

Fig.3: Chloride penetration area in the mortar specimen and testing, (a) Normal cube, (b) Chloride penetration area in mortar specimen, (c) Chloride solution reacted with mortar specimen, (d) Testing of mortar specimen

a) Initially 25V current is supplied to the solution and it is observed for 24 hours.

b) Due to the chemical reaction, surface of the cementitious material is dissolved in the solution.

c) The cube is exposed to the natural drying.

d) On reacting with the HCL solution the top layer of the cube gets eroded. The dimensions of the cube are measured after scrubbing the all sides of cube.

e) The strength of cube is measured using UTM.

f) Repeat the procedure for different voltages and calculate the strength of the mortar cube.

Ultrasonic Pulse velocity values:

Ultrasonic pulse velocity range is greater than 4500(m/s) in maximum number of cubes the quality of this cube is excellent in range.

Table.3 Values of Ultrasonic Pulse velocity

Cubes	Pulse velocity(m/s)
Cube-1	4695
Cube-2	4843
Cube-3	4724
Cube-4	4843
Cube-5	4783

Table.4 Change in Volume of Cube

Voltage (V)	Original dimensions (mm)	Change in dimensions (mm)	Change in volume (%)
0	70.6x70.6x70.6	-	0
25	70.6x70.6x70.6	69.1x69.6x70.2	4.05
30	70.6x70.6x70.6	69.1x68.8x69.2	6.43
35	70.6x70.6x70.6	70.3x69.2x70.0	3.25
40	70.6x70.6x70.6	69.4x68.2x68.8	7.99

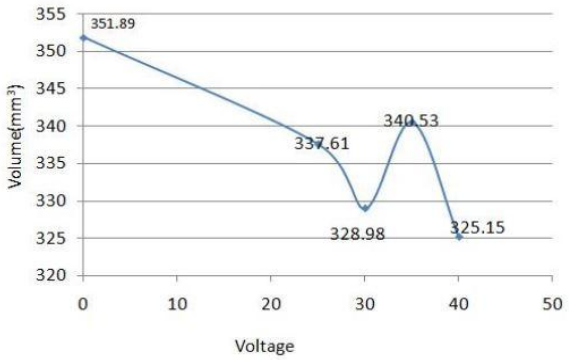

Fig.4: Graphical View of Voltage vs Volume

Table.5 Compressive strength of cubes at different Voltages

Voltage (V)	Normal cube dimensions (mm)	Change in dimensions (mm)	compressive strength (N/mm^2)
0	70.6x70.6x70.6	-	25
25	70.6x70.6x70.6	69.1x69.6x70.2	9
30	70.6x70.6x70.6	69.1x68.8x69.2	10
35	70.6x70.6x70.6	70.3x69.2x70.0	13
40	70.6x70.6x70.6	69.4x68.1x68.8	11

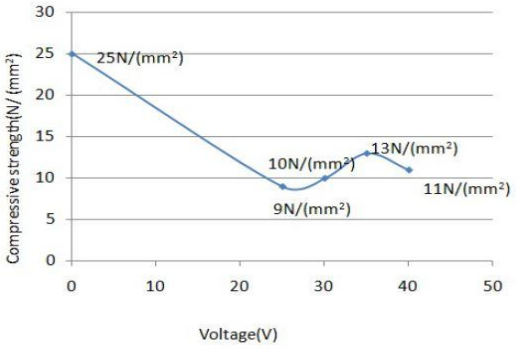

Fig.5: Graphical View of Voltage vs Compressive Strength

VII. CONCLUSION

- Volume change in percentage with respective voltages of 25V, 30V, 35V and 40V is 4.05%, 6.43%, 3.25% and 7.99%.
- Compressive strength in percentage with respective voltages of 25V, 30V, 35V and 40V is 64%, 60%, 48% and 56%.
- Chloride attack is one of the most important aspects while dealing with durability of concrete to overcome from this chloride attack adopts cathodic protection and special concrete.

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