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Evaluation of chloride absorption in pre-conditioned concrete cubes

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ABSTRACT

The chloride contamination will occur from the application of de-icing salts. It was confirmed that the application of de-icing salts caused a significant reduction in structural and serviceability reliabilities. The chemicals used in the snow and ice control operations (de-icers) may cause corrosion damage to the transportation infrastructure such as reinforced/pre-stressed concrete structures and steel bridges. There are many ways to manage the corrosive effects of de-icers, such as selection of high-quality concrete, adequate concrete cover and alternative reinforcement, control of the ingress and accumulation of deleterious species, injection of beneficial species into concrete, and use of non-corrosive de-icer alternatives and optimal application rates. In fact, snow and ice on streets and highways are a major threat to human life and limb. Traffic accidents and fatalities climb as snow and ice reduce traction on roadways. Lengthened emergency response times create additional risks for persons in urgent need of medical care, particularly in cases of heart attacks, burns, childbirth and poisoning. Thus the de-icing salts are necessary to provide safe winter driving conditions and save lives by preventing the freezing of a layer of ice on concrete infrastructure. However, the safety and sense of comfort provided by these salts is not without a price, as these salts can greatly contribute to the degradation and decay of reinforced concrete transportation systems. The importance of chloride concentration as a durability-based material property has received greater attention only after the revelation that chloride-induced corrosion is the major problem for concrete durability. Therefore, there is a need to quantify the chloride concentration in concrete which is of paramount importance. The present research work was made an attempt to interpret the concrete chloride absorption in ordered to characterize the different concrete mixtures design for in case of pre-conditioned concrete cubes such as dry/fully/partially saturated condition and salt ponded with chloride solution for about 160 days. Thus the objectives of this present research are such as: First, this research will examine the influence of conditioning such as dry/fully/partially saturated condition on the results of chloride concentration performed on concrete cubes with different mixtures proportion in which slump, and w/c ratio value was varied with constant compressive strength as in the First case and compressive strength, and w/c ratio value varied with constant slump as in the Second case. Seventy-two concrete cubes (100 mm^3) with Grades of concrete ranges from 25 to 40 N/mm^2 were prepared and evaluate the chloride absorption under different exposure condition. It's concluded from the results that, in dry/saturated conditioned concrete cubes, the chloride absorption value was increased in all designed mixtures type. Similarly, the average chloride concentration was decreased in solvent based and water based impregnation DCC/PSC/FSC cubes as when compared to control DCC/PSC/FSC cubes for constant higher compressive strength and varied slump value as well as varied compressive strength and constant slump value. Whereas the average chloride absorption was increased in solvent based and water based impregnation DCC/PSC/FSC cubes for lesser compressive strength and constant slump value as when compared to constant higher compressive strength and varied slump value and the chloride concentration was going on decreases with increased compressive strength and constant slump value.

Keywords: Concrete, Mixture proportion, Grade of concrete, pre-conditioning, Slump, Water-cement ratio, Chloride absorption, De-icer, snow and ice control, reinforcing steel, corrosion

1. INTRODUCTION

The prolonged periods of snowfall in countries with advanced infrastructure and transport systems have rendered the use of de-icing agents to a common occurrence on roads and highway structures. They are necessary in order to maintain a good level of service with respect to the transport systems, thus avoiding traffic jams and disruptions, but also to provide a high level of road safety. Today, chloride-based products, such as rock salt, are the most commonly encountered de-icers as they are easy to apply and store but mostly because they efficiently melt ice at an affordable price [1]. However, their widespread use over a long period has left the construction industry and the engineering community with a grave problem regarding the durability of highway reinforced concrete bridges and multi-storey parking structures [2], due mainly to the fact that they cause corrosion of the reinforcement and steel components [2].In cold-climate regions, snow and ice control operations are crucial to maintaining highways that endure cold and snowy weather. The growing use of de-icers has raised concerns about their effects on motor vehicles, transportation infrastructure, and the environment. The deleterious effect of chloride-based de-icers on reinforcing steel bar in concrete structures is well known [3]. De-icers may also pose detrimental effects on concrete infrastructure through their reactions with cement paste and/or aggregates and thus reduce concrete integrity and strength, which in turn may foster the ingress of moisture, oxygen and other aggressive agents onto the rebar surface and promote rebar corrosion. Large amounts of solid and liquid chemicals (known as de-icers) as well as abrasives are applied onto winter highways to keep them clear of ice and snow. De-icers applied on to highways often contain chlorides because of their cost-effectiveness, including mainly sodium chloride (NaCl), magnesium chloride ($MgCl_2$), and calcium chloride ($CaCl_2$), sometimes blended with proprietary corrosion inhibitors. The rock salt/sodium chloride (NaCl), is the most commonly used de-icing agent. It was first used to control snow and ice on roadways to improve transportation safety in the 1930s, and became widespread by the 1960s. The salt works by dissolving into precipitation on roadways and lowering the freezing point, thereby melting ice and snow. Eliminating the ice has enormous safety benefits, but depending on the amount of chemicals used, the dissolved salt can have negative effects on the surrounding environment. The melting snow and ice carries de-icing chemicals onto vegetation and into soils along the roadside where they eventually enter local waterways. Elevated salt levels in soils can inhibit the ability of vegetation to absorb both water and nutrients, which can slow plant growth and ultimately affect animal habitats. This degradation also affects the ability of these areas to act as buffers to slow the runoff of other contaminants into the watershed. Once the salt enters freshwater it can build up to concentration levels that further affect aquatic plants and other organisms. Salt deposits along roadways also attract birds, deer, and other animals which increases the chance of animal-vehicle accidents. While the major effect on public drinking water supplies for humans is merely an alteration of taste, high concentrations of sodium in drinking water can lead to increased dietary intake and possibly hypertension. Since salt is corrosive to automobiles, bridge decks, and other roadway infrastructure, de-icing chemicals are often combined with other substances to block corrosion. While eliminating ice is of great benefit to commerce and human safety, these drawbacks must be taken into consideration by communities as they plan for regular maintenance of the concrete infrastructure, as well as the health of the local ecosystem.

The costs of maintaining reinforced concrete infrastructure (bridges, tunnels, harbours, parking structures) are increasing due to aging of structures, which are being exposed to aggressive environment. Corrosion of reinforcement due to chloride ingress is the main problem for existing structures in marine and de-icing salt environments [4].In The Netherlands 5% of motorway bridges, built predominantly between 1960 and1980, shows cracking and spalling of the concrete cover due to chloride induced corrosion [5]. This corresponds to 10% of the bridges showing corrosion initiation at an age of 40 years [6]. Older structures have been built according to older codes, which may not have provided sufficient protection. Moreover, for new infrastructure corrosion cannot be ruled out completely, even with today's emphasis on design for long service life (typically 100 years), either by composition requirements (Eurocodes) or based on service life modelling and performance testing [7].This may be due to various factors, such as unforeseen aggressive loads, e.g. leakage of joints; or to deviations from the intended concrete quality or cover thickness; or to modelling inadequacies (e.g. for carbonation induced corrosion see [8].Repair of corrosion damage is possible, but costly, potentially disruptive and not necessarily long lived. A European study has shown that 50% of repairs fail within 10years [9]. These results were confirmed by a study in The Netherlands [10]. In the worst case, this means that after about ten years the structure must again be repaired, involving more costs; and possibly this will go on until the structure is taken out of service. Thus in the present research work, an attempt was made to interpret the concrete chloride absorption in ordered to characterize the different concrete mixtures type for in case of 72 pre-conditioned concrete cubes (100 mm^3) such as dry/fully/partially saturated condition and salt ponded with chloride solution for about 160 days. This research will examine the influence of conditioning such as dry/fully/partially saturated condition on the results of chloride absorption performed on concrete cubes with different mixtures proportion in which slump (0-10, 10-30, 60-180) mm, and w/c ratio value was varied with constant compressive strength (40 N/mm^2) as in the First case and compressive strength (25-40 N/mm^2), and w/c ratio value varied with constant slump (10-30) mm as in the Second case.

2. RESEARCH OBJECTIVES

The interpretation of the performance of a concrete mix is not limited to the determination of its mechanical properties since it is of paramount importance to characterize the material in terms of the parameters that rate its durability. The importance of chloride concentration as a durability-based material property has received greater attention only after the revelation that chloride-induced corrosion is the major problem for concrete durability. The present research work was made an attempt to interpret the concrete chloride absorption in ordered to characterize the different concrete mixtures design for in case of pre-conditioned concrete cubes such as dry/fully/partially saturated condition and salt ponded with chloride solution for about 160 days with 10% Nacl solution. Thus the objectives of this present research is to examine the influence of conditioning such as dry/fully/partially saturated condition on the results of chloride absorption performed on concrete cubes with different mixtures proportion in which slump, and w/c ratio value was varied with constant compressive strength as in the First case and compressive strength, and w/c ratio value varied with constant slump as in the Second case. Seventy-two concrete cubes (100 mm^3) with Grades of concrete ranges from 25 to 40 N/mm^2 were prepared and evaluate the chloride absorption under different exposure condition.

3. EXPERIMENTAL PROGRAM

In the present research work, six different mixtures type were prepared in total as per BRE, 1988 [11] code standards with a concrete cubes of size (100 mm^3). Three of the mixtures were concrete cubes (100 mm^3) with a compressive strength 40 N/mm^2, slump (0-10, 10-30, and 60-180 mm), and different w/c (0.45, 0.44, and 0.43). These mixtures were designated as M1, M2, and M3. Another Three of the mixtures were concrete cubes with a compressive strength (25 N/mm^2, 30 N/mm^2, and 40 N/mm^2), slump (10-30 mm), and different w/c (0.5 0.45, and 0.44). These mixtures were designated as M4, M5, and M6. The overall details of the mixture proportions were to be represented in Table.1-2. Twelve concrete cubes of size (100 mm^3) were cast for each mixture and overall Seventy-two concrete cubes were casted for six types of concrete mixture. The coarse aggregate used was crushed stone with maximum nominal size of 10 mm with grade of cement 42.5 N/mm^2 and fine aggregate used was 4.75 mm sieve size down 600 microns for this research work.

Table 1 (Variable: Slump & W/C value; Constant: Compressive strength)

Mix No	Comp/mean target strength(N/mm^2)	Slump (mm)	w/c	C (Kg)	W (Kg)	FA (Kg)	CA(Kg) 10 mm	Mixture Proportions
M1	40/47.84	0-10	0.45	3.60	1.62	5.86	18.60	1:1.63:5.16
M2	40/47.84	10-30	0.44	4.35	1.92	5.62	16.88	1:1.29:3.87
M3	40/47.84	60-180	0.43	5.43	2.34	6.42	14.30	1:1.18:2.63

Table 2 (Variable: Compressive strength & W/C value; Constant: Slump)

Mix No	Comp/mean target strength(N/mm^2)	Slump (mm)	w/c	C (Kg)	W (Kg)	FA (Kg)	CA(Kg) 10 mm	Mixture Proportions
M4	25/32.84	10-30	0.50	3.84	1.92	5.98	17.04	1:1.55:4.44
M5	30/37.84	10-30	0.45	4.27	1.92	6.09	16.50	1:1.42:3.86
M6	40/47.84	10-30	0.44	4.35	1.92	5.62	16.88	1:1.29:3.87

4. INTERPRETATION OF CHLORIDE ABSORPTION

The primary aim of this research was to interpret the effectiveness of wetting and drying pre-conditioned concrete cubes on chloride absorption, which was exposed to different pre-determined conditions such as dry/fully saturated/partially saturated condition was evaluated in control/impregnation concrete cubes for about 160 days salt ponding test in all designed six mixtures type (M1-M6).The pre-conditioning was induced in order to achieve desired dry condition in specified 24 concrete cubes. In which all 24 concrete cubes were exposed to natural room temperature for about 28 days. The pre-conditioned fully saturated condition was achieved in specified 24 concrete cubes by partially submerged in water with one surface exposed for about 31 days. The pre-conditioned partially saturated condition was assessed in specified 24 concrete cubes by partially submerged in water with one surface exposed for about 21 days. The chloride ingress in to the concrete can only take place if the concrete pores are totally/partly filled with water. The penetration occurs either through the capillary pores/through cracks by permeation, capillary suction, and diffusion. In the exposure conditions, the concrete moisture content, and the pore structure will determine the relative importance of those penetration mechanisms. The variation of average weight loss/weight gain (water)/standard deviation/minimum/maximum values in pre-conditioned control concrete cubes such as DCC/PSC/FSC was represented in Tables.3-5.

Table 3 Interpretation of weight loss (water) in DCC cubes

Water loss (%) in DCC concrete cubes				
Cube ID	Average	STD	Min,value	Max,value
M1CC	-0.561	0.570	-1.441	-0.022
M2CC	-0.697	0.742	-1.856	-0.018
M3CC	-0.516	0.530	-1.356	-0.017
M4CC	-0.994	1.058	-2.624	-0.025
M5CC	-0.538	0.553	-1.402	-0.017
M6CC	-0.663	0.675	-1.703	-0.024

Table 4 Interpretation of weight gain (water) in PSC cubes

Water gain (%) in PSC concrete cubes				
Cube ID	Average	STD	Min,value	Max,value
M1CC	0.617	0.712	0.049	1.817
M2CC	0.567	0.625	0.050	1.445
M3CC	0.565	0.622	0.050	1.397
M4CC	0.657	0.749	0.051	1.856
M5CC	0.138	0.101	0.050	0.334
M6CC	0.113	0.064	0.050	0.236

Table 5 Interpretation of weight gain (water) in FSC cubes

Water gain (%) in FSC concrete cubes				
Cube ID	Average	STD	Min,value	Max,value
M1CC	1.091	1.159	0.063	2.933
M2CC	1.152	1.401	0.063	4.088
M3CC	1.261	1.602	0.063	4.428
M4CC	1.417	1.827	0.063	5.070
M5CC	0.965	1.457	0.070	4.393
M6CC	0.665	0.971	0.065	2.926

The concrete is a porous material with a wide range of pore sizes. Nano-pores are predominant in the hydration products of cements. In fact the concrete was just as other similar porous systems which have an intense interaction with moisture of its environment. If the concrete surface is in contact with liquid water or with aqueous salt solutions, significant quantities of water are absorbed by capillary suction. Under drying conditions, the moisture content is reduced again with a marked hysteresis. All changes of moisture content will induce volume changes which are at the origin of crack formation. The durability of a concrete structure depends essentially on this complex interaction between the porous material and its surrounding. It has been shown by a number of authors that, the deep impregnation of the concrete surfaces with water repellent agents forms an efficient and long lasting barrier with respect to chloride ingress [12-14]. In this way service life of reinforced concrete structures situated in an aggressive environment such as marine climate/de-icing performance can be significantly extended/improved in different concrete infrastructures. Thus in the present research work that, the effectiveness of impregnation materials such as solvent/water based impregnation materials was evaluated in pre-conditioned concrete cubes in ordered to reduce chloride absorption for in case of designed mixtures type. The variation of average (1-160) days concrete chloride absorption, standard deviation, minimum, as well as maximum values under various pre-conditioned control/impregnation concrete cubes such as DCC/PSC/FSC(SB/WB) was represented in Tables 6-8.

Table 6 Interpretation of chloride absorption in DCC/IC cubes

Chloride absorption (%) in DCC/IC concrete cubes									
Cube ID	Average	STD	Min,value	Max,value	Cube ID	Average	STD	Min,value	Max,value
M1CC	1.97	0.75	0.31	2.89	M4CC	3.17	0.68	1.61	4.04
M1SB	1.59	0.61	0.21	2.38	M4SB	2.62	0.63	1.24	3.42
M1WB	1.72	0.62	0.25	2.50	M4WB	2.82	0.68	1.45	3.71
M2CC	2.66	0.75	0.67	3.55	M5CC	2.38	0.72	0.71	3.27
M2SB	1.75	0.62	0.41	2.56	M5SB	1.63	0.66	0.31	2.48
M2WB	1.88	0.64	0.51	2.72	M5WB	1.89	0.63	0.46	2.68
M3CC	2.45	0.75	0.43	3.37	M6CC	2.19	0.66	0.48	3.02
M3SB	1.94	0.64	0.33	2.78	M6SB	1.66	0.64	0.34	2.50
M3WB	2.06	0.69	0.34	2.92	M6WB	2.00	0.67	0.40	2.84

Table 7 Interpretation of chloride absorption in PSC/IC cubes

Chloride absorption (%) in PSC/IC concrete cubes									
Cube ID	Average	STD	Min,value	Max,value	Cube ID	Average	STD	Min,value	Max,value
M1CC	0.75	0.39	0.23	1.40	M4CC	0.82	0.42	0.24	1.63
M1SB	0.63	0.35	0.15	1.21	M4SB	0.63	0.35	0.16	1.25
M1WB	0.65	0.34	0.19	1.24	M4WB	0.67	0.35	0.21	1.36
M2CC	0.76	0.41	0.21	1.46	M5CC	0.73	0.40	0.21	1.52
M2SB	0.61	0.35	0.16	1.25	M5SB	0.62	0.35	0.15	1.23
M2WB	0.64	0.36	0.20	1.33	M5WB	0.64	0.36	0.16	1.33
M3CC	0.77	0.46	0.17	1.62	M6CC	0.66	0.35	0.18	1.32
M3SB	0.60	0.35	0.12	1.22	M6SB	0.61	0.34	0.15	1.24
M3WB	0.62	0.35	0.14	1.23	M6WB	0.63	0.35	0.16	1.25

Table 8 Interpretation of chloride absorption in FSC/IC cubes

Chloride absorption (%) in FSC/IC concrete cubes									
Cube ID	Average	STD	Min,value	Max,value	Cube ID	Average	STD	Min,value	Max,value
M1CC	0.37	0.32	0.10	1.16	M4CC	0.43	0.29	0.21	1.31
M1SB	0.11	0.04	0.06	0.22	M4SB	0.22	0.10	0.12	0.44
M1WB	0.13	0.05	0.07	0.28	M4WB	0.25	0.12	0.14	0.53
M2CC	0.34	0.29	0.07	1.10	M5CC	0.31	0.25	0.12	1.03
M2SB	0.16	0.09	0.06	0.31	M5SB	0.19	0.12	0.09	0.45
M2WB	0.21	0.16	0.07	0.59	M5WB	0.21	0.16	0.10	0.64
M3CC	0.25	0.20	0.10	0.78	M6CC	0.24	0.17	0.10	0.74
M3SB	0.14	0.09	0.08	0.36	M6SB	0.17	0.10	0.05	0.40
M3WB	0.19	0.11	0.09	0.43	M6WB	0.20	0.13	0.09	0.53

The variation of average chloride absorption was compared in pre-conditioned control/impregnation concrete cubes at different time duration such as 31th, 61th, 91th, 121th, and 160th days to determine the effectiveness of impregnation materials (solvent/water) based impregnation material for long time duration. The variation of average chloride absorption in pre-conditioned control/impregnation concrete cubes was recorded at different time duration as represented in Table.9. The average chloride absorption in DCC control/impregnation concrete cubes was pre-dominantly increased with constant higher concrete compressive strength and varied slump values as when compared to pre-conditioned DCC control/impregnation concrete cubes with constant slump value and varied concrete compressive strength. The average chloride absorption in DCC control/impregnation concrete cubes was pre-dominantly increased with lesser concrete compressive strength and constant slump value as when compared to pre-conditioned DCC control/impregnation concrete cubes with constant slump value and varied concrete compressive strength as well as it goes on decreases with increased concrete compressive strength.

Table 9 Variation of chloride absorption in pre-conditioned concrete cubes

Average chloride absorption (%) in DCC/IC concrete cubes											
		Time, day							Time, day		
Cube ID	31	61	91	121	160	Cube ID	31	61	91	121	160
M1CC	1.13	1.65	2.27	2.68	2.89	M4CC	2.47	2.90	3.36	3.81	4.04
M1SB	1.04	1.35	1.75	2.16	2.38	M4SB	1.94	2.36	2.78	3.23	3.42
M1WB	1.10	1.49	1.92	2.31	2.50	M4WB	2.04	2.55	3.01	3.47	3.71
M2CC	1.86	2.36	2.94	3.37	3.55	M5CC	1.57	2.17	2.61	3.06	3.27
M2SB	1.12	1.46	1.89	2.35	2.56	M5SB	0.99	1.37	1.82	2.26	2.48
M2WB	1.21	1.62	2.05	2.49	2.72	M5WB	1.22	1.65	2.09	2.50	2.68
M3CC	1.62	2.25	2.72	3.13	3.37	M6CC	1.53	1.93	2.38	2.79	3.02
M3SB	1.26	1.71	2.09	2.54	2.78	M6SB	1.11	1.47	1.78	2.24	2.50
M3WB	1.27	1.81	2.28	2.69	2.92	M6WB	1.28	1.82	2.22	2.61	2.84
		Time, day							Time, day		
Average chloride absorption (%) in PSC/IC concrete cubes											
Cube ID	31	61	91	121	160	Cube ID	31	61	91	121	160
M1CC	0.31	0.52	0.87	1.06	1.40	M1CC	0.29	0.70	0.98	1.11	1.63
M1SB	0.19	0.46	0.74	0.93	1.20	M1SB	0.21	0.52	0.76	0.90	1.25
M1WB	0.24	0.50	0.75	0.93	1.24	M1WB	0.26	0.58	0.76	0.92	1.36
M2CC	0.26	0.56	0.87	1.10	1.46	M2CC	0.26	0.56	0.88	0.99	1.52
M2SB	0.20	0.42	0.73	0.83	1.25	M2SB	0.19	0.50	0.72	0.87	1.22
M2WB	0.24	0.42	0.74	0.92	1.33	M2WB	0.21	0.48	0.74	0.87	1.33
M3CC	0.21	0.53	0.94	1.11	1.62	M3CC	0.23	0.50	0.77	0.93	1.32
M3SB	0.17	0.47	0.74	0.84	1.21	M3SB	0.20	0.43	0.69	0.89	1.24
M3WB	0.18	0.48	0.74	0.88	1.23	M3WB	0.21	0.47	0.74	0.89	1.25
		Time, day							Time, day		
Average chloride absorption (%) in FSC/IC concrete cubes											
Cube ID	31	61	91	121	160	Cube ID	31	61	91	121	160
M1CC	0.13	0.14	0.30	0.54	1.16	M1CC	0.25	0.26	0.39	0.45	1.31
M1SB	0.07	0.08	0.10	0.13	0.22	M1SB	0.14	0.16	0.21	0.25	0.44
M1WB	0.09	0.09	0.12	0.14	0.28	M1WB	0.15	0.16	0.23	0.29	0.53
M2CC	0.17	0.18	0.27	0.41	1.10	M2CC	0.14	0.16	0.30	0.35	1.03
M2SB	0.07	0.09	0.11	0.24	0.31	M2SB	0.10	0.11	0.19	0.22	0.45
M2WB	0.08	0.10	0.23	0.28	0.59	M2WB	0.10	0.11	0.19	0.23	0.64
M3CC	0.11	0.13	0.23	0.28	0.78	M3CC	0.12	0.14	0.22	0.29	0.74
M3SB	0.08	0.09	0.12	0.14	0.36	M3SB	0.08	0.10	0.18	0.22	0.40
M3WB	0.10	0.12	0.20	0.24	0.43	M3WB	0.10	0.11	0.18	0.23	0.53

The average chloride absorption in PSC control/impregnation concrete cubes was slightly increased/decreased with constant higher concrete compressive strength and varied slump values as when compared to pre-conditioned PSC control/impregnation concrete cubes with constant slump value and varied concrete compressive strength. The average chloride absorption in PSC control/impregnation concrete cubes was slightly decreased with lesser concrete compressive strength and constant slump value as when compared to pre-conditioned PSC control/impregnation concrete cubes with constant slump value and varied concrete compressive strength as well as it goes on decreases with increased concrete compressive strength. The average chloride absorption in FSC control/impregnation concrete cubes was slightly decreased with constant higher concrete compressive strength and varied slump values as when compared to pre-conditioned FSC control/impregnation concrete cubes with constant slump value and varied concrete compressive strength. The average chloride absorption in FSC control/impregnation concrete cubes was slightly increased with lesser concrete compressive strength and constant slump value as when compared to pre-conditioned FSC control/impregnation concrete cubes with constant slump value and varied concrete compressive strength as well as it goes on decreases with increased concrete compressive strength.

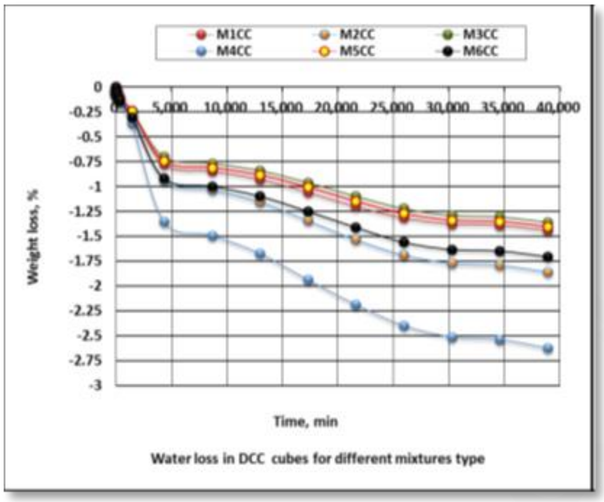

Figure 1 Water weight loss in DCC cubes

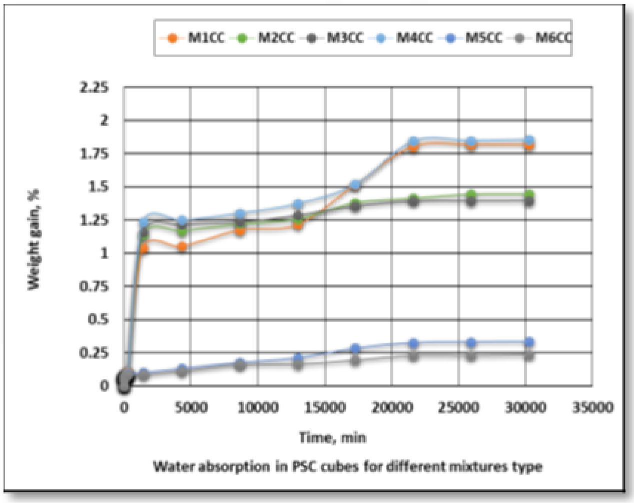

Figure 2 Water weight gain in PSC cubes

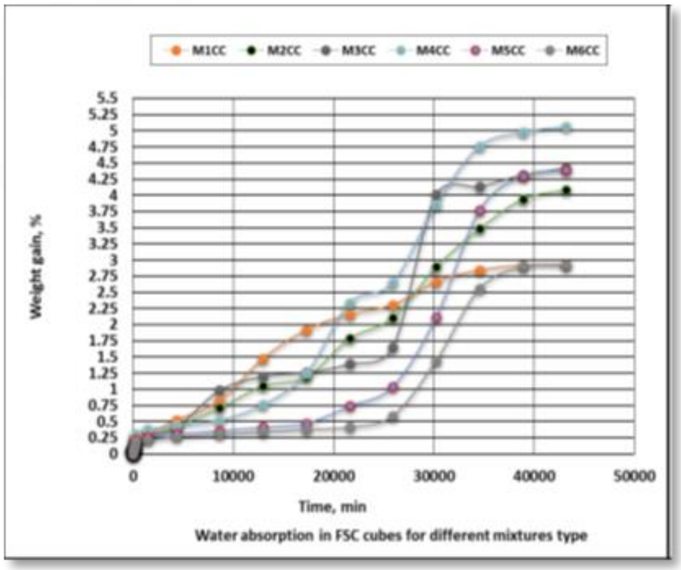

Figure 3 Water weight gain in FSC cubes

5. DISCUSSION ABOUT RESULTS

Thus in the present research work, the effectiveness of 72 preconditioned concrete cubes of size (100) mm on chloride absorption under various pre-conditions such as dry/fully/partially saturated condition was evaluated for in case of six designed mixtures type (M1-M6).The variation of weight loss/gain (water) in pre-conditioned concrete cubes such as dry/partially/fully saturated conditioned concrete cubes was represented in Figs.1-3. The variation of average water weight loss in control DCC cubes was more/less more with constant higher compressive strength and varied slump value as when compared to variation of average water weight loss in control DCC cubes with varied compressive strength and constant slump value. But, the variation of average water weight loss in DCC cubes was pre-dominantly increased with lesser compressive strength and constant slump value and goes on decreased somewhat with increased compressive strength. The variation of average water weight gain in control PSC cubes was lesser with constant higher compressive strength and varied slump value/varied compressive strength and constant slump value as when compared to variation of average water weight gain in control FSC cubes with constant compressive strength and varied slump value/varied compressive strength and constant slump value. In fact, the variation of average water weight gain in control PSC/FSC cubes was pre-dominantly depends on saturation time duration and mixture proportioning method, pore structure, packing density of concrete, cement content, concrete matrix and cement paste interface zone, as well as aggregate volume fraction ratio in the concrete matrix.

In fact, the average chloride absorption value in control and impregnation DCC/SB/WB cubes was found to be higher with higher constant concrete compressive strength, and varied slump values, as well as varied concrete compressive strength and constant slump value as when compared to average chloride absorption in control and impregnation PSC and FSC/SB/WB cubes at longer time duration (160 day). The average chloride absorption was pre-dominantly increased in control and impregnation DCC/SB/WB cubes for lesser compressive strength and constant slump value and the chloride absorption value was decreases with increased compressive strength and constant slump value for in case of designed mixtures type at longer time duration (160 day). Similarly, the average chloride absorption was decreased in solvent based and water based impregnation DCC cubes as when compared to control DCC cubes for constant higher compressive strength and varied slump value as well as varied compressive strength and constant slump value at longer time duration. The variation of average chloride absorption in control/solvent/water based impregnation DCC cubes at longer time duration (160 day) was represented in Fig.4 for different designed mixtures type (M1-M6). In fact, the average chloride absorption value in control and impregnation PSC/SB/WB cubes was found to be higher with higher constant concrete compressive strength, and varied slump values, as well as varied concrete compressive strength and constant slump value as when compared to average chloride absorption in control and impregnation FSC/SB/WB cubes at longer time duration (160 day). The average chloride absorption was pre-dominantly increased in control and impregnation PSC/SB/WB cubes for lesser compressive strength and constant slump value and the chloride absorption value was decreases with increased compressive strength and constant slump value for in case of designed mixtures type at longer time duration (160 day). Similarly, the average chloride absorption was decreased in solvent and water based impregnation PSC cubes as when compared to control PSC cubes for constant higher compressive strength and varied slump value as well as varied compressive strength and constant slump value at longer time duration. The variation of average chloride absorption in control/solvent/water based impregnation PSC cubes at longer time duration (160 day) was represented in Fig.5 for different designed mixtures type (M1-M6).

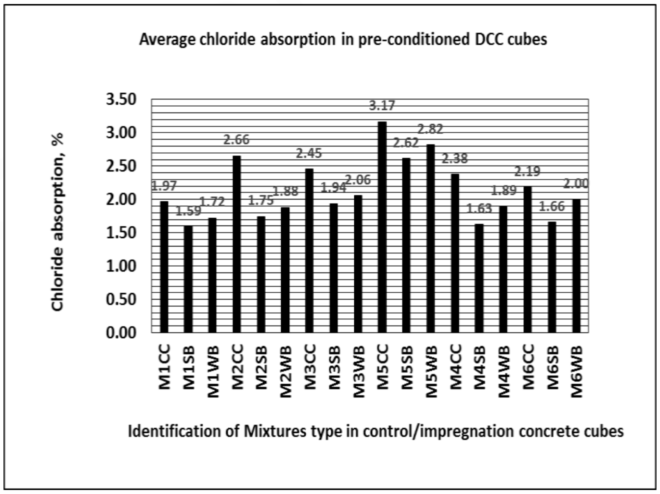

Figure 4 Chloride absorption in DCC cubes

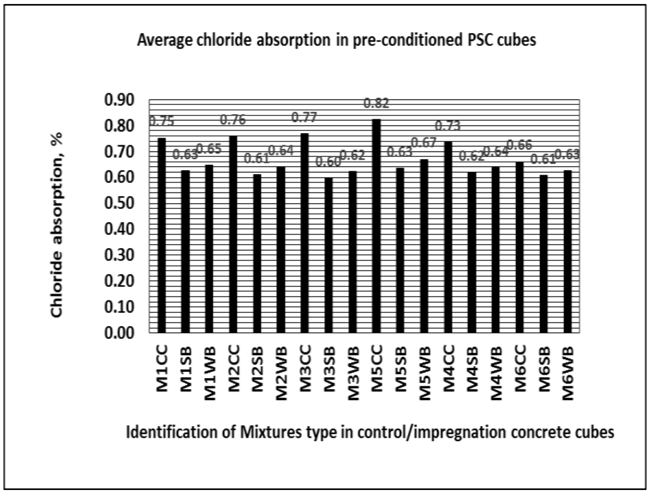

Figure 5 Chloride absorption in PSC cubes

The average chloride absorption value in control/impregnation FSC/SB/WB cubes was found to be pre-dominantly decreased with constant higher concrete compressive strength and varied slump values as well as varied concrete compressive strength and constant slump value as when compared to average chloride absorption in control/impregnation DCC/SB/WB cubes. The average chloride absorption was more increased in control/impregnation FSC/SB/WB cubes for lesser compressive strength and constant slump value. Whereas the average chloride absorption in control/impregnation FSC/SB/WB cubes was goes on decreases with increased compressive strength and constant slump value. The variation of average chloride absorption in control/solvent/water based impregnation FSC cubes at longer time duration (160 day) was represented in Fig.6 for different designed mixtures type (M1-M6).

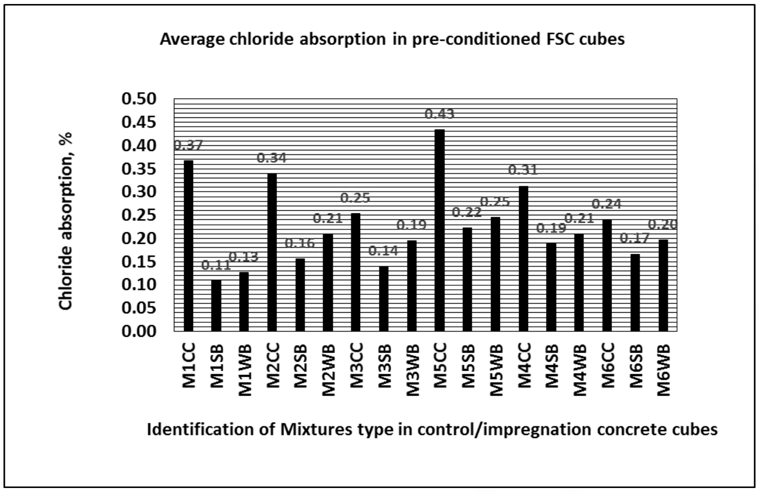

Figure 6 Chloride absorption in FSC cubes

The transport mechanism of chloride absorption in concrete cubes during wetting/drying pre-conditioned concrete cubes is evaluated in this research work. The dry-wet pre-condition accelerate the transport process of chloride absorption within a certain distance from the surface, beyond this distance, chloride absorption in the complete immersion specimens migrate more rapidly than those under dry-wet pre-condition [15]. Especially, in case of absolute dry condition, the penetration rate of chloride ion will be much larger because of advection process than that in diffusion process in mortar with water saturated condition. Moreover, at the surface part of mortar, additional chloride content due to diffusion process can be also confirmed on distribution of chloride content due to advection process during absorption test. Therefore, in order to assess the penetration of chloride ion, effects of both advection and diffusion processes depending on moisture condition of mortar should be considered. The concrete are in a state of flux between saturated and partially saturated conditions as they undergo continuous cycles of wetting and drying. In saturated concrete, dissolved ions enter through diffusion, whereas in partially saturated concrete, ion-containing fluids are absorbed by capillary suction and concentrated by evaporation of water. It was found from the researchers [16] that, the longer drying times increase the rate of chloride ingress. A good relationship exists between the depth of chloride penetration and the square root of the number of cycles. In fact several authors have shown that an effective chloride barrier can be established in pre-conditioned concrete by surface impregnation with a liquid water repellent. However, the question arises frequently as to whether chloride contaminated concrete structures with high moisture content can still be protected from further chloride penetration into the porous structure by surface impregnation. There is a need to determine the efficiency of surface impregnation of chloride-contaminated concrete before any protective treatment applied on the concrete. In the present research work, tests were run to investigate the influence of pre-condition such as DCC/PSC/FSC cubes on the efficiency of surface impregnation. It's actually confirmed from the results that, higher saturation degree reduces the efficiency of surface impregnation. Thus, pre-drying of concrete with high saturation degree is essential for the establishment of an effective, reliable, and long lasting chloride barrier. The chloride absorption was increased in pre-conditioned control/impregnation (SB/WB) DCC cubes as when compared to control/impregnation (SB/WB) PSC, and control/impregnation (SB/WB) FSC conditioned cubes as represented in Figs.7-9.Thus the average variation of chloride absorption at different time duration until 160 days for in case of DCC/PSC/FSC (SB/WB) cubes was represented in Table.9.

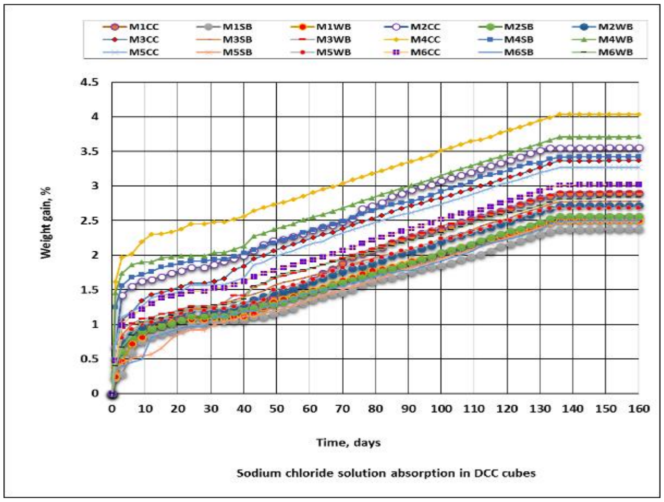

Figure 7 Chloride diffusion coefficient in DCC cubes

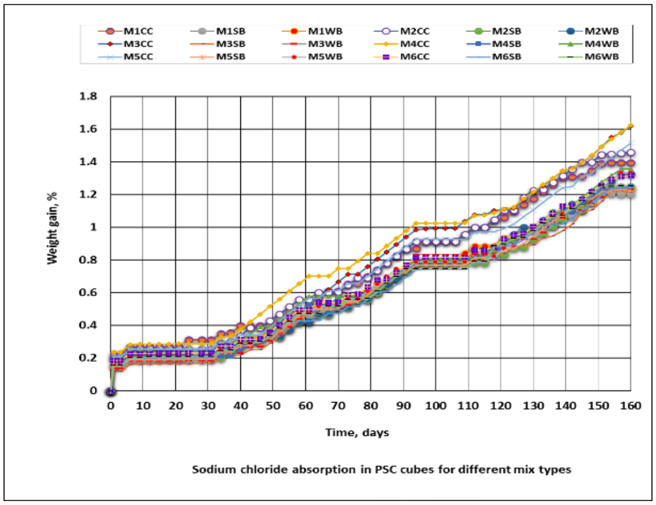

Figure 8 Chloride diffusion coefficient in PSC cubes

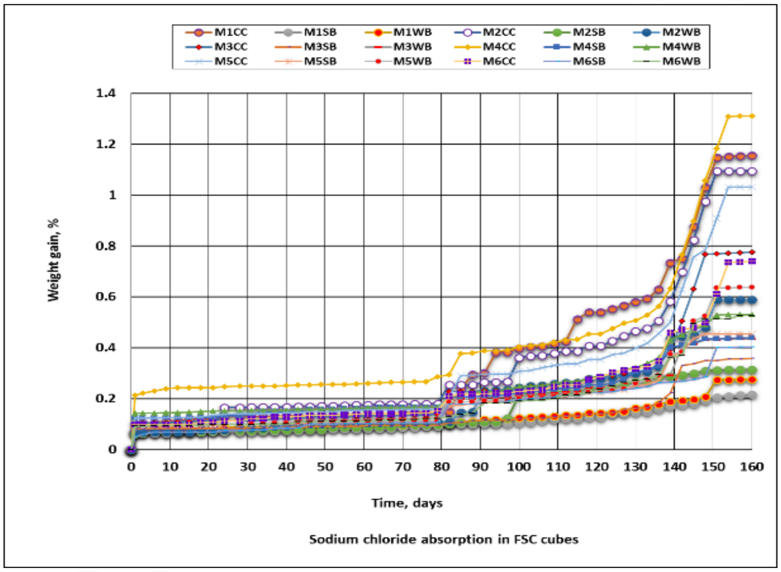

Figure 9 Chloride diffusion coefficient in FSC cubes

6. CONCLUSION

The process of wetting/drying is a major problem for concrete infrastructures which was exposed to chlorides and its effects are most severe in many concrete infrastructures locations such as marine structures, particularly in the splash and tidal zones, parking garages exposed to deicer salts, and highway structures, such as bridges and other elevated roadways for instance the Gardner expressway. When the concrete is dry/partially dry, which was then exposed to salt water, it will imbibe the salt water by capillary suction. The concrete will continue to suck in the salt water until saturation or until there is no more reservoir of salt water. A concentration gradient of chlorides will develop in the concrete, stopping at some point in the interior of the concrete. If the external environment becomes dry, then pure water will evaporate from the pores, and salts that were originally in solution may precipitate out in the pores close to the surface. The point of highest chloride concentration may exist within the concrete. On subsequent wetting, more salt solution will enter the pores, while re-dissolving and carrying existing chlorides deeper into the concrete. The rate to which the chlorides will penetrate the concrete depends on the duration of the wetting/drying periods. If the concrete remains wet, some salts may migrate in from the concrete surface by diffusion. However, if the wetting period is short, the entry of salt water by absorption will carry the salts into the interior the concrete and be further concentrated during drying. The process of wetting/drying increases the concentrations of ions such as chlorides, by evaporation of water. The drying of the concrete also helps to increase the availability of the oxygen required for steel corrosion, as oxygen has a substantially lower diffusion coefficient in saturated concrete. As the concrete dries and the pores become less saturated, oxygen will have a better chance to diffuse into the concrete and attain the level necessary to induce and sustain corrosion. There is an increased availability of oxygen that also contributes to the deterioration compared to the submerged part of the structure. The concrete is fully submerged; less chloride would enter the concrete as the dominant penetration rnechanism is diffusion through the pore solution. There are several factors that can affect the degree that chlorides will enter concrete through wetting/drying. In fact the ingress of chlorides into concrete is strongly influenced by the sequence of wetting/drying, and on the time duration. The following principal conclusions have been drawn:

1. The wetting/drying tests can be considered for the most part as a test of sorption cycles. In fact at partially saturated condition, sorption is the controlling rnechanism until a state of saturation has occurred, at which time diffusion becomes the controlling mechanism in the surface layers of the concrete.
2. For different designed mixtures type of concrete, varying time durations are required in ordered to achieve a desired pre-conditions such as DCC/PSC/FSC conditioned cubes. Actually for constant higher concrete compressive strength, varied slump values and higher/lower w/c ratio, as well as varied concrete compressive strength, constant slump value and higher/lower w/c ratio, a true state of saturation is difficult to obtain. The rate of absorption (sorptivity) is controlled by the pore structure of the concrete and its degree of saturation for in case of PSC and FSC cubes
3. The chloride diffusion in saturated pores at greater depths continues to occur during the drying phase. In which an extending the drying period appears to increase the chloride ingress by capillary sorption in subsequent wetting process, rather than by continued diffusion during the drying phase. Furthermore the rate of drying is dependent on the pore structure of the concrete and as a result higher quality concretes dry at a slower rate.
4. The variation of average water weight loss in control DCC cubes was more/less more with constant higher compressive strength and varied slump value as when compared to variation of average water weight loss in control DCC cubes with varied compressive strength and constant slump value. But, the variation of average water weight loss in DCC cubes was pre-dominantly increased with lesser compressive strength and constant slump value and goes on decreased somewhat with increased compressive strength.
5. The variation of average water weight gain in control PSC cubes was lesser with constant higher compressive strength and varied slump value/varied compressive strength and constant slump value as when compared to variation of average water weight gain in control FSC cubes with constant compressive strength and varied slump value/varied compressive strength and constant slump value. In fact, the variation of average water weight gain in control PSC/FSC cubes was pre-dominantly depends on saturation time duration and mixture proportioning method, pore structure, packing density of concrete, cement content, concrete matrix and cement paste interface zone, as well as aggregate volume fraction ratio in the concrete matrix.
6. The average chloride absorption in DCC control/impregnation (SB/WB) concrete cubes were pre-dominantly increased with constant higher concrete compressive strength and varied slump values as when compared to pre-conditioned DCC control/impregnation (SB/WB) concrete cubes with constant slump value and varied concrete compressive strength. The average chloride absorption in DCC control/impregnation (SB/WB) concrete cubes was pre-dominantly increased with lesser concrete compressive strength and constant slump value as when compared to pre-condition DCC control/impregnation (SB/WB) concrete cubes with constant slump value and varied concrete compressive strength as well as it goes on decreases with increased concrete compressive strength.
7. The average chloride absorption in PSC control/impregnation (SB/WB) concrete cubes were slightly increased/decreased with constant higher concrete compressive strength and varied slump values as when compared to pre-conditioned PSC control/impregnation (SB/WB) concrete cubes with constant slump value and varied concrete compressive strength. The average chloride absorption in PSC control/impregnation (SB/WB) concrete cubes was slightly decreased with lesser concrete compressive strength and constant slump value as when compared to pre-condition PSC control/impregnation (SB/WB) concrete cubes with constant slump value and varied concrete compressive strength as well as it goes on decreases with increased concrete compressive strength.
8. The average chloride absorption in FSC control/impregnation (SB/WB) concrete cubes were slightly decreased with constant higher concrete compressive strength and varied slump values as when compared to pre-conditioned FSC control/impregnation (SB/WB) concrete cubes with constant slump value and varied concrete compressive strength. The average chloride absorption in FSC control/impregnation (SB/WB) concrete cubes was slightly increased with lesser concrete compressive strength and constant slump value as when compared to pre-conditioned FSC control/impregnation (SB/WB) concrete cubes with constant slump value and varied concrete compressive strength as well as it goes on decreases with increased concrete compressive strength.

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