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Comparison of Chloride Ingress in Pre-Conditioned Concrete Cubes-Slabs

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Abstract- Ice builds up on the top surface of concrete slabs and bridge decks during the winter. De-icing agents are used to try and get rid of the snow and ice. Through tiny cracks in the concrete, these salts penetrate the reinforcing steel. These salts' chlorides may interact with the reinforcing steel over time, causing the passive layer to dissolve and the steel to corrode. One of the most common reasons for the early demise of concrete infrastructure facilities, is reinforcement corrosion in concrete has significant negative effects on both the economy and public safety. In addition, atmospheric carbon dioxide may slowly seep into the concrete and interact with the alkaline pore solution. Through the pores in the concrete, chloride ions from winter maintenance tasks, the sea environment, or other contaminants might reach the reinforcement's passive layer and de-passivate it. Thus, steel corrosion in concrete can be caused by chloride penetration, carbonation, and poor concrete cover quality. This results in a build-up of tension in the concrete, which deteriorates and dangerously reduces its structural durability. As a result, it is necessary to measure the chloride concentration in concrete slabs and cubes, which is a crucial element. In the current research, an effort was made to interpret the concrete chloride concentration in order characterizes the various concrete mixtures designed for pre-conditioned concrete slabs and cubes that were salt ponded with chloride solution for approximately 160 days in dry, fully saturated, and partially saturated conditions. Consequently, the goals of this research are, First, this study will look at how different conditions, such as dry, fully or partially saturated conditions, affected the results of chloride concentration in concrete slabs and cubes at different drill depths (30-40-50 mm) with different mixture proportions, in which compressive strength, slump, and w/c ratio value varied with constant slump as in the first case and with constant compressive strength as in the second case. In order to assess the chloride concentration under various exposure conditions, 72 concrete cubes (100 mm3) and 18 concrete slabs (450x450x100 mm) with concrete grades ranging from 25 to 40 N/mm2 were constructed. The findings indicate that the chloride concentration value increased in all planned mixture types in dry/saturated conditioned concrete slabs at lower drill depths as compared to greater drill depths. Comparing DCC/PSC/FSC slabs impregnated with solvent/water to control slabs for both constant higher compressive strength and variable slump value as well as variable compressive strength and constant slump value, it can be shown that the average chloride content was reduced in both cases. The average chloride content at drill depths (30-50 mm) in control concrete cubes was found to be somewhat larger in magnitude as compared to solvent-based and water-based impregnation concrete cubes for higher compressive strength and varied slump value. The average chloride concentration was found to be slightly lower in magnitude in control/solvent/water based impregnated partially/fully saturated concrete cubes at drill depths (30-50) mm as compared to dry conditioned control/solvent/water based impregnated concrete cubes for higher/lower compressive strength and varied/constant slump value. The average chloride concentration at drill depths (30–50 mm) in partially saturated control/solvent/water-based impregnation concrete cubes was found to be slightly higher in magnitude as compared to fully saturated conditioned control/solvent/water-based impregnation concrete cubes for higher/lower compressive strength and varied/constant slump value.

Keywords- Concrete, mixture proportion, grade of concrete, pre-conditioning, w/c ratio, chloride penetration

I. INTRODUCTION

It is commonly known that de-icing agents like sodium, potassium, and magnesium chloride can cause serious harm to concrete structures and pavements, decreasing their performance and durability. Despite being one of the primary causes of concrete deterioration through scaling, spalling, physical and chemical salt attack, and the corrosion of embedded steel, the application of de-icing salts cannot be stopped for safety reasons. The simultaneous mechanisms of chloride ingress into concrete structures, including capillary absorption, diffusion in pores and cracks, and permeation under hydraulic pressure, can occur depending on the environmental conditions, making it more difficult to comprehend and evaluate the transport properties of concrete. Pure diffusion, for instance, is unlikely to be the main mechanism causing chloride infiltration since concrete is rarely entirely saturated; rather, the uneven distribution of moisture is more likely to result in capillary absorption and, in certain situations, entrance under pressure. Much faster chloride penetration results from the synergistic interaction of diffusion and absorption (Fraj, et al. 2012). When concrete is exposed to significant amounts of chemicals used in chloride-based de-icing, two types of deterioration can take place. The first is the actual deterioration of the concrete, and the second is the corrosion of embedded steel that causes the concrete to deteriorate. Concrete deteriorates due to exposure to de-icing chemicals due to both physical and chemical causes. Scaling or crazing of the slab surface is caused by physical mechanisms linked to the repetitive use of de-icing chemicals (Van Dam et al.2002). The main mechanisms under consideration are not completely understood, but they probably combine increased saturation, thermal stresses brought on by ice melting, and increased osmotic pressures brought on by the de-unbalanced icer's effect on the ionic concentration in the concrete's capillary pore solution (Mindesset, al. 2003). In over-vibrated or subpar concrete, de-icer scaling and deterioration are more likely to happen. According to recent studies, chemical change of the cement paste can also happen. This can cause calcium hydroxide to dissolve, the concrete pore system to become coarser, and harmfully expansive oxychloride compounds to develop (Sutter, 2008). When concrete laboratory specimens were exposed to intense calcium chloride or magnesium chloride solutions, this latter distress mechanism was discovered. The application intensities of the solutions utilised in the cited study were roughly 30 to 50 percent less than those typically applied for de-icing or anti-icing [Sutter, 2008]. Along with severe cracking and expansion, significant strength losses and declines in freeze-thaw performance were also noted (Sutter, 2008). In the same investigation, concrete specimens subjected to highly concentrated NaCl solutions did not show signs of chemical degradation. Due to its significant strength and variety of qualities, reinforced concrete is arguably the most often used construction material in the world. Reinforced concrete buildings last for many years in service when they are properly designed, constructed, and maintained. Performance and durability of concrete structures are influenced by a variety of elements throughout their service life. In reinforced concrete constructions, several physicochemical processes occur that could cause degradation and suffering. One of the main mechanisms for reinforced concrete's deterioration, corrosion of the reinforcing steel threatens the structure's structural integrity and safety. In the United States alone, the costs of repairing structures harmed by reinforcement corrosion have been put in the billions of dollars (Lorentz and French, 1995). The most typical type of concrete bridge deterioration is the corrosion of reinforcement brought on by chloride contamination and carbonation of the concrete. A number of situations are recounted, based on the author's experience, in which the deterioration of regular and pre-stressed reinforcement as well as the reasons for and effects of the deterioration seen are portrayed. According to investigations, the major causes are a lack of concrete cover, poor concrete quality, and salt penetration that is aggressive. The histogram of rebar cover depths and the carbonation depth must be connected in order to forecast the likelihood of their coincidence. Monitoring the status of the tendons in pre-stressed concrete precast post-tensioned segmental bridge decks reveals that voids and water are frequently present in the ducts, which causes the tendons to rust locally. Tension failure of the wires used in tendons has been seen in some pre-stressed concrete bridges. Sadly, there are no trustworthy methods for evaluating the state of the pre-stressing steel in existing structures (Zenonas Kamaitis, 2002). According to AC1 222R-96, the most common type of early corrosion of steel reinforcement is chloride-induced corrosion. Chloride ions entering from the outside are the usual cause of the chloride attack problem. Chloride ions may occasionally be found in the original components of concrete, but it is the external chloride ions that are introduced during the structure's exposure to service that cause an increase in their concentration up to and above the threshold level, a critical concentration of chlorides that signifies the beginning of corrosion. The types of concrete structures most prone to corrosion brought on by chlorides are marine structures, bridge decks, road slabs, and parking structures (ACI Comrnitte 222R-96, 1999).

The effectiveness of conventional concrete cover with a water-cement ratio of 0.36 and 0.43 in airborne-chloride environments is discussed in this paper, and the authors also suggest a practical evaluation method based on Japanese surveys of the distribution of airborne chloride and the deterioration of existing concrete highway bridges. The boundary chloride level and its relationship to airborne chloride levels are used in the suggested evaluation method for uncracked concrete exposed to the choride atmosphere. The findings of this study serve as the foundation for a persuasive policy for the prevention of corrosion for concrete bridges with 100-year design lifetimes in coastal areas (Yoshiki Tanakaet, et al. 2006). The report included a portion of the laboratory research that was done to determine the behaviour of the concrete cover submerged in salt water. To examine chloride penetration, samples from three distinct concrete mixtures were created. For a certain concrete mix, the profiles of chloride penetration were identified. Bulk Diffusion Test and Pressure Penetration Test of concrete submerged in salt water were used to compare the processes of chloride penetration through the concrete cover and through the concrete, respectively. The relationship between BDT diffusion coefficients and PPT permeation coefficients was examined and more study was advised (Damir Zenunovicet, et al. 2017) at the conclusion of the work. For the majority of deterioration processes affecting the durability of reinforced concrete, the parameter concrete permeability is essential. Since aggregates typically have limited permeability, the cement paste's pore system, the interfacial transition zone, and cracks or fissures in the concrete serve as the main channels for transport mechanisms (Neville, 1995; Rostam, et al. 1989). Depending on the driving power, multiple methods allow chloride ions to pass through concrete. The most well-known chloride transport modes through concrete include capillary suction, migration, diffusion, and penetration. For concrete exposed to wetting and drying cycles, capillary suction is typically the main mechanism (Bioubakhsh, 2011). The wetting stage of these cycles sees capillary water intake, whereas the drying step allows the capillaries to be partially emptied, enhancing capillary suction in the following wetting cycle (Rostam, et al. 1989). The extent to which capillary suction affects the level of moisture in concrete is constrained. The capillary pore system's minimal interconnectedness is to blame. In the presence of an electric field, chloride ions migrate or electromigration. Ionic mobility and the strength of the electric field both affect how quickly ions migrate (Bockris and Reddy, 2000). Diffusion is the primary method of transportation in the case of water-saturated concrete. The process of diffusion is able to raise chlorides to the level of the reinforcing steel, speeding up the corrosion of the rebar. Concentration gradients act as a driving force for the diffusion of dissolved chloride ions. To determine the likelihood that a typical reinforced concrete continuous slab bridge will collapse structurally, a structural deterioration reliability model was created. De-icing salt treatment or air exposure in a marine setting can both start corrosion. It is anticipated that corrosion will cause the cross-sectional area of the reinforcing steel to decrease. Over the course of the structure's life, annual increments' failure probabilities are calculated using the Monte Carlo simulation method (75 years). It has been demonstrated that the use of de-icing salts or exposure to the marine atmosphere significantly reduces structural safety over the long run. The likelihood of failure increases noticeably when the cover is less than what is currently required for design (Mark Stewart and David V.Rosowsky, 1998). Depending on the driving force at play, chloride ions and other hostile chemicals permeate through concrete using various ways. The most well-known methods of transporting chloride through concrete include diffusion, permeability, and absorption. The pushing force and, consequently, the methods by which chloride penetrates concrete are determined by the fresh state of the concrete and the service environment. Chloride is transported by diffusion via the pore solution in saturated concrete that is submerged continuously in aqueous solution. Movement into and through unsaturated concrete, a typical condition for concrete with surfaces exposed to the atmosphere, is primarily regulated by absorption through the capillary pore system and diffusion of chlorides through pore solution. Concrete is intermittently wetted by rain or condensation in highway buildings and bridges, and it dries out in between these wetting occurrences. Corrosion of the steel reinforcement is the most significant and expensive deterioration mechanism impacting reinforced concrete structures. Progressive surface evaporation occurs for liquid in the pores. The most likely scenario in this instance is that chloride will initially enter the concrete through absorption, creating a pool of chloride ions only a short distance from the concrete surface from which diffusion can take place. Subsequent wettings take the chlorides further into the concrete if it dries out to a deeper depth. Therefore, it would seem that absorption and diffusion are significant transport modes linked to chloride ingress in bridges, marine structures, and highway constructions. The following provides a quick overview of permeability, which is required for understanding the idea of absorption, before going into detail about these two methods of chloride intrusion (Shankar Badakundri, et al. 2018).

This study discusses a number of steel-fibre reinforced concrete durability factors. According to published research findings, despite having high chloride concentrations, steel fibres embedded in concrete do not exhibit corrosion because of the short length of the fibres and the casting circumstances. Additionally, it was claimed that permeability for cracked concrete compared to plain concrete was significantly impacted by the fibres' capacity to stop the spread of crack width. In accordance with recent research, some of the fibres may be attached to and in contact with the regular steel reinforcement, establishing a galvanic couple where the fibres would serve as sacrificial anodes shielding the rebar and slowing or even preventing the corrosion process. It is stated that steel fibres could be used in reinforced concrete structures exposed to chloride conditions to increase their overall durability performance based on evaluated durability attributes. However, additional experimental findings in favour of this theory are required (Berrocal Carlos, et al. 2013). Cores from four concrete from bridge decks in New York State and one in Ohio were procured in 2001 and 2002 with assistance from the Silica Fume Association in the United States. Additionally, cores were extracted from two Ohio buildings and four Wisconsin, Utah, and Wisconsin parking garage decks. All concrete buildings that were cored ranged in age from 6 to 15 years and had been in contact with de-icing salts. The cores were subjected to tests for chloride penetration profiles utilizing millimeter profiling, chloride bulk diffusion by ASTM C 1556 (according to Nordtest NT Build 443), and quick chloride penetration (ASTM C 1202). Where visible, the level of cover was also documented. According to the findings, all full-depth bridge decks made with silica fume concrete exhibited high resistance to chloride penetration, with an average of between 290 and 690 coulombs, compared to 3900 coulombs for Portland cement concrete. Coulomb values for parking decks ranged from 620 to 980. The silica fume concretes were predicted to have a residual life of between 30 and 61 years using the Life-365 program's predicted time-to-corrosion service life. When utilized as a control in one instance, Portland cement concrete on an approach slab to a bridge deck was discovered to have been susceptible to corrosion at the time of coring. For the three new bridges and all of the parking garage decks produced using silica fume concrete, predicted residual service lives based on extrapolation from existing chloride penetration profiles gave longer projections by an average of 10 years (Hooton, et al.

2010). The impact of 1D and 2D chloride ingress on concrete resistivity and steel reinforcement corrosion rate is the subject of ongoing research, the findings of which are presented in this publication. This laboratory-based experiment used 12 concrete beams constructed with concrete of binder blend PC (50)/GGBS (50), w/b = 0.40, and 10mm steel reinforcement rods at concrete cover of 20 mm. The concrete beams that were subjected to 1D and 2D chloride ingress, respectively, had the steel reinforcing bars placed in the middle or at an orthogonal corner. On one-half of the beams, 3-point bending was used to create a single crack. The beams underwent a repeated cycle of two weeks of ponding in 5 percent NaCl and two weeks of air drying in standard laboratory conditions. In comparison to beams exposed to 1D chloride intrusion, the corrosion rate of both cracked and uncracked specimens exposed to 2D chloride ingress was substantially higher. Despite higher corrosion rates being observed, the uncracked specimens had lower concrete resistivity values than the cracked ones (ZeGyangZakka and Mike Otieno, 2018). Concrete deterioration has been attributed mostly to steel corrosion in the concrete over time. According to Torres-Luque et al. (2014) and Broomfield (2007), the main causes of steel corrosion are the breakdown (de-passivation) of the thin oxide protective layer on the steel surface brought on by carbonation of the concrete to the depth of the reinforcement bar or the presence of a sufficient concentration of chlorides at the steel surface. Although steel corrosion in concrete has been attributed mostly to chloride exposure, a rising danger of carbonation-induced corrosion due to climate change has also been predicted (Peng and Stewart, 2015). The topic of this essay is corrosion brought on by chloride. In chloride-rich environments like sea zones and places where chloride-based solutions (such de-icing salts) are used, corrosion caused by chloride is common. By using chloride-based admixtures, contaminating the raw materials used to make concrete, and penetrating from the outside environment, chlorides can contaminate concrete. After de-passivation, the quality of the steel-concrete interface, the degree of concrete exposure, the concrete cover's resistance to the penetration of agents that cause corrosion, such as oxygen and moisture, and the rate of steel corrosion all play a role (Broomfield, 2007; Castel, et al. 2003; Castel, et al. 2015; Papakonstantinou, and Shinozuka, 2013). In order to remove ice from transportation infrastructure, a variety of techniques can be used, including plowingg, natural melting, moving traffic, and chemical treatment. Additionally, the de-icing and anti-icing of these infrastructures depend on chemicals and fine aggregates (Kuemmel, 1994). In actuality, a variety of chemical de-icing solutions are offered for sale in the market. Sodium chloride is the chemical agent that is most economical. However, concrete structures, such as concrete bridge decks, have been harmed by the use of chloride as a de-icing agent. Additionally, a de-icing agent may cause harm to an automobile's body, the dirt at the side of the road, and water runoff (Mcelroy, et al. 1988). In addition, de-icing agents can create osmotic pressure, which pushes the water out of the slab layer where it freezes (Neville, 1996). Numerous researchers' investigations have proven that regular/pre-stressed reinforcement can corrode (Zenonas Kamaitis, 2002). Additionally, in many cold areas, the de-icing agents may also result in road scaling. due to the rapid infiltration of aggressive chemicals that may induce concrete reinforcement corrosion (Bertolinie, et al. 2005). When there is a higher degree of saturation and a de-icing agent present, the de-icing salts may also cause strength loss from frost action in certain structural elements [Scherer and Valenza, 2005]. Thus, scaling and frost action were regarded as the two most significant aspects that affected how long concrete infrastructure would last (Vesikari and Ferreria, 2011). It is necessary to interpret the chloride concentration in Committees slabs in situations like dry, fully saturated, or partially saturated salt ponds with chloride solution for a considerable amount of time. Only since it was discovered that chloride-induced corrosion is the main issue affecting concrete durability has the significance of chloride concentration as a durability-based material parameter been given more consideration. In order to characterize the various concrete mixtures designed for pre-conditioned concrete slabs such as dry/fully/partially saturated conditions that were salt ponded with chloride solution for approximately 160 days, the current research work was made in an effort to interpret the concrete chloride concentration. The purpose of the current study is to investigate how different conditions, such as dry, fully or partially saturated conditions, affect the results of chloride concentration in concrete slabs with different mixture proportions, where compressive strength, slump, and w/c ratio value varied with the constant slump in the first case and in the second case. The chloride content was assessed in 18 concrete slabs (450x450x100 mm) with concrete grades ranging from 25 to 40 N/mm2 and in comparison, to concrete cubes under various exposure conditions (100mm3).

II. METHODOLOGY

In the present research work, six different mixtures type were prepared in total as per (BRE, 1988) code standards with concrete slabs of size (450x450x100) mm. Thus totally 18 concrete slabs of size (450x450x100) mm were fabricated with different six mixtures type (M1-M6). Out of which three mixtures type with constant compressive strength (40 N/mm2) and varied slump (0-10, 10-30, and 60-180 mm) were designed as one group (M1-M3). In second group (M4-M6), rest of three mixtures type were designed as with different compressive strength (25 N/mm2, 30 N/mm2, and 40 N/mm2), and constant slump (10-30 mm). Actually, the mixture ingredients quantities were found to be more or less same/equivalent that is why, the mixture proportions were adopted in dry conditioned concrete slabs (DCC) as mixture type (M1=M2), (M3=M5), and (M4=M6) for in case of partially saturated (PSC) as well as fully saturated conditioned concrete (FSC) slabs.

As concern to DCC concrete slabs, the control/impregnation concrete slabs were represented as (M1CS, M2CS) with solvent based/water based concrete slabs as (M1S1, M2S3) and (M1S2, M2S4). For in case of PSC concrete slabs, the control/impregnation concrete slabs were represented as (M3CS, M5CS) with solvent based/water based concrete slabs as (M3S5, M5S7) and (M3S6, M5S8). With reference to FSC concrete slabs, the control/impregnation concrete slabs were represented as (M4CS, M6CS) with solvent based/water based concrete slabs as (M4S9, M6S11) and (M4S10, M6S12). After 28 days of initial curing in water, the concrete slabs were subjected to different exposure conditions such as drying/fully/partially saturated conditions for specified time duration.

Hence, it's possible to develop a better understanding of the long-term tests to assess the resistance of concrete to chloride concentration under different pre-conditions such as drying/partially/fully saturated conditions with/without impregnation. In which totally 12 concrete slabs were treated with two different impregnation materials such as Solvent based (M1S1, M2S3, M3S5, M5S7, M4S9, M6S11) and Water based (M1S2, M2S4, M3S6, M5S8, M4S10, M6S12). The other 6 concrete slabs were left untreated as control concrete slabs (M1CS, M2CS, M3CS, M4CS, M5CS, and M6CS).

The overall details of the mixture proportions were to be represented in (Table 1-2). Three concrete slabs of size (450x450x100) mm were cast for each mixture and overall, eighteen concrete slabs were cast for six types of concrete mixture. The coarse aggregate used was crushed stone with maximum nominal size of 10 mm with a grade of cement 42.5 N/mm2 and fine aggregate used was 4.75 mm sieve size down 600 microns for this research work. As concern to impregnation materials, Water based (WB) and Solvent based (SB) impregnate materials were used in this present research work.

To avoid criticizing or promoting one particular brand of impregnation materials and for confidentiality reasons, the names of the products used will not be disclosed and they will be referred to as WB and SB respectively. WB is a water-borne acrylic co-polymer-based impregnation material which is less hazardous and environmentally friendly.

It is silicone and solvent free and achieves a penetration of less than 10mm. SB consists of a colourless silane with an active content greater than 80% and can achieve penetration greater than 10mm.

Table 1: Concrete slabs mixture proportion (M1-M3)

Mix	Comp/mean	Slump	w/c	C (K	W (K	FA (K	CA	Mix
M1	40/47.84	0-10	0.45	18.23	8.20	29.70	94.16	1:1.63:5.17
M2	40/47.84	10-30	0.44	22.05	9.72	28.49	85.47	1:1.29:3.88
M3	40/47.84	60-180	0.43	27.51	11.85	32.50	72.41	1:1.18:2.63

Table 2: Concrete slabs mixture proportion (M4-M6)

Mix ID	Comp/mean target strength (N/mm^2)	Slump (mm)	w/c	C (Kg)	W (Kg)	FA (Kg)	CA (Kg)	Mixture Proportions
M4	25/32.84	10-30	0.50	19.44	9.72	30.31	86.27	1:1.55:4.44
M5	30/37.84	10-30	0.45	21.63	9.72	30.86	83.55	1:1.42:3.86
M6	40/47.84	10-30	0.44	22.05	9.72	28.49	85.47	1:1.29:3.87

1. Salt Ponding Test

The unidirectional salt ponding was adopted as per AASHTO T259 method. In which the slabs are typically moist cured for a length of time followed by a period of drying at 50% relative humidity before ponding with a 10% sodium chloride solution. AASHTO T259 calls for 14 days moist curing followed by 28 days of drying. The ponded slabs are stored to allow air circulation around the slabs in a room at 50% relative humidity. A cover is placed over the solution pond to prevent evaporation of water from the solution. AASHTO T259 stipulates for a ponding period of 90 days. For low-permeability concretes, this is typically found to be too short for significant penetration of chloride ions into the concrete, and ponding is often extended for longer periods. But in this present research work, certain concrete slabs were pre-conditioned such as fully saturated (60 days)/partially saturated (40 days) conditioned in water for certain time duration and dry pre-conditioning for specified time duration (28 days) before salt ponding test which was carried out for about 160 days at 10% Nacl solution.

The chloride profiles were analysed by drilling the slabs. The drilling was done with a diameter of 20 mm (max aggregate size) and drill depths of (30, 40, and 50) mm. The dust sample were collected, weighted between 1-5 grams as specified by (BS EN 15629:2007) for the determination of the chloride penetration. The chloride concentration for each of the dust samples, including from the control specimens was determined in accordance with BS EN 15629:2007 in hardened concrete.

The chloride content was calculated as a percentage of chloride ion by mass of the sample of concrete. Volhard's Method was used for the determination of the total chloride content in the concrete. Samples of dust powder drilled from the concrete specimens at different drill depths of 30 mm, 40 mm, and 50 mm were used for the determination of the chloride penetration in the concrete samples for in case of six mixtures type (M1-M6). The chloride salt ponding, and analysis in pre-conditioned concrete slabs as shown in Figure 1.

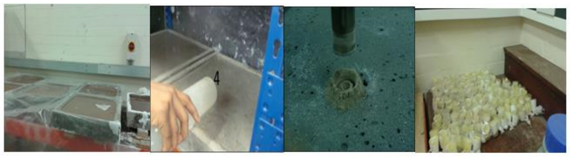


Figure 1: Cl- profile analysis in pre-conditioned concrete slabs

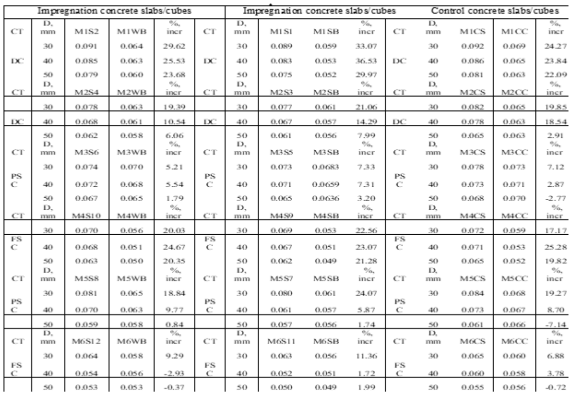
The variation of chloride concentration in pre-conditioned control/impregnation concrete slabs is represented in Table 3. As observed from the results (Table.3), the chloride concentration was found to be increased at drill depth (30 mm) in DCC/PSC/FSC control/impregnation concrete slabs as when compared to DCC/PSC/FSC control/impregnation concrete slabs at drill depths (40 mm, 50 mm) respectively.

Table 3: Cl- concentration in different pre-conditioned concrete slabs

Final cc(%) results for DCC slabs				Final cc(%) results for PSC slabs				Final cc(%) results for FSC slabs			
Mix type[M1=M2]				Mix type[M3=M5]				Mix type[M4=M6]			
Slab ID	30 mm	40 mm	50 mm	Slab ID	30 mm	40 mm	50 mm	Slab ID	30 mm	40 mm	50 mm
M1CS	0.092	0.086	0.082	M3CS	0.079	0.073	0.069	M4CS	0.072	0.071	0.065
M1S1	0.089	0.084	0.075	M3S5	0.074	0.071	0.066	M4S9	0.069	0.067	0.062
M1S2	0.092	0.085	0.080	M3S6	0.075	0.072	0.067	M4S10	0.070	0.069	0.063
M2CS	0.082	0.078	0.065	M5CS	0.085	0.074	0.062	M6CS	0.065	0.060	0.056
M2S3	0.077	0.067	0.061	M5S7	0.080	0.061	0.058	M6S11	0.063	0.052	0.050
M2S4	0.078	0.068	0.063	M5S8	0.081	0.071	0.059	M6S12	0.064	0.055	0.054

The variation of chloride concentration in pre-conditioned control/impregnation concrete slabs/cubes was represented in Table 4. As observed from the results that (Table 4), the chloride concentration was found to be increased in DCC/PSC/FSC control/impregnation concrete slabs as when compared to DCC/PSC/FSC control/impregnation concrete cubes as confirmed from drill depths (30 mm, 40 mm, and 50 mm) respectively.

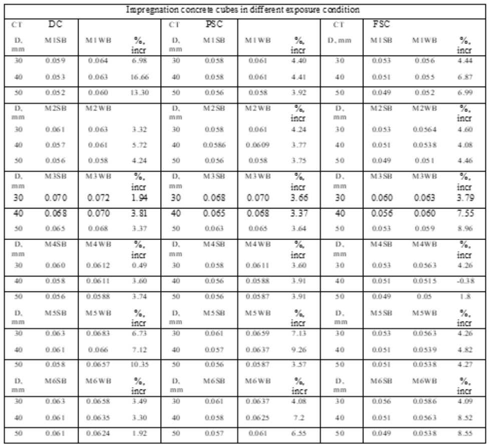
Table 4: Cl- concentration in pre-conditioned concrete slabs/cubes



Impregnation concrete slabs/cubes					Impregnation concrete slabs/cubes					Control concrete slabs/cubes				
CT	D, mm	M1S2	M1WB	%, incr	CT	D, mm	M1S1	M1SB	%, incr	CT	D, mm	M1CS	M1CC	%, incr
	30	0.091	0.064	29.62		30	0.089	0.059	33.07		30	0.092	0.069	24.27
DC	40	0.085	0.063	25.53	DC	40	0.083	0.053	36.53	DC	40	0.086	0.065	23.84
	50	0.079	0.060	23.68		50	0.075	0.052	29.97		50	0.081	0.063	22.09
CT	D, mm	M2S4	M2WB	%, incr	CT	D, mm	M2S3	M2SB	%, incr	CT	D, mm	M2CS	M2CC	%, incr
	30	0.078	0.063	19.39		30	0.077	0.061	21.06		30	0.082	0.065	19.85
DC	40	0.068	0.061	10.54	DC	40	0.067	0.057	14.29	DC	40	0.078	0.063	18.54
	50	0.062	0.058	6.06		50	0.061	0.056	7.99		50	0.065	0.063	2.91
CT	D, mm	M3S6	M3WB	%, incr	CT	D, mm	M3S5	M3SB	%, incr	CT	D, mm	M3CS	M3CC	%, incr
	30	0.074	0.070	5.21		30	0.073	0.0683	7.33		30	0.078	0.073	7.12
PSC	40	0.072	0.068	5.54	PSC	40	0.071	0.0659	7.31	PSC	40	0.073	0.071	2.87
	50	0.067	0.065	1.79		50	0.065	0.0636	3.20		50	0.068	0.070	-2.77
CT	D, mm	M4S10	M4WB	%, incr	CT	D, mm	M4S9	M4SB	%, incr	CT	D, mm	M4CS	M4CC	%, incr
	30	0.070	0.056	20.03		30	0.069	0.053	22.56		30	0.072	0.059	17.17
FSC	40	0.068	0.051	24.67	FSC	40	0.067	0.051	23.07	FSC	40	0.071	0.053	25.28
	50	0.063	0.050	20.35		50	0.062	0.049	21.28		50	0.065	0.052	19.82
CT	D, mm	M5S8	M5WB	%, incr	CT	D, mm	M5S7	M5SB	%, incr	CT	D, mm	M5CS	M5CC	%, incr
	30	0.081	0.065	18.84		30	0.080	0.061	24.07		30	0.084	0.068	19.27
PSC	40	0.070	0.063	9.77	PSC	40	0.061	0.057	5.87	PSC	40	0.073	0.067	8.70
	50	0.059	0.058	0.84		50	0.057	0.056	1.74		50	0.061	0.066	-7.14
CT	D, mm	M6S12	M6WB	%, incr	CT	D, mm	M6S11	M6SB	%, incr	CT	D, mm	M6CS	M6CC	%, incr
	30	0.064	0.058	9.29		30	0.063	0.056	11.36		30	0.065	0.060	6.88
FSC	40	0.054	0.056	-2.93	FSC	40	0.052	0.051	1.72	FSC	40	0.060	0.058	3.78
	50	0.053	0.053	-0.37		50	0.050	0.049	1.99		50	0.055	0.056	-0.72

The variation of chloride concentration in pre-conditioned impregnation concrete cubes was represented in Table 5. Chloride concentration were found to be increased in DCC/PSC/FSC impregnation concrete cubes (M1WB-M6WB) as when compared to DCC/PSC/FSC impregnation concrete cubes (M1SB-M6SB) at different drill depths (30 mm, 40 mm, and 50 mm) respectively.

Table 5: Cl- concentration in pre-conditioned impregnation concrete cubes



Impregnation concrete cubes in different exposure condition											
CT	DC			CT	PSC			CT	FSC		
D, mm	M1SB	M1WB	%, incr	D, mm	M1SB	M1WB	%, incr	D, mm	M1SB	M1WB	%, incr
30	0.059	0.064	6.98	30	0.058	0.061	4.40	30	0.053	0.056	4.44
40	0.053	0.063	16.66	40	0.058	0.061	4.41	40	0.051	0.055	6.87
50	0.052	0.060	13.30	50	0.056	0.058	3.92	50	0.049	0.052	6.99
D, mm	M2SB	M2WB		D, mm	M2SB	M2WB	%, incr	D, mm	M2SB	M2WB	%, incr
30	0.061	0.063	3.32	30	0.058	0.061	4.24	30	0.053	0.0564	4.60
40	0.057	0.061	5.72	40	0.0586	0.0609	3.77	40	0.051	0.0538	4.08
50	0.056	0.058	4.24	50	0.056	0.058	3.75	50	0.049	0.051	4.46
D, mm	M3SB	M3WB	%, incr	D, mm	M3SB	M3WB	%, incr	D, mm	M3SB	M3WB	%, incr
30	0.070	0.072	1.94	30	0.068	0.070	3.66	30	0.060	0.063	3.79
40	0.068	0.070	3.81	40	0.065	0.068	3.37	40	0.056	0.060	7.55
50	0.065	0.068	3.37	50	0.063	0.065	3.64	50	0.053	0.059	8.96
D, mm	M4SB	M4WB	%, incr	D, mm	M4SB	M4WB	%, incr	D, mm	M4SB	M4WB	%, incr
30	0.060	0.0612	0.49	30	0.058	0.0611	3.60	30	0.053	0.0563	4.26
40	0.058	0.0611	3.60	40	0.056	0.0588	3.91	40	0.051	0.0515	-0.38
50	0.056	0.0588	3.74	50	0.056	0.0587	3.91	50	0.049	0.05	1.8
D, mm	M5SB	M5WB	%, incr	D, mm	M5SB	M5WB	%, incr	D, mm	M5SB	M5WB	%, incr
30	0.063	0.0683	6.73	30	0.061	0.0659	7.13	30	0.053	0.0563	4.26
40	0.061	0.066	7.12	40	0.057	0.0637	9.26	40	0.051	0.0539	4.82
50	0.058	0.0657	10.35	50	0.056	0.0587	3.57	50	0.051	0.0538	4.27
D, mm	M6SB	M6WB	%, incr	D, mm	M6SB	M6WB	%, incr	D, mm	M6SB	M6WB	%, incr
30	0.063	0.0658	3.49	30	0.061	0.0637	4.08	30	0.056	0.0586	4.09
40	0.061	0.0635	3.30	40	0.058	0.0625	7.2	40	0.051	0.0563	8.52
50	0.061	0.0624	1.92	50	0.057	0.061	6.55	50	0.049	0.0538	8.55

The variation of chloride concentration in pre-conditioned control concrete slabs/cubes was represented in Table 6. Chloride concentration were found to be increased in DCC/PSC/FSC control concrete slabs (M1CS-M6CS) as when compared to DCC/PSC/FSC control concrete cubes (M1CC-M6CC) at different drill depths (30 mm, 40 mm, and 50 mm) respectively.

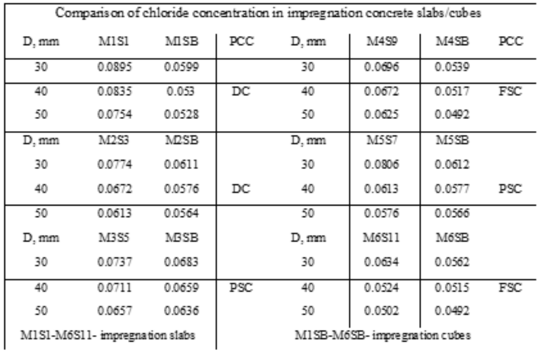
Table 6: Cl- concentration in pre-conditioned control concrete slabs/cubes

Comparison of chloride concentration in control concrete							
D, mm	M1CS	M1CC	PCC	D, mm	M4CS	M4CC	PCC
30	0.0923	0.070		30	0.0722	0.0598	
40	0.0864	0.066	DC	40	0.0716	0.0535	FSC
50	0.0815	0.064		50	0.0651	0.0522	
D, mm	M2CS	M2CC		D, mm	M5CS	M5CC	
30	0.0821	0.066		30	0.0846	0.0683	
40	0.0782	0.064	DC	40	0.0736	0.0672	PSC
50	0.0653	0.063		50	0.0616	0.066	
D, mm	M3CS	M3CC		D, mm	M6CS	M6CC	
30	0.0787	0.073		30	0.0654	0.0609	
40	0.0731	0.071	PSC	40	0.0609	0.0586	FSC
50	0.0687	0.071		50	0.0558	0.0562	
M1CS-M6CS- control				M1CC-M6CC- control cubes			

The variation of chloride concentration in pre-conditioned impregnation concrete slabs/cubes was represented in Table 7.

Chloride concentration were found to be increased in DCC/PSC/FSC impregnation concrete slabs (M1S1-M2S3-M3S5-M4S9-M5S7-M6S11) as when compared to DCC/PSC/FSC impregnation concrete cubes (M1SB-M6SB) at different drill depths (30 mm, 40 mm, and 50 mm) respectively.

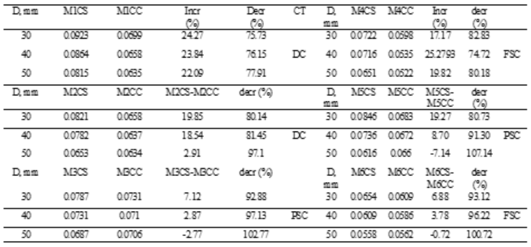
Table 7: Cl- concentration in pre-conditioned impregnation concrete slabs/cubes



Comparison of chloride concentration in impregnation concrete slabs/cubes							
D, mm	M1S1	M1SB	PCC	D, mm	M4S9	M4SB	PCC
30	0.0895	0.0599		30	0.0696	0.0539	
40	0.0835	0.053	DC	40	0.0672	0.0517	FSC
50	0.0754	0.0528		50	0.0625	0.0492	
D, mm	M2S3	M2SB		D, mm	M5S7	M5SB	
30	0.0774	0.0611		30	0.0806	0.0612	
40	0.0672	0.0576	DC	40	0.0613	0.0577	PSC
50	0.0613	0.0564		50	0.0576	0.0566	
D, mm	M3S5	M3SB		D, mm	M6S11	M6SB	
30	0.0737	0.0683		30	0.0634	0.0562	
40	0.0711	0.0659	PSC	40	0.0524	0.0515	FSC
50	0.0657	0.0636		50	0.0502	0.0492	
M1S1-M6S11- impregnation slabs				M1SB-M6SB- impregnation cubes			

The variation of chloride concentration in pre-conditioned control concrete slabs/cubes was indicated as in Table 8. Chloride concentration were found to be increased in DCC/PSC/FSC control concrete slabs (M1CS-M6CS) as when compared to DCC/PSC/FSC control concrete cubes (M1CC-M6CC) and it's also possible to interpret the decrease in chloride concentration in control concrete cubes as against control concrete slabs at different drill depths (30 mm, 40 mm, and 50 mm) respectively.

Table 8: Cl- concentration in pre-conditioned control concrete slabs/cubes



D, mm	M1CS	M1CC	Incr (%)	Decr (%)	CT	D, mm	M4CS	M4CC	Incr (%)	decr (%)	
30	0.0923	0.0699	24.27	75.73		30	0.0722	0.0598	17.17	82.83	
40	0.0864	0.0658	23.84	76.15	DC	40	0.0716	0.0535	25.2793	74.72	FSC
50	0.0815	0.0635	22.09	77.91		50	0.0651	0.0522	19.82	80.18	
D, mm	M2CS	M2CC	M2CS-M2CC	decr (%)		D, mm	M5CS	M5CC	M5CS-M5CC	decr (%)	
30	0.0821	0.0658	19.85	80.14		30	0.0846	0.0683	19.27	80.73	
40	0.0782	0.0637	18.54	81.45	DC	40	0.0736	0.0672	8.70	91.30	PSC
50	0.0653	0.0634	2.91	97.1		50	0.0616	0.066	-7.14	107.14	
D, mm	M3CS	M3CC	M3CS-M3CC	decr (%)		D, mm	M6CS	M6CC	M6CS-M6CC	decr (%)	
30	0.0787	0.0731	7.12	92.88		30	0.0654	0.0609	6.88	93.12	
40	0.0731	0.071	2.87	97.13	PSC	40	0.0609	0.0586	3.78	96.22	FSC
50	0.0687	0.0706	-2.77	102.77		50	0.0558	0.0562	-0.72	100.72	

The variation of chloride concentration in pre-conditioned impregnation concrete slabs/cubes was indicated as in Table 9.

Chloride concentration were found to be increased in DCC/PSC/FSC impregnation concrete slabs (M1S1-M2S3-M3S5-M4S9-M5S7-M6S11) as when compared to DCC/PSC/FSC impregnation concrete cubes (M1SB-M6SB) and it's also possible to interpret the decrease in chloride concentration in impregnation concrete cubes as against impregnation concrete slabs at different drill depths (30 mm, 40 mm, and 50 mm) respectively.

Table 9: Cl- concentration in pre-conditioned impregnation concrete slabs/cubes

D, mm	M1S1	M1SB	Incr (%)	decr (%)	CT	D, mm	M4S9	M4SB	Incr (%)	decr (%)	CT
30	0.0895	0.0599	33.07	66.93		30	0.0696	0.0539	22.56	77.44	
40	0.0835	0.053	36.53	63.47	DC	40	0.0672	0.0517	23.0655	76.93	FSC
50	0.0754	0.0528	29.97	70.03		50	0.0625	0.0492	21.28	78.72	
D, mm	M2S3	M2SB	M2S3-M2SB			D, mm	M5S7	M5SB	M5S7-M5SB		
30	0.0774	0.0611	21.06	78.94		30	0.0806	0.0612	24.07	75.93	
40	0.0672	0.0576	14.29	85.71	DC	40	0.0613	0.0577	5.87	94.13	PSC
50	0.0613	0.0564	7.99	92.01		50	0.0576	0.0566	1.74	98.26	
D, mm	M3S5	M3SB	M3S5-M3SB			D, mm	M6S11	M6SB	M6S11-M6SB		
30	0.0737	0.0683	7.33	92.67		30	0.0634	0.0562	11.36	88.64	
40	0.0711	0.0659	7.31	92.69	PSC	40	0.0524	0.0515	1.72	98.28	FSC
50	0.0657	0.0636	3.20	96.80		50	0.0502	0.0492	1.99	98.01	

The variation of chloride concentration in pre-conditioned impregnation concrete slabs/cubes was indicated as in Table 10. Chloride concentration were found to be increased in DCC/PSC/FSC impregnation concrete slabs (M1S1-M2S3-M3S5-M4S9-M5S7-M6S11) as when compared to DCC/PSC/FSC impregnation concrete cubes (M1WB-M6WB) and it's also possible to interpret the decrease in chloride concentration in impregnation concrete cubes as against impregnation concrete slabs at different drill depths (30 mm, 40 mm, and 50 mm) respectively.

Table 10: Cl- concentration in pre-conditioned impregnation concrete slabs/cubes

D, mm	M1S2	M1WB	Incr (%)	decr (%)	CT	D, mm	M4S10	M4WB	M4S10-M4WB	decr (%)	CT
30	0.0915	0.0644	29.62	70.38		30	0.0704	0.0563	20.03	79.97	
40	0.0854	0.0636	25.53	74.47	DC	40	0.0685	0.0516	24.6715	75.33	FSC
50	0.0798	0.0609	23.68	76.32		50	0.0634	0.0505	20.35	79.65	
D, mm	M2S4	M2WB	M2S4-M2WB	decr (%)		D, mm	M5S8	M5WB	M5S8-M5WB	decr (%)	
30	0.0784	0.0632	19.39	80.61		30	0.0812	0.0659	18.84	81.16	
40	0.0683	0.0611	10.54	89.46	DC	40	0.0706	0.0637	9.77	90.23	PSC
50	0.0627	0.0589	6.06	93.94		50	0.0592	0.0587	0.84	99.16	
D, mm	M3S6	M3WB	M3S6-M3WB	decr (%)		D, mm	M6S12	M6WB	M6S12-M6WB	decr (%)	
30	0.0748	0.0709	5.21	94.79		30	0.0646	0.0586	9.29	90.71	
40	0.0722	0.0682	5.54	94.46	PSC	40	0.0547	0.0563	-2.93	102.93	FSC
50	0.0671	0.0659	1.79	98.21		50	0.0537	0.0539	-0.37	100.37	

The variation of chloride concentration in pre-conditioned impregnation concrete cubes was noted as in the Table 11. Chloride concentration were found to be decreased in DCC/PSC/FSC impregnation concrete cubes (M1SB-M6SB) as when compared to DCC/PSC/FSC impregnation concrete cubes (M1WB-M6WB) and it's also possible to interpret the increase in chloride concentration in impregnation concrete cubes (M1WB-M6WB) as against impregnation concrete cubes (M1SB-M6SB) at different drill depths (30 mm, 40 mm, and 50 mm) respectively.

Table 11: Cl- concentration in pre-conditioned impregnation concrete cubes

	DC					PSC					FSC			
D, mm	M1SB	M1WB	decr (%)	incr (%)	D, mm	M1SB	M1WB	decr (%)	incr (%)	D, mm	M1SB	M1WB	decr (%)	incr (%)
30	0.059	0.064	-7.51	92.4	30	0.058	0.061	-4.61	95.3	30	0.053	0.056	-4.65	95.35
40	0.053	0.063	-20.00	80.0	40	0.058	0.061	-4.62	95.3	40	0.051	0.055	-7.38	92.62
50	0.052	0.060	-15.34	84.6	50	0.056	0.058	-4.09	95.9	50	0.049	0.052	-7.52	92.48
D, mm	M2SB	M2WB	M2SB-M2WB	incr (%)	D, mm	M2SB	M2WB	M2SB-M2WB	incr (%)	D, mm	M2SB	M2WB	M2SB-M2WB	incr (%)
30	0.061	0.063	-3.44	96.5	30	0.058	0.061	-4.43	95.5	30	0.053	0.056	-4.83	95.17
40	0.057	0.061	-6.08	93.9	40	0.058	0.060	-3.92	96.0	40	0.051	0.053	-4.26	95.74
50	0.056	0.058	-4.43	95.5	50	0.056	0.058	-3.90	96.1	50	0.049	0.051	-4.67	95.33
D, mm	M3SB	M3WB	M3SB-M3WB	incr (%)	D, mm	M3SB	M3WB	M3SB-M3WB	incr (%)	D, mm	M3SB	M3WB	M3SB-M3WB	incr (%)
30	0.070	0.072	-1.98	98.0	30	0.068	0.070	-3.81	96.1	30	0.060	0.063	-3.94	96.06
40	0.068	0.070	-3.97	96.0	40	0.065	0.068	-3.49	96.5	40	0.056	0.060	-8.17	91.83
50	0.065	0.068	-3.50	96.5	50	0.063	0.065	-3.78	96.2	50	0.053	0.059	-9.85	90.15
D, mm	M4SB	M4WB	M4SB-M4WB	incr (%)	D, mm	M4SB	M4WB	M4SB-M4WB	incr (%)	D, mm	M4SB	M4WB	M4SB-M4WB	incr (%)
30	0.060	0.061	-0.49	99.5	30	0.058	0.061	-3.74	96.2	30	0.053	0.056	-4.45	95.55
40	0.058	0.061	-3.74	96.2	40	0.056	0.058	-4.07	95.9	40	0.051	0.051	0.39	100.3
50	0.056	0.058	-3.89	96.1	50	0.056	0.058	-4.08	95.9	50	0.049	0.05	-1.83	98.17
D, mm	M5SB	M5WB	M5SB-M5WB	incr (%)	D, mm	M5SB	M5WB	M5SB-M5WB	incr (%)	D, mm	M5SB	M5WB	M5SB-M5WB	incr (%)
30	0.063	0.068	-7.22	92.7	30	0.061	0.065	-7.68	92.3	30	0.053	0.056	-4.45	95.55
40	0.061	0.066	-7.67	92.3	40	0.057	0.063	-10.21	89.7	40	0.051	0.053	-5.07	94.93
50	0.058	0.065	-11.54	88.4	50	0.056	0.058	-3.71	96.2	50	0.051	0.053	-4.47	95.53
D, mm	M6SB	M6WB	M6SB-M6WB	incr (%)	D, mm	M6SB	M6WB	M6SB-M6WB	incr (%)	D, mm	M6SB	M6WB	M6SB-M6WB	incr (%)
30	0.0635	0.065	-3.62	96.3	30	0.061	0.063	-4.26	95.7	30	0.056	0.058	-4.27	95.73
40	0.0614	0.063	-3.42	96.5	40	0.058	0.062	-7.76	92.2	40	0.051	0.056	-9.32	90.68
50	0.0612	0.062	-1.96	98.0	50	0.057	0.061	-7.02	92.9	50	0.049	0.053	-9.35	90.65

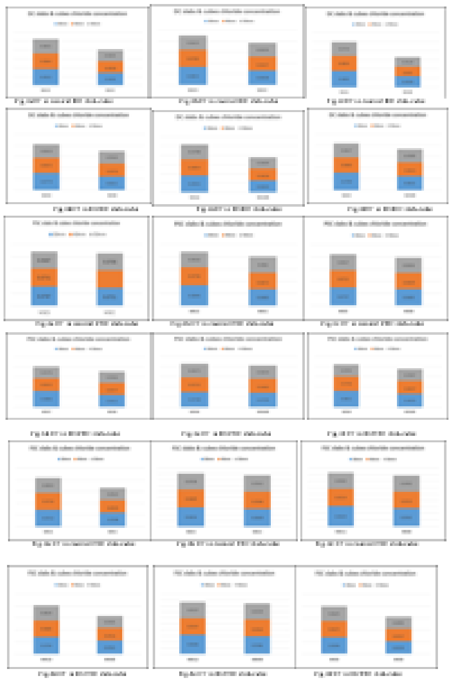
III. DISCUSSION ABOUT RESULTS

In fact, the de-icing compounds are used to melt ice and snow on streets, roads, and motorways to improve public safety. Most de-icing agents are salts which melt ice by lowering the freezing point of water below 00C. Among these compounds, sodium chloride (NaCl) is the cheapest and most commonly used de-icing agent. As much as 40-80 tons of salt per lane kilometre are applied to many roads for ice and snow control each year. In Britain and other European countries, several million tons of NaCl is used annually for de-icing purposes. In Canada and USA, 5 and 10 million tons of the salt is applied on roads each year (Transportation Research Board, 1991). However, their widespread use over a long period has left the construction industry and the engineering community with a huge problem regarding the durability of highway reinforced concrete bridges and multi-storey parking structures, due mainly to the fact that they cause corrosion of the reinforcement and steel components.The primary focus of this present study is to examine the effects of wetting and drying with 10%sodium chloride solution in concrete cubes (100 mm3) with/without impregnation material (solvent based and water based) for about 160 days. Chloride profiles of samples exposed to wetting and drying cycles were determined. From these profiles, the rate and depths of chloride ingress were calculated and compared for six different mixtures type of concrete. There have been a number of studies in which the chloride penetration profile of concretes exposed to a chloride solution for different defined periods of time. But in this present research work, chloride concentration at different drill depths such as 30-40-50 mm was interpreted for in case of designed concrete mixtures type and compared as against pre-conditioned concrete slabs (450x450x100 mm) with/without impregnation material.

It's possible to compare the variations in chloride concentration for in case of control/impregnation concrete slabs/cubes in order to characterize designed concrete mixtures type at different drill depths (30-40-50 mm) under various exposures conditions such as dry (Figures 2a-2f), partially (Figures 3a-3f), and fully saturated conditioned (Figures.4a-4f) concrete slabs as well as concrete cubes respectively.

The variation of chloride concentration is interpreted by chemical analysis at different drill depths (30-40-50) mm and it's as shown in (Figure.5a) for in case of control/impregnation (SB/WB) pre-conditioned concrete slabs in order to characterize various designed mixtures type. Its varied average chloride concentration at different drill depths is increased for in case of DCC slabs as when compared to PSC concrete slabs. Its varied values are represented as M1CS (15.23%), M1S1 (15.23%), M1S2 (16.61%), M2CS (2.55%), M2S3 (3.08%), M2S4 (0.8%) respectively.

In addition to that, the chloride concentration is also increased in case of DCC concrete slabs as when compared to FSC concrete slabs and its varied average chloride concentration at drill depths are interpreted as M1CS (19.73%), M1S1 (19.78%), M1S2 (21.21%), M2CS (19.74%), M2S3 (19.39%), M2S4 (17.38%) respectively. Similarly, the chloride concentration is also increased in PSC concrete slabs as when compared to FSC concrete slabs in which its average variation of chloride concentration at different drill depths were represented as M3CS (5.30%), M3S5 (5.36%), M3S6 (5.52%), M5CS (17.64%), M5S7 (16.82%), and M5S6 (18.04) respectively.



The average chloride concentration at different drill depths from (30-50) mm is found to be slightly increased in control concrete slabs for in case of mixtures type (M1CS-M2CS). As concerned to the average chloride concentration at different drill depths from (30-50) mm is reduced in solvent-based impregnation concrete slabs as when compared to control concrete. Furthermore, the chloride concentration in water-based impregnation concrete slabs is slightly increased as when compared to solvent-based impregnation concrete slabs in all mixtures type (M1CS-M2CS). The chloride concentration is also increased at drill depth 30 mm for in case of control, solvent, and water-based impregnation concrete cubes as when compared to drill depths (40-50) mm and its varied values were represented as M1CS (6.42%, 11.66%), M1S1 (6.65%, 15.77%), M1S2 (6.67%, 12.82%), M2CS (4.84%, 20.46%), M2S3 (13.20%, 20.74%), M2S4 (12.79%, 20%) respectively.

The chloride concentration in solvent-based impregnation concrete slabs was decreased as when compared to control concrete slabs at different drill depths (30-50) mm and in which its varied values were determined as M1S1 (96.95%, 96.71%, 92.44%), and M2S3(94.20%, 85.92%, 93.87%) respectively. Whereas the chloride concentration in water-based impregnation concrete slabs was reduced at different drill depths (30-50) mm as when compared to control concrete slabs for in case of all mixtures type (M1CS-M2CS) in its varied values are at different drill depths (30, 40, and 50) mm as M1S2 (99.16%, 98.90%, 97.86%), and M2S4 (95.42%, 87.44%, 95.97%) respectively. Similarly, the chloride concentration in solvent-based impregnation concrete slabs is decreased as when compared to water-based impregnation concrete cubes in which its varied values at different drill depths (30-50) mm as M1S1 (97.77%, 97.78%, 94.46%), M2S3 (98.72%, 98.25%, 97.81%) respectively.

The average chloride concentration is increased in control concrete slabs for in case of mixtures type (M3CS and M5CS) at different drill depths (30-40-50) mm as when compared to impregnation concrete slabs. The average chloride concentration at different drill depths from (30-50) mm is reduced in solvent-based impregnation concrete slabs as when compared to control concrete slabs for in case of mixture type (M3CS) and (M5CS). Furthermore, the chloride concentration in water-based impregnation concrete slabs was slightly increased as when compared to solvent-based impregnation concrete slabs in all mixtures type (M3CS-M5CS).

The chloride concentration is also increased at drill depth 30 mm for in case of control, solvent, and water-based impregnation concrete slabs as when compared to drill depths (40-50) mm and its varied values were represented as M3CS (7.12%, 12.70%), M3S5 (3.54%, 10.85%), M3S6 (3.46%, 10.29%), M5CS (12.93%, 27.11%), M5S7 (23.89%, 28.44%), M5S8 (13.25%, 27.21%) respectively.

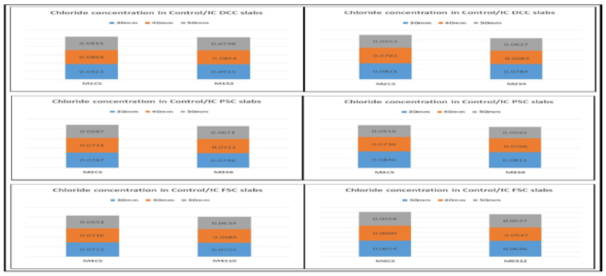


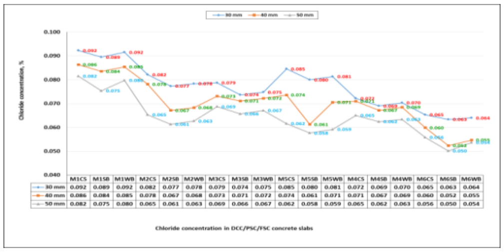
Fig.5a Cl- in control impregnation DCC/PSC/FSC impregnation concrete slab

The chloride concentration in solvent-based impregnation concrete slabs is decreased as when compared to control concrete slabs at different drill depths (30-50) mm and in which its varied values were determined as M3S5 (93.64%, 97.26%, 95.63%), and M5S7 (95.24%, 83.25%, 93.51%) respectively. Whereas the chloride concentration in water-based impregnation concrete slabs is reduced at different drill depths (30-50) mm as when compared to control concrete slabs for in case of all mixtures type (M3CS-M5CS) and its varied values are at different drill depths (30, 40, and 50) mm as M3S6 (95%, 98.75%, 97.62%), and M5S8 (96.16%, 95.81%, 96.04%) respectively. Similarly, the chloride concentration in solvent-based impregnation concrete slabs was decreased as when compared to water-based impregnation concrete cubes in which its varied values at different drill depths (30-50) mm as M3S5 (98.56%, 98.49%, 97.95%), M5S7 (99.04%, 86.88%, 97.36%) respectively.

The average chloride concentration is increased in control concrete slabs for in case of mixtures type (M4-M6) at different drill depths (30-40-50) mm as when compared to impregnation concrete slabs and their varied valued were interpreted as M4CS (0.072%, 0.071%, 0.065%), M6CS (0.065%, 0.059%, 0.055%). Similarly, the average chloride concentration at different drill depths from (30-50) mm is reduced in solvent-based impregnation concrete slabs as when compared to control concrete slabs for in case of mixture type (M4CS) and (M6CS). The interpreted average values of chloride concentration at different drill depth from (30-50) mm is represented as M4S9 (0.069%, 0.067%, 0.062%), M6S11 (0.063%, 0.052%, 0.050%) respectively. Furthermore, the chloride concentration in water-based impregnation concrete slabs is slightly increased as when compared to solvent-based impregnation concrete slabs in all mixtures type (M4CS-M6CS). Its varied values is found to be as MS10 (0.070%, 0.068%, 0.063%), M6S12 (0.064%, 0.054%, 0.053%) respectively. The chloride concentration is also increased at drill depth 30 mm for in case of control, solvent, and water-based impregnation concrete slabs as when compared to drill depths (40-50) mm and its varied values were represented as M4CS

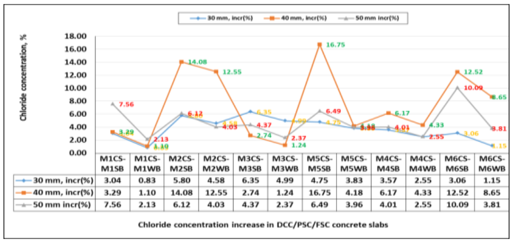
(0.80%, 9.87%), M4S9 (3.47%, 10.28%), M4S10 (2.61%, 9.87%), M6CS (8.38%, 14.61%), M6S11 (17.32%, 20.80%), M6S12 (15.33%, 16.91%) respectively. The chloride concentration in solvent-based impregnation concrete slabs is decreased as when compared to control concrete slabs at different drill depths (30-50) mm and in which its varied values were determined as M4S9 (96.42%, 93.82%, 95.98%), and M6S11 (96.94%, 87.47%, 89.91%) respectively. Whereas the chloride concentration in water-based impregnation concrete slabs is reduced at different drill depths (30-50) mm as when compared to control concrete slabs for in case of all mixtures type (M4-M6) in its varied values are at different drill depths (30, 40, and 50) mm as M4S10 (97.45%, 95.67%, 97.44%), and M6S12 (98.85%, 91.34%, 96.18%) respectively.

Similarly, the chloride concentration in solvent-based impregnation concrete slabs is decreased as when compared to water-based impregnation concrete cubes in which its varied values at different drill depths (30-50) mm as M4S9 (98.94%, 98.07%, 98.50%), M6S11 (98.06%, 95.76%, 93.47%) respectively. It's possible to represent the variation in the chloride concentration for in case of dry/partially/fully saturated conditioned control/impregnation concrete slabs at different drill depths (30-40-50 mm) as indicated in the (Figures 6a-6d).



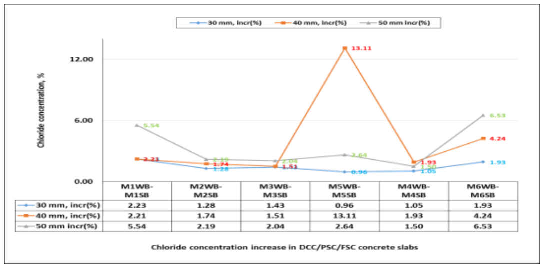
	M1CS	M1SB	M1WB	M2CS	M2SB	M2WB	M3CS	M3SB	M3WB	M5CS	M5SB	M5WB	M4CS	M4SB	M4WB	M6CS	M6SB	M6WB
30 mm	0.092	0.089	0.092	0.082	0.077	0.078	0.079	0.074	0.075	0.085	0.080	0.081	0.072	0.069	0.070	0.065	0.063	0.064
40 mm	0.086	0.084	0.085	0.078	0.067	0.068	0.073	0.071	0.072	0.074	0.061	0.071	0.071	0.067	0.069	0.060	0.052	0.055
50 mm	0.082	0.075	0.080	0.065	0.061	0.063	0.069	0.066	0.067	0.062	0.058	0.059	0.065	0.062	0.063	0.056	0.050	0.054

Fig.6a Cl- concentration in control/IC concrete slab



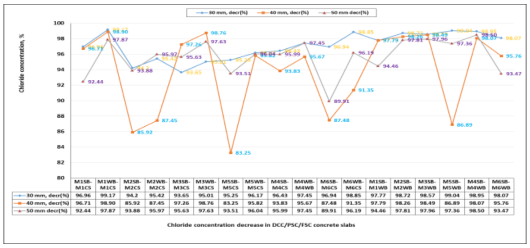
	M1CS-M1SB	M1CS-M1WB	M2CS-M2SB	M2CS-M2WB	M3CS-M3SB	M3CS-M3WB	M5CS-M5SB	M5CS-M5WB	M4CS-M4SB	M4CS-M4WB	M6CS-M6SB	M6CS-M6WB
30 mm, incr(%)	3.04	0.83	5.80	4.58	6.35	4.99	4.75	3.83	3.57	2.55	3.06	1.15
40 mm, incr(%)	3.29	1.10	14.08	12.55	2.74	1.24	16.75	4.18	6.17	4.33	12.52	8.65
50 mm incr(%)	7.56	2.13	6.12	4.03	4.37	2.37	6.49	3.96	4.01	2.55	10.09	3.81

Fig.6bCl- concentration in control/IC concrete slab



	M1WB-M1SB	M2WB-M2SB	M3WB-M3SB	M5WB-M5SB	M4WB-M4SB	M6WB-M6SB
30 mm, incr(%)	2.23	1.28	1.43	0.96	1.05	1.93
40 mm, incr(%)	2.21	1.74	1.51	13.11	1.93	4.24
50 mm incr(%)	5.54	2.19	2.04	2.64	1.50	6.53

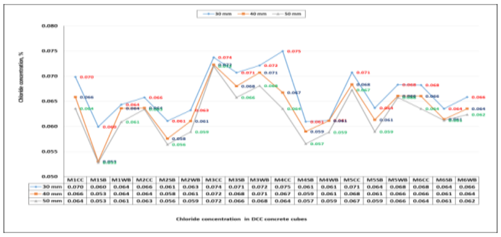
Fig.6cCl- concentration in IC concrete slab



	M1SB-M1CS	M1WB-M1CS	M2SB-M2CS	M2WB-M2CS	M3SB-M3CS	M3WB-M3CS	M5SB-M5CS	M5WB-M5CS	M4SB-M4CS	M4WB-M4WB	M6SB-M6CS	M6WB-M6CS	M1SB-M1WB	M2SB-M2WB	M3SB-M3WB	M5SB-M5WB	M4SB-M4WB	M6SB-M6WB
30 mm, decr(%)	96.96	99.17	94.2	95.42	93.65	95.01	95.25	96.17	96.43	97.45	96.94	98.85	97.77	98.72	98.57	99.04	98.95	98.07
40 mm, decr(%)	96.71	98.90	85.92	87.45	97.26	98.76	83.25	95.82	93.83	95.67	87.48	91.35	97.79	98.26	98.49	86.89	98.07	95.76
50 mm decr(%)	92.44	97.87	93.88	95.97	95.63	97.63	93.51	96.04	95.99	97.45	89.91	96.19	94.46	97.81	97.96	97.36	98.50	93.47

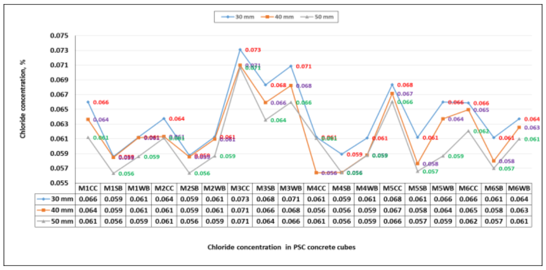
Fig.6dCl- concentration in control/IC concrete slab

It's also possible to represent the variation in the chloride concentration for in case of dry/partially/fully saturated conditioned control/impregnation concrete cubes at different drill depths (30-40-50 mm) as indicated in the (Figures7a-7i) respectively.



	M1CC	M1SB	M1WB	M2CC	M2SB	M2WB	M3CC	M3SB	M3WB	M4CC	M4SB	M4WB	M5CC	M5SB	M5WB	M6CC	M6SB	M6WB
30 mm	0.070	0.060	0.064	0.066	0.061	0.063	0.074	0.071	0.072	0.075	0.061	0.061	0.071	0.064	0.068	0.068	0.064	0.066
40 mm	0.066	0.053	0.064	0.064	0.058	0.061	0.072	0.068	0.071	0.067	0.059	0.061	0.068	0.061	0.066	0.066	0.061	0.064
50 mm	0.064	0.053	0.061	0.063	0.056	0.059	0.072	0.066	0.068	0.064	0.057	0.059	0.067	0.059	0.066	0.064	0.061	0.062

Fig.7aCl- concentration in control/IC DCC concrete cubes



	M1CC	M1SB	M1WB	M2CC	M2SB	M2WB	M3CC	M3SB	M3WB	M4CC	M4SB	M4WB	M5CC	M5SB	M5WB	M6CC	M6SB	M6WB
30 mm	0.066	0.059	0.061	0.064	0.059	0.061	0.073	0.068	0.071	0.061	0.059	0.061	0.068	0.061	0.066	0.066	0.061	0.064
40 mm	0.064	0.059	0.061	0.061	0.059	0.061	0.071	0.066	0.068	0.056	0.056	0.059	0.067	0.058	0.064	0.065	0.058	0.063
50 mm	0.061	0.056	0.059	0.061	0.056	0.059	0.071	0.064	0.066	0.061	0.056	0.059	0.066	0.057	0.059	0.062	0.057	0.061

Fig.7bCl- concentration in control/IC PSC concrete cubes

Fig.7cCl- concentration in control/IC PSC concrete cubes

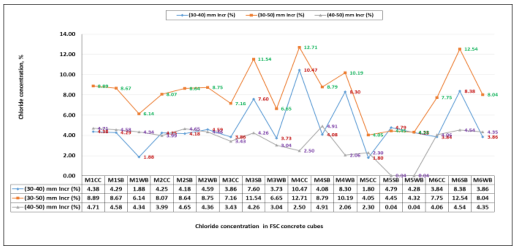


Fig.7dCl- concentration in control/IC FSC concrete cubes

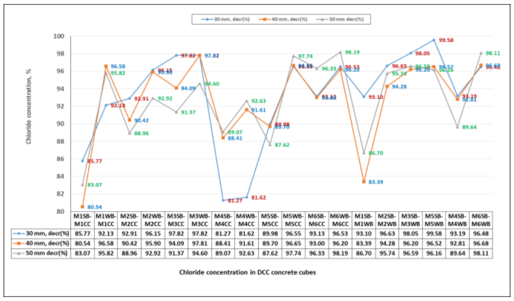


Fig.7eCl- concentration in control/IC DCC concrete cubes

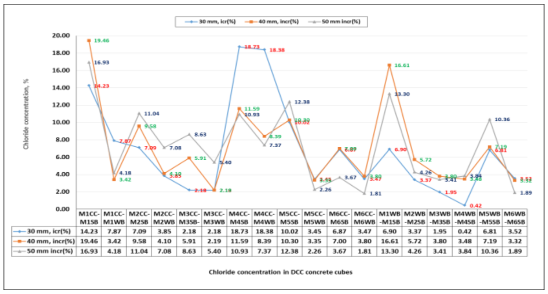


Fig.7fCl- concentration in control/IC DCC concrete cubes

Fig.7gCl- concentration in control/IC PSC concrete cubes

Fig.7hCl-concentration in control/IC PSC concrete cubes

Fig.7iCl- concentration in control/IC FSC concrete cubes

IV. CONCLUSION

1. The chloride concentration is increased in DCC pre-conditioned concrete slabs at different drill depths (30-40-50) mm as when compared to PSC/FSC pre-conditioned concrete slabs at different drill depths. Chloride concentration is decreased in solvent/water-based impregnation DCC/PSC/FSC concrete slabs as when compared to control DCC/PSC/FSC concrete slabs.

2. In addition to that, the chloride concentration is decreased in solvent-based impregnation DCC/PSC/FSC as when compared to water-

based impregnation DCC/PSC/FSC concrete slabs. It's also observed from the results that, the chloride concentration is slightly increased in control/ impregnation PSC (SB/WB) as when compared to control/impregnation FSC (SB/WB) concrete slabs.

3. It's confirmed that for higher compressive strength and varied slump value, the average chloride concentration at drill depths (30-50) mm in control concrete cubes was found to be slightly higher in magnitude as when compared to solvent based and water-based impregnation concrete cubes. Also, it's observed from the results that, for lower compressive strength and constant slump value, the average chloride concentration at drill depths (30-50) mm in control concrete cubes was found to be slightly more as when compared to higher compressive strength.

4. It's confirmed that for higher/lower compressive strength and varied/constant slump value, the average chloride concentration at drill depths (30-50) mm in control/solvent/water-based impregnation pre-partially/fully saturated concrete cubes was found to be slightly lower in magnitude as when compared to dry conditioned control/solvent/water-based impregnation concrete cubes.

5. It's also clear that for higher/lower compressive strength and varied/constant slump value, the average chloride concentration at drill depths (30-50) mm in pre-partially saturated control/solvent/water-based impregnation concrete cubes was found to be slightly higher in magnitude as when compared to fully saturated conditioned control/solvent/water-based impregnation concrete cubes.

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