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DISCOVERY

Chloride solution absorption-moisture content in pre-conditioned FSC cubes

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ABSTRACT

The premature deterioration of RC structures is a major concern for infrastructure owners. The most predominant process associated with reinforced concrete deterioration is the ingress of water contaminated with chloride either from de-icing salt used for snow and ice control on roads for winter maintenance purposes or from the marine environment where, for example, bridges span tidal estuaries. Because the use of de-icing salt is likely to continue for the foreseeable future, and concrete structures will always be placed in, or near, the marine environment, little can be done to prevent structures from being exposed to chloride salts. The premature deterioration of concrete structures due to chloride ingress and subsequent corrosion of the steel reinforcement is a worldwide problem and imparts a significant drain on maintenance resources, not only in terms of the remedial work required, but also in the costs associated with periodic inspections and testing together with indirect costs such as traffic delays and lost productivity. The exposure of concrete infrastructures to chloride ions is the primary cause of premature corrosion of steel reinforcement. The intrusion of chloride ions, present in de-icing salts into reinforced concrete can cause steel corrosion if oxygen and moisture are also available to sustain the reaction. In fact that, the chlorides dissolved in water can also permeate through sound, concrete/reach the steel reinforcement through cracks. 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 fully saturated condition which is salt ponded with chloride solution for about 160 days at 10% Nacl solution. Thus, the objectives of this present research are such as; first, this research will examine the influence of conditioning such as fully 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 vary 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. Twenty four concrete cubes (100 mm^3) with grades of concrete ranges from 25-40 N/mm^2 were prepared and evaluate the chloride absorption under specified exposure condition. It has concluded from the results that, in fully saturated conditioned concrete cubes, the chloride absorption value was increase in all designed mixtures type at longer time duration. Similarly, the average chloride absorption was decrease in solvent/water based impregnation FSC cubes as when compared to control 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 increase in solvent/water based impregnation FSC cubes for lesser compressive strength and constant slump value as when compare to constant higher compressive strength and varied slump value and the chloride absorption was goes on decreases with increased compressive strength and constant slump value.

Keywords: Concrete, mixture proportion, grade of concrete, water-cement ratio, slump, chloride absorption, impregnation, solvent/water based impregnate, moisture content, fully saturated condition

1. INTRODUCTION

During the last several decades, a large number of reinforced concrete (RC) infrastructures have been built using steel and concrete. It is estimated that, at present, about 2 billion tons of reinforced concrete is being built every year [Alexander *et al.,* 2010]. However, the deterioration of constructed infrastructures using RC directly affects everyday life in terms of safety, economy, and sustainability. A significant fraction of concrete produced is increasingly being used for repair and rehabilitation rather than new construction and it poses an economic burden on the society [Al-Kutti, 2011]. Deterioration of RC structures due to chloride-induced reinforcement corrosion has been reported to be a major durability problem worldwide. A large number of RC infrastructures are affected by reinforcement corrosion, particularly those which are exposed to coastal/marine conditions. In the chloride-laden environment, the fluctuations in the diurnal and seasonal temperature and humidity initiate cycles of expansion-contraction and hydration-dehydration that results into initiation and propagation of reinforcement corrosion leading to cracking, spalling, and loss of load bearing capacity of the RC structures [Baluch *et al.,* 2002]. In order to protect the reinforcing steel from corrosion, the mechanism of chloride penetration into concrete and the factors influencing it should be understood. Unlike the cases of other porous mediums, the penetration of chloride ions into concrete is a complex nonlinear dynamic phenomenon including several transport mechanisms such as ionic diffusion, capillary sorption, permeation, and dispersion [Neville, 2011]. Ionic diffusion is considered to have the most dominant effect under the assumption that concrete cover is fully saturated [Marto, 2000]. In saturated state, chloride ions enter concrete by ionic diffusion due to concentration gradient between the exposed surface and the pore solution inside concrete. This process is often described by Fick's second law of diffusion [Que, 2007]. Crank gave the solution of this governing partial differential equation with semi-infinite boundary conditions and assumed the coefficient of chloride diffusion as a constant [Sun *et al.* 2012]. However, various researchers have reported that the coefficient of chloride diffusion varies with time and space [Han, 2007]. The effects of chloride binding and multidirectional chloride ingress on chloride diffusion coefficient are also reported [Nilsson *et al.,* 1996]. Chlorides diffusing inside concrete can be either dissolved in the pore solution or bound to the cement hydrates chemically and physically along the diffusion path [Sun *et al.,* 2012]. Therefore, we can divide total chloride into bound and free chloride. It is the free chloride that diffuses to the rebar and breaks the passive layer resulting into initiation of reinforcement corrosion [Tuutti, 1982]. The effect of chloride binding in concrete on the corrosion initiation is twofold: (i) the rate of ionic diffusion of chloride in concrete is reduced, since the amount of available mobile ions (free chloride) is reduced due to binding mechanisms and (ii) the reduction of free chlorides in concrete results in lower amounts of chlorides being accumulated at the reinforcing steel layer [Tang, and Nilsson, 1996]. Theoretically, the concrete matrix becomes denser with the passage of time; therefore, the chloride binding ability of concrete should also improve based on the same principle. This makes it necessary to consider the effect of chloride binding with age in chloride diffusion models. The interaction between moisture diffusion and chloride penetration becomes more important in concrete structures subjected to repeated wetting and drying cycles. Those structures include bridge decks, parking garage floors and marine structures in the splash and tidal zones. Chloride diffusion due to concentration gradient is the dominant penetration mechanism in fully saturated concrete, where pores inside concrete become completely filled with solution and water movement ceased. On the other hand, chloride penetration in partially saturated concrete involved many mechanisms besides diffusion due to concentration gradient. Those mechanisms include water movement (carrying chloride ions) due to diffusion, sorption and permeability. The review of the available literature showed that very few experimental studies were conducted on the coupled effect of moisture and chloride penetration. [Swaddiwudhipong *et al.,* 2000] investigated the effect of moisture transport due to concentration gradient, capillary suction and pressure gradient on chloride ingress in partially saturated concrete. Their experimental results show that moisture transport has no effect on chloride penetration for long term exposure period and chloride concentration gradient is the most dominant mechanism for chloride penetration in concrete. [Buenfeld *et al.,* 1995] studied the effect of wick action on chloride penetration in concrete. Wick action can be defined as the transport of water or solution through concrete from a wet front (face in contact with solution) to dry front (face in contact with atmosphere). Chloride transport property is very important for the durability and service life of reinforced concrete structures subjected to marine environments and de-icing salt. In reality, for different reasons, concrete structures are frequently cracked, and cracks can alter the chloride transport properties of concrete. Recently, several studies have been conducted by both experiment and simulation on the influence of cracks on the chloride transport properties of concrete. The aim of this paper is to review these research efforts. The experimental methods and simulation approaches on the chloride transport properties of cracked concrete are introduced. Detailed discussions on the findings from these experimental and simulation studies are given. The chloride transport properties of cracked concrete are influenced by various factors, such as crack geometry, concrete composition, and load condition. Research in this area is still on-going, and many problems need to be settled before proposing reliable models for predicting the service life of real cracked concrete structures in chloride environments. Hence, some further research topics are recommended. The influences of other factors, such as carbonation, freeze-thaw, fatigue, and saturation degree, on the transport properties of cracked concrete should be revealed [Chun-ping Gu et al., 2015]. The simulation of moisture movement in concrete is vital for estimating its durability performance under the given conditions of service. A robust analysis of the nonlinear phenomenon relies on the implementation of an efficient numerical algorithm. This entails a comprehension of the underlying mathematical models, the numerical analysis scheme and the related issues of stability and convergence. This paper describes a computational scheme to facilitate the estimation of moisture distribution in concrete subjected to wetting–drying exposure due to intermittent rains, an exposure type which severely impairs the durability performance of structural concrete under tropical climatic conditions. Beginning with a brief review of the conventional moisture transport models for concrete, this paper proposes a modified model using dimensionless parameters, which enhances the computational efficiency of the delineated scheme. This paper also describes the formulation of a one-dimensional, nonlinear finite element scheme for the modified model and discusses the issue of numerical oscillations concomitant to the numerical analysis of the problem. The suitability of the first-order element in providing stable convergence when implemented in conjunction with a lumped-mass scheme has been mathematically interpreted. The validity of the delineated proposition has been illustrated using a test problem [Kaustav Sarkar, and Bishwajit Bhattacharjee, 2014]. Portland cement-based concrete is one of the most widely used construction materials in infrastructure throughout the world [Bentur, 2002]. However, one of the pressing issues faced by the construction industry is how to sustain durable service life performance during the design life of concrete structures. It has been recognized that the microstructure-transport property relationships of concrete play a key role in its durability, and therefore in its sustainability and high performance. For instance, water permeability is a good indicator of the durability of concrete particularly under coupled mechanical load and environmental factors [Mehta, and Monteiro, 2006]. Exposure to water during its service life is one of the primary causes of deterioration, as water percolates through an open crack or connected pore space and transports aggressive ions such as chlorides and sulfates. Moreover, progressive deterioration of concrete due to leaching also begins at the surface of the material where abrasion occurs when in contact with water for a long time, as seen in concrete used in dams, underground storage, and radioactive waste repository. The microstructure of cementitious matrix becomes more porous as leaching of calcium ions induces the dissolution of cement hydrates, and eventually leads to increased permeability [Gallé *et al.*, 2004] and degraded mechanical properties [Carde and Francois, 1997]. This slow leaching-induced degradation process opens up the material to even more water flow; hence, such vicious circles and synergistic interactions between leaching and other degradation mechanisms may speed up the deterioration and shorten the service life of concrete structures.

The concrete infrastructures such as bridge decks, parking garages, pre-stressed concrete structures, steel structures, and marine structures may deteriorate when they are exposing to de-icing agents. The de-icing agents can be absorbed into the pores of concrete and can modify the cementitious matrix structure. The interaction between the de-icing agents and the cementitious matrix may result in the deterioration of concrete structures [Jones, 2013]. Physical damage can occur due to a number of processes such as exposure of concrete with a high degree of saturation to freeze-thaw cycles [Li, *et al.*, 2012], scaling of concrete surfaces [Jacobsen, *et al*, 1997], crystallization of salt in concrete pores that results in production of an internal stress [Scherer, 1999], and expansive forces as a result of corrosion of reinforcement when a chloride-based de-icing salt is used [Wang, *et al.,* 2014]. While the physical attack of de-icing salts has been widely investigated, the chemical reaction between the matrix and the de-icing salts has been investigated often less frequently. The use of de-icing salts can cause damage in cementitious materials even if a concrete does not experience freezing and melting [Marchand *et al.*, 1994]. This may be cause by the formation of Friedel's salt, Kuzel's salts [Collepardi *et al.,* 1994], and/or calcium oxychloride, changes in the pore solution properties [Farnam *et al.*, 2014], or changes in the microstructure of hydration products [Pigeon and Regourd, 1986]. De-icing salt solution, like many external solutions, dissolve calcium hydroxide, causing leaching that leads to an increase in permeability and a reduction of concrete alkalinity [Muethel, 1997]. De-icing salts have different chemical and physical interactions with cementitious materials. The usage of NaCl de-icing salt increases freeze-thaw damage in concrete. This increase in freeze-thaw damage has been explained by the formation of an unexpected phases and the creation of osmotic pressures [Farnam *et al.,* 2014]. Concrete exposed to $CaCl_2$ and $MgCl_2$ de-icing salts exhibited changes in the concrete microstructure. These changes have been accompanied by a severe cracking and deterioration, even if the concrete did not experience any freeze-thaw cycles [Collepardi *et al.,* 1994]. The concrete infrastructures were deteriorating in different regions of the world without satisfying the stipulated service life. Therefore, there is a need to predict service life, which is a major task in the design of concrete infrastructures. In fact, the chloride concentration is a major cause of any early deterioration of reinforced concrete infrastructures. Because of this concrete deterioration, it may lead to cracking, spalling, and delamination of concrete cover, reduce load carrying capacity, and cross sectional area of reinforcement. Whereas, in the cold countries region it may lead to pre-mature deterioration of concrete infrastructures due to the application of de-icing salts on roads and concrete infrastructures. In fact, the bridge-decks were simultaneously expose to wetting-drying condition and, it has subjected to direct impact as well as repeated loading by continuous flow of traffic. Almost all the concrete structures were working under dry conditions. Even though most of the researchers have dedicated their efforts to study transport of chloride in concrete under wet conditions with limited publication data on dry concrete. In fact major diffusion models are applicable to the concrete structures that remains fully wet condition at all the times. They underestimate the amount of chloride penetrating a concrete structure, which is subject to wetting/drying for in case of splash/tidal zones of structures exposed to marine environment/highway structures exposed to de-icing salts. An experimental study is performing on the influence of water absorption in ordered to evaluate the effectiveness of durability of concrete by researchers [Zhang and Zong, 2014]. It is confirm from results that the most significant effect of sorptivity on long-term chloride ingress to concrete is its effect on surface chloride content. It has decided to consider an effective amount of absorption when modelling chloride ingress under cyclic wetting and drying conditions. It is also possible from research work to produce higher surface chloride contents (0·29–0·62%) that would lower the time to corrosion using the cover depths recommended in the code. Its confirmed long time ago that [Zhao *et al.,* 2008], young and uncontaminated concrete can be surface impregnated by liquid silanes in order to provide a protective barrier against ingress of chloride ions and moderate chloride content allows to apply surface impregnation of silanes successfully as a protective measure as well as to avoid further chloride ingress. It is also confirm that, higher chloride concentration and low water-cement ratio make surface impregnation more difficult. It has confirmed that deep impregnation of the concrete surfaces with water repellent agent's forms an efficient and long lasting barrier with respect to chloride ingress [Wittmann *et al.,* 2006]. In this way, service life of reinforced concrete structures erected in an aggressive environment such as marine climate can be significantly extend for long time duration. It is cite by investigators [Brandt, 2009] that, the corrosion of steel reinforcement induces expansion in volume due to corrosion products, cracking, and spalling of concrete from the reinforcement. Furthermore, chloride concentration together with frost attack can cause another form of concrete deterioration such as concrete scaling. As confirmed that [Hall, 1994], the pore space of concrete is not fully saturated. If the moisture content inside concrete is less than the saturation moisture content, it may be absorb by the concrete through large capillary forces arising from the contact of the very small pores of the concrete with the liquid phase. Therefore, determination of the moisture retention function is necessary for the modelling of moisture flow and transport of chlorides in concrete. In fact, there has been very little effort to establish relationships for the capillary pressure as a function of degree of saturation for concrete. The chloride diffusion can only occur for a continuous water phase is present in the capillary pores of concrete in order to provide a path for diffusion. Therefore, in the case of dry concrete, the diffusion process is lessen since the number of water filled pores decreases and that decreases the continuity of pore solution [Saetta *et al.*, 1993]. Under dry conditions, the effective diffusion coefficient is no longer a constant but a function of saturation [Garboczi, 1990] and therefore cannot be describe by simple diffusion theory. This is noted by researchers that [Vriesl *et al.,* 1998], hydrophobic treatment makes a concrete surface absorb lesser water and chloride. It is confirm that, the corrosion, which had already started before application of the hydrophobic agent was not influence by hydrophobic treatment. No effect of hydrophobic treatment is measure on carbonation. It has also shown that, long term absorption tests with drinking and salt water showed significantly less absorption by hydrophobic concrete. Furthermore, its highlighted by researchers [Jacob *et al.,* 1998] that, hydrophobic agents could be effective for at least 10 years when applied to a 6-month-old concrete façade provide that, the concrete of the substrate needs to have a minimum age of 28 days or more. In addition to that, some conditions must be avoid when applying hydrophobic agents such as high or low temperatures, high air humidity and high construction element humidity. Therefore there is a need to investigate about the rapid deterioration of concrete structures due to reinforcement corrosion has now become a day-day growing problem in recent years at all over the world in so many cold countries region. Considerable resources were used to repair and rehabilitate deteriorated structures around the world. In addition to that, consequently, an extensive research [McCarter, 1996] has been conduct to evaluate the effectiveness of sealers and other concrete surface treatment materials. Among the various procedures used to protect concrete surfaces, hydrophobic impregnations are the least harmful to essential concrete appearance, mainly inhibiting capillary water absorption of the concrete.

Research Objectives

The importance of chloride absorption 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 is made an attempt to interpret the concrete chloride absorption in ordered to characterize the different concrete mixtures design for in case of pre-conditioned fully saturated conditioned concrete cubes which is salt ponded with chloride solution for about 160 days. Thus the objectives of this present research is to examine the influence of conditioning such as fully saturated condition on the results of chloride absorption performed on concrete cubes with different mixtures proportion. In which slump, and w/c ratio value 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. Twenty four concrete cubes (100 mm^3) with grades of concrete ranges from 25-40 N/mm^2 were prepared and evaluate the chloride absorption under specified exposure condition.

2. EXPERIMENTAL PROGRAM

In the present research work, six different mixtures type were prepared in total as per [BRE, 1988] code standards with concrete cubes of size (100 mm^3). Three of the mixtures type 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 designate as M1, M2, and M3. Another Three of the mixtures type 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 designate as M4, M5, and M6. The overall details of the mixture proportions were represent in Table 1-2. Concrete cubes of size (100 mm^3) were overall Twenty four specimens were casted for six types of concrete mixture. The coarse aggregate used was crush 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. 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 could not be disclose and they could be refer to as WB and SB respectively. WB is water borne acrylic co-polymer based impregnation material, which is less hazardous and environmental 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 (Variable: Slump & W/C value; Constant: Compressive strength)

Mix ID	Comp/mean target stg, N/mm^2	Slump (mm)	w/c	C (Kg)	W (Kg)	FA (Kg)	CA (Kg) 10 mm	Mix 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 ID	Comp/mean target stg, N/mm^2	Slump (mm)	w/c	C (Kg)	W (Kg)	FA (Kg)	CA (Kg) 10mm	Mix 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

Salt ponding test

The chloride absorption tests were conduct out on concrete cubes of size (100 mm^3), and tested in accordance to [BS: 1881-122]. They were water cured before subjected to the salt ponding test for about160 days. Before testing, the concrete specimens were oven dried to constant mass at 105±5^{0}C for 72±2 hours and then stored in airtight containers before subjected to testing. The chloride absorption test with 10% Nacl solution is carried out on pre-conditioned dry concrete cubes of size (100 mm^3) which is fully submerged and noted their weights at each time interval for about 160 days. For chloride absorption test, totally 24 concrete cubes were casted, out of which 12 control concrete cubes, and 6 solvent based concrete cubes as well as 6 water based concrete cubes. The chloride penetration and moisture diffusion are two important transport processes for studying the long-term durability of concrete. The chloride penetration and moisture transfer in concrete are consider as two coupled transport processes. The interaction between moisture diffusion and chloride penetration in concrete affects the durability of reinforced concrete structures. The corrosion of the reinforcement in concrete takes place when the chloride content of concrete near steel bar has reached a threshold value and the moisture content in concrete is sufficiently high. Therefore, moisture and chloride ions are two necessary conditions for the onset of corrosion of rebar in concrete. The diffusion of chloride and moisture in concrete were study for two different situations such as fully and partially saturated condition. In fist instance, the concrete is fully saturated and dominant mechanisms for both chloride diffusion and moisture diffusion is the concentration gradient of chloride. In turn, the chloride concentration gradient drives not only the chloride penetration but also the moisture movement in the concrete. In another instance, the concrete is partially saturated, and the moisture concentration gradient (in addition to the chloride concentration gradient) results in the moisture penetration as well as the chloride diffusion. In this case, both concentration gradients are driving forces. Thus in the present research work chloride absorption test was carried out on pre-conditioned concrete cubes (100 mm^3) such as fully saturated condition concrete cubes in order to evaluate the effectiveness of two impregnation materials namely solvent/water based impregnation material respectively.

3. DISCUSSION ABOUT RESULTS

There is widespread consensus among the concrete industry, that the most common and serious cause of deterioration in structural concrete members is corrosion of reinforcing steel induced by chloride ion ingress and oxygen ingress into reinforced concrete. Durability of concrete structures is of major importance to society, and most degradation of concrete structures is closely related to the transport of moisture and ions, inside or outside of the material. Chloride ingress, sulfate attack, alkali silica reactions, carbonation, and leaching are all related to ion transport. Ion transport is strongly dependent on the moisture content of the material, and all concrete structures undergo a variation in moisture distribution over time owing to self-desiccation from hydration and the surrounding climatic conditions. These variations cause ion and moisture movements within the material and in many cases, degradation of the material [Nilsson, 2005]. Corrosion induced cracking is the most commonly encountered deterioration mechanism in reinforced concrete structures, which involves the transformation of steel reinforcement into corrosion products, which occupy a greater volume than the original steel. This volume expansion due to this chemico-mechanical process results in internal pressure acting on the concrete, which is equilibrated by circumferential tensile stresses leading to cracks in, and potentially spalling of the concrete. According to the survey by [Nwaubani and Katsanos, 2014], the maintenance expenditure of many developed countries including the US, Canada, Japan, Australia and the UK resulting from the premature deterioration of concrete bridges was estimated to be in the range 0.01-0.1% of gross domestic product (GDP); in addition, the indirect costs due to traffic delays and lost productivity resulting from bridge maintenance and superstructure replacement programmes are more than ten times the direct cost of corrosion. The deterioration of concrete structures exposed to chloride-rich environments is in-evitable; hence the long-term performance of concrete assumes an important role in ensuring durable concrete structures. The concrete composition and the constituent materials need to be closely defined to enable the required level of performance to be maintained, hence the growing interest, and indeed need, for performance-based specifications. Performance-related methods which are more relevant to corrosion resistance - consider, in a quantitative way, each relevant deterioration mechanism, the working life of the element or structure and the criteria that define the end of this working life (e.g. time to corrosion initiation). The level of knowledge of the ambient and local micro-climate is thus critical in establishing the reliability of performance-related design methods. Thus in the present research work chloride absorption test was carried out on pre-conditioned concrete cubes (100 mm^3) such as fully saturated conditioned concrete cubes in order to evaluate the effectiveness of two impregnation materials namely solvent/water based impregnation material respectively. It's observed from results that (FSC concrete cubes) for higher compressive strength and varied slump value, the chloride absorption was found to be slightly higher in magnitude as when compared to solvent based and water based impregnation concrete cubes for in case of mixtures type (M1-M3). In addition, it is observe from the results that, for lower compressive strength and constant slump value, the chloride absorption was found to be slightly more as when compared to higher compressive strength for in case of mixtures type (M5-M6). The average chloride absorption for in case of FSC concrete cubes is increased at 61th, 91th, 121th, and 160th days as when compared to 31th day in control concrete cubes, solvent based impregnation concrete cubes (SB), and water based impregnation concrete cubes (WB) in mixtures type (M1-M6) respectively. In the same way, the chloride absorption was decrease in solvent-based impregnation concrete cubes as when compared to water based impregnation concrete cubes. It's possible to correlate chloride absorption with time for in case of control/impregnation FSC cubes at different time intervals (31, 61, 91, 121, and 160) days respectively as representing in the (Figs.1a-f, 2a-f, 3a-f). From this relationship between chloride absorption and time, it's possible to determine chloride absorption at any specified time duration in the concrete mixes design for in the case of control/impregnation concrete cubes.

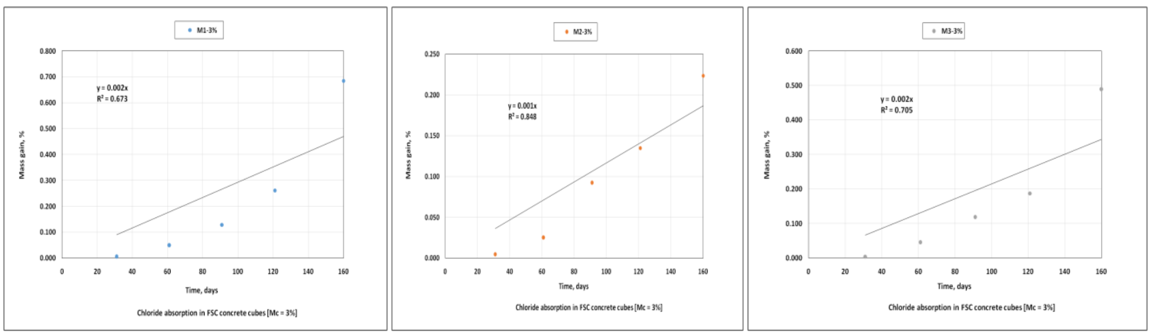
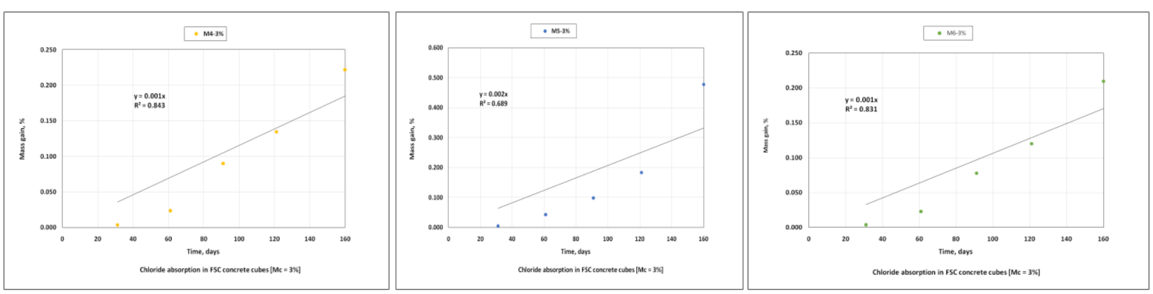


Figure 1 a) Mass gain-time in Mix type 1 b) Mass gain-time in Mix type 2. c) Mass gain-time in Mix type 3



d) Mass gain-time in Mix type 4 e) Mass gain-time in Mix type 5 f) Mass gain-time in Mix type 6

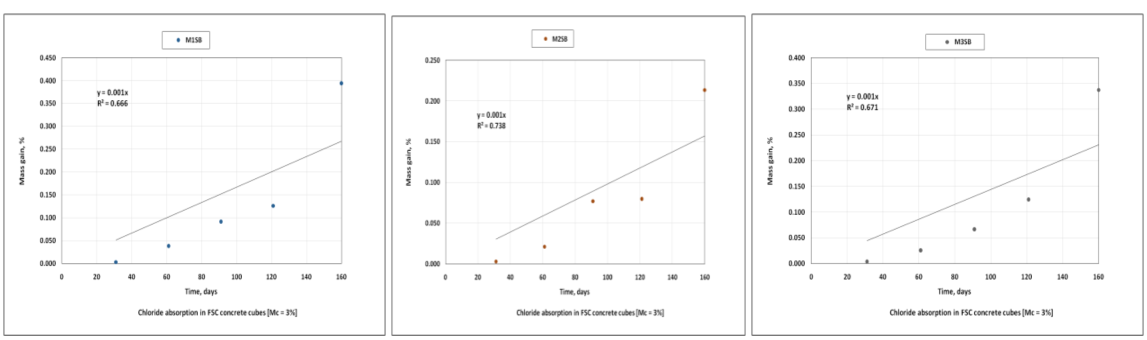
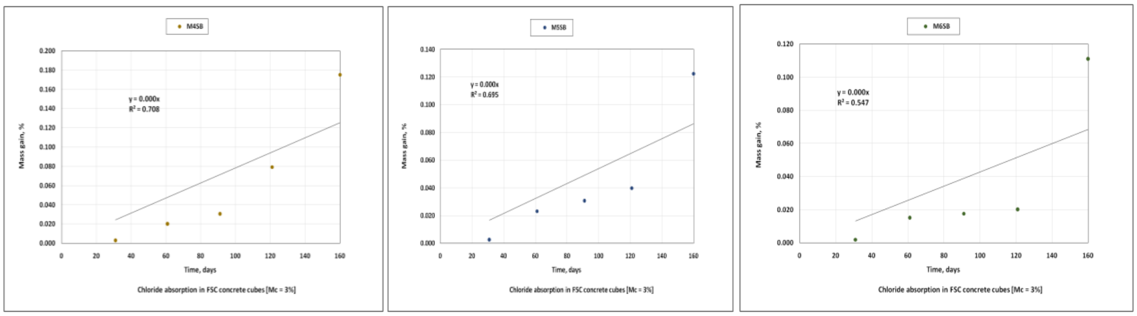


Figure 2 a) Mass gain-time in Mix type 1 b) Mass gain-time in Mix type 2 c) Mass gain-time in Mix type 3



d) Mass gain-time in Mix type 4 e) Mass gain-time in Mix type 5 f) Mass gain-time in Mix type 6

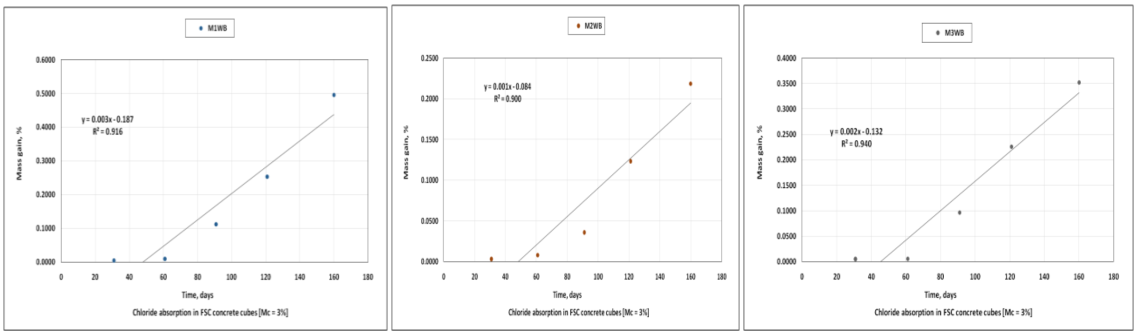
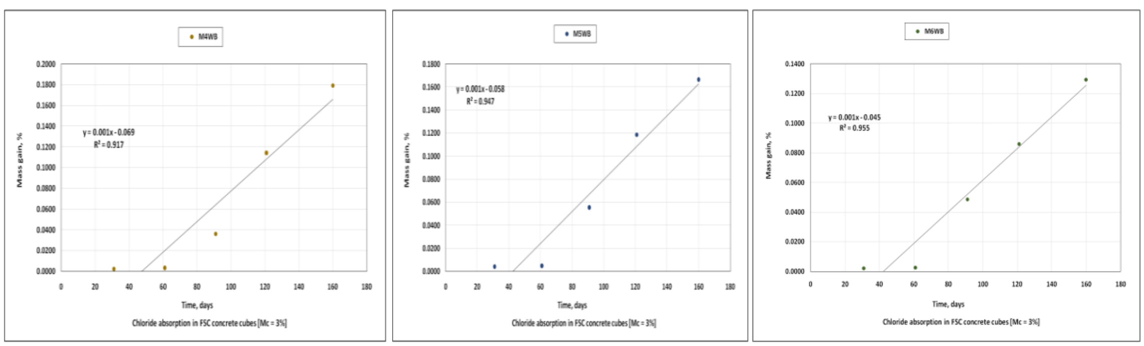


Figure 3 a) Mass gain-time in Mix type 1 b) Mass gain-time in Mix type 2 c) Mass gain-time in Mix type 3



d) Mass gain-time in Mix type 4 e) Mass gain-time in Mix type 5 f) Mass gain-time in Mix type 6

It's possible to interpret chloride absorption with time for in case of control/impregnation DCC cubes at different time intervals (31, 61, 91, 121, and 160) days respectively as representing in the (Figs.4a-d). The chloride solution absorption was observed to lesser in magnitude at short time duration (31days) as when compared to longer time duration (160 days). It's also confirmed from the results that, the chloride solution absorption was predominantly increased in control concrete cubes (M1-3%-M6-3%) as when compared to impregnation concrete cubes (M1SB-M6SB and M1WB-M6WB) respectively.

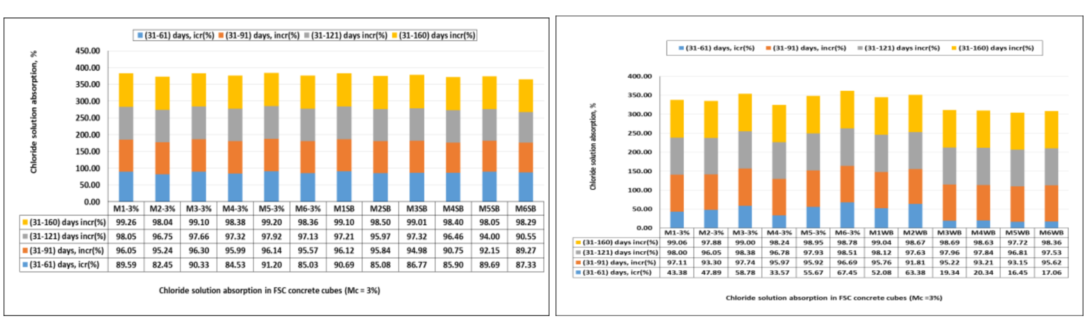
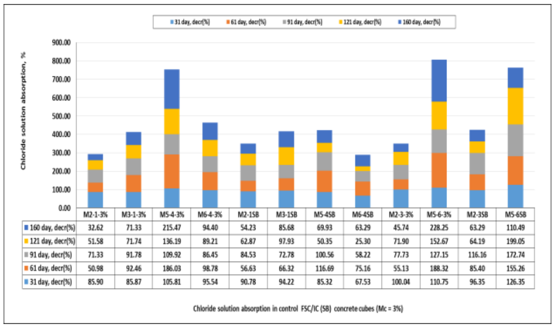
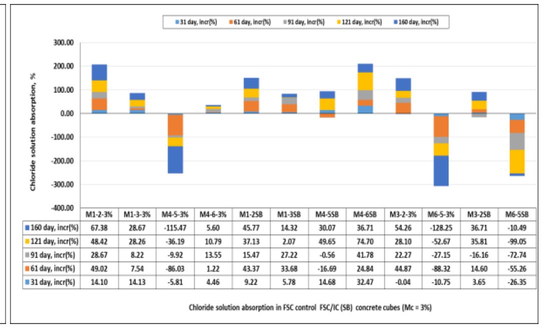


Figure 4 a) Cl^- absorption in control/IC cubes (SB) b) Cl^- absorption in IC cubes (WB)



c) Cl^- absorption in control/IC cubes (SB)



d) Cl^- absorption in control/IC cubes (SB)

4. CONCLUSIONS

Thus in the present research work chloride absorption test was carried out on 24 pre-conditioned concrete cubes such as fully saturated conditioned concrete cubes in order to evaluate the effectiveness of two impregnation materials namely solvent based and water based impregnation material respectively. In turn to interpret the effectiveness of impregnation concrete cubes with control cubes for six mixtures type under pre-conditioned concrete cubes with constant compressive strength, and varied slump in one case as well as varied compressive strength with constant slump in second case.

- It's possible to correlate chloride absorption with time for in case of control/impregnation FSC cubes at different time intervals (31, 61, 91, 121, and 160) days.
- It is observed from results that, the chloride absorption in FSC control concrete cubes was increased as when compared to the chloride absorption in FSC (SB) and FSC (WB) impregnation concrete cubes.
- From this chloride absorption-time relationship, it's possible to interpret the chloride absorption at any specified time duration in order to characterize the designed concrete mixtures type.

REFERENCE

1. Alexander, M.G, Santhanam, M, and Ballim, Y. (2010). Durability design and specification for concrete structures-the way forward, International Journal of Advances in Engineering Sciences and Applied Mathematics, 2(3):95-105.
2. Al-Kutti, W.A.S. (2011).Simulation of chloride transport in concrete with stress induced damage [Ph.D. thesis], King Fahd University of Petroleum and Minerals, Dhahran, Saudi Arabia.
3. Baluch, M.H,Rahman, M.K, and Al-Gadhib, A. H. (2002). Risks of cracking and delamination in patch repair, Journal of Materials in Civil Engineering, 14(4):294-302.
4. Buenfeld, N. R., Shurfa-Daoudi, M. T. and McLoughlin, I. M. (1995). Chloride transport due to wick action in concrete, Proc. of International RILEM workshop on chloride penetration in concrete, France, 315-324pp.
5. Bentur A. (2002). Cementitious materials-Nine millennia and a new century: Past, present, and future. J. Mater. Civ. Eng. 14:2-22.
6. Brandt, A. M. (2009). Cement based composites: materials, mechanical properties and performance, Taylor and Francis.
7. Chun-ping Gu, Guang Ye, and Wei Sun. (2015).A review of the chloride transport properties of cracked concrete: experiments and simulations, Journal of Zhejiang University-SCIENCE A, Issue 2, 16:81–92.
8. Carde C., and Francois R. (1997). Effect of the leaching of calcium hydroxide from cement paste on mechanical and physical properties. Cem.Concr. Res, 274:539-550.
9. Collepardi. M, Coppola. L, and Pistolesi. C. (1994).Durability of concrete structures exposed to $CaCl_2$ based de-icing salts, in: V.M. Malhotra (Ed.), Durab. Concr.ACI SP-145, 3rd CANMET/ACI Int. Conf, 107-120pp.
10. Farnam. Y, Bentz. D, Sakulich. A, Flynn. D and Weiss. J. (2014).Measuring freeze and thaw damage in mortars containing De-icing salt using a low-temperature longitudinal guarded comparative calorimeter and acoustic emission, Adv. Civ. Eng. Mater. 3:316–337.
11. Gallé C., Peycelon H., Le Bescop P. (2004).Effect of an accelerated chemical degradation on water permeability and pore structure of cement-based materials. Adv. Cem. Res, 16:105-114.
12. Garboczi, E.J. (1990). Permeability, diffusivity, and micro structural parameters: A Critical review, Cement and Concrete Research, 20:591-601.
13. Han, S. H. (2007). Influence of diffusion coefficient on chloride ion penetration of concrete structure, Construction and Building Materials, 21(2):370–378.
14. Hall, C. (1994). Barrier performance of concrete: A review of fluid transport theory, Materials and Structures, 27:291-306.
15. Jones. W, Farnam. Y, Imbrock. P, Sprio. J, Villani. C and Olek. J. (2013).An overview of joint deterioration in concrete pavement: Mechanisms, solution properties, and sealers.
16. Jacobsen. S, Sœther. D, and Sellevold. E. (1997). Frost testing of high strength concrete: Frost/salt scaling at different cooling rates, Mater. Struct. 30: 33–42.

17. Jacob. T, and Hermann. K (1998). Protection of concrete surfaces: hydrophobic impregnations. Construction Technology's. (March) 18–23 (only available in Spanish).
18. KaustavSarkar, and BishwajitBhattacharjee. (2014). Wetting and Drying of Concrete: Modelling and Finite Element Formulation for Stable Convergence, Structural Engineering International, 192-200pp.
19. Li, L.Y, Xia, J, and Lin, S.S. (2012). A multi-phase model for predicting the effective diffusion coefficient of chlorides in concrete, Construction and Building Materials, 26(1):295-301.
20. Li. W, Pour-Ghaz. M, Castro. J, and Weiss. J. (2012).Water absorption and critical degree of saturation relating to freeze-thaw damage in concrete pavement joints, J. Mater. Civ. Eng. 24:299–307.
21. Marto, B. (2000). A study of the effect of chloride binding on service life predictions, Cement and Concrete Research, vol. 30, no. 8, pp. 1215–1223.
22. Mehta P.,and Monteiro P. (2006). Concrete: Microstructure, Properties, and Materials. McGraw-Hill Companies; New York, NY, USA.
23. Marchand. J, Sellevold. E. J and Pigeon. M. (1994).The De-icer Salt Scaling Deterioration of Concrete - An Overview, in: V.M. Malhotra (Ed.), Third Int. Conf. Durab. Concr., Nice, France, pp. 1–46.
24. Muethel. R. W. (1997). Investigation of calcium hydroxide depletion as a cause of concrete pavement deterioration.
25. McCarter. W. J. (1996). Assessing the protective qualities of treated, and untreated concrete surfaces under cyclic wetting and drying. Building Environ, 31(6):551–556.
26. Neville, A.M. (2011). Properties of Concrete, Pearson Education, 5th edition.
27. Nilsson, L. O, Poulsen, E, Sandberg, P, Surensen,H. E, and Klinghoffer, O. (1996). Chloride penetration into concrete, state-of-theart, transport processes, corrosion initiation, test methods and penetration models, Tech. Rep. 53.
28. Nilsson, L. O. (2005). On the role of moisture in degradation of concrete structures, in: R.K. Dhir, M.R. Jones, L. Zheng (Eds.) International Congress-Global Construction: Ultimate Concrete Opportunities Dundee, Scotland, United Kingdom, 15-24pp.
29. Nwaubani SO, Katsanos A. (2014). Effect of Alternative De-icers on the Corrosion Resistance of Reinforced Concrete Bridges and Highway Structures. In: Developments in Corrosion Protection, Aliofkhazraei M (Ed.), InTech(ISBN 978-953-51-1223-5; doi: 10.5772/57551).
30. Pigeon M and Regourd M. (1986). The effects of freeze-thaw cycles on the microstructure of hydration products, Durab. Build. Mater. 4:1-19.
31. Que, N.S. (2007). History and development of prediction models of time-to-initiate-corrosion in reinforced concrete structures in marine environment, Philippine Engineering Journal, 28:29-44.
32. Sun, Y.M, Liang, M.T and Chang, T.P. (2012). Time/depth dependent diffusion and chemical reaction model of chloride transportation in concrete, Applied Mathematical Modelling. Simulation and Computation for Engineering and Environmental Systems, 36(3):1114-1122.
33. Swaddiwudhinpong, S., Wong, S. F., Wee, T. H. and Lee, S. L. (2000). Chloride ingress in partially and fully saturated concretes, Concrete Science and Engineering, 2:17-31.
34. Scherer. G. (1999). Crystallization in pores, Cem.Concr. Res. 29:1347-1358.
35. Saetta, A.V., Scotta, R.V. and Vitaliani, R.V. (1993). Analysis of chloride diffusion into partially saturated concrete, ACI Materials journal, 90-M47.
36. Tuutti.K. (1982).Corrosion of steel in concrete, Cement and Concrete Research, 4:468-472.
37. Tang, L, and Nilsson, L. O. (1996).Service life prediction for concrete structures under seawater by a numerical approach, in Durability of Building Materials and Components, 7(2):97-106.
38. Teychenné, D. C, Franklin. R. E, Erntroy. H. C. (1988). Design of normal concrete mixes, Second edition, BRE.
39. Vriesl.J. de, Polde.R.B, and Borsje.H. (1998). Durability of hydrophobic treatment of concrete, Water repellent treatment of building materials, Proceedings of Hydrophobell, ZLirich, Aedificatio Publishers 77-90pp.
40. Wang. Z, Zeng. Q, Wang. L, Yao. Y, and Li. K. (2014). Corrosion of rebar in concrete under cyclic freeze–thaw and Chloride salt action, Constr. Build.Mater. 53:40–47.
41. Wittmann. F. H, Zhao. T. J, Zhan. H, and Xian. Y. (2006). Establishment of an effective chloride barrier in reinforced concrete structures by means of water repellent agents, Proc. Int. Workshop on Life Cycle Management of Coastal Concrete Structures, Nagaoka University, Japan, H. Yokota and T. Shimomura, editors, 201-208pp.
42. Zhang. S. P, and Zong.L. (2014). Evaluation of Relationship between Water Absorption and Durability of concrete Materials, Advances in materials science and Engineering, Article ID 650373.
43. Zhao. T, Zhu. G, F. H. Wittmann. F. H, and Li. W. (2008). On surface impregnation of chloride contaminated cement based materials, Hydrophobe V, 5th International conference on water repellent treatment of building materials Aedificatio Publishers, 311-324p.