



Chloride ingress-moisture content in pre-conditioned concrete cubes

Balakrishna MN¹✉, Robert Evans², Fouad Mohamad², Rahman MM²

¹School of Architecture, Design and the Built Environment, Research scholar, Nottingham Trent University, Nottingham, NG1 4FQ, UK

²School of Architecture, Design and the Built Environment, Faculty of Engineering, Nottingham Trent University, Nottingham, NG1 4FQ, UK

✉Correspondence author

School of Architecture, Design and the Built Environment, Research scholar, Nottingham Trent University, Nottingham, NG1 4FQ, UK

Email: N0413461@my.ntu.ac.uk

Article History

Received: 05 June 2019

Reviewed: 10/June/2019 to 13/July/2019

Accepted: 17 July 2019

Prepared: 21 July 2019

Published: September 2019

Citation


Balakrishna MN, Robert Evans, Fouad Mohamad, Rahman MM. Chloride ingress-moisture content in pre-conditioned concrete cubes. *Discovery*, 2019, 55(285), 453-461

Publication License



© The Author(s) 2019. Open Access. This article is licensed under a [Creative Commons Attribution License 4.0 \(CC BY 4.0\)](https://creativecommons.org/licenses/by/4.0/).

General Note

 Article is recommended to print as color digital version in recycled paper.

ABSTRACT

The chloride contamination will occur from the application of de-icing salts. It was confirmed that the application of de-icing salts caused a significant reduction in structural and serviceability reliabilities. The chemicals used in the snow and ice control operations (de-icers) may cause corrosion damage to the transportation infrastructure such as reinforced/pre-stressed concrete structures and steel bridges. There are many ways to manage the corrosive effects of de-icers, such as selection of high-quality concrete, adequate concrete cover and alternative reinforcement, control of the ingress and accumulation of deleterious species, injection of beneficial species into concrete, and use of non-corrosive de-icer alternatives and optimal application rates. In fact, snow and ice on streets

and highways are a major threat to human life and limb. Traffic accidents and fatalities climb as snow and ice reduce traction on roadways. Lengthened emergency response times create additional risks for persons in urgent need of medical care, particularly in cases of heart attacks, burns, childbirth and poisoning. Thus the de-icing salts are necessary to provide safe winter driving conditions and save lives by preventing the freezing of a layer of ice on concrete infrastructure. However, the safety and sense of comfort provided by these salts is not without a price, as these salts can greatly contribute to the degradation and decay of reinforced concrete transportation systems. The importance of chloride concentration as a durability-based material property has received greater attention only after the revelation that chloride-induced corrosion is the major problem for concrete durability. Therefore, there is a need to quantify the chloride concentration in concrete which is of paramount importance. The present research work was made an attempt to interpret the concrete chloride absorption in order to characterize the different concrete mixtures design for in case of pre-conditioned concrete cubes such as dry/fully/partially saturated condition and salt ponded with chloride solution for about 160 days. Thus the objectives of this present research are such as: First, this research will examine the influence of conditioning such as dry/fully/partially saturated condition on the results of chloride concentration performed on concrete cubes with different mixtures proportion in which slump, and w/c ratio value was varied with constant compressive strength as in the first case and compressive strength, and w/c ratio value varied with constant slump as in the second case. Seventy-two concrete cubes (100 mm³) with grades of concrete ranges from 25-40 N/mm² were prepared and evaluate the chloride absorption under different exposure condition. It's concluded from the results that, in dry/saturated conditioned concrete cubes, the chloride absorption value was increased in all designed mixtures type. Similarly, the average chloride concentration was decreased in solvent based and water based impregnation DCC/PSC/FSC cubes as when compared to control DCC/PSC/FSC cubes for constant higher compressive strength and varied slump value as well as varied compressive strength and constant slump value. Whereas the average chloride absorption was increased in solvent based and water based impregnation DCC/PSC/FSC cubes for lesser compressive strength and constant slump value as when compared to constant higher compressive strength and varied slump value and the chloride concentration was going on decreases with increased compressive strength and constant slump value.

Keywords: Concrete, mixture proportion, grade of concrete, pre-conditioning, slump, w/c ratio, chloride absorption, de-icer, snow and ice control, reinforcing steel, corrosion

1. INTRODUCTION

The prolonged periods of snowfall in countries with advanced infrastructure and transport systems have rendered the use of de-icing agents to a common occurrence on roads and highway structures. They are necessary in order to maintain a good level of service with respect to the transport systems, thus avoiding traffic jams and disruptions, but also to provide a high level of road safety. Today, chloride-based products, such as rock salt, are the most commonly encountered de-icers as they are easy to apply and store but mostly because they efficiently melt ice at an affordable price [TRB, 1991]. However, their widespread use over a long period has left the construction industry and the engineering community with a grave problem regarding the durability of highway reinforced concrete bridges and multi-storey parking structures [Pullar-Strecker, 2002], due mainly to the fact that they cause corrosion of the reinforcement and steel components [Pullar-Strecker, 2002]. In cold-climate regions, snow and ice control operations are crucial to maintaining highways that endure cold and snowy weather. The growing use of de-icers has raised concerns about their effects on motor vehicles, transportation infrastructure, and the environment. The deleterious effect of chloride-based de-icers on reinforcing steel bar in concrete structures is well known [Shi *et al.* 2009]. De-icers may also pose detrimental effects on concrete infrastructure through their reactions with cement paste and/or aggregates and thus reduce concrete integrity and strength, which in turn may foster the ingress of moisture, oxygen and other aggressive agents onto the rebar surface and promote rebar corrosion. Large amounts of solid and liquid chemicals (known as de-icers) as well as abrasives are applied onto winter highways to keep them clear of ice and snow. De-icers applied onto highways often contain chlorides because of their cost-effectiveness, including mainly sodium chloride (NaCl), magnesium chloride (MgCl₂), and calcium chloride (CaCl₂), sometimes blended with proprietary corrosion inhibitors. The rock salt/sodium chloride (NaCl), is the most commonly used de-icing agent. It was first used to control snow and ice on roadways to improve transportation safety in the 1930s, and became widespread by the 1960s. The salt works by dissolving into precipitation on roadways and lowering the freezing point, thereby melting ice and snow. Eliminating the ice has enormous safety benefits, but depending on the amount of chemicals used, the dissolved salt can have negative effects on the surrounding environment. The melting snow and ice carries de-icing chemicals onto vegetation and into soils along the roadside where they eventually enter local waterways. Elevated salt levels in soils can inhibit the ability of vegetation to

absorb both water and nutrients, which can slow plant growth and ultimately affect animal habitats. This degradation also affects the ability of these areas to act as buffers to slow the runoff of other contaminants into the watershed. Once the salt enters freshwater it can build up to concentration levels that further affect aquatic plants and other organisms. Salt deposits along roadways also attract birds, deer, and other animals which increase the chance of animal-vehicle accidents. While the major effect on public drinking water supplies for humans is merely an alteration of taste, high concentrations of sodium in drinking water can lead to increased dietary intake and possibly hypertension. Since salt is corrosive to automobiles, bridge decks, and other roadway infrastructure, de-icing chemicals are often combined with other substances to block corrosion. While eliminating ice is of great benefit to commerce and human safety, these drawbacks must be taken into consideration by communities as they plan for regular maintenance of the concrete infrastructure, as well as the health of the local ecosystem. The costs of maintaining reinforced concrete infrastructure (bridges, tunnels, harbours, parking structures) are increasing due to aging of structures, which are being exposed to aggressive environment. Corrosion of reinforcement due to chloride ingress is the main problem for existing structures in marine and de-icing salt environments [Bertolini *et al.*, 2013]. In The Netherlands 5% of motorway bridges, built predominantly between 1960 and 1980, shows cracking and spalling of the concrete cover due to chloride induced corrosion [Gaal, 2004]. This corresponds to 10% of the bridges showing corrosion initiation at an age of 40 years [Polder *et al.*, 2012]. Older structures have been built according to older codes, which may not have provided sufficient protection. Moreover, for new infrastructure corrosion cannot be ruled out completely, even with today's emphasis on design for long service life (typically 100 years), either by composition requirements (Euro codes) or based on service life modelling and performance testing [Fib, 2006]. This may be due to various factors, such as unforeseen aggressive loads, e.g. leakage of joints; or to deviations from the intended concrete quality or cover thickness; or to modelling inadequacies [Bertolini *et al.*, 2011]. Repair of corrosion damage is possible, but costly, potentially disruptive and not necessarily long lived. A European study has shown that 50% of repairs fail within 10 years [Tilly, 2011]. These results were confirmed by a study in the Netherlands [Visser *et al.*, 2012]. In the worst case, this means that after about ten years the structure must again be repaired, involving more costs; and possibly this will go on until the structure is taken out of service. Thus in the present research work, an attempt was made to interpret the concrete chloride absorption in order to characterize the different concrete mixtures type for in case of 72 pre-conditioned concrete cubes (100 mm^3) such as dry/fully/partially saturated condition and salt ponded with chloride solution for about 160 days. This research will examine the influence of conditioning such as dry/fully/partially saturated condition on the results of chloride absorption performed on concrete cubes with different mixtures proportion in which slump (0-10, 10-30, 60-180) mm, and w/c ratio value was varied with constant compressive strength (40 N/mm^2) as in the First case and compressive strength ($25\text{-}40 \text{ N/mm}^2$), and w/c ratio value varied with constant slump (10-30) mm as in the Second case.

Research Objectives

The interpretation of the performance of a concrete mix is not limited to the determination of its mechanical properties since it is of paramount importance to characterize the material in terms of the parameters that rate its durability. The importance of chloride concentration as a durability-based material property has received greater attention only after the revelation that chloride-induced corrosion is the major problem for concrete durability. The present research work was made an attempt to interpret the concrete chloride absorption in order to characterize the different concrete mixtures design for in case of pre-conditioned concrete cubes such as dry/fully/partially saturated condition and salt ponded with chloride solution for about 160 days with 10% NaCl solution. Thus the objectives of this present research is to examine the influence of conditioning such as dry/fully/partially saturated condition on the results of chloride absorption performed on concrete cubes with different mixtures proportion in which slump, and w/c ratio value was varied with constant compressive strength as in the First case and compressive strength, and w/c ratio value varied with constant slump as in the Second case. Seventy-two concrete cubes (100 mm^3) with grades of concrete ranges from $25\text{-}40 \text{ N/mm}^2$ were prepared and evaluate the chloride absorption under different 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 were concrete cubes (100 mm^3) with a compressive strength 40 N/mm^2 , slump (0-10, 10-30, and 60-180 mm), and different w/c (0.45, 0.44, and 0.43). These mixtures were designated as M1, M2, and M3. Another Three of the mixtures were concrete cubes with a compressive strength (25 N/mm^2 , 30 N/mm^2 , and 40 N/mm^2), slump (10-30 mm), and different w/c (0.5, 0.45, and 0.44). These mixtures were designated as M4, M5, and M6. The overall details of the mixture proportions were to be represented in Table 1-2. Twelve concrete cubes of size (100 mm^3) were cast for each mixture and overall Seventy-two concrete cubes were casted for six types of concrete mixture. The coarse aggregate used was crushed stone with maximum nominal

size of 10 mm with grade of cement 42.5 N/mm² and fine aggregate used was 4.75 mm sieve size down 600 microns for this research work.

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

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

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

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

Chloride ingress in concrete cubes

The primary aim of this research was to interpret the effectiveness of wetting and drying pre-conditioned concrete cubes on chloride absorption, which was exposed to different pre-determined conditions such as dry/fully saturated/partially saturated condition was evaluated in control/impregnation concrete cubes for about 160 days salt ponding test in all designed six mixtures type (M1-M6). The pre-conditioning was induced in order to achieve desired dry condition in specified 24 concrete cubes. In which all 24 concrete cubes were exposed to natural room temperature for about 28 days. The pre-conditioned fully saturated condition was achieved in specified 24 concrete cubes by partially submerged in water with one surface exposed for about 31 days. The pre-conditioned partially saturated condition was assessed in specified 24 concrete cubes by partially submerged in water with one surface exposed for about 21 days. The chloride ingress in to the concrete can only take place if the concrete pores are totally/partly filled with water. The penetration occurs either through the capillary pores/through cracks by permeation, capillary suction, and diffusion. In the exposure conditions, the concrete moisture content, and the pore structure will determine the relative importance of those penetration mechanisms. The concrete is a porous material with a wide range of pore sizes. Nano-pores are predominant in the hydration products of cements. In fact the concrete was just as other similar porous systems which have an intense interaction with moisture of its environment. If the concrete surface is in contact with liquid water or with aqueous salt solutions, significant quantities of water are absorbed by capillary suction. Under drying conditions, the moisture content is reduced again with a marked hysteresis. All changes of moisture content will induce volume changes which are at the origin of crack formation. The durability of a concrete structure depends essentially on this complex interaction between the porous material and its surrounding. It has been shown by a number of authors that, the deep impregnation of the concrete surfaces with water repellent agents forms an efficient and long lasting barrier with respect to chloride ingress [Zhao *et al.*, 2006]. In this way service life of reinforced concrete structures situated in an aggressive environment such as marine climate/de-icing performance can be significantly improved in different concrete infrastructures. Thus in the present research work that, the effectiveness of impregnation materials such as solvent/water based impregnation materials was evaluated in pre-conditioned concrete cubes in ordered to reduce chloride absorption for in case of designed mixtures type. The variation of average chloride absorption was compared in pre-conditioned control/impregnation concrete cubes at different time duration such as 31th, 61th, 91th, 121th, and 160th days to determine the effectiveness of impregnation materials (solvent/water) based impregnation material for long time duration. The average chloride absorption in DCC control/impregnation concrete cubes was pre-dominantly increased with constant higher concrete compressive strength and varied slump values as when compared to pre-conditioned DCC control/impregnation concrete cubes with constant slump value and varied concrete compressive strength. The average chloride absorption in DCC control/impregnation concrete cubes was pre-dominantly increased with lesser concrete compressive strength and constant slump value as when compared to pre-conditioned DCC control/impregnation concrete cubes with constant slump value and varied concrete compressive strength as well as it goes on

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

3. DISCUSSION ABOUT RESULTS

The process of wetting/drying is a major problem for concrete infrastructures which was exposed to chlorides and its effects are most severe in many concrete infrastructures locations such as marine structures, particularly in the splash and tidal zones, parking garages exposed to de-icer salts, and highway structures, such as bridges and other elevated roadways for instance the Gardner expressway. When the concrete is dry/partially dry, which was then exposed to salt water, it will imbibe the salt water by capillary suction. The concrete will continue to suck in the salt water until saturation or until there is no more reservoir of salt water. A concentration gradient of chlorides will develop in the concrete, stopping at some point in the interior of the concrete. If the external environment becomes dry, then pure water will evaporate from the pores, and salts that were originally in solution may precipitate out in the pores close to the surface. The point of highest chloride concentration may exist within the concrete. On subsequent wetting, more salt solution will enter the pores, while re-dissolving and carrying existing chlorides deeper into the concrete. The rate to which the chlorides will penetrate the concrete depends on the duration of the wetting/drying periods. If the concrete remains wet, some salts may migrate in from the concrete surface by diffusion. However, if the wetting period is short, the entry of salt water by absorption will carry the salts into the interior the concrete and be further concentrated during drying. The process of wetting/drying increases the concentrations of ions such as chlorides, by evaporation of water. The drying of the concrete also helps to increase the availability of the oxygen required for steel corrosion, as oxygen has a substantially lower diffusion coefficient in saturated concrete. As the concrete dries and the pores become less saturated, oxygen will have a better chance to diffuse into the concrete and attain the level necessary to induce and sustain corrosion. There is an increased availability of oxygen that also contributes to the deterioration compared to the submerged part of the structure. The concrete is fully submerged; less chloride would enter the concrete as the dominant penetration mechanism is diffusion through the pore solution. There are several factors that can affect the degree that chlorides will enter concrete through wetting/drying. In fact the ingress of chlorides into concrete is strongly influenced by the sequence of wetting/drying, and on the time duration. Thus in the present research work, the effectiveness of 72 preconditioned concrete cubes of size (100) mm on chloride absorption under various pre-conditions such as dry/fully/partially saturated condition was evaluated for in case of six designed mixtures type (M1-M6). The variation of average water weight loss in control DCC cubes was more/less more with constant higher compressive strength and varied slump value as when compared to variation of average water weight loss in control DCC cubes with varied compressive strength and constant slump value. But, the variation of average water weight loss in DCC cubes was pre-dominantly increased with lesser compressive strength and constant slump value and goes on decreased somewhat with increased compressive strength. The variation of average water weight gain in control PSC cubes was lesser with constant higher compressive strength and varied slump value/varied compressive strength and constant slump value as when compared to variation of average water weight gain in control FSC cubes with constant compressive strength and varied slump value/varied compressive strength and constant slump value. In fact, the variation of average water weight gain in control PSC/FSC cubes was pre-dominantly depends on saturation time duration and mixture proportioning method, pore structure, packing density of concrete, cement content, concrete matrix and cement paste interface zone, as well as aggregate volume fraction ratio in the concrete matrix. It's possible to interpret the variations (increase/decrease) in chloride absorption and compare the variations in chloride absorption for in case of in case of control (M1-0%-M6-0%, M1-2%-M6-2%, and M1-3%-M6-3%)/impregnation concrete cubes (M1SB-M6SB and M1WB-M6WB) as represented in the (Figs.1-18).

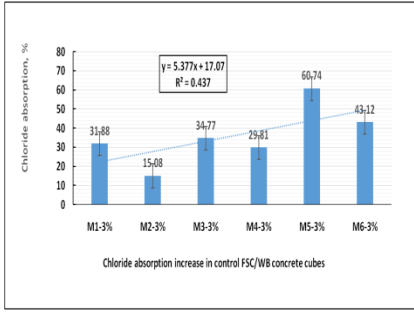


Fig.1 Cl⁻ absorption in FSC cubes

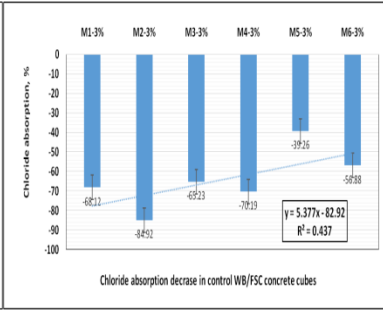


Fig.2 Cl⁻ absorption in FSC cubes

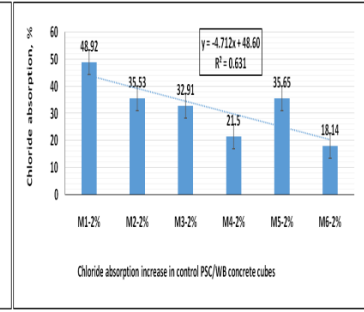


Fig.3 Cl⁻ absorption in PSC cubes

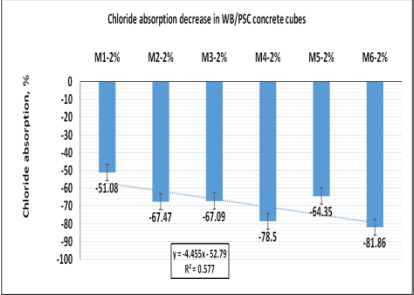


Fig.4 Cl⁻ absorption in PSC cubes

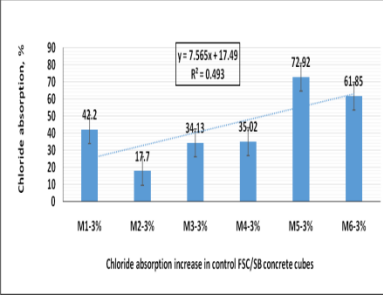


Fig.5 Cl⁻ absorption in FSC cubes

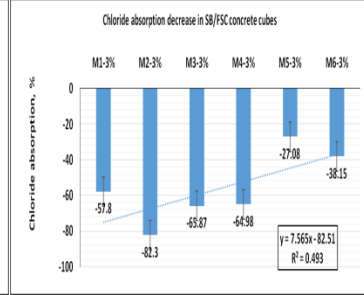


Fig.6 Cl⁻ absorption in FSC cubes

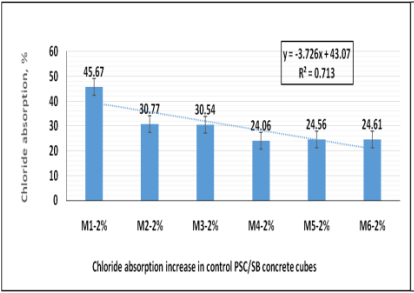


Fig.7 Cl⁻ absorption in PSC cubes

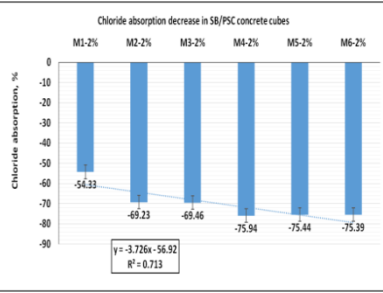


Fig.8 Cl⁻ absorption in PSC cubes

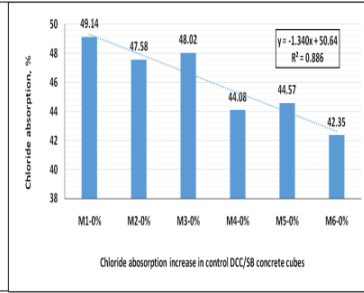


Fig.9 Cl⁻ absorption in DCC cubes

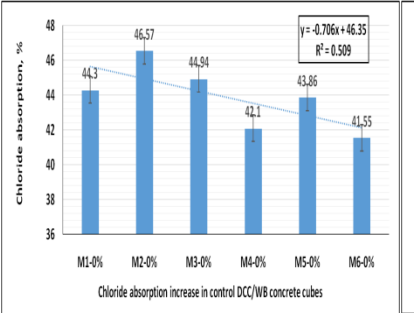


Fig.10 Cl⁻ absorption in DCC cubes

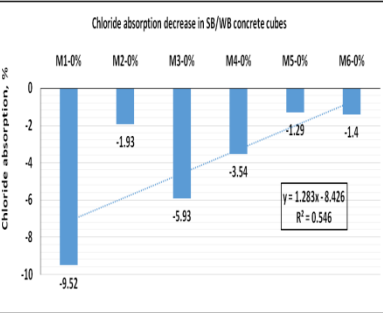


Fig.11 Cl⁻ absorption in SB/WB cubes

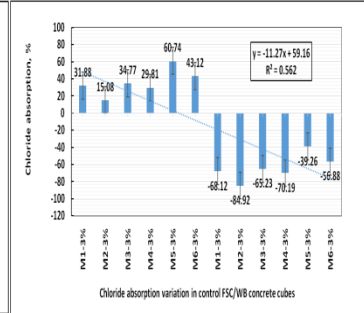


Fig.12 Cl⁻ absorption in FSC cubes

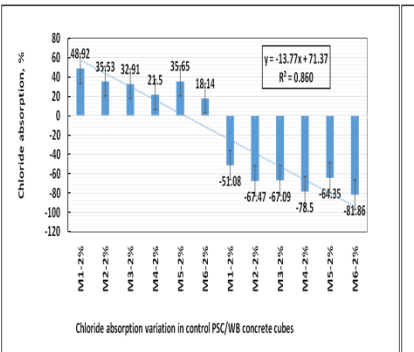


Fig.13 Cl⁻ absorption in PSC cubes

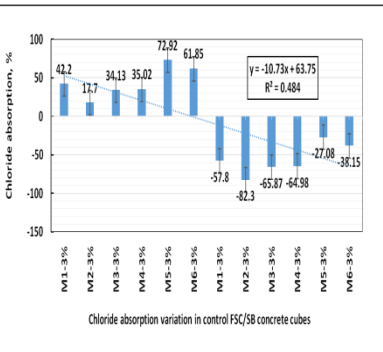


Fig.14 Cl⁻ absorption in FSC cubes

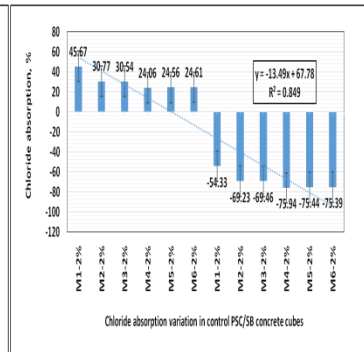


Fig.15 Cl⁻ absorption in PSC cubes

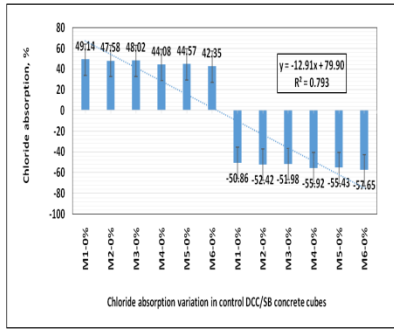


Fig.16 Cl⁻ absorption in DCC cubes

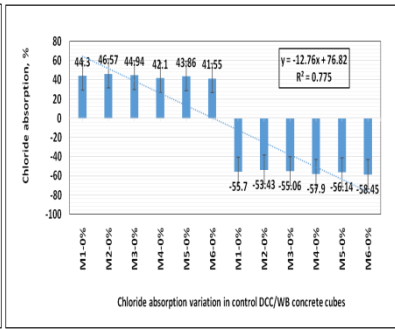


Fig.17 Cl⁻ absorption in DCC cubes

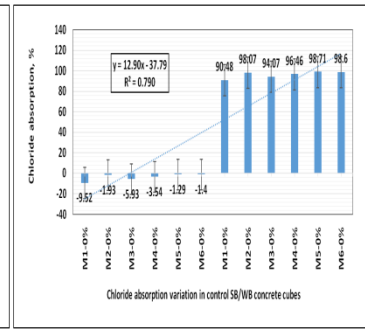


Fig.18 Cl⁻ absorption in SB/WB cubes

It's also possible to interpret the variations (increase/decrease) in chloride absorption and compare the variations in chloride absorption for in case of in case of control (M1-0%-M6-0%, M1-2%-M6-2%, and M1-3%-M6-3%)/impregnation concrete cubes (M1SB-M6SB and M1WB-M6WB) at different time duration (31, 61, 91, 121, and 160) days as represented in the (Figs.19-30).

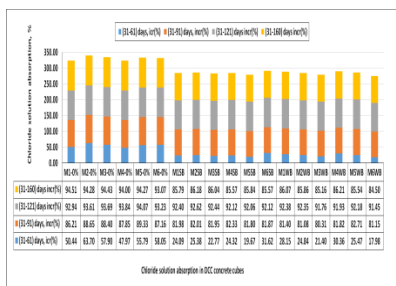


Fig.19 Cl⁻ absorption in DCC cubes

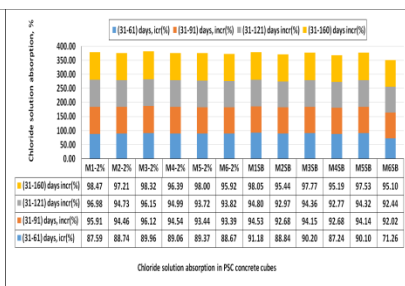


Fig.20 Cl⁻ absorption in PSC cubes

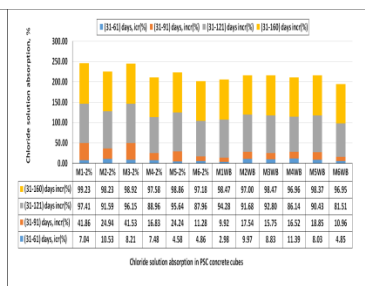


Fig.21 Cl⁻ absorption in PSC cubes

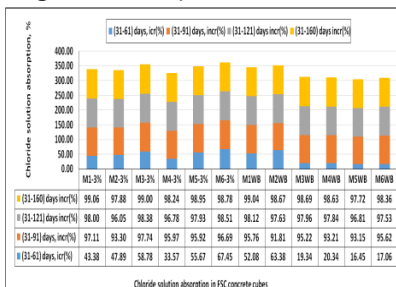


Fig.22 Cl⁻ absorption in PSC cubes

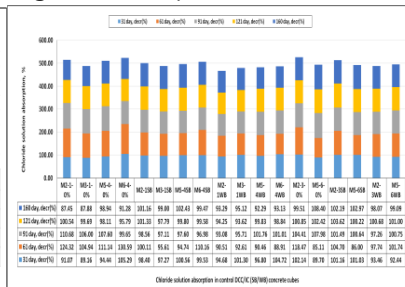


Fig.23 Cl⁻ absorption in DCC cubes

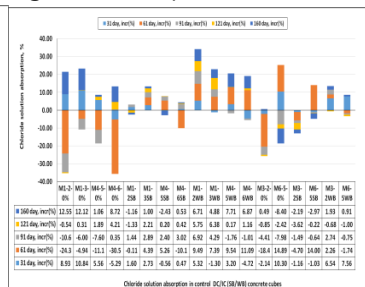


Fig.24 Cl⁻ absorption in DCC cubes

As its observed from the results that, the chloride absorption were decrease at lesser time duration (31 day) as when compared to longer time duration (61, 91, 121, 161) days for in case of control/impregnation concrete cubes.

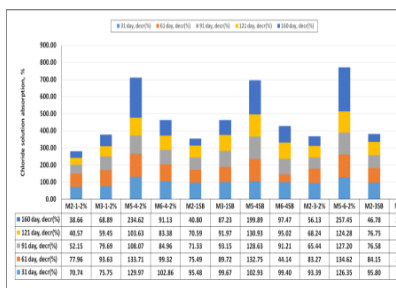


Fig.25 Cl⁻ absorption in PSC cubes



Fig.26 Cl⁻ absorption in PSC cubes



Fig.27 Cl⁻ absorption in FSC cubes

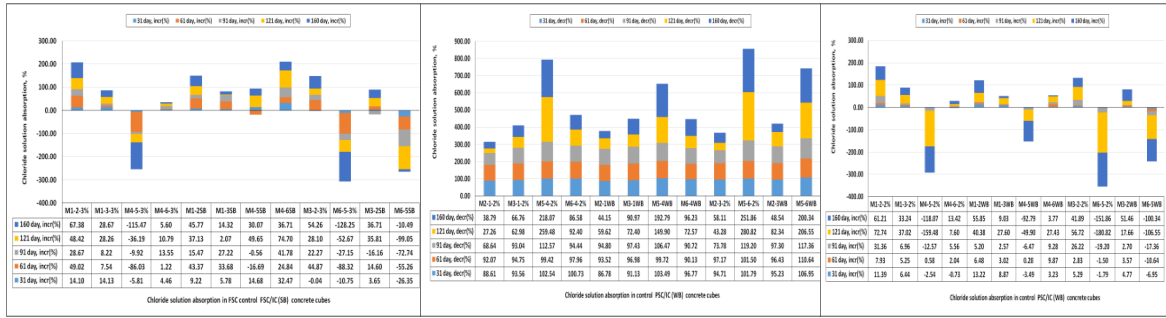


Fig.28 Cl⁻ absorption in FSC cubes Fig.29 Cl⁻ absorption in FSC cubes Fig.30 Cl⁻ absorption in PSC cubes

The transport mechanism of chloride absorption in concrete cubes during wetting/drying pre-conditioned concrete cubes is evaluated in this research work. The dry-wet pre-condition accelerate the transport process of chloride absorption in the complete immersion specimens migrate more rapidly than those under dry-wet pre-condition [Xu Gang *et al.*, 2015]. Especially, in case of absolute dry condition, the penetration rate of chloride ion will be much larger because of advection process than that in diffusion process in mortar with water saturated condition. Moreover, at the surface part of mortar, additional chloride content due to diffusion process can be also confirmed on distribution of chloride content due to advection process during absorption test. Therefore, in order to assess the penetration of chloride ion, effects of both advection and diffusion processes depending on moisture condition of mortar should be considered. The concrete are in a state of flux between saturated and partially saturated conditions as they undergo continuous cycles of wetting and drying. In saturated concrete, dissolved ions enter through diffusion, whereas in partially saturated concrete, ion-containing fluids are absorbed by capillary suction and concentrated by evaporation of water. It was found from the researchers [Hong and Hooton, 1999] that, the longer drying times increase the rate of chloride ingress. A good relationship between the depth of chloride penetration and the square root of the number of cycles. In fact several authors have shown that an effective chloride barrier can be established in pre-conditioned concrete by surface impregnation with a liquid water repellent. However, the question arises frequently as to whether chloride contaminated concrete structures with high moisture content can still be protected from further chloride penetration into the porous structure by surface impregnation. There is a need to determine the efficiency of surface impregnation of chloride-contaminated concrete before any protective treatment applied on the concrete. In the present research work, tests were run to investigate the influence of pre-condition such as DCC/PSC/FSC cubes on the efficiency of surface impregnation. It's actually confirmed from the results that, higher saturation degree reduces the efficiency of surface impregnation. Thus, pre-drying of concrete with high saturation degree is essential for the establishment of an effective, reliable, and long lasting chloride barrier. The chloride absorption was increased in pre-conditioned control/impregnation (SB/WB) DCC cubes as when compared to control/impregnation (SB/WB) PSC, and control/impregnation (SB/WB) FSC conditioned cubes.

4. CONCLUSION

For different designed mixtures type of concrete, varying time durations are required in ordered to achieve a desired pre-conditions such as DCC/PSC/FSC conditioned cubes. Actually for constant higher concrete compressive strength, varied slump values and higher/lower w/c ratio, as well as varied concrete compressive strength, constant slump value and higher/lower w/c ratio, a true state of saturation is difficult to obtain. The rate of absorption (sorptionity) is controlled by the pore structure of the concrete and its degree of saturation for in case of PSC and FSC cubes

The chloride diffusion in saturated pores at greater depths continues to occur during the drying phase. In which an extending the drying period appears to increase the chloride ingress by capillary sorption in subsequent wetting process, rather than by continued diffusion during the drying phase. Furthermore the rate of drying is dependent on the pore structure of the concrete and as a result higher quality concretes dry at a slower rate.

The variation of average water weight loss in control DCC cubes was more/less more with constant higher compressive strength and varied slump value as when compared to variation of average water weight loss in control DCC cubes with varied compressive strength and constant slump value. But, the variation of average water weight loss in DCC cubes was pre-dominantly increased with lesser compressive strength and constant slump value and goes on decreased somewhat with increased compressive strength.

The variation of average water weight gain in control PSC cubes was lesser with constant higher compressive strength and varied slump value/varied compressive strength and constant slump value as when compared to variation of average water weight gain in control FSC cubes with constant compressive strength and varied slump value/varied compressive strength and constant slump

value. In fact, the variation of average water weight gain in control PSC/FSC cubes was pre-dominantly depends on saturation time duration and mixture proportioning method, pore structure, packing density of concrete, cement content, concrete matrix and cement paste interface zone, as well as aggregate volume fraction ratio in the concrete matrix.

The average chloride absorption in DCC control/impregnation (SB/WB) concrete cubes were pre-dominantly increased with constant higher concrete compressive strength and varied slump values as when compared to pre-conditioned DCC control/impregnation (SB/WB) concrete cubes with constant slump value and varied concrete compressive strength. The average chloride absorption in DCC control/impregnation (SB/WB) concrete cubes was pre-dominantly increased with lesser concrete compressive strength and constant slump value as when compared to pre-condition DCC control/impregnation (SB/WB) concrete cubes with constant slump value and varied concrete compressive strength as well as it goes on decreases with increased concrete compressive strength.

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

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

REFERENCE

- Bertolini, L., Elsener, B., Pedferri, P., Redaelli, E., Polder, R.B. (2013). *Corrosion of steel in concrete: Prevention, Diagnosis, Repair*, 2nd Edition, Wiley-VCH Verlag GmbH & Co.KGaA, Weinheim, ISBN 3-527-33146-8, 414 pp.
- Fib, 2006, *Model code for service life design*, fib Bulletin 34, Model Code, 116 pages, ISBN978-2-88394-074-1.
- Bertolini, L., Lollini, F., Redaelli, E. (2011). Durability design of reinforced concrete Structures, Institution of Civil Engineers Construction Materials, (CM6), 64: 273-282.
- Gaal, G.C.M. (2004). *Prediction of deterioration of concrete bridges*, Ph.D. thesis, Delft University Press, Delft, NL.
- Pullar-Strecker, P. (2002). *Concrete reinforcement corrosion from assessment to repair decisions*, 1st edition, Thomas Telford Ltd, London.
- Hong, K, and Hooton. R. D. (1999). *Effects of cyclic chloride exposure on penetration of concrete cover*, Cement and Concrete Research 29:1379-1386.
- Polder, R.B., Peelen, W.H.A., Courage, W.M.G. (2012). *Non-traditional assessment and Maintenance methods for aging concrete structure -Technical and non-technical Issues*, Materials and Corrosion, 63(12):1147-1153.
- Shi,X Fay L, Yang, Z, Nguyen, T.A, and Liu.Y. (2009). *Corrosion of de-icers to metals in transportation infrastructure: introduction and recent developments 0/00"*, Corrosion. Reviews, in press.
- TRB, *Highway De-icing*. (1991). *Comparing salt and calcium magnesium acetate*, TRB, National Research Council, Washington D.C., Special Report, 235.
- Tilly, G. P. (2011). Durability of concrete repairs. Concrete repairs, M. Grantham, ed., Taylor and Francis, Oxford, U.K.
- Teychenné, D. C, R E Franklin., H. C, Erntroy. (1988). *Design of normal concrete mixes*, Second edition, BRE.
- Visser, J.H.M, Zon, Q. van. (2012). *Performance and service life of repairs of concrete structures in The Netherlands*, International conference on concrete repair, rehabilitation and retrofitting III, Alexander et al. (eds.), Taylor & Francis, London, ISBN 978-0-415-89952-9.
- Xu Gang, Li Yun-pan, Su Yi-biao, and XuKe. (2015). *Chloride ion transport mechanism in concrete due to wetting and drying cycles*, Structural concrete, Issue 2, 16:289-296.
- Zhao, T.J, Zhang, P, and Wittmann, F.H. (2006). *Influence of freeze-thaw cycles on carbonation and chloride penetration*, Proc. Int. Workshop on life cycle management of coastal concrete Structures, Nagaoka University, Japan, H. Yokota and T. Shimomura, editors, 37-42pp.