RESEARCH

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Prediction of chloride concentration in pre-conditioned concrete slabs

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ABSTRACT

In winter season, ice accumulates on the top surface of concrete slabs and bridge decks. For the purpose of removing the snow and ice, de-icing agents are applied. These salts migrate down to the reinforcing steel through small pores in the concrete. Over time, the chlorides in these salts can react with the reinforcing steel, breaking down the passive layer and causing the steel to corrode. Reinforcement corrosion in concrete is one of the most encountered causes of premature failure of infrastructure concrete structures as well as has serious economic and safety implications. Moreover, carbon dioxide from the atmosphere can gradually migrate into the concrete and react with the alkaline pore solution. Chloride ions from winter maintenance operations, marine environment or other contamination can penetrate through the concrete pores to the passive layer on the reinforcement and de-passivate the passive film. Thus in turn chloride ingress, carbonation, and low quality of the concrete cover can induce steel corrosion in concrete. This causes a build-up stress in concrete and leads to concrete deterioration and dangerous loss of structural durability. Therefore, there is a need to quantify the chloride concentration in concrete slabs which is of most important factor. The present research work was made an attempt to interpret the concrete chloride concentration in ordered to characterize the different concrete mixtures design for in case of pre-conditioned concrete slabs such as dry/fully/partially saturated condition which were 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 slabs at various drill depths 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. Eighteen concrete slabs (450x450x100) mm with Grades of concrete ranges from 25 to 40 N/mm ^{2} were prepared and evaluate the chloride concentration under different exposure condition. It's concluded from the results that, in dry/saturated conditioned concrete slabs, the chloride concentration value was increased in all designed mixtures type at lesser drill depth as when compared to higher drill depth. Similarly, the average chloride concentration was decreased in solvent/water based impregnation DCC/PSC/FSC slabs as when compared to control DCC/PSC/FSC slabs for constant higher compressive strength and varied slump value as well as varied compressive strength and constant slump value.

Keywords: Concrete, Mixture proportion, Grade of concrete, pre-conditioning, Water-cement ratio, chloride diffusion, chloride absorption

1. INTRODUCTION

The removal of ice from transport infrastructure can be accomplished by a combination of several methods, such as plowing, natural melting, traffic movement, and chemical treatment. And these infrastructures maintenance depends on chemicals and fine aggregates for de-icing and anti-icing [1]. In fact, various de-icing chemical agents are available commercially at market. The most cost-effective chemical agent is sodium chloride. However, by using chloride as de-icing agent has caused damage to concrete infrastructure such as concrete bridge decks. In addition to that, the de-icing agent may induce damage to an automobile bodies, roadside soils and water runoff [2]. Moreover, de-icing agent may induces osmotic pressure which causes water to move upward the slab layer where freezing takes place [3]. The ain reason for the corrosion of ordinary/pre-stressed reinforcement such as concrete cover, concrete poor quality, and ingress of aggressive salts which was confirmed from so many researchers investigation [4]. In addition to that, the de-icing agents may also cause scaling on roads in many cold countries. As a result of accelerated ingress of aggressive substances which may cause reinforcement corrosion in concrete [5]. The de-icing salts may also induced strength loss due to frost action in different structural members with the presence of higher degree of saturation as well as de-icing agent [6]. Thus both the scaling frost action were considered to be the most important factors which was reduces the service life of concrete infrastructure [7]. There is a need to interpret chloride concentration in designed concrete slabs under pre-conditions such as dry/fully/partially saturated condition which was salt ponded with chloride solution for about long term time duration.

2. RESEARCH OBJECTIVES

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 concentration in ordered to characterize the different concrete mixtures design for in case of pre-conditioned concrete slabs such as dry/fully/partially saturated condition which was 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 dry/fully/partially saturated condition on the results of chloride concentration performed on concrete slabs 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. Eighteen concrete slabs (450x450x100) mm with Grades of concrete ranges from 25 to 40 N/mm^2 were prepared and evaluate the chloride concentration under different exposure condition at various drill depth (30-40-50) mm.

3. EXPERIMENTAL PROGRAM

In the present research work, six different mixtures type were prepared in total as per BRE, 1988 [8] code standards with a 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/mm^2) 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/mm^2, 30 N/mm^2, and 40 N/mm^2), 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) an (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 a 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 a 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 casted for six types of concrete mixture . The coarse aggregate used was crushed stone with maximum nominal size of 10 mm with grade of cement 42.5 N/mm^2 and fine aggregate used was 4.75 mm sieve size down 600 microns for this research work. 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 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 gr ater than 80% and can achieve penetration greater than 10mm.

Table 1 Concrete slabs mixture proportion (M1-M3)

Mix ID	Comp/mean target strength (N/mm^2)	Sl mp (mm)	w/c	C (Kg)	W (Kg)	FA (Kg)	CA (Kg)	Mix Proportions
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)	lump (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

4. SALT PONDING TEST

The unidirectional salt ponding was adopted as per AASHTO T 259 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 T 259 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 T 259 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 t 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 Fig.1.

Figure 1 Chloride profile analysis in pre-conditioned concrete slabs

The variation of chloride concentration in pre-conditioned control/impregnation concrete slabs was represented in Table.3. As observed from the results that (Table 3), the chloride concentration were 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 Chloride 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			
Mixture type [M1=M2]				Mixture type [M3=M5]				Mixture 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	M3C5	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	0.05
M2S4	0.078	0.068	0.063	M5S8	0.081	0.071	0.059	M6S12	0.064	0.055	0.054

Similarly the comparison of chloride concentration at different drill depth (30-40-50) mm in DCC/PSC/FSC control/impregnation concrete slabs were to be represented in Table.4. Furthermore, the variation of chloride concentration in solvent/water based impregnation concrete slabs as when compared to control, and chloride concentration variation in solvent based impregnation concrete slabs as when compared to water based impregnation concrete slabs were to be represented in Table.5.

Table 4 Comparison of Chloride concentration at different drill depth in concrete slabs

Comparison of Final CC Results for DCC Slabs					
Mixture type [M1=M2]					
Slab ID	30 mm	40 mm	Incr (%)	50 mm	Incr (%)
M1CS	0.092	0.0864	6.42	0.082	11.67
M1S1	0.089	0.0835	6.66	0.075	15.78
M1S2	0.092	0.0854	6.68	0.08	12.83
M2CS	0.082	0.0782	4.85	0.065	20.47
M2S3	0.077	0.0672	13.21	0.061	20.74
M2S4	0.078	0.0683	12.80	0.063	20.01
Comparison of Final CC Results for PSC Slabs					
Mixture type [M3=M5]					
Slab ID	30 mm	40 mm	Incr (%)	50 mm	Incr (%)
M3C5	0.079	0.0731	7.13	0.069	12.70
M3S5	0.074	0.0711	3.54	0.066	10.85
M3S6	0.075	0.0722	3.46	0.067	10.30
M5CS	0.085	0.0736	12.94	0.062	27.11
M5S7	0.081	0.0613	23.90	0.058	28.44
M5S8	0.081	0.0706	13.25	0.059	27.21
Comparison of Final CC Results for FSC Slabs					
Mixture type [M4=M6]					
Slab ID	30 mm	40 mm	Incr (%)	50 mm	Incr (%)
M4CS	0.072	0.0716	0.80	0.065	9.88
M4S9	0.07	0.0672	3.48	0.062	10.29
M4S10	0.07	0.0685	2.62	0.063	9.88
M6CS	0.065	0.0599	8.38	0.056	14.61
M6S11	0.063	0.0524	17.33	0.05	20.80
M6S12	0.065	0.0547	15.34	0.054	16.91

Table 5 Interpretation of Chloride concentration in control/impregnation concrete slabs

Comparison of Final CC Results for DCC Slabs at diiferent drill depths									
Mixture type [M1=M2]									
Slab ID	30 mm	Incr (%)	Incr (%)	40 mm	Incr (%)	Incr (%)	50 mm	Incr (%)	Incr (%)
M1CS	0.0923	0.00		0.086	0.00		0.082	0.00	
M1S1	0.0895	3.04		0.084	3.29		0.075	7.56	
M1S2	0.0915	0.83	2.23	0.085	1.10	2.21	0.08	2.13	5.54
M2CS	0.0821	0.00		0.078	0.00		0.065	0.00	
M2S3	0.0774	5.80		0.067	14.08		0.061	6.12	
M2S4	0.0784	4.58	1.28	0.068	12.55	1.74	0.063	4.03	2.19
Comparison of Final CC Results for PSC Slabs at diiferent drill depths									
Mixture type [M3=M5]									
Slab ID	30 mm	Incr (%)	Incr (%)	40 mm	Incr (%)	Incr (%)	50 mm	Incr (%)	Incr (%)
M3C5	0.0787	0		0.073	0		0.069	0	
M3S5	0.0737	6.35		0.071	2.74		0.066	4.37	
M3S6	0.0748	4.99	1.43	0.072	1.24	1.51	0.067	2.37	2.04
M5CS	0.0846	0.00		0.074	0.00		0.062	0.00	
M5S7	0.0806	4.75		0.061	16.75		0.058	6.49	
M5S8	0.0813	3.83	0.96	0.071	4.18	13.11	0.059	3.96	2.64
Comparison of Final CC Results for FSC Slabs at diiferent drill depths									
Mixture type [M4=M6]									
Slab ID	30 mm	Incr (%)	Incr (%)	40 mm	Incr (%)	Incr (%)	50 mm	Incr (%)	Incr (%)
M4CS	0.0722	0		0.072	0		0.065	0	
M4S9	0.0696	3.57		0.067	6.17		0.062	4.01	
M4S10	0.0704	2.55	1.05	0.069	4.33	1.93	0.063	2.55	1.50
M6CS	0.0654	0		0.06	0.00		0.056	0.00	
M6S11	0.0634	3.06		0.052	12.52		0.05	10.09	
M6S12	0.0646	1.15	1.93	0.055	8.65	4.24	0.054	3.81	6.53

5. DISCUSSION ABOUT RESULTS

The variation of chloride concentration is interpreted by chemical analysis at different drill depths (30-40-50) mm and it's as shown in Fig.2-3 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 conc rete 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.

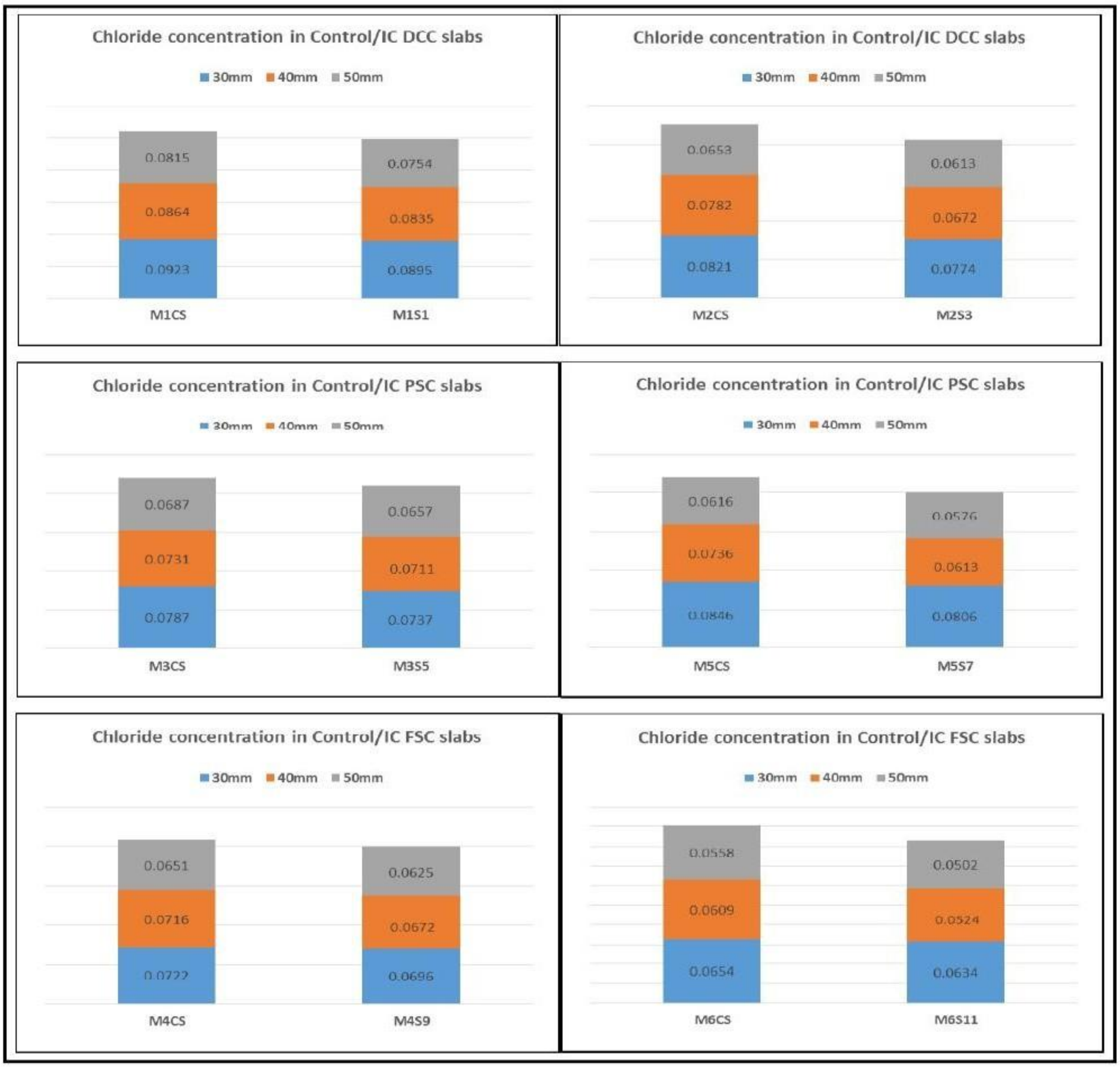

Figure 2 Chloride concentration in pre-conditioned control/IC slabs (SB)

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 sla bs 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.

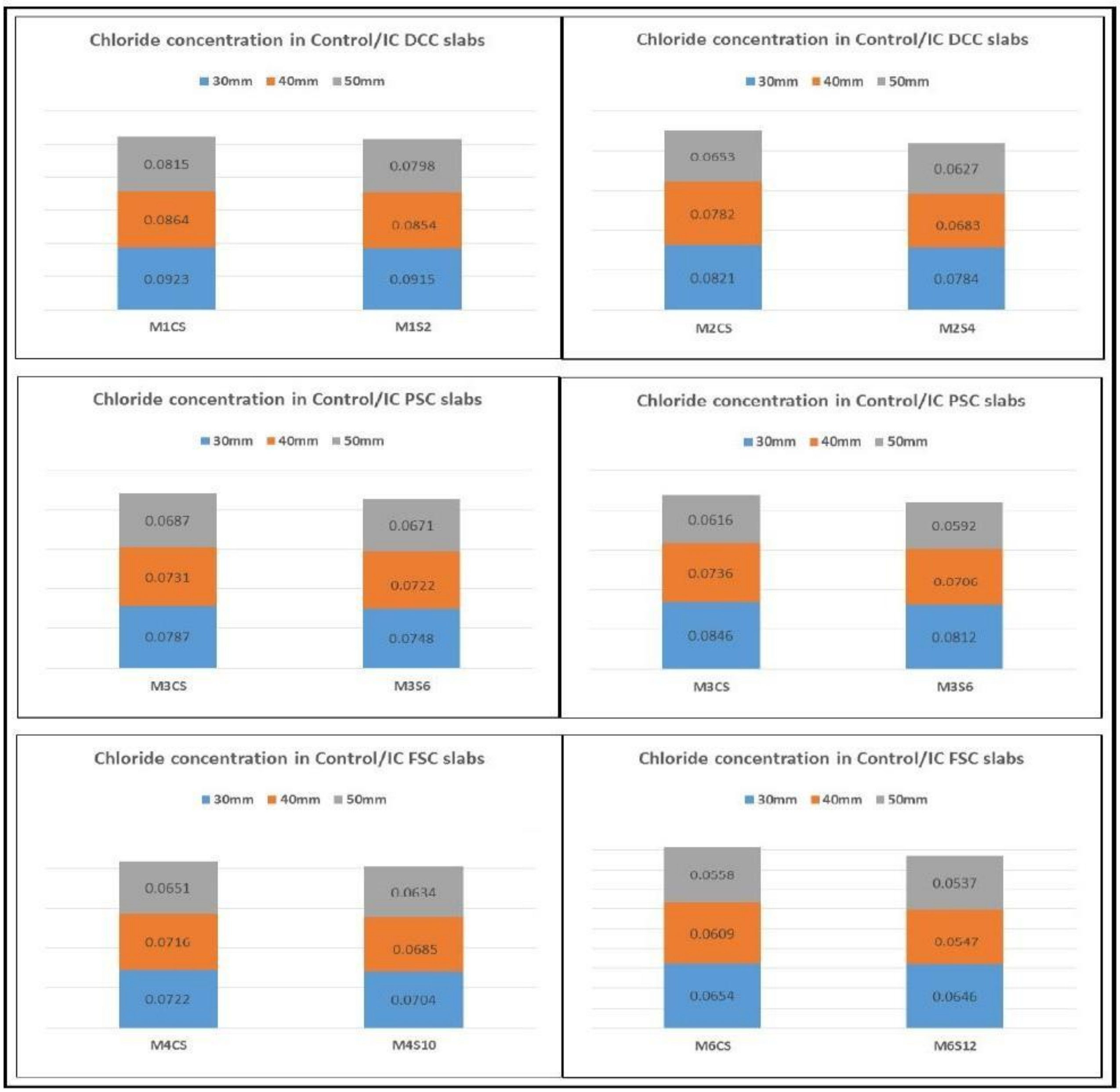

Figure 3 Chloride concentration in pre-conditioned control/IC slabs (WB)

The average chloride concentration is increased in control concrete slabs for in case of mixtures type (M3CSM5CS) 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. 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 impre nation 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.

6. CONCLUSIONS

- 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.
- The chloride concentration is decreased in solvent/water based impregnation DCC/PSC/FSC concrete slabs as when compared to control DCC/PSC/FSC concrete slabs.
- 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.

REFERENCE

1. Kuemmel, D. E. Managing Roadway Snow and Ice Control Operations. *Transportation Research Record*, NCHRP, Synthesis 207, 1994.
2. Mcelroy, A. D., R. R. Blackburn, J. Hagymassy, and H. W. Kirchner. Comparative Study of Chemical De-icers. Transportation Research *Record*, No. 1157, pp. 1-11, 1988.

3. Neville, A. M. Properties of Concrete. John Wiley and Sons, Inc., New York, 1996.
4. Zenonas Kamaitis, Damage to concrete bridges due to reinforcement corrosion. Part I. Site investigations, Transport-2002, V. XVII. No.4, 137-142.
5. Bertolini, L., Elsener, B., Pedeferri, P. and Polder, R. 'Corrosion of steel in concrete: Prevention, diagnosis, repair.' Wiley-VCH Verlag GmbH. 2005. 409 p.
6. Scherer, G.W., Valenza, J.J., 'Mechanisms of frost damage', in: J. Skalny, F. Young (Eds.), Materials Science of Concrete, vol. VII, American Ceramic Society, (2005) 209–246.
7. Vesikari, E., Ferreria, R.M., 'Frost Deterioration Process and Interaction with Carbonation and Chloride Penetration-Analysis and Modelling of Test Results.' VTT Research Report. VTT-R- 02782-11. 2011, 40.