

Corrosion Analysis in Concrete

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Abstract

Reinforcement corrosion in concrete is a widespread problem in reinforced concrete structures in cold climates due to the heavy use of de-icing salts during winter. This research project studies two aspects of chloride-induced reinforcement corrosion: chloride contamination in concrete and non-destructive corrosion rate testing. It is important to examine the behaviour of corrosion in structures as this phenomenon plays an important part in the durability and strength of our structures. With these two test methods, researchers are able to predict how many years of service life remain in the examined structures. These predictions allow owners to plan rehabilitation or reconstruction projects ahead of time. They also allow researchers to develop new products in order to further withstand corrosion.

Résumé

La corrosion des armatures dans le béton est un problème répandu dans les structures en béton armé dans les climats froids en raison de l'utilisation intensive de sels de dégivrage pendant l'hiver. Ce projet de recherche étudie deux aspects de la corrosion des armatures induites par les chlorures: la contamination par les chlorures dans le béton et les essais de vitesse de corrosion non destructive. Il est important d'examiner le comportement de la corrosion dans les structures comme ce phénomène joue un rôle important dans la durabilité et la force de nos structures. Avec ces deux méthodes d'essai, les chercheurs sont en mesure de prédire combien d'années de vie de service restent dans les structures examinées. Ces prévisions permettent aux propriétaires de planifier des projets de réhabilitation ou de reconstruction à l'avance. Il permet également aux chercheurs de développer de nouveaux produits afin de résister davantage à la corrosion.

What is Reinforcing Steel Corrosion?

Reinforcing steel corrosion is one of the main degradation causes for reinforced concrete. The rust created by the corrosion causes the rebar to occupy more space within the concrete. This phenomenon creates tensile stresses which causes the concrete to crack. With a greater number of voids, it is then even easier for foreign elements to penetrate the concrete cover and cause the steel to further corrode.



Fig. 1: Corroded reinforced concrete member

Objective

The purpose of this research is to assess the presence of reinforcing steel corrosion by: (i) detecting the amount of chlorides present in the concrete, and (ii) measuring the rate at which corrosion proceeds.

Methods

1. Chloride Contamination

Various types of concrete cylinders were submerged in a chloride solution for multiple weeks before being grinded into concrete powder. These powder samples were extracted at gradual depths in order to conduct chloride titration to determine the chloride penetration front.

$$Cl (\%) = 3.545 * \{(V_1 - V_2) * N\} / W$$

V_1 = ml of 0.05 N $AgNO_3$ solution used for sample titration (equivalence point),

V_2 = ml of 0.05 N $AgNO_3$ solution used for blank titration (equivalence point),

N = exact normality of 0.05 N $AgNO_3$ solution,

W = mass of sample, g.

2. Non-Destructive Corrosion Rate Testing

Various types of concrete slabs were submerged in salt water to simulate a 100% humid environment. The slabs were then tested weekly with electric sensors to record the rate at which the corrosion was progressing through the rebar. The final mass of the rebar was then compared to the initial mass to determine the complete mass loss due to corrosion.

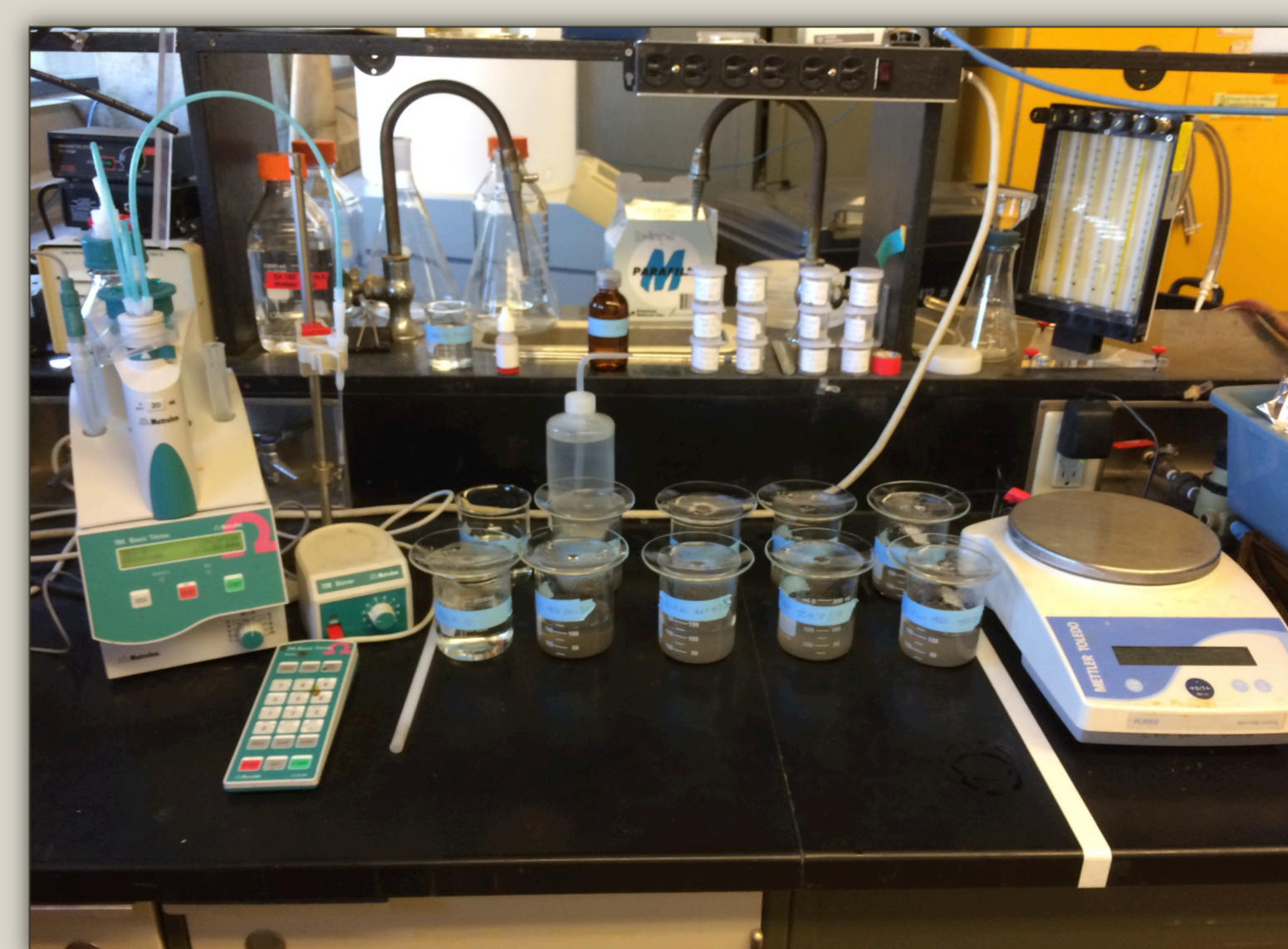


Fig. 2: Titration testing of the chloride samples using the 794 Basic Titrino.



Fig. 3: Corrosion rate testing with the Gecor sensor.

Results

1. Chloride Contamination

The data obtained in the laboratory is placed into Excel tables as shown below:

Table 1: Chloride titration results.

Zone	Date Tested	Sample Size of powder (g)	Sample Size of DW (g)	Sample Size Inputted (g)	ppm	0.05 N $AgNO_3$ (mL)	mV	% Chloride
17-Feb-17								
Blank			75.00	100.00	39.15	2.209	185	
1-1B (1-2)		5.00	75.02	100.02	53.33	3.009	131	0.028360000
1-1B (2-3)		5.00	75.00	100.00	55.48	3.130	109	0.032649450
1-2T (1-2)		5.01	75.07	100.07	53.95	3.044	128	0.029541667
1-2T (2-3)		4.99	75.01	100.01	50.71	2.861	160	0.023159719

2. Corrosion Rate

The Gecor device displays the following values once the recording is finished:

- The corrosion rate ($\mu A/cm^2$),
- The corrosion potential (mV),
- The electric resistance ($K\Omega$),
- The error obtained, if present.

The data obtained in the laboratory is placed into Excel tables as shown below:

Table 2: Gecor measurements.

#2 3A INV	2	Corrosion Rate	0.024	0.001
		Corrosion Pot.	-265.8	-276
		Elec. Resist.	2.35	2.12
		Pot. Time		
		Error?		
	4	Corrosion Rate	0.019	0.002
		Corrosion Pot.	-278.3	-247.1
		Elec. Resist.	2.22	1.94
		Pot. Time		
		Error?		
		Avg. corrosion rate	0.0215	0.0015
		Avg pot	-272.05	-261.55
		Avg. resistance	2.285	2.03

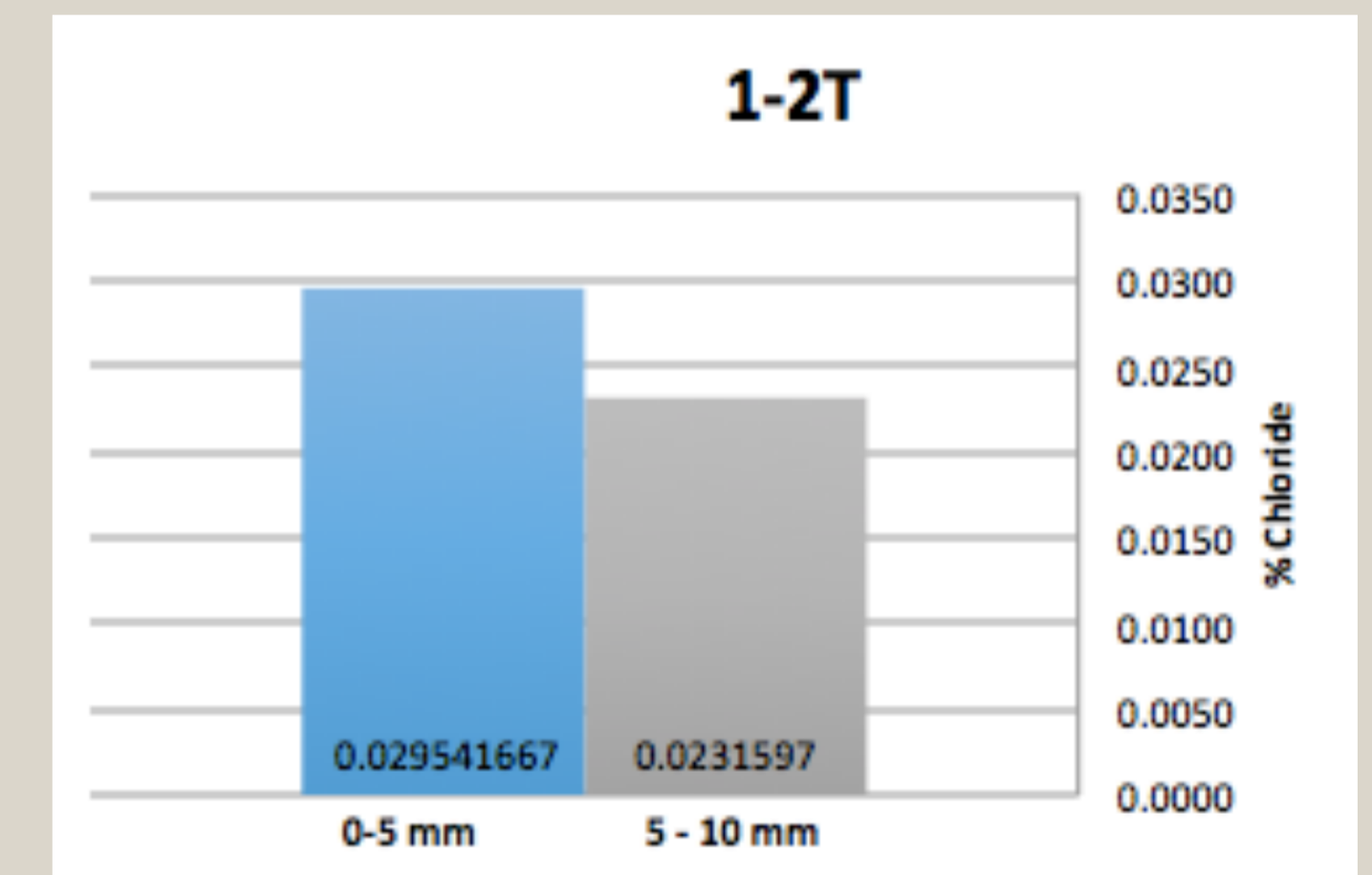
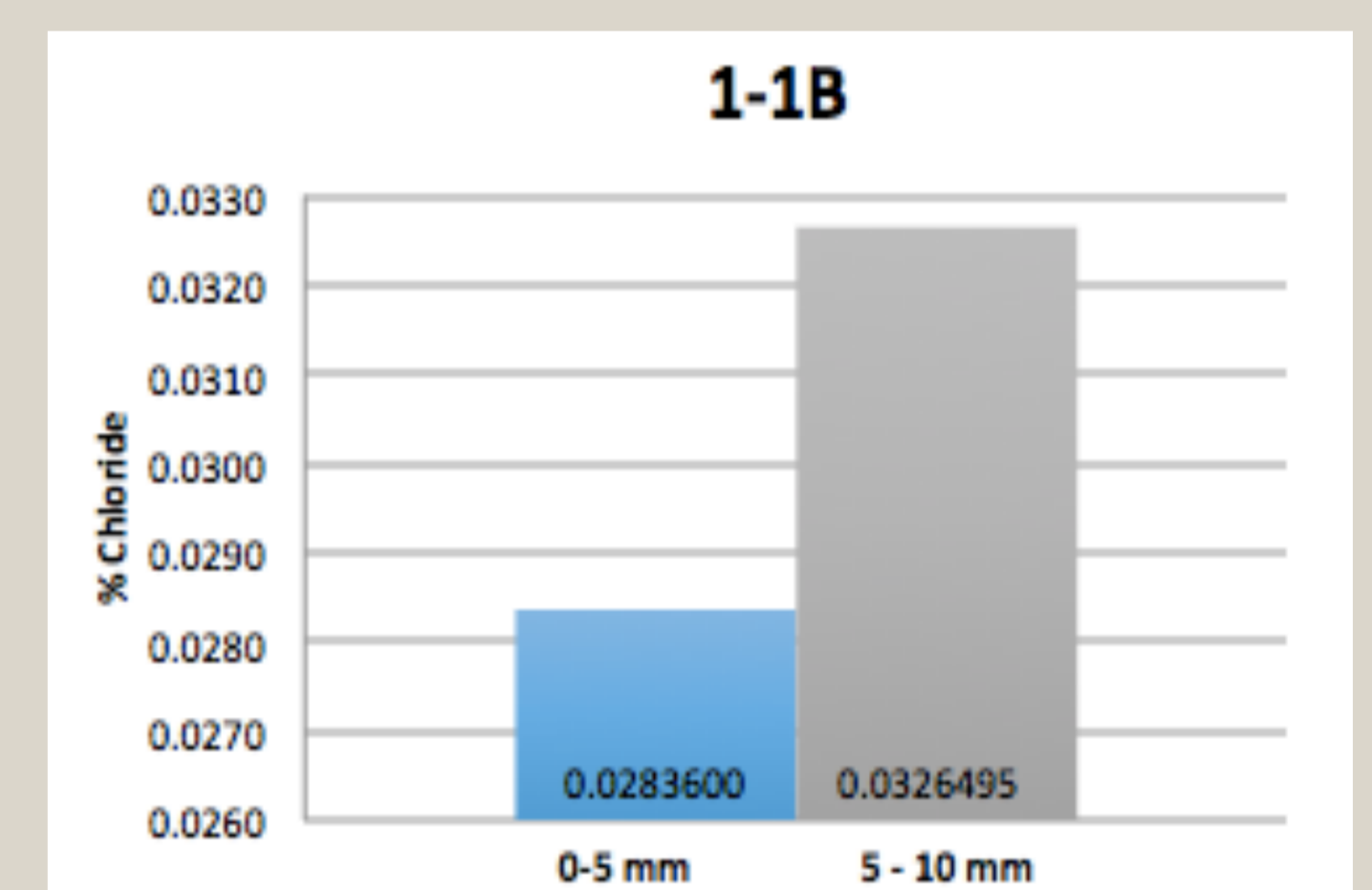


Fig. 4: Chloride profiles.

Conclusions

1. Chloride Contamination

Among the 53 samples tested over the last 4 months, the majority have chloride percentages ranging from 1% to 4% by mass of concrete. Approximately 5 samples had faulty results either caused by faulty samples or experimental errors.

2. Corrosion Rate

The results obtained from the 18 slabs containing 36 reinforcing steel bars (for a total of 42 measurements) were consistent with values obtained from current practice. Minor fluctuations were noticed as the weeks progressed.

References

ASTM C1152; Fig. 1: Chloride attack, 2016, Vancouver, blog.kryton.com, March 10th 2017

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