NON-DESTRUCTIVE TECHNIQUE TO IDENTIFY THE PRESENCE OF SILANE ON CONCRETE

By

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NON-DESTRUCTIVE TECHNIQUE TO IDENTIFY

THE PRESENCE OF SILANE ON CONCRETE

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CHAPTER I

INTRODUCTION

Exposure of concrete to adverse conditions eventually may lead to harmful attacks like corrosion of reinforced steel, freeze and thaw effect, alkali-sulfate reaction and sulfate attack. Most of these cases are due to penetration of water or fluids into the concrete. So, permeability of concrete is an important factor and lowering it will decrease the rate of deterioration thus improving concrete durability. Permeability is defined as the ease with which the liquid can pass through a solid. Seishi Goto et al. (1981) presented some experimental results showing a relationship between permeability and water-cement ratio. His results explain that permeability values decreased exponentially with decreasing water-cement ratio.

The cost for repair of highway infrastructure is very high and sometimes it may be more than the original cost. So, it is essential to avoid early deterioration and surface treatment of the concrete is one of the economical and effective methods to minimize early deterioration. M. Ibrahim (1997) et al. in his research showed that the silane /siloxane coating on concrete are useful to enhance the life of concrete structures in chloride-dominated environments. When silane is applied to concrete, it reacts and forms a hydrophobic coating on the surfaces of the concrete. When water contacts the surface of the concrete, the coating repels the water molecules to bead up and evaporates before penetrating into the concrete. The Oklahoma Department of Transportation (ODOT) commonly uses a silane or siloxane chemical sealer on bridge decks to reduce the penetration of external chemicals and hence enhancing the life of the bridge. Currently, it is unknown how long these sealers are effective, and if these sealers can be reapplied to continue to help protect the concrete. Because of this ODOT has sponsored a research project at OSU to estimate the long term performance of these sealers. As part of this study it would be desirable to produce a quick, economical, and non-destructive technique for indicating the presence of silane on concrete bridge decks.

The focus of this thesis will be to examine non-destructive testing methods that can be used in the field on in place bridge decks to evaluate the presence and effectiveness of silane sealers on the surface of concrete. These tests should be easy to use and give clear information about the silane at the concrete surface. Two different testing methods will be investigated. In Chapter 2 the Germann Water Permeability test was investigated and in Chapter 3 a surface resistivity test was used. For each of these tests their repeatability and reliability was investigated with concrete of different w/cm with and without silane.

CHAPTER II

EVALUATION OF GWT UNIT

2.1 Overview

In this chapter the Germann water permeability unit (GWT) was investigated in hopes to develop a non-destructive methodology for ODOT to measure the efficiency of water proofing agents applied on concrete bridge decks. The instrument is developed by GERMANN INSTRUMENTS, INC for measuring water penetration in surface concrete and also for testing micro cracking of a concrete surface. This study attempts to provide an onsite non-destructive technique to estimate the presence of water proofing solution by penetrating water through silane coated surface concrete under pressure. The penetration depth of pressurized water over time into saturated concrete can be estimated by Darcy's law (Jo-Hyeong Yoo, 2006).

A.I.Cark (1999) carried out an experimental study to determine the effect of silica fume and curing temperature on the permeability of concrete. In this study he used the GWT on the concrete cylinders to identify the permeability of concrete. However, the results in his study do not investigate the consistency or variability of the measurements.

This study of water penetration has been observed under a constant pressure by taking water-cement ratio of the concrete as variable. Based on the results obtained, the reliability of the instrument is presented as well as a few modifications that may improve the method.

2.2 Experiment methods

2.2.1 Methodology

In the GWT, a sealed pressure chamber is attached to the concrete surface using anchors; the chamber is filled with water, and the required water pressure is applied to the surface. The amount of water penetrating the surface concrete is measured by keeping the pressure constant by using a micrometer gauge with an attached pin which substitutes the water leaving the chamber (Germann Instruments, 2010).

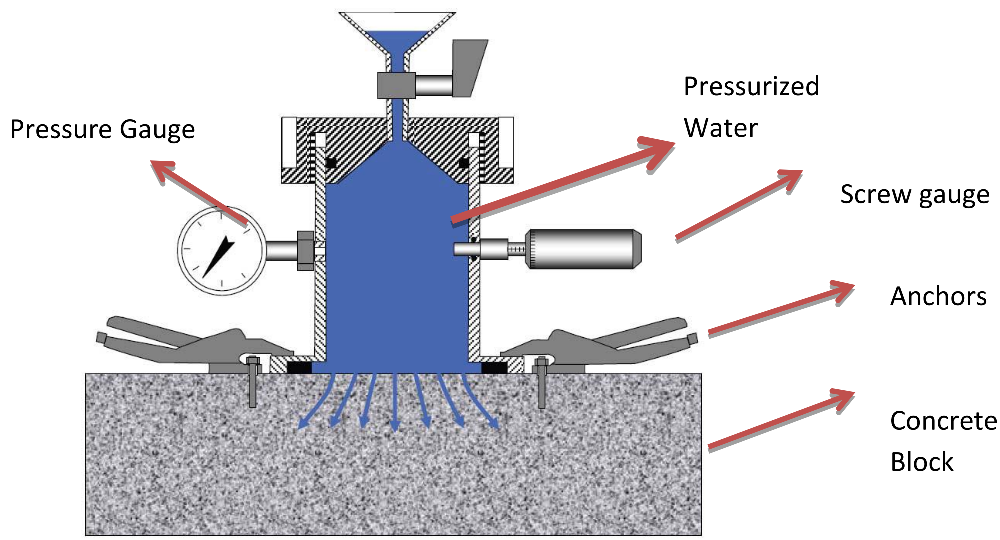

Figure 1: Cross-sectional view of GWT unit (image courtesy of Germann instruments)

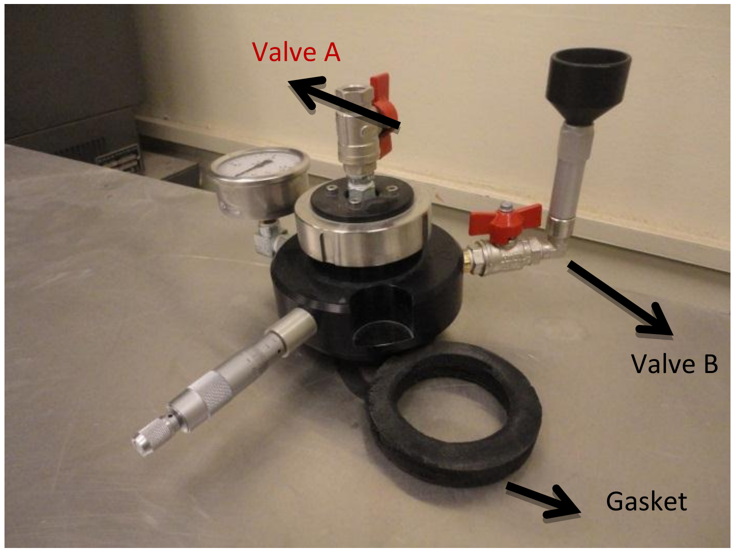

Figure 2: The GWT Unit

For testing a horizontal surface, water filling cup with an L-joint is attached to the valve B, as shown in figure 2. The cup is turned so that it is pointing upwards and parallel to the other outlet valve of the pressure chamber (valve A). The lid is unthreaded so that 3-4 threads are visible and the micrometer gauge is set to an initial position. The gasket of 0.6” (15 mm) was used as an interface between the concrete surface and the apparatus. A wooden box with fixed anchors and a hole for the cylinder to sit in, as shown in the figure 3, was built in the lab to conduct the experiments on the cylinders. Using the anchors, the housing is compressed fully against the water saturated concrete surface so that the gasket is invisible. The valves are closed and checked for any water leaks after filling them with boiled water. The lid is turned until the desired pressure is obtained. A pressure of 1 BAR was selected for all the results in this paper as recommended by Germann instruments. The pressure selected is maintained constant by turning the micrometer gauge clockwise, and gauge readings are noted every 10 minutes. Experiments were conducted for 15 minutes and 25 minutes but the change in flux was found to be similar. So, 10 different experiments were completed on each sample with water being forced into the concrete over a 10 minute period. The difference in the gauge reading is an index for the water penetration into the concrete. After testing if any water is visible on the surface under the compressed gasket this means that water has escaped between the gasket and the concrete and the experiment must be repeated (Germann Instruments, 2010).

Figure 3: Wooden box with anchors fixed to it for testing concrete cylinders

Figure 4: Conducting experiment on cylinder using GWT unit

2.2.2 Material preparation

In this testing two different concrete mixtures were cast according to ASTM C192 standards. These mixtures were chosen on the basis of their water-cement ratio. One mixture had a water-cement ratio of 0.5 and the other one of 0.7. These ratios resulted in two different sets of samples with an ample difference in their permeability. The cement used for these mixtures is Lafarge (ASTM C 150 type I/II cement). A summary of these mixtures is given in table 1. For every batch of concrete, 20 cylinders were prepared. All the cylinders were cured in a fog room for 7 days and later dried in a chamber room with a temperature of 73^{o}F and 40% relative humidity for 20 days. After 27 days of curing, the reserve samples are stored in a freezing chamber at -5^{o}F to stop any further hydration. The flat surfaces of the cylinders were lapped with 80 grit pads to remove any residue and to make sure that the surface is level with no cracks. Later, the cylinders are submerged in water until a steady weight is obtained and then they are tested with the GWT unit.

Table 1: Concrete mix proportions

Mix	Cement type	Cement(lbs/yd^3)	CA(lbs/yd^3)	FA(lbs/yd^3)	Water(lbs/yd^3)	w/cm
1	Lafarge	611	1850	1290	306	0.5
2	Lafarge	564	1755	1063.7	395	0.7

2.2.3 Application of Silane and Depth of Penetration

The silane (water proofing solution) used in this experiment is SIL-ACT ATS-42 from ADVANCED CHEMICAL TECHNOLOGIES, Oklahoma City. The cylinders are dried for 24 hours to remove any water absorbed by the concrete during grinding as the penetration of silane is better with dried concrete. Cylinders are submerged into silane for 20 minutes and allowed to dry for 24 hours before testing. By trial and error method it was found that minimum of 20 minutes of submerging is required for the 0.5 w/c concrete to achieve a depth of penetration of 0.12”. To simplify the tests the same time of ponding was used for the 0.7 w/c concrete since the depth of penetration is not a major concern of this research.

After measuring the flux of the surface concrete coated with silane, the cylinders are split and are dipped into colored dye to measure the average depth of penetration. The concrete dipped in dye is shown in the figure 5.

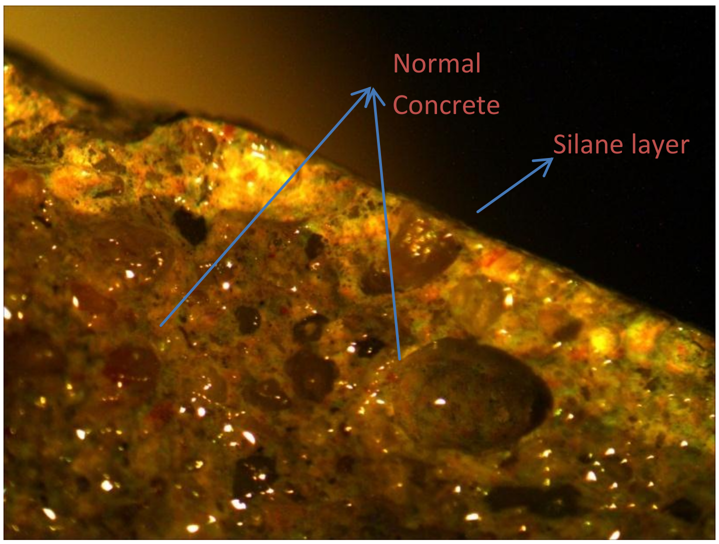

Figure 5: Microscopic image of concrete dipped in dye and showing the layer of silane on the surface of the cylinder.

2.2.4 Evaluating the Test Results

The initial and final readings of the micrometer gauge are noted over a period of time, and the flux Q is calculated for given water pressure as

Q= B*(g1-g2)/ (A*t)

Where g1 and g2 are final and initial reading measured on the micrometer gauge in inches and t is the time of the test performed in seconds.

B is the area of the micrometer pin that substitutes water leaving the chamber. The diameter of the micrometer pin used in the GWT unit is 0.394'' (10 mm). Therefore area "B" is 0.122 in^2 (78.6 mm^2).

A is the area of the concrete pressurized which is 4.678 in^2 (3018 mm^2) (Germann Instruments, 2010).

Therefore the flux q is

Q= 0.026*(g1-g2)/t [inch /sec]

2.3 Results

Tests are conducted on both 0.5 and 0.7 water-cement ratio concrete with and without silane applied using a GWT unit. The test results are compared to determine the accuracy and repeatability of this technique.

The water flux for 0.5 and 0.7 concrete before and after application of silane are calculated and shown in figure 6. The flux for individual specimen is the average of 10 measurements and the average flux is the average of all the three respective cylinders.

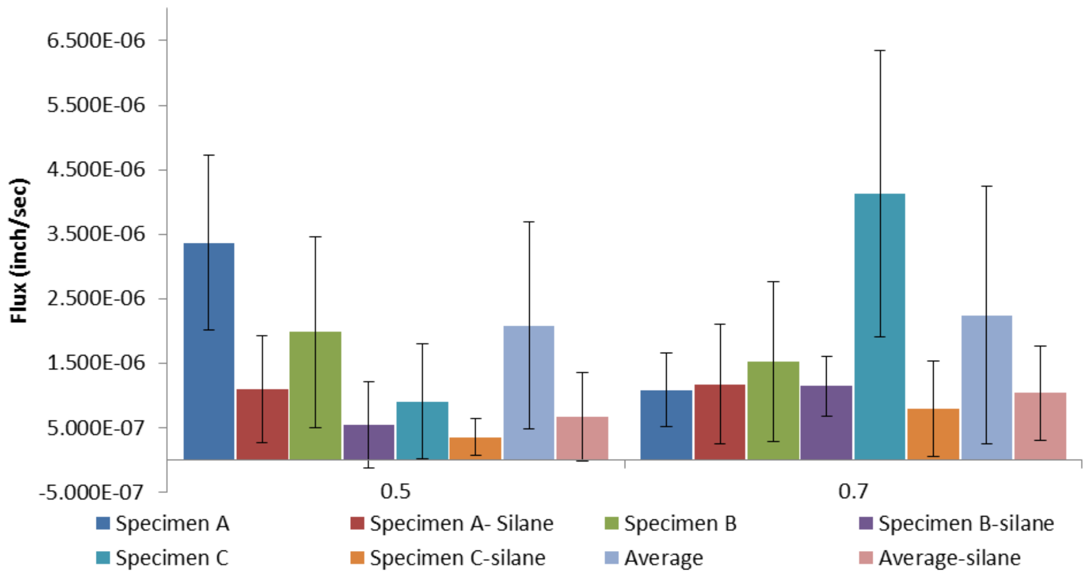

Figure 6: Flux results on 0.5 and 0.7 concrete with their averages

2.4 Discussion

2.4.1 Normal Concrete cylinders

From the results obtained in figure 6, it can be seen that the standard deviation of the measurements is very high for every cylinder. The high standard deviation means that the results are inconsistent. The surface water absorption for both 0.5 and 0.7 w/cm ratio concrete has nearly identical values, and a huge overlap of the range of flux is observed. However, it would be expected that the 0.7 w/c concrete would have an exponentially higher permeability than 0.5 w/c concrete as shown in the table 2 (Kosmatka, 2002). This data implies that this testing device has too much variability to accurately determine the difference in permeability between concrete with 0.5 and 0.7 w/cm.

Table 2: Permeability of concretes moist cured 7 days and tested after 90 days (Kosmatka, 2002).

Water-cement ratio	Permeability	
	ASTM C1202 (RCPT, Coulombs)	API RP 27 (Water, m/s)
0.5	4315	1.94×10^{-9}
0.6	4526	2.23×10^{-9}
0.75	5915	8.32×10^{-9}

2.4.2 Silane Coated Cylinders

Measurements are taken on silane coated cylinders to observe if the instrument can differentiate the surface water penetration for the cylinders with and without application of silane. In figure 6 again it can be seen that the standard deviation of the measurements were very high. However in all cases it appears that the silane treatment did reduce the average measured permeability. Unfortunately, since the standard deviations are so high it would take a large number of measurements to determine this information. For concrete with 0.5 w/cm ratio, the application of silane reduced the surface penetration by 60 to 70% and for concrete with 0.7 w/c showed either no change or a decrease. It does appear that the GWT is capable of determining the difference in the water penetration between normal concrete and silane coated concrete, but the measurements are very inconsistent. While it may be possible to measure concrete before and after it has been treated with silane and determine the presence and effectiveness of the silane, this does not seem convenient to evaluate silane coatings for field concrete. Also because of the significant inconsistencies in the measurements with the devices it was decided that the

GWT is not recommended to evaluate the performance of silane coatings on field concrete.

Possible Reasons for the Inconsistency in the Data

Water was found on the edges of the gasket if the experiment is left under pressure for 30 minutes or sometimes more. Therefore the probable reason for this inconsistency might be the improper interface between the gasket and concrete allows water to escape between the interface of the gasket and the concrete.

Some possible modifications to the apparatus include using a plastic O-ring with an inner and outer diameter the same as that of the gasket could be glued to surface of the concrete to be tested, and the apparatus should be placed on the plastic O-ring to the conduct the experiment. This prevents any water from escaping from the interface between the concrete and the gasket. The gasket could also be replaced with soft neoprene or rubber which can be better compressed to the surface of the concrete.

2.5 Conclusion

The objective of the project was to develop a non–destructive approach for finding the presence of silane using the GWT apparatus. The experimental results in this study show that this technique has proven to have a very high variability in its measurements in laboratory testing where a special frame was used to consistently connect the apparatus to the surface of concrete. The apparatus was not able to determine the difference between concrete without silane that had significantly different w/cm (0.5 and 0.7) and therefore different permeability. The system was able to measure the reduction in permeability from the application of a silane sealer if a measurement could be taken before and after the silane application. The method was not recommended for field use because of its high variability and the inconvenience of having to measure the concrete prior to the application of the silane.

CHAPTER III

IDENTIFICATION OF SILANE ON CONCRETE USING THE FOUR-POINT WENNER PROBE METHOD

3.1 Overview

The focus of this research is to develop a methodology to identify the presence of silane on concrete using the four-point Wenner Probe Method. Concrete resistivity is affected by water-cement ratio, moisture content (degree of saturation) and degree of hydration. It varies over a wide range from 1 to 104 k Ω.cm (Polder 2001). In past, researchers were successful in proving that the concrete resistivity measurements of a saturated concrete is an indicator of permeability (Kessler 2005). N.S. Rengaswamy et al. (1986) in his research states that four point resistivity meter is a useful nondestructive technique to assess the quality of concrete and also explains that the porosity of the dry and wet concrete can be assessed by measuring the resistivity of concrete. In dry concrete, the voids are filled with air and so it is more difficult for current to pass through the concrete. This makes the resistivity of dry concrete high. For wet concrete, the pores are filled with water and this establishes electrical connectivity for the current to pass. So, the resistivity of wet concrete is lower compared to that of dried concrete. In this paper, a study is conducted to understand the change of concrete resistivity for different w/c ratios with and without silane and with changes in moisture content. Correlating these results a method for identifying the presence of silane is proposed.

3.2 Methodology

3.2.1 Material Preparation

For this testing four different concrete mixtures were cast according to ASTM C192 standards. These mixtures are chosen on basis of their water-cement ratio 0.35, 0.4, 0.5 and 0.7 producing samples with significant differences in their permeability. The cement used for these mixtures meets ASTM C 150 type I/II cement and the rock and sand are commonly used in transportation construction in Oklahoma. A summary of these mixtures are given in table 3. For every batch of concrete 20 cylinders were cast and cured in the fog room for 7 days and later dried in a chamber room with temperature 73^0 F and 40% relative humidity for 20 days. After 27 days of curing, the reserve samples are stored in a freezing chamber under temperature -5^0F to stop hydration. The surface of cylinders were ground with 60 grit sand paper (as shown in the figure 7) to remove any residue and dirt before testing the resistivity.

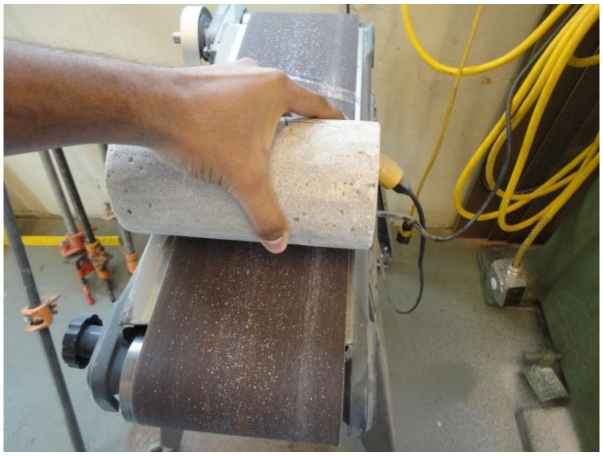

Figure 7: Sand grinding the surface of the concrete cylinder

Table 3: Mixture proportions

Mix	Cement type	Cement(lbs/yd^3)	CA(lbs/yd^3)	FA(lbs/yd^3)	Water(lbs/yd^3)	w/cm
1	Lafarge	611	1875	1375	214	0.35
2	Lafarge	611	1755	1325	245	0.4
3	Lafarge	611	1850	1290	306	0.5
4	Lafarge	564	1755	1063.7	395	0.7

3.2.2 Test Methods and analysis of test results

In this paper, the resistivity of the concrete is measured using two methods Two Plate Resistivity Method and four-point Wenner probe method.

3.2.2.1 Two Plate Resistivity Method

In this method, the cylindrical concrete specimen is placed in between two metal plates via wet sponge as an interface between the flat concrete surface and the metal plates as shown in the figure 8. The resistance between the two plates is measured and the resistivity is calculated by

$P_{concrete} = R_{Measured} * A/L$

Where

$P_{concrete}$ = Resistivity (kohm-cm)

$R_{Measured}$ = Resistance Measure (kohm)

A = Area of the circular face (cm^2)

L = Length of the cylinder (cm)

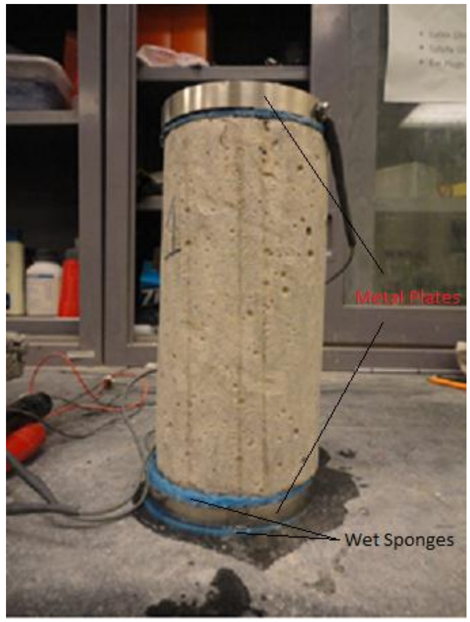

Figure 8: Measuring resistivity of concrete by two-plate resistivity method

3.2.2.2 Four-point Wenner probe method

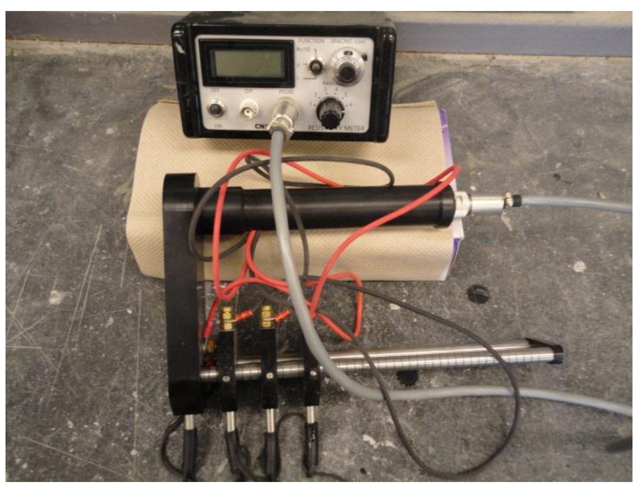

Figure 9: Four-point Wenner resistivity meter

In this method, four equally placed point electrodes with water saturated wooden tips are pressed on to the concrete face longitudinally (as shown in the figure 11) and a small ac current(I) is passed through outer contacts and the resultant potential difference (v) between the inner contacts is measured. The apparent resistivity is measured from the resistivity meter using the equation $\rho_{app} = 2\Pi a \frac{V}{I}$, where “a” is the probe spacing. A total of eight reading are taken at different spots for each cylinder and the spots are marked as shown in the figure 10a&b.

Figure 10a&b: Cylinder with spots marked at the places where resistivity is measured.

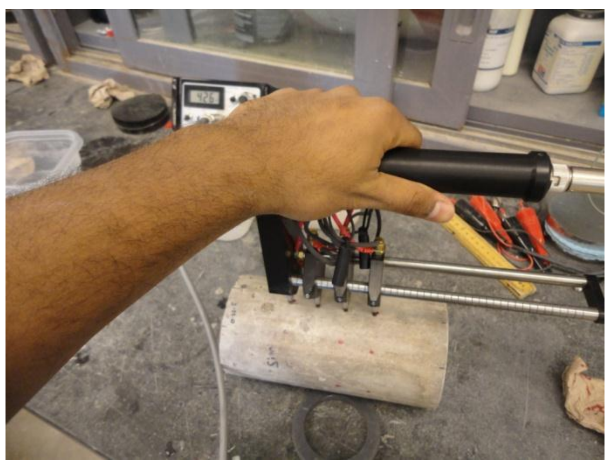

Figure 11: Resistivity measured using the Wenner four-point probe method.

Selection of Probe Spacing

The value of the probe spacing should not be greater than four times the length or depth of the specimen (Millard, 1991). As the specimens used in this experiment are 4” x 8” cylinders, the probe spacing was chosen as 1” (2.54 cm) to satisfy the limits.

Calculation of exact resistivity

If the probe is applied to a wide concrete slab with thickness much larger than the probe spacing and there is no interference from the reinforcing steel, then p_{app}= p. For smaller bodies such as the concrete cylinders, a cell constant correction K can be defined such that (Morris et al., 1996)

$$\rho = \rho_{app} / K$$

Where

ρ= exact resistivity

ρ_{app}= apparent resistivity measured by four-point probe

K= cell constant, function of probe spacing “a” and geometry of the specimen

Calculation of Cell Constant (K)

The cell constant correction is determined from the graph below suggested by Morris (1996). These values were determined through a combination of experiments and finite element analysis.

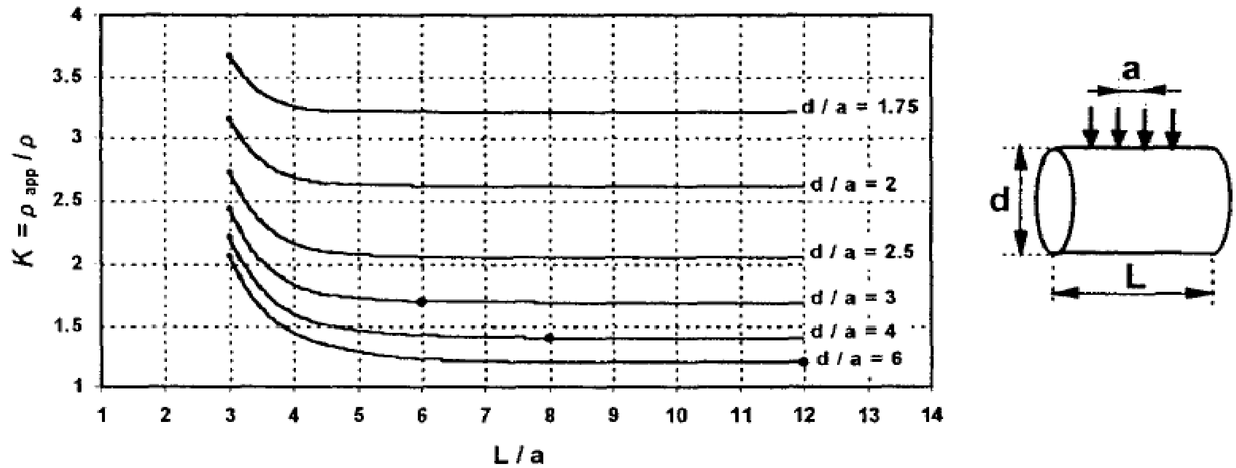

Figure 12: Graph with Cell constant (k) values (Morris 1996)

For cylinders of size 4”x8” and probe spacing of 1”, the value of cell constant correction (K) is determined to be 1.41.

Experimental Method

Three concrete cylinder samples from each concrete mixtures of different w/cm of 0.35, 0.4, 0.5 and 0.7 are taken and submerged in water until the weight remains constant. Concrete resistivity of the cylinders is measures using both the two plate method and the four-point Wenner probe method.

Also, six cylinder samples from each mixture (with w/c ratio 0.35, 0.4 and 0.5) are taken and oven dried at 110^0C until there is no change in weight of the cylinders and the cylinders are left to cool down under room temperature. Three of the cylinders are applied with silane thus having total of six cylinders, three with silane coated and three with no silane coated from each mixture. The weight and resistivity of the cylinders are measured over time by submerging them in water until the measurements were constant. Total of eight resistivity measurements are taken for each cylinder as shown in figure 10.

It is also observed that the measurements taken on dry concrete are highly unstable and takes 4-5 minutes to stabilize.

3.2.3 Application of Silane and Depth of Penetration

The water proofing solution, silane used in this experiment is SIL-ACT ATS-42 from ADVANCED CHEMICAL TECHNOLOGIES, Oklahoma City. All cylinders were submerged in silane for 20 minutes and allowed to dry for 24 hours before testing. To simplify the testing a constant amount of ponding time was used for all of the tests. The difference in w/cm for the concrete would be expected to cause different depth of penetrations with less depth of penetration for lower w/c concrete. This helps to determine the effect of depth of penetration of silane on the concrete resistivity.

After measuring the resistivity of the concrete coated with silane, the cylinders were broken in half and stained with colored dye to differentiate silane coated concrete form normal concrete. The depth of silane penetration is measured using calipers.

3.3 Results

The resistivity measured by two-plate resistivity method and Wenner probe method for saturated concrete with different water –cement ratios are compared and are presented in Figure13.

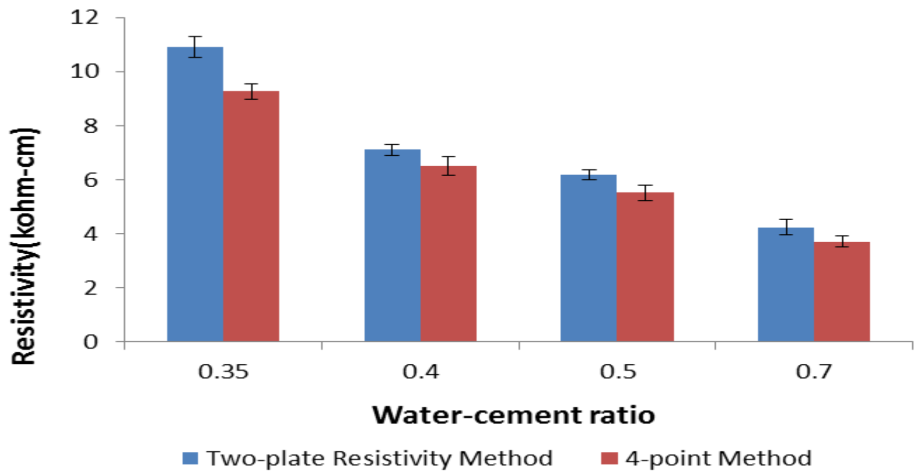

Figure 13: Comparison between resistivity method and Wenner probe method

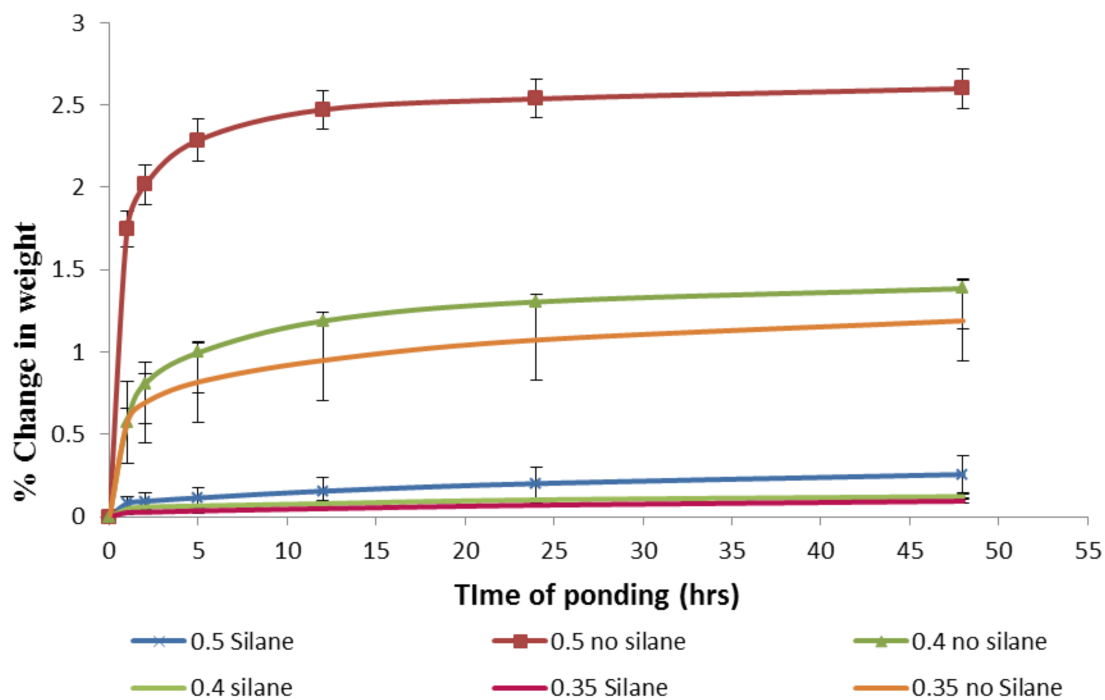

Figure 14: Time of ponding vs. Change of weights

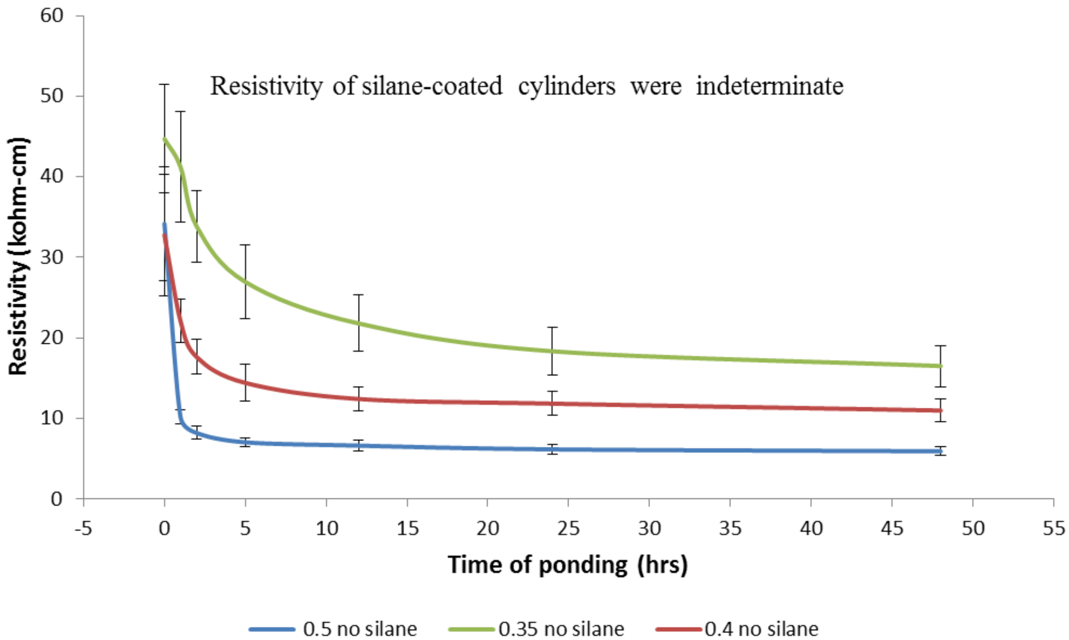

Figure 15: Time of Ponding vs. Resistivity of Concrete

The measured average depth of penetration of silane in concrete with different w/c ratio is presented in table 4. Each measurement is the average of 45 readings with 15 measurements from each cylinder.

Table 4: Depth of penetration of silane

w/c Ratio	Depth of penetration(inches)		
	Average	Standard Deviation	Coefficient of Variance
0.7	0.18	0.11	0.58
0.5	0.09	0.06	0.59
0.4	0.08	0.04	0.51
0.35	0.06	0.04	0.58

3.4 DISCUSSION

In figure 13, it is shown that the resistivity of the concrete measured by the Wenner probe method is similar to the resistivity measured by the two plate method. The low standard deviation of the measurements shows the high precision of the tests on saturated concrete. The classification of 28 day resistivity of saturated concrete for different w/c for the four-point Wenner probe is as follows for the limited specimens investigated in this thesis:

Table 5: Classification of resistivity for variable w/c ratio concrete

water-cement ratio	Resistivity (KOhm-cm) for a=1 inch
0.35	8-10
0.4	6-8
0.5	5-6
0.7	3-4

These results show that both the Wenner probe method and the two plate resistivity method could be used to find the resistivity that should give an indication of the permeability of saturated concrete.

In figure 14, it is observed that the change in weight increase of concrete was significantly reduced after the application of silane. Also, it is observed that for normal concrete, the maximum change in weight was in the first hour and becomes constant over time.

In figure 15, the results show that the resistivity is high and more variable for dry concrete and decreases with the increase in moisture content. Since the pores in wet concrete are close to saturation the resistivity of wet concrete is lower compared to that of dry concrete. It should also be noted that it was not possible to obtain a reading for the cylinders that had been coated with silane due to high contact resistance between the surface layer and the probes**.** The resistivity of the concrete coated with silane, regardless of the w/cm, was shown to be out of range or with high instability. In figure 15, it can be seen that the standard deviation of the measurement decreased as the increase in moisture content. "If the concrete has recently been wetted or is drying out after a period of saturation, then there will be effectively layers of concrete with different resistivity values" (concrete resistivity manual 2008). This could be an explanation for the reason the variability in measurements for moist concrete compared to saturated concrete.

In figure 15, it is also observed that regardless of the w/cm, the resistivity of concrete significantly dropped in the first two hours and then slowly decreases over time. This is because the rate of absorption of water by concrete is high initially (from figure 14). From the data it can be seen that when the concrete is dry the resistivity measurement with the Wenner probe will be high with or without silane. If the concrete surface absorbs water then the resistivity measured by the Wenner probe will also decrease. However only concrete that does not have an effective layer of silane on the surface would be expected to allow water to absorb over time. Since this absorption can happen in a very short period of time the Wenner probe could be used on a bridge deck before and after a short ponding period. If the resistivity changes over this period then it must be due to water penetration into concrete with an ineffective silane layer.

3.4.1 Proposed Method

By correlating the results in figure 14 &15, a non-destructive field method is proposed for finding the presence of silane in concrete.

An area to be tested is selected on the bridge deck which was not affected by any moisture for past 7 days to make sure it is dry and scrubbed without using water to remove any oil or dust present on it. A square grid of 4’’× 4’’ is marked with sixteen nodes placed equally spaced one inch apart making a total of eight readings with four in horizontal direction and four in vertical direction as shown in figure below.

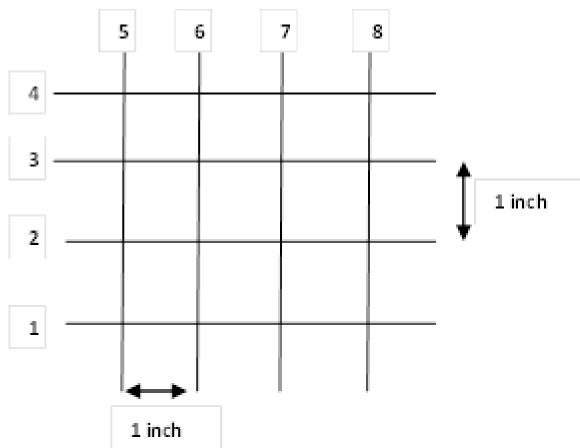

Figure 16: Sample proposed grid for measurements

The resistivity is measured with the Wenner four-point probe on each line with the probes at each node. Next a cylindrical frame with open end on both sides is placed on the grid such that whole grid is covered as shown in figure 17. The frame is filled with water and left undisturbed for 45-60 minutes. The frame is removed and the surface is wiped with a towel to remove any water on the surface. The resistivity is measured at the same spots with Wenner probe and compared with the previously measured results (as shown in figure 18). If there is silane present on the surface of the concrete then resistivity of the first reading should be high and remain high after the water is ponded on the surface. If silane is not present then the resistivity should decrease in the concrete between the initial measurement and after it was ponded. The concrete investigated in this test should not be exposed to water or a rainfall for at least the previous 24 hours.

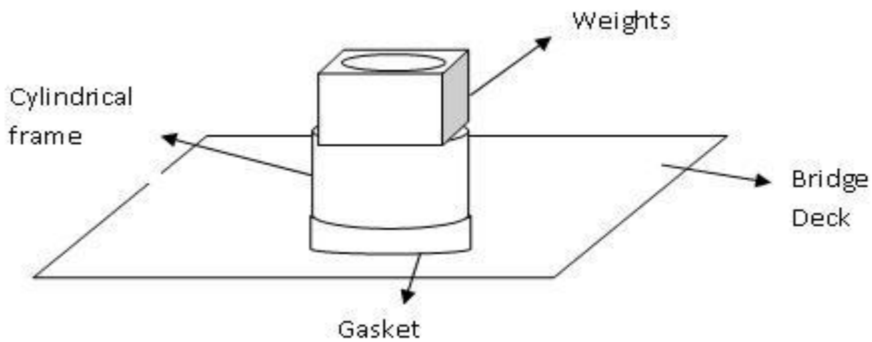

Figure 17: Schematic representing on site arrangement

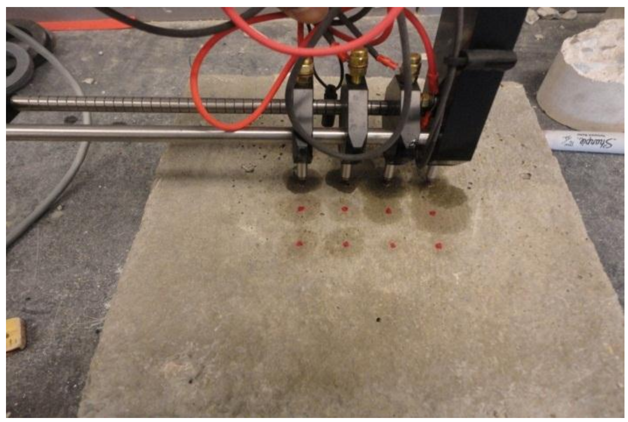

Figure 18: Measuring resistivity of flat surface concrete

3.5 CONCLUSION

The objective of this chapter is to develop a non-destructive approach for finding the presence of silane using a resistivity method. Several experiments were conducted to understand the reliability of the methods. Concrete resistivity was measured using the two plate resistivity and the Wenner probe method for w/cm of 0.35, 0.4 and 0.5 concrete and the results were compared. These results concluded that both methods are reliable and provide close results that give a relative indication of the permeability of concrete. Because of this the Wenner probe appears to be a promising tool to investigate field concrete.

The resistivity of concrete that was dry or contained a silane coating was found to be difficult to measure due to high contact resistance between the concrete surface and tips of the probe. Furthermore, it was shown that the resistivity of the dry concrete decreased as water was absorbed. By using this information a field test method was proposed that uses a resistivity measurement before and after a wetting period for concrete to determine if an effective silane coating is on the surface.

CHAPTER IV

CONCLUSIONS

The goal of this thesis is to find a non-destructive technique to identify the presence of silane on the surface of concrete bridge decks. Two different techniques used to finding the permeability of concrete that are currently commercially available are reviewed and tested to understand the repeatability and relative accurately with concretes of different w/cm and with and without silane. The finding and recommendations are as follows:

4.1 Germann Water Permeability Test

The experimental study of this apparatus shows that this test is highly variable. This large variance makes it complicated to understand the results of the test. The results could also be widely affected by various parameters such as the anchor force, gasket type and surface of the concrete tested. Though, the apparatus was successful in showing the difference in the water absorption of surface concrete with and without silane, the reliability is too low due to high standard deviations. Also one would have to have original measurements of water permeability of the concrete before the silane is applied to determine the difference which may not be practically possible.

4.2 Four-Point Wenner Probe Resistivity Method

The laboratory phase of this study showed that this technique is quick, reliable and accessible. Tests are conducted with four-point Wenner probe resistivity meter on concrete cylinders with different water-cement ratios and are compared with two-plate resistivity method. Both results were found to be comparable and to have a low variance. The change in resistivity for normal concrete with change in degree of saturations was also observed. The high surface resistance of the concrete with silane makes the resistivity of the silane applied concrete immeasurable. A simple field method is proposed to find the presence of silane sealer on a bridge deck based on the measurement of the change in resistivity of the concrete before and after being ponded with water.

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Scope and Method of Study:

The Oklahoma Department of Transportation (ODOT) wants to develop a non-destructive technique to identify the presence of silane on bridge decks. Two of the methods (Germann Water Permeability Test and Wenner probe resistivity method) were examined to understand the consistency of the technique and their accuracy. A simple field technique was developed to identify the presence of concrete sealer on concrete.

Findings and Conclusions:

From the results it has been observed that Germann Water Permeability Test is highly inconsistent and very sensitive to various parameters such as the anchor force, gasket type and surface of the concrete tested. The apparatus was successful in showing the difference in the water absorption of surface concrete with and without silane but the reliability is too low. Also one would have to have original measurements of water permeability of the concrete before the silane is applied to determine the difference which may not be practically possible. Wenner probe method showed that this technique is quick, reliable and accessible. A simple field method is proposed to find the presence of silane sealer on a bridge deck based on the measurement of the change in resistivity of the concrete before and after being ponded with water.

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