Atlantic Consultants

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August 2, 2017
Ref AJ 2017-032

RMA Group, Inc.
3150 Fitzgerald Rd.
Rancho Cordova, CA 95742

Attn: Mr. Josh Summers, PE

Subject: Corrosion Investigation for Contra Costa Community College District - Brentwood Campus

Dear Mr. Summers,

This will serve as our letter report for the recommendations for corrosion protection of pipe, appurtenances and reinforced concrete for the proposed Community College Campus in Brentwood, CA. The recommendations are based upon chemical analysis of fifteen soil samples, which were obtained by your office and provided to Atlantic Consultants for laboratory testing. This report is being provided in accordance with our proposal of October 1, 2016.

The data from the laboratory analysis of the samples is shown below.

| Sample Number Sample Depth | As Rec'd Resistivity (ohm-cm) | [1]Minimum Resistivity (ohm-cm) | pH | Sulfate % | Chloride Ppm |
|---|---|---|---|---|---|
| TP-1 0 - 2' | 34,800 | 1,920 | 5.95 | 0.0098 | 3 |
| TP-4 1 - 3' | 18,000 | 1,200 | 6.13 | 0.0280 | 9 |
| TP-6 2.8 - 4.8' | 4,400 | 1.640 | 5.56 | 0.0110 | 2 |
| TP-7 1.6 - 3' | 4,800 | 2,280 | 6.67 | <0.0005 | 2 |
| TP-11 0 - 2.2' | 34,800 | 6,400 | 6.75 | <0.0005 | 1 |
| TP-11 2.2 - 3.6' | 19,600 | 2,560 | 6.28 | <0.0005 | <1 |
| TP-12 1.6 - 4.7' | 48,000 | 9,200 | 6.95 | <0.0005 | 5 |

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|---|---|---|---|---|---|
| TP-13<br>0 - 3.5' | 12,000 | 2,120 | 6.60 | <0.0005 | 6 |
| TP-13<br>3.5 - 4.8' | 10,800 | 1,440 | 6.73 | 0.0045 | 72 |
| TP-15<br>3' | 14,000 | 2,960 | 6.80 | 0.0032 | 5 |
| TP-15<br>5' | 4,400 | 1,040 | 7.24 | 0.0044 | 3 |
| TP-15<br>7' | 2,440 | 640 | 7.37 | 0.0100 | 240 |
| TP-16<br>3' | 4,800 | 1,200 | 5.94 | <0.005 | 7 |
| TP-16<br>5' | 3,480 | 1,400 | 6.60 | 0.0029 | 5 |
| TP-16<br>7' | 4,400 | 2,350 | 7.06 | 0.0022 | 5 |

**TEST METHODS**

In attempting to predict corrosion problems associated with pipeline materials and reinforced concrete slab foundations - either conventionally reinforced or post tensioned - which are to be installed as part of construction of the proposed college campus, it is necessary to investigate the soil conditions the materials will be exposed to. Since corrosion of metal is fundamentally an electrochemical process which is, by definition, accompanied by current flow, the electrochemical characteristics of a soil are of primary importance when evaluating corrosivity. Test methods utilized during this investigation reflect the most practical methods of evaluating corrosivity.

**Soil Resistivity**

Soil resistivity measurements are typically conducted in accordance with California Test Method 643, which typically utilizes a Soil Resistance Meter, and a soil box, specifically designed for laboratory analysis of soil samples. An alternating current from the Soil Resistance Meter causes a current to flow through the soil between the outside probes, C1 and C2. Due to the resistance of the soil, the current creates a voltage gradient, which is proportional to the average resistance of the soil mass to a depth equal to the distance between probes. A voltage drop is then measured across pins, P1 and P2. Resistivity of the soil is then computed from the instrument reading according to the following formula:

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**p = 2 pi AR**

where: p = soil resistivity (ohm-cm)
A = distance between probes (cm)
R = soil resistance, instrument reading (ohms)
pi = 3.14159

The minimum resistivity values are determined by adding water to the samples, in 50 milliliter increments. The resistivity value will decrease with the addition of distilled water as the conductive chemicals in the sample go into solution, at which point the resistivity increases with additional water.

The pH, and concentrations of chlorides and sulfates are also shown in the table above.

Corrosion is a natural electrochemical process which is, by definition, accompanied by the flow of electrical current. Therefore, it is important to understand how easily current will travel through a medium surrounding a metal object. Resistivity is a measure of the ability of a soil to conduct an electric current. The higher the resistivity the more difficult it is for the soil to conduct a current. Soil resistivity is primarily dependent on the chemical and moisture content of the soil. Typically, the higher the level of chemical constituents, the lower the soil resistivity. Additional moisture decreases the soil resistivity up to the point where the maximum solubility for the dissolved ionic chemicals is achieved. Beyond this point, an increase in moisture causes an increase in the resistivity as the chemicals become more diluted. Since corrosion rate depends on current flow to and from a metal and the adjacent medium, the corrosion activity of steel in soil normally increases as soil resistivity decreases. The following table correlates resistivity values with degree of corrosivity. The interpretation of corrosivity varies among corrosion engineers. However, this table is a generally accepted guide.

| SOIL RESISTIVITY (ohm-cm) | DEGREE OF CORROSIVITY |
|---|---|
| 0 - 500 | Very Corrosive |
| 500 - 1,000 | Corrosive |
| 1,000 - 2,000 | Moderately Corrosive |
| 2,000 - 10,000 | Mildly Corrosive |
| Above 10,000 | Negligible |

Reference: NACE Corrosion Basics, page 191

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The As Received resistivity values for the samples ranged from 2,440 to 48,000 ppm. Seven of the samples are in the mildly corrosive range and eight are in the negligibly corrosive range. The minimum or saturated resistivity values for the samples tested ranged from 640 to 9,200 ppm, with one sample being corrosive, seven samples being moderately corrosive and the remaining seven being mildly corrosive.

A wide variety of soluble salts is typically found in soils. Two soils having the same resistivity may have significantly different corrosion characteristics, depending on the specific ions present. The major constituents which accelerate corrosion of metallic piping and reinforcing steel or high strength cables in concrete are chlorides, sulfates and the acidity (pH) of the soil. Calcium and magnesium tend to form insoluble oxide and bicarbonate precipitates, in basic environments, which can create a protective layer over the metal surface and reduce corrosion activity. Chloride ions tend to break down otherwise protective surface deposits, and can result in corrosion of buried metallic structures and reinforcing steel in concrete structures. Sulfates in soil can be highly aggressive to portland cement concrete by combining chemically with certain constituents of the concrete, principally tricalcium aluminate. This reaction is accompanied by expansion and eventual disruption of the concrete matrix. High concentrations of bicarbonates tend to decrease soil resistivities. However, bicarbonates are not aggressive to buried steel and concrete. Although bicarbonates are not aggressive, lower resistivity environments can promote corrosion activity.

The following tables correlate the effect of chlorides and sulfates on the corrosion of steel or reinforcing steel in concrete:

| **WATER SOLUBLE CHLORIDE CONCENTRATION (ppm)** | **DEGREE OF CORROSIVITY** |
|---|---|
| Over 5,000 | Severe |
| 1,500 - 5,000 | Considerable |
| 500 - 1,500 | Corrosive |
| 0 – 500 | Negligible |

Reference: Extrapolation from California Test Method 532, Method for Estimating the Time To Corrosion of Reinforced Concrete Substructures and Previous experience

The chloride concentrations found in the 15 samples tested ranged from 1 to 240

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ppm. All of the samples are therefore negligibly corrosive. In addition to the California Test Method referred to above, research by the Federal Highway Administration has proven that corrosion of reinforcing steel in concrete can be initiated when the chloride concentration in the concrete reaches 1 pound of chloride ions per cubic yard of concrete, or the equivalent of 200 ppm. In this instance, the chloride concentrations in all but one of the samples are below that level.

| **WATER SOLUBLE SULFATE CONCENTRATION (% by weight of soil)** | **DEGREE OF CORROSIVITY** |
|---|---|
| Over 2.00 | Very Severe |
| 0.20 - 2.00 | Severe |
| 0.10 - 0.20 | Moderate |
| 0.0 – 0.10 | Negligible |

Reference: ACI-318, Building Code Requirements for Reinforced Concrete

The sulfate concentrations for the samples tested ranged from <0.0005 to 0.0280 percent by weight, with all 15 samples in the negligible range.

The pH of the samples tested ranged from 5.56 to 7.37, which is neutral to somewhat acidic.

**CONCLUSIONS**

- The minimum soil resistivity values indicate that the soils at the site are corrosive to buried metals.
- The pH values for the soil samples tested are neutral to somewhat acidic.
- The chloride concentrations found in the soil samples are negligibly corrosive to buried metals and reinforcing steel in concrete.
- The sulfate concentrations found in the soil samples are negligibly corrosive to buried metals and concrete.
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- In order to prevent moisture intrusion into the concrete slabs, it is recommended that a minimum 10 mil visqueen barrier be placed under the slabs. The visqueen should be underlain by sand, and care shall be taken during placement of reinforcement and concrete to ensure that the visqueen

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barrier is not damaged during placement of the concrete. All reinforcement shall be provided with 2-inches of concrete cover, and 3-inches of cover where concrete will be placed in contact with soil. Type II Portland cement is acceptable for use in concrete, given the sulfate concentrations in the soil samples obtained at the site. Post-tensioning cables should be located within a water resistant sheathing, where the cable is coated with grease to repel moisture. The exterior ends of the cables and anchors, which are not encased in concrete, should be coated with a waterproof epoxy, bitumastic, end cap or non shrink grout to prevent moisture intrusion at the ends of the cables, between the individual wires.

- Steel or ductile iron pipe, fittings and appurtenances, which will be operating under pressure, to be placed in the soils at the site should be installed with coatings and cathodic protection to provide corrosion control for buried steel or other ferrous metal piping. Steel and copper piping should be electrically isolated from one and other.

Please review the information contained in this report and let me know if you or your colleagues have any questions or require additional information. It has been a pleasure to be of service.

Sincerely,

**ATLANTIC CONSULTANTS, INC.**

Ms. Kerri M. Howell, P.E.
President