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A Report on the Investigation of the Corrosion of the Underground Piping System Located at the National Horse Show and Flower Show Grounds at Santa Barbara

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16. ABSTRACT
On October 10, 1959, Mr. Sidney Paule, District Construction Supervisor, Division of Architecture, informed Mr. O.E. Anderson, Supervising Mechanical and Electrical Engineer, that there had been three (3) leaks in the water line under the concrete bleacher areas of the 19th D.A.A. Horse Show and Flower Show Grounds at Santa Barbara. This corrosion had occurred during the one-year construction guarantee period The leakage of water lines was brought to the attention of the contractor, who submitted a sample of the pipe to the California Testing Laboratories, Inc., to determine the cause of the leaks.

In a report of May 28, 1959, the California Testing Laboratories, Inc., suggested that the causes of the pitting in the pipe were: "(1) electrolytic corrosion and (2) presence of the galvanizing flux still on the pipe and preventing proper adherence of the zinc with release of the flux, which is usually ammonium chloride, under service conditions setting up a galvanic action".

The California Testing Laboratories, Inc., further suggested that other sections of pipe be examined for loose asphaltic wrap and that the apparent removal or etching of the galvanizing under these sections be examined.

As a result of these preliminary studies, Mr. Anderson wrote to Mr. E.G. Van Cleve, Manager 19th D.A.A., on October 15, 1959, and suggested that the California Division of Highways, Materials and Research Department, be requested to make a corrosion survey of the fairgrounds area and that an engineered protective system be designed.

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STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF HIGHWAYS

A REPORT ON THE INVESTIGATION OF THE CORROSION OF THE UNDERGROUND PIPING SYSTEM LOCATED AT THE NATIONAL HORSE SHOW AND FLOWER SHOW GROUNDS AT SANTA BARBARA

59-03

November 1959

MATERIALS & RESEARCH DEPARTMENT

State of California
Department of Public Works
Division of Highways
Materials and Research Department

November 1959

Laboratory Project
Auth. 72-S-6204

Mr. Robert P. Rowe, President
Santa Barbara National Horse and Flower Show
P. O. Box 3006
Las Positas Road & Highway 101
Santa Barbara, California

Dear Sir:

Submitted for your consideration is:

A REPORT ON
THE INVESTIGATION OF THE CORROSION OF THE UNDERGROUND PIPING SYSTEM LOCATED AT THE NATIONAL HORSE SHOW AND FLOWER SHOW GROUNDS AT SANTA BARBARA

Study made by . . . . Structural Materials Section
Under general direction of . . . . J. L. Beaton
Work supervised and report prepared by . . . R. F. Stratfull

Very truly yours,

F. N. Hveem
Materials and Research Engineer

RFS/mw
cc: J. W. Trask
Donald Van Riper
O. E. Anderson
R. L. Ashby
S. Paule
I. Schultz

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I. INTRODUCTION AND HISTORY

On October 10, 1959, Mr. Sidney Paule, District Construction Supervisor, Division of Architecture, informed Mr. O. E. Anderson, Supervising Mechanical and Electrical Engineer, that there had been three (3) leaks in the water line under the concrete bleacher areas of the 19th D.A.A. Horse Show and Flower Show Grounds at Santa Barbara. This corrosion had occurred during the one-year construction guarantee period. The leakage of water lines was brought to the attention of the contractor, who submitted a sample of the pipe to the California Testing Laboratories, Inc., to determine the cause of the leaks.

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As a result of these preliminary studies, Mr. Anderson wrote to Mr. E. G. Van Cleve, Manager 19th D.A.A., on October 15, 1959, and suggested that the California Division of Highways, Materials and Research Department, be requested to make a corrosion survey of the fairgrounds area and that an engineered protective system be designed.

On October 26, 1959, Mr. Robert P. Rowe wrote to Mr. F. N. Hveem, Materials and Research Engineer, and requested that a corrosion survey of the water piping be made by this department. The work was to be performed under Inter-Departmental Service Agreement No. 17 as submitted by the 19th D.A.A.

A project was then initiated to determine the causes and possible methods of control of the corrosion of the water lines, which have had 5 leaks in the first 6 months of service.

The field studies of the corrosion problem were performed during the week of November 2, 1959, at the Santa Barbara National Horse Show and Flower Show grounds at Santa Barbara.

II. SUMMARY AND CONCLUSIONS

The predominant cause of the accelerated corrosion is that the concrete embedded steel is electrically connected to the steel embedded in the soil.

Evidence of this cause of corrosion was found in the Flower Show Building. When the water piping was electrically disconnected from the electrical conduit and the reinforcing steel and connection through a milliammeter was substituted, it was found that 0.21 amperes of electrical current would flow.

A current flow of 0.21 amperes could cause about 3.5 lineal feet of 3/4" steel pipe to be completely consumed by corrosion each year.

In order to stop the corrosion of the water lines beneath the concrete slabs, it is recommended that cathodic protection by means of galvanic anodes be installed.

It is recommended that the electrical conduit and other piping that either directly or indirectly contact concrete embedded steel be electrically disconnected from the water system. Also, it is recommended that ground rods be placed to eliminate any electrical hazards due to the loss of the water pipe ground.

Based upon the field measurements of corrosion, it is suggested that the sprinkler system not be placed under complete cathodic protection, but that magnesium anodes be placed in the recommended locations shown on Exhibit II for the partial or "hot spot" protection of these lines. If leaks begin to appear in the sprinkler lines, the leaks should be repaired in a normal manner and a magnesium anode placed at the location of the repair to prevent further deterioration at this location.

The cost of the suggested cathodic protection system is estimated at $3800.00.

III. RECOMMENDATIONS

It is recommended that:

(1) A galvanic anode cathodic protection system be installed as soon as possible.

(2) Plastic tubing or a di-electric coupling be installed in the water piping contained in the floor boxes adjacent to the Flower Show Building columns.

(3) Plastic tubing or a di-electric coupling be installed in the water pipe that serves the drinking fountains in the Flower Show Building.

(4) The electrical grounding of the electrical conduit to the water pipe be discontinued in the floor boxes of the Flower Show Building.

(5) Ground rods be driven and electrically connected to the electrical conduit in the Flower Show Building and the Horse Show Arena.

(6) All galvanized steel water pipe in direct connection with the pipe in the Horse Show Arena be electrically isolated on the soil side of the adjacent but separate buildings that these pipes service. The cast iron pipe is not considered to be electrically continuous.

(7) All electrical grounding of water pipe to concrete embedded steel be removed in the Horse Show Arena.

(8) Magnesium anodes be utilized as the galvanic metal for cathodic protection.

(9) The magnesium anodes be installed in a manner similar to that described in the typical instructions for galvanic anodes found in the Appendix of this report.

(10) When future leaks are repaired in the galvanized water sprinkler system, a magnesium anode be installed at the location of the repair to prevent further corrosion.

(11) Magnesium anodes be installed at the locations shown on Exhibit II Equi-Resistivity Contour Map.

(12) The Division of Architecture prepare the final plans, specifications and the field inspection of the cathodic protection system.

(13) A semi-annual inspection and test of the completed facilities be performed as a check for satisfactory operation.

(14) A partial equi-potential survey of the piping adjacent to the affected structures be made between 30 and 45 days after installation of the cathodic protection system.

(15) The current output of all anodes be recorded at the time of installation, and those with metering circuit have their current output recorded at the time of the equi-potential survey.

(16) All present leaks be repaired after completion of the above work. It is very probable that a few additional leaks will develop during the first year of operation of the protection system. These should be repaired as they occur.

IV. TESTS

A. Pipe to Soil Measurements

The flow of galvanic current from a corroding metallic structure can be detected by measuring the electrical voltage drop in the soil about the structure.

The voltage drop, or the pipe to soil potential, of the underground structure was measured with a standard copper sulfate half cell and a vacuum tube voltmeter.

The results of the pipe to soil measurements are shown on Exhibit I, Equi-Potential Contours.

The stability and reproducibility of the pipe to soil potential measurements indicated that the corrosion problem is typically galvanic and is not caused by a fluctuating stray electrical current.

As an additional check for stray electrical currents, the pipe to soil potential was automatically recorded for 24 hours. The continuous recording showed that there was no voltage variation during the 24 hour recording period.

B. Electrical Resistivity of the Soil

Since the corrosion of the underground piping is electrochemical in nature, either the presence or the absence of certain chemicals will affect the magnitude of the galvanic currents developed. Likewise, the electrical resistivity of the soil, through which the electrical corrosion currents must flow, has a direct bearing on the rate of corrosion -- the lower the electrical resistivity of the soil, the greater the possible flow of current.

In the final analysis a high current flow is directly related to a high rate of corrosion attack.

The electrical resistivity of the soil at the Horse Show and Flower Show is shown on Exhibit II, Equi-Resistivity Contour Map. As shown by the earth resistivity measurements, the soil varies from 500 to 2800 ohm cm. The average soil resistivity is approximately 1100 ohm cm, which indicates a moderately corrosive soil.

C. Miscellaneous Tests

1. Galvanic Current Flow

In the Flower Show Building it was possible to electrically isolate the underground water piping from the concrete embedded steel for test purposes.

When the water piping was electrically connected to the concrete embedded steel through a zero resistance milliammeter, it was found that 0.21 amperes would flow. This flow of electrical current is resulting in the corrosion of the underground steel pipe at an approximate rate of about 4 pounds per year, which is approximately equivalent to a yearly loss of 3.5 lineal feet of 3/4" steel pipe. Since the water pipe is coated, the entire loss of metal is concentrated at pin holes in the coating. The corrosion at the pin holes tends to amplify the corrosion rate as compared to an uncoated pipe.

The open circuit voltage which is causing the flow of electrical current is about 0.31 volts. The cause of this electrical voltage is the potential difference between steel embedded in soil and that in concrete.

2. Laboratory Soil Tests

Laboratory tests were performed on two soil samples obtained from the site. One sample was a sandy material obtained from the Horse Show Arena, and the other sample was a clay soil found at the location of a water leak at the Flower Show Building.

The minimum soil resistivity of the sandy soil was 900 ohm cm, and it had a pH of 7.4. The minimum resistivity of the clay soil was 450 ohm cm, and it had a pH of 7.4. The estimated time to a corrosion perforation of a 3/4" pipe in the sandy soil near the Horse Show Arena is 20 years, if there are no causes of corrosion other than "normal soil action". The estimated time to a corrosion perforation of a 3/4" pipe in the clay soil found at the water leak near the Flower Show Building is approximately 17 years if there are no causes of corrosion other than "normal soil action".

V. LEAK FREQUENCY

The frequency of leaks in an underground piping system follows a definite methematical relationship which is indicated by the plot of the accumulated leaks against time shown on Exhibit III in the Appendix.

Based upon the history of pipe replacement and the frequency of leaks at other State facilities, it has been observed that when 21 leaks occur in a piping system in a twelve month period, portions of that system are either abandoned or replaced. The 6 leaks which have appeared within the last 6 months indicate that during 1960 portions of the piping will be beyond economical repair or salvage.

In the case of the Horse Show Arena and the Flower Show Building, the corrosion problem is a great deal more critical than at other locations of underground piping corrosion. This present problem is regarded as critical because some of the water leaks are occurring under the concrete flooring; and the cost of repairing leaks under a concrete floor is more than the nominal value of the pipe.

VI. DISCUSSION

A. Electrical Interconnection of Underground Structures

Usually if a metallic pipe is buried in the earth, the possibility of corrosion will depend upon differences in the environment of the system. For instance, when a network of different types of metallic pipes is placed in a corrosive soil and electrically interconnected, conditions that create the corrosion voltage are built into the system. The rate of corrosion will usually be controlled either by the anode to cathode area ratio, depolarization or the electrical resistance of the ground.

In the Flower Show Building, where it was possible to disconnect the water lines from the electrical conduit and reinforcing steel, it was found that corrosion of the underground steel is being caused by the concrete embedded steel. Because of the many electrically interconnected facilities adjacent to the Horse Show Arena, it was not possible to determine definitely whether the corrosion of the piping in this area is caused by concrete embedded steel.

In the locations (of the Horse Show Arena) where alterations of the facilities are being made, it was observed that the wire mesh reinforcing steel that was in contact with the soil is in an advanced stage of corrosion. The corrosion of the wire mesh reinforcing is the result of partial embedment of the mesh in soil and concrete.

The corrosion of underground steel due to its interconnection with steel embedded in concrete has been observed in other State facilities. The simplest method for preventing accelerated corrosion of this nature is to electrically insulate all water lines before they pass into any reinforced concrete structure. Naturally, the electrical isolation of water lines could result in an electrical safety hazard, as the electrical system could not utilize the water lines as an electrical ground. However, this safety hazard can be readily eliminated if an electrical ground bed is constructed for the electrical facilities.

B. Soil Corrosivity

One of the most widely used simple criteria for anticipating or comparing the corrosivity of soils is the measurement of their electrical resistivity. The resistivity of a soil is described in ohm cm., which is the electrical resistance, in ohms, of a cubic centimeter of soil.

The August 1931 issue of Western Gas presented the following classification of soil corrosivity as related to the specific electrical resistance of such soils:

Resistivity ohm-cm	Corrosivity
0 - 400	Severely corrosive
400 - 1200	Moderately corrosive
1200 - 4000	Mildly corrosive
4000 - 10000	Slightly corrosive

Resistivity ohm-cm	Probable Life of Bare Steel Pipe in Years
0 - 1000	0 - 9
1000 - 2500	9 - 15
2500 - 10000	15 or more

As will be noted, the soil at the Santa Barbara Horse Show and Flower Show falls in the general classification of moderately corrosive.

The table indicates that a bare steel pipe buried in the moderately corrosive soil will have a service life between 9 and 15 years.

Based upon the preliminary studies of the Materials and Research Department on estimating the life of underground pipe, the time to perforation of 3/4" bare steel pipe in the soil located at the Flower Show Building could be about 17 years.

C. Cathodic Protection

The use of cathodic protection for protecting underground metals is a common engineering practice. Such a method is quite practical, but cathodic protection requires that close attention be directed to the possibility of corroding adjacent piping systems not included in the piping network under consideration.

When using a high voltage impressed current cathodic protection system, it is necessary that all underground metallic structures be electrically interconnected. It is not considered economically feasible in this case to electrically interconnect all underground structures, because the water main has a plastic type of connecting seal, which would require that the water main be exposed at each joint and a jumper wire be installed to insure electrical continuity.

Because of the cost of an impressed current system, as well as the high cost of operation due to the high current demand of protecting bare pipe, it is considered economically impractical to use this method of corrosion control.

If water leaks occur in the sprinkler system, the leaks should be repaired and a magnesium anode installed to prevent further perforations at the locations of repair.

It is suggested that magnesium anodes be installed for the control of corrosion at the Horse Show Arena and also the Flower Show Building. It is considered that leaks of the piping system beneath the concrete will result in considerable expense for their repair, so the future leaks in these areas should be controlled. The use of the low voltage anodes will limit the possibility of corrosion to other lines in the vicinity that are not electrically interconnected.

There is the possibility that a leak or two will appear in the piping soon after the application of cathodic protection. The reason for these new leaks is that the pipe may already be so corroded that the corrosion products are acting as a temporary "plug". Movements of the soil or variations in moisture content or the action of the protective current can loosen the "plug" and a noticeable leak will result.

In the application of the cathodic protection currents in the Horse Show Arena and the Flower Show Building, it is necessary that the concrete embedded steel be electrically isolated from the water piping. If there is just one electrical interconnection between the piping in concrete and the piping in the soil, the control of corrosion will be difficult, in that the concrete embedded steel will receive the corrosion protecting currents; and the protection obtained with a given amount of current will be greatly reduced. Also, current can be prevented from being distributed on the steel embedded in the soil because of the shielding action of the concrete embedded steel.

Since the water piping will be electrically disconnected from the buildings, ground rods may have to be driven to satisfy the electrical safety requirements for the transformers and other electrical equipment in the buildings.

VII. TENTATIVE SPECIFICATIONS

Sacrificial Anodes - Galvanic

Dow Type 32-D galvo-pak (Galvo Mag) magnesium anodes or equal with 10 foot length of lead wire.

Placement of Galvanic Anodes

1. Auger 10" diameter hole 5' 6" deep, 5' distant from the pipe.
2. Place anode in hole and compact soil around and to the top of the anode.
3. Moisten anode with water until air bubbles cease to rise to the surface of the water.
4. Anode lead wire, which is to be buried 1' below ground, should be connected to the pipe by brazing, Cadweld Process, or by an approved type of compression clamp. The electrical connection to the pipe shall be coated with "Oakite" or an epoxy type of resin coating. The protective coating over the joint of wire to pipe shall be at least 1/8" thick.

Miscellaneous

At the four designated locations shown on the plans, a current metering shunt shall be installed in the anode lead wire. These shunts shall have a D.C. ohmic resistance of 0.01 ohm and be accurate to within 1% of the indicated resistance. The shunts shall be placed in a container buried in the soil or on a post and shall have a lid or screw cap that will permit ready access to the shunt for current measurement of the anode.

The electrical resistance shunts are commercially available under the trade name of "Holloway Shunts".

A suitable housing or container for the electrical shunts is commercially available under the trade name of "Electrolysis check point", complete unit.

The anodes placed adjacent to the Flower Show Building should be as close as possible to the building wall wherever possible; the digging of trenches and anode holes should be so located on the final plans as to prevent the cutting of asphalt or concrete surfaces.

VIII. ESTIMATED COSTS OF CATHODIC PROTECTION

34 each - Type 32-D Galvo-pak . . . . (Galvo Mag) Magnesium Anodes at $18.25 each	$ 620.50
1000 LF Size AWG 8, Type TW 600 volt cable . . .	120.00
Diaelectric couplings	50.00
Installation of Anodes at $25.00 each	850.00
4 each metering shunts, at $13.00 each	52.00
Installation of wiring	500.00
Engineering	1000.00
Miscellaneous wire and connectors	100.00
Subtotal	$ 3292.50
+ 15% Contingencies	493.88
Total	$ 3786.38
Say	$ 3800.00