Technical Report Documentation Page

1. REPORT No.

2. GOVERNMENT ACCESSION No.

3. RECIPIENT'S CATALOG No.

4. TITLE AND SUBTITLE

Field Method of Detecting Corrosive Soil Conditions

5. REPORT DATE

January 1963

6. PERFORMING ORGANIZATION

7. AUTHOR(S)

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8. PERFORMING ORGANIZATION REPORT No.

9. PERFORMING ORGANIZATION NAME AND ADDRESS

State of California
Department of Public Works
Division of Highways

10. WORK UNIT No.

11. CONTRACT OR GRANT No.

13. TYPE OF REPORT & PERIOD COVERED

12. SPONSORING AGENCY NAME AND ADDRESS

14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES

Presented at the Fifteenth Annual California Street and Highway Conference By the Institute of Transportation and Traffic Engineering and University Extension, University of California Los Angeles Campus January 1963

16. ABSTRACT

In highway construction and design the structural adequacy of the various facilities has been a primary consideration. However, investigations of the conditions after the long time exposure of some highway structures have indicated that consideration of a durability factor should be included in the economics of design.

This is illustrated by this slide (1) in which these two 30 year old culverts in different locations show the effect of corrosion. As will be observed, one culvert invert has been perforated by corrosion while the other has not. It is interesting to note the deformation of the latter culvert that was caused by differential settlement of the fill.

This slide (2) shows a crack in a 9 year old reinforced concrete headwall which is located in a soil that contains about 3 times as great a salt concentration as if found in the ocean. As shown on this slide (3) the removal of the cracked concrete shows that the reinforcing steel is corroding and is a cause of concrete cracking.

17. KEYWORDS

18. No. OF PAGES:

5

19. DRI WEBSITE LINK

http://www.dot.ca.gov/hq/research/researchreports/1961-1963/63-15.pdf

20. FILE NAME

63-15.pdf

STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF HIGHWAYS

FIELD METHOD OF DETECTING CORROSIVE SOIL CONDITIONS

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Presented at the Fifteenth Annual California
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ORAL PRESENTATION Jan. 1963

FIELD METHOD OF DETECTING CORROSIVE SOIL CONDITIONS

By R. F. Stratfull*

INTRODUCTION

In highway construction and design the structural adequacy of the various facilities has been a primary consideration. However, investigations of the conditions after the long time exposure of some highway structures have indicated that consideration of a durability factor should be included in the economics of design.

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This slide (2) shows a crack in a 9 year old reinforced concrete headwall which is located in a soil that contains about 3 times as great a salt concentration as is found in the ocean. As shown on this slide (3) the removal of the cracked concrete shows that the reinforcing steel is corroding and is a cause of concrete cracking.

Unfortunately, there are no means by which the durability or maintenance-free life of a bridge or similar structure can be predetermined with absolute certainty. Nevertheless, it is not only advisable, but it is the responsibility of the engineer to determine whether the existing facilities have required excessive maintenance. All field tests that are utilized for detecting corrosive soil conditions should be accompanied by an inspection of any existing structures so as to determine the confidence level for the application of an empirical test in a specific situation. For instance, there may be environmental variables which may be averaged but are not specifically considered in the test and could be a predominant cause of deterioration. As one example, there are instances when the flow contains an excessive amount of abrasive material which results in the premature loss by abrasion of the culvert invert.

THE MECHANICS OF A FIELD SURVEY

The two instruments which are normally used in making a field survey are (1) pH meter and (2) electrical resistivity meter. In the field survey, the soils adjacent to the proposed structures are measured for their electrical resistivity and pH.

This slide (4) shows the field use of the pH meter for determining the hydrogen-ion concentration of a stream which will be carried beneath a highway by a hydraulic structure.

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This slide (5) shows the field use of the resistivity equipment to measure the conductivity of the soil at a culvert site. The specific number of measurements required at a structure location or, for that matter, for a project containing numerous installations depends upon engineering judgment. For example, numerous geographic locations may contain more than one soil type, and the evidence of a composite soil warrants a more thorough investigation.

In the areas of abnormally low and also of average resistivity, samples of the soil are obtained. Then the pH of the soil sample is measured by mixing it with water in the range of one through a maximum of four parts of water to one part of soil. The quantity of water that is added to the soil depends upon its consistency.

In resistivity measurements, water is added to the soil in various increments to determine the minimum or least value of resistivity which can be obtained.

This slide (6) shows the measurement of the minimum resistivity of a soil. It should be noted that the same meter is used for making the field and the minimum soil resistivity measurements. The rod that is used in the field measurements has been replaced by a soil box whose dimensions are such that the minimum specific electrical resistance of the soil may be directly read on the same meter.

After the measured soil characteristics of pH and resistivity are determined, they are then compared with the performance of the existing facilities. This general procedure can provide the engineer with the best objective information for use in evaluating the variables that usually influence the durability of structures.

SOIL CHEMICALS

When other conditions are equal, the corrosion rate of steel will increase in proportion to the concentration of the commonly found sulfates and chlorides, up to some limiting concentration.

Testing and prediction could be simplified if all soils in California contained the same chemicals in equal proportions. However, such is not the case. As shown by this slide (7) the arithmetical sum of the chlorides, as Cl, and the sulfates, as SO_4, in parts per million for California soils may be roughly estimated from the minimum soil resistivity.

At arithmetical sum values of less than 100 parts per million, the minimum soil resistivity is not indicative of the concentration of sulfates and chlorides. It is assumed that factors other than chlorides and sulfates may have a greater influence on the measured resistivity of the soil.

METAL CULVERTS

When the soil variables of pH and resistivity are compared with the rate of corrosion of metal culverts, a correlation similar to that shown by this slide (8) may be obtained. As will be observed on this slide, the time to perforation of a culvert is proportional to the pH and resistivity of the channel soils or flow.

The accuracy of this new mathematically simplified chart is comparable to that which has been previously published. As will be observed, it is required that the thickness of the metal should be considered as it is a direct variable affecting perforation time. Also, the chart does not consider the influence of a protective coating which can considerably extend the anticipated perforation time of the metal.

REINFORCED CONCRETE

A field survey that determines the pH and minimum resistivity of soils can be indicative of the environmental conditions which could cause concrete embedded reinforcing steel to corrode. For equivalent exposure conditions where a portion of the reinforced concrete member is embedded in soil and also exposed to the atmosphere, as in the case of a culvert headwall, it has been found that the time to corrosion of reinforcing steel is inversely proportional to an exponential function of the chloride concentration.

Therefore, when the field survey indicates that the minimum soil resistivity is less than a "relatively safe" value of 3000 ohm cm, the soil should be chemically analyzed for chloride content.

For the normal exposure of highway structures such as reinforced concrete headwalls, retaining walls and piling, the expected number of years in which there could be visible evidence of corrosion of the reinforcing steel is shown by this nomograph (slide 9).

As shown by this chart (slide 9), the factors of cement content, mixing water, the inches of concrete cover over the steel and the quantity of chlorides in the environment are primary variables to be considered when anticipating the time to corrosion of reinforcing steel.

As indicated by the data shown on this nomograph and the culvert chart, the performance of a field structure in any location must be tempered by the variables that can cause the facility to have an inherently large or small corrosion resistance to the environment.

DISCUSSION

Some of the factors which are determined in a field survey have been described in terms of material durability. However, it must be emphasized that the data presented are representative of an

average of conditions that have been found in the State of California. Therefore, there may be variations in the performance of facilities in certain geographic areas. It is the responsibility of the engineer to determine by inspection whether the existing facilities represent an average or extreme condition. This is an important and inseparable part of the field method for detecting and evaluating corrosive soil conditions.