Corrosion Evaluation

Geotechnical Services (GS) is responsible for investigating and reporting corrosion potential at project sites. Corrosive soils can react with construction materials, such as concrete and ferrous metals, and damaging foundation elements. Concrete and steel are affected by sulfates, chlorides, and other adverse minerals in the soil and water. Evaluating the potential for corrosion is an essential part of the design process. This module provides the Geoprofessional with guidance for assessment, testing, and reporting of site corrosion.

Geotechnical reports do not provide corrosion mitigation measures. However, staff should be aware of corrosion mitigation practices when recommending pile and other foundations. Generally, corrosion mitigation measures for structures are selected by Structure Design. Information regarding selecting appropriate corrosion mitigation measures may be obtained from the DES/METS Corrosion Branch if needed.

Standards and guidelines relating to corrosion investigations and reporting are (including but not limited to):

- Caltrans Corrosion Guidelines
- Caltrans Memo to Designers MTD 10-5
- Geotechnical Manual
    - Foundation Reports for Bridges
    - Foundation Reports for Earth Retaining Systems
    - Foundation Reports for Buildings
    - Geotechnical Design Reports
    - Earth Retaining Systems (ERS) Modules
    - Geotechnical Investigations

- Caltrans Soil and Rock Logging, Classification, and Presentation Manual
- AASHTO LRFD BDS Section 10.4.2, *Subsurface Exploration*

Investigation

Corrosion investigation is required for any structure in contact with the ground or surface water.

A corrosion investigation will typically include sampling soil and water for corrosion testing, laboratory testing, and a discussion of corrosivity in the geotechnical report. The purpose of the corrosion investigation is to evaluate or identify:

- Extent of corrosive soil and corrosive water based on existing information such as public reports, and As-built data from nearby sites.
- Presence of fill material, and its potential corrosivity.
- A general description of the condition of existing structures near the proposed structures. Identifying signs of corrosion such as spalling and scaling concrete,

exposed reinforcement, rust stains, failed coatings, or excessive wear.

- Distance from salt water or brackish water or marine atmosphere (if within 1000 feet)
- Proximity to natural features such as mineral springs or local geothermal activity (1000 feet or closer).
- Exposure to deicing salts (Climate Area III environments, where salt is applied to roadways and structures).
- Sources of stray currents such as light rail, or cathodic protection systems on pipelines, structures and underground storage.

Existing Data

Perform a literature search (see *Geotechnical Investigations*) and evaluate archived test results.

For rehabilitation and realignment projects check the Area Bridge Maintenance Engineers' (ABME) records, in the Bridge Inspection Records Information System (BIRIS). The METS Corrosion Branch also maintains a geospatial database of corrosion test results.

Corrosive Atmosphere Proximity Test

Determine if the site is within 1000 feet of a body of marine or brackish water. Caltrans Memo to Designers (MTD) 10-5 (June 2010) indicates this is considered within the effects of salt fog or wind driven salts. This an atmospheric limit and is distinct from corrosion due to soil and/ or groundwater.

Field Sampling and Laboratory Testing

Sample both the soil and the groundwater to provide representative test material for the site.

Select representative samples for corrosion analysis. These should represent the worst-case corrosivity condition. Do not combine individual samples to make composite samples as this would dilute the concentration of corrosive materials, and underestimate corrosion potential.

Soil Sampling

An appropriate number of corrosion samples must be collected and analyzed to determine corrosive rock, soil, or water for all subsurface structure elements. Samples should be collected for each foundation element (e.g. abutment, bent, column, footing, wall, etc.) and to each element's dimension (i.e. length of wall, depth of pile). Representative samples must be collected and analyzed from each type of unique

geologic medium (solid and liquid) and unit (rock, soil, and on-site or imported fill material) that the structure might contact.

The Geoprofessional should consider the entire project and its site-specific geologic setting, the sources of imported fill material, and the effects of seasonal and long-term changes to groundwater and surface water influences (i.e. tidal fluctuations and sea-level rise).

The sampling guidelines listed below should be considered as minimum for sampling requirements to the depth of the anticipated foundation element.

- One sample collected from the near surface between 1 to 5 feet depth.
- Subsurface samples should be collected from each layer or soil type or at representative intervals to the bottom of the borehole or to the groundwater surface. In instances where the groundwater surface location is not known (i.e., mud rotary drilling), collect samples to the bottom of anticipated foundation elevation.
- One soil sample at the groundwater table or within 5 feet below the groundwater table (if the groundwater table is anticipated within the limits of the proposed foundation). Perched water should not be considered the same as groundwater.
- In uniform soil conditions, sample at a maximum interval of **20 feet**. Do not take or combine composite or bulk samples from more than one soil type or formation.
- Sample borrow material that may contact a structure (e.g., MSE walls) if the borrow source has been identified.
- Test every culvert location.
- Corrosion tests (pH, Resistivity, Sulfate, and Chlorides), require at least about 10 lbs. of soil (about a large plastic bag).
- Do not combine and test samples from different boreholes or from different soil types/geologic units.

Label soil samples in accordance with the Caltrans Soil and Rock Logging, Classification, and Presentation Manual.

<u>Water Sampling</u>

Ground water and/or surface water (e.g., rivers, seasonal creeks, lakes, estuaries, etc.) that may contact the project foundation(s) must be sampled. Groundwater samples should be collected if encountered in test holes, and/or available in wells within project limits. Surface water should be collected at or near the project site.

- Use a clean bottle to directly collect surface water. One liter of water is required for both surface and groundwater samples.

- For groundwater sampling, a narrow plastic sampling tube or bailer may be lowered into a clean, stabilized borehole, well or piezometer. The Geoprofessional should request downhole sampling equipment on the drill request.
- Allow each sample to settle and pour off and film or organic material that is on the surface of the sample.
- Pour the water sample into a clean bottle.
- Seal and Label the containers and send to the testing laboratory.

When collecting surface water samples from water bodies, low level flow time is recommended. High flow and high tides can significantly dilute the otherwise concentrated minerals in the flowing water.

Label all water samples with relevant information including Project ID, EA No, Sample ID, Depth, Source (for water sample), Date, and Initials of Geoprofessional.

Typical Examples for labelling water sample are given below:

a) For a groundwater sample from an auger boring at 48 feet

   A-21-008

   GWS-1 @ 48’

b) For a surface water sample from a stream

   SWS-1 @ 2’ depth

   (25’ Upstream from the Bridge # XX-XXXX)

Laboratory Testing

Refer to the OGD-QMP for instructions on how to submit samples for laboratory testing. The Department defines a corrosive area in terms of the resistivity, pH, and soluble salt content of the soil and/or water. The following tests are typically performed:

- Resistivity (Ohm-cm), Testing Method: CT 643
- pH, Testing Method: CT 643
- Chloride, Testing Method: CT 422
- Sulfate, Testing Method: CT 417

Corrosion Evaluation

Overall corrosion potential should be evaluated based on all applicable test results. In general, the higher the resistivity, the lower the rate for corrosion. The resistivity and pH are evaluated first in the laboratory. A minimum resistivity value for soil and/or water less than 1,500 ohm-cm indicates the presence of high quantities of soluble salts and a higher propensity for corrosion. Soil or water that have a minimum resistivity equal to or less than 1,500 ohm-cm are required to be tested by a certified laboratory for chlorides and sulfates per CT 417 and CT 422. The soils or water with higher than 1,500 ohm-cm of resistivity and pH higher than 5.5 are considered non-corrosive. The Department uses the terms **"corrosive"** and **"non-corrosive"** to describe the corrosion potential of the soil or water.

For structural elements, the Department considers a site to be corrosive if one or more of the following conditions exist for the representative soil and/or water samples taken at the site:

- Chloride concentration is 500 ppm or greater,
- Sulfate concentration is 1500 ppm or greater,
- pH is 5.5 or less.

For bridge structural elements, the term “site” above extends from Abutment 1 to Abutment X. For structural elements, appropriate corrosion mitigation measures for “corrosive” conditions are selected depending on the service environment, amount of aggressive ion salts (chloride or sulfate), pH level and the desired service life of the structure.

Archive corrosion test results from the “site” may be used for determination of corrosivity.

MSE Structure Backfill

Corrosion Requirements for Mechanically Stabilized Earth (MSE) Structure Backfill is slightly different.

The Department's Standard Specifications (2018) Section 47-2.02 Structure Backfill requires that the structure backfill material for an MSE structure meet the following corrosion related requirements:

- Minimum resistivity must be greater than 2000 ohm-cm, CT 643
- Chloride concentration must be less than 250 ppm, CT 422
- Sulfate concentration must be less than 500 ppm, CT 417
- pH must be between 5.5 and 10.0 for metal and 4.5 and 9.0 for geosynthetic, CT 643

Reporting

Corrosion test results (including those found via the literature search) must be presented in accordance with the applicable reporting standard (e.g., FR for Bridges, Geotechnical Design Reports), which include a tabulated format shown below.

Table X – Summary of Corrosion Test Results

Borehole ID	Elevation (feet)	Minimum Resistivity (Ohm-cm)	pH	Sulfate Content (ppm)	Chloride Content (ppm)	Corrosive?
A-20-016	102	750	8.34	642	850	Yes
A-20-019	81	4800	7.1	58	101	No

Caltrans currently defines a corrosive environment as an area where the soil has either a chloride concentration of 500 ppm or greater, a sulfate concentration of 1500 ppm or greater, or has a pH of 5.5 or less. With the exception of MSE walls, soil and water are not tested for chlorides and sulfates if the minimum resistivity is greater than 1,500 Ohm-cm.

Separate from the sub-surface elements and their corrosive designation, the structural elements not in contact with soil or water can be corrosive based solely on the atmosphere and should be reported appropriately (Caltrans MTD 10-5).