American Railway Engineering and Maintenance-of-Way Association
Ballot

1. **Committee and Subcommittee: 8**

2. **Ballot Number: 08-19-16**

3. **Assignment:**

4. **Ballot Item:** Edits to Part 22 Geotechnical Subsurface Investigation

5. **Rationale:**

AREMA
AMERICAN RAILWAY ENGINEERING AND MAINTENANCE-OF-WAY ASSOCIATION

Part 22

Geotechnical Subsurface Investigation[1]

–2022~~3~~3 –

TABLE OF CONTENTS

LIST OF TABLES

[1] References, Vol. 78, 1977, p. 102; Vol. 93, 1992, pp. 78,98.

SECTION 22.1 GENERAL (20232)

The intent of this part is to provide guidelines for geotechnical investigations to evaluate the subsurface conditions that will be used ~~in development of~~ to develop geotechnical recommendations for the design and construction of structures. Site investigations for fills and cuts shall follow the requirements of Chapter 1, Roadway and Ballast, Part 1, Roadbed. It is recommended that a licensed professional engineer with geotechnical expertise be retained to plan and implement the investigation, conduct the laboratory and/or in-situ testing program, and prepare the geotechnical analysis and report.

~~a.~~

~~b. It is recommended that a licensed geotechnical professional engineer with geotechnical expertise be retained to plan and implement the investigation, conduct the laboratory and/or in-situ testing program, and prepare the geotechnical analysis and report.~~

SECTION 22.2 PURPOSES OF INVESTIGATIONS

22.2.1 NEW STRUCTURES (20223)

For a new structure, a subsurface investigation should be performed to evaluate the soil or rock properties required to develop geotechnical design parameters and provide information on groundwater conditions.

22.2.2 EXISTING STRUCTURES (20223)

If changes are made to an existing structure, which would result in a change to the ~~service~~ loading on the foundation system, a geotechnical ~~analysis~~ evaluation should be performed to determine the effect of the changed loads on the existing foundation. If ~~sufficient~~ geotechnical information to perform the evaluation is unavailable, an additional subsurface investigation should be performed to characterize geotechnical conditions and obtain the data required ~~for performance of the evaluation.~~

22.2.3 FAILURE INVESTIGATION (20223)

If a structure foundation fail~~sure occurs~~, a geotechnical investigation should be performed to assist in the analysis of the failure mechanism(s).

SECTION 22.3 INVESTIGATIONS

22.3.1 PLANNING AN INVESTIGATION PROGRAM (20223)

a. Preliminary site reconnaissance and review of existing information will facilitate the understanding of the potential site subsurface information. Useful information includes:

(1) Topographic, ~~and~~ geologic maps, NRCS Soil Surveys~~,~~.

(2) Aerial photographs, LIDAR, and UAV surveys, if approved by railroad.

~~(2)~~(3) Seismic and ground hazard maps (i.e., sinkholes, karst, expansive soils, peat/muskeg, etc.).

~~(3)~~(4) Existing geologic and subsurface exploration reports, including publicly available water well ~~logs~~ logs.

~~(4)~~(5) Related articles in engineering and geologic journals.

~~(5)~~(6) Study of local ground features and groundwater levels.

~~(6)~~(7) Survey of existing or adjacent structures and utilities on site.

~~(7)~~(8) Condition, performance, and foundation type of existing or adjacent structures, including results of any deep foundation testing.

~~(8)~~ Information on previous use of the site, including underground use, ~~i.e~~e.g.,~~,~~ mining.

(9)

~~(9)~~ Evaluation of site access and property boundaries.

(10)

~~(10)~~ Permitting requirements.

(11)

~~(11)~~(12) Environmental considerations.

b. ~~The~~ A structural design engineer should provide the following information on the proposed or modified structures:

(1) Location, including elevations, of proposed and existing structures and foundations.

(2) Anticipated foundation loads.

~~(2)~~(3) ~~or o~~Other special/project-specific performance criteria.

c. If project funding and scheduling permits, explorations ~~can~~ may be conducted in a phased sequence: site reconnaissance, ~~investigation~~investigation, and explorations for preliminary design, followed by explorations for final design.

d. Thorough research for details of any contaminated materials and associated appurtenances must be made. A Risk Management procedure needs to be implemented that conforms with federal, state, and local government guidelines for removal of these materials and/or mitigation of contaminants.

e. All necessary permits shall be secured before the work is started as provided by the contract. Permits ~~can~~ should include, but are not limited to, encroachment permits, traffic control plans, private property permissions, environmental, utility clearances, and health and safety.

22.3.2 TYPES OF INVESTIGATIONS (202~~2~~3)

~~Subsurface~~ Geotechnical investigations are an essential element of rail structure foundation design, retaining wall~~s~~ stability evaluations, liquefaction/lateral spread evaluation, embankment static and seismic stability evaluations, settlement evaluations and structure location selection. There are three main types of subsurface investigation methods: Intrusive, Geophysical, and Remote Sensing. The appropriate investigation methods should be selected based on the project requirements and site conditions and shall be performed or supervised by ~~,~~personnel thoroughly experienced in exploration methods. FHWA Geotechnical Engineering Circular No. 5 - Geotechnical Site Characterization 2nd edition (2017) provides guidance ~~and information~~and information on the different types of investigations and site characterization.

22.3.2.1 Intrusive Subsurface Exploration

Intrusive subsurface explorations include geotechnical borings, ~~cone penetration~~in situ tests, hand auger~~s~~ings, test pits/trenches, and rock coring.

a. Geotechnical Borings: The most ~~used~~ commonly used subsurface exploration tests for soil include, but are not limited to, the performance of soil borings using solid or hollow stem augers. For borings where the hole fails to stand open, a casing, hollow stem auger, wet (i.e., mud rotary) drilling methods or other acceptable procedure shall be used. Standard Penetration Test (SPT) in accordance with ASTM D1586 Standard Test Method for Standard Penetration Test (SPT) and Split-Barrel Sampling of Soils or collection of undisturbed samples shall be performed in conjunction with geotechnical borings. Methods for advancing geotechnical borings should be in accordance with the following ASTM standards:

i. ASTM D6151 Standard Practice for Using Hollow-Stem Augers for Geotechnical Exploration and Soil Sampling

ii. ASTM D5876 Standard Guide for Use of Direct Rotary Wireline Casing Advancement Drilling Methods for Geoenvironmental Exploration and Installation of Subsurface Water-Quality Monitoring Devices

~~and the Cone Penetration Test (CPT) in accordance with ASTM D5778. Supplement SPT and CPT testing with other types of in situ testing or soil sampling as appropriate to characterize the subsurface materials. Use a given type of in situ testing only with a prior understanding of the applicability and limitations of the method to be employed.~~

b. In situ Tests: In situ testing, including but not limited to, Cone Penetration Test (CPT), dilatometer (DMT), Pressuremeter (PMT), and Field Vane Shear Test (VST) can be used to characterize ~~the~~ subsurface conditions. A given type of in situ testing shall only be used with a prior understanding of the applicability and limitations of the method to be employed. Soil samples are not obtained during the performance of in situ testing and soil properties are estimated using empirical correlations for each of the test methods. In situ testing -shall be performed in accordance with the applicable ASTM standards.

i. ASTM D5778 Standard Test Method for Electronic Friction Cone and Piezocone Penetration Testing of Soils
ii. ASTM D4719 Standard Test Methods for Prebored Pressuremeter Testing in Soils
iii. ASTM D6635 Standard Test Method for Performing the Flat Plate Dilatometer
iv. ASTM D2573 Standard Test Method for Field Vane Shear Test in Cohesive Soil

~~a.~~ Hand Augers: Hand augers may ~~also~~ be useful to define lateral and vertical extent of shallow, near surface soil deposits or assess areas where drill access is severely restricted. Hand auger borings are limited in depth by the presence of ground water or collapsible soils that cause caving of the borehole. Representative disturbed samples of the formations shall be taken progressively where requested by the Engineer, placed in suitable sample jars or containers, and properly labeled. ~~All exploratory locations should be backfilled in accordance with local, state, or federal regulations as appropriate.~~

c.

d. Test Pits: Test pits are used to examine large volumes of near surface soils and obtain bulk samples of soil for additional testing. Test pits and exploratory trenches are advanced by hand or by a mechanical excavator for shallow investigations. The excavation of test pits can provide ~~valuable~~ subsurface information not determinable or well characterized by test borings. ~~Hand augers or t~~Test ~~pits and exploratory trenches are advanced by hand or by an excavator for shallow investigations.~~ The advancement of test pits through soft or loose soils or below the water table can be extremely difficult. ~~Test pits are used to examine large volumes of near surface soils and obtain bulk samples of soil for additional testing.~~ Personnel overseeing test pit activities must be familiar with health and safety requirements and local, state, and federal regulations governing excavations. Test pits are normally backfilled on the day of excavation using the excavated material.

e. Rock Coring: Experienced personnel are necessary to run the equipment and to interpret the results of the drill action and the samples recovered during rock coring. Material recovered may not actually represent the subsurface conditions present if not correctly sampled. Observation and interpretation of the drill action, fluid return, and other characteristics provide indications of the actual validity of the core sample as well as other information concerning the actual conditions in the subsurface. Rock coring shall be performed in accordance with ASTM-D 2113 Standard Practice for Rock Core Drilling and Sampling of Rock for Site Exploration.

~~b. Representative samples of the formations shall be taken progressively from the formation where requested by the Engineer, placed in suitable sample jars or containers, and properly labeled. Bulk samples are considered disturbed. Personnel overseeing test pit activities must be familiar with health and safety requirements and local, state, and federal regulations governing excavations. Test pits are normally backfilled on the day of excavation using the excavated material.~~

~~c.~~

~~Rock Coring: Rock core drilling should be carried out according to ASTM D 2113-99. Experienced personnel are necessary to run the equipment and to interpret the results of the drill action and the samples recovered during rock coring. Material recovered may not actually represent the subsurface conditions present if not correctly sampled. Observation and interpretation of the drill action, fluid return, and other characteristics provide indications of the actual validity of the core sample as well as other information concerning the actual conditions in the subsurface. Rock coring shall be performed in accordance with the applicable ASTM standards.~~
~~ASTM D 2113 Standard Practice for Rock Core Drilling and Sampling of Rock for Site Exploration~~

~~d.~~

22.3.2.2 Geophysical Investigation

Geophysical methods provide non-intrusive subsurface information and include, but are not limited to, surface resistivity (SR), ground penetrating radar (GPR), and electromagnetic conductivity (EM), which may be effective in establishing ground stratigraphy, detecting sudden changes in subsurface formations, locating underground cavities, or identifying underground utilities and/or obstructions.

22.3.2.3 Remote Sensing

Remote sensing methods can generally be used to identify terrain conditions, geologic formations, escarpments, and surface reflection of faults and buried stream beds, site access conditions, and general soil and rock formations. Remote sensing data from satellites, aerial photographs, ~~and data from~~ Unmanned Aerial Vehicles (UAV) (if approved by railroad), USGS, ~~or~~ state geologists, U.S. Corps of Engineers, and commercial aerial mapping service organizations can be obtained. Remote sensing is typically part of a desktop evaluation or can be used during a failure investigation if site conditions warrant.

22.3.3 SAMPLING METHODS (2022~~2~~3)

22.3.3.1 Split Barrel Sampling of Soil

~~a.~~

a. Split-barrel sampling borings shall conform to current ASTM D1586 Standard Test Method for Standard Penetration Test (SPT) and Split-Barrel Sampling of Soils or D3550 Standard Practice for Thick Wall, Ring-Lined, Split Barrel, Drive Sampling of Soils requirements. This procedure covers the method for recovering disturbed samples with a split-barrel sampler and to obtain a record of the resistance of the soil to the penetration of the sampler.

b. The soil shall be promptly removed from the sampler and immediately placed in airtight suitable containers of sufficient size to hold a section of the sample intact. The containers shall be marked to indicate the job designation, boring number, sample number and elevation or depth at which the soil was taken. The samples obtained by this methodology are disturbed samples. Strength or compressibility testing results should be viewed with caution. In cohesionless or nearly cohesionless soils located below the water table, a core catcher attached to the lower end of the sampler, or a scraper bucket or other similar devices shall be used ~~in order~~ to prevent the sample from falling out before it can be brought to the surface.

22.3.3.2 Thin-Walled Tube Sampling of Soil

~~a.~~ Thin-walled tube samplers shall conform to the current ASTM D1587 Standard Practice for Thin-Walled Tube ~~e~~ Sampling of Soils for Geotechnical Purposes requirements. This procedure covers the method of obtaining relatively undisturbed samples of suitable size of cohesive soils for laboratory testing. Typical samples are 2 to 5 inches (51 to 127 mm) outside diameter. Piston-type samples shall be used if satisfactory samples cannot be obtained with the thin-walled tube samplers.

22.3.3.3 Rock Cores

Rock cores are samples of record of the existing subsurface conditions at given borehole locations and can be used for a variety of strength tests. The samples are expected to provide indications about the geological, physical, and engineering nature of the subsurface for use in the design and construction of an engineered structure. The core samples should be obtained, recovered, logged, and tested according to applicable ASTM standards.

22.3.4 EXPLORATION FREQUENCY AND DEPTH (2022~~2~~3)

Engineering judgement should be used when planning and performing subsurface explorations. The frequencies and depths will vary depending on site conditions, existing information, existing cut and fill performance, and the requirements of specific railroad ~~clients~~. In general, borings should be taken at each substructure location, but this recommendation can be modified at the direction of the Professional Engineer.

The following should be considered:

a. Type, size, and ~~criticality~~ importance of project elements.
b. Soil and rock formations and characteristics.
c. Subsurface variability at the site.
d. Foundation loading.
e. Availability and applicability of previous investigations at the site.
f. Groundwater characteristics and conditions.
g. Depth of potential failure surfaces.

The number, location, and depth of borings should be based on the magnitude and distribution of the load imposed by the ~~proposed~~ structure or track system and by the characteristics and sequence of subsurface strata. In all projects, the borings, at a minimum, must extend to a depth sufficient to reveal the nature of all materials which could be significantly affected by ~~the~~ loads imposed by the structure or embankment ~~and~~ and which by settlement and/or shear failure could affect the structure integrity ~~of the structure~~.

22.3.4.2 Structures

Guidance for determining the minimum number, location, and depth of exploration points for structures is included in Table 8-22-1.

Table 8-22-1. Guidelines for ~~minimum~~ Minimum ~~number~~Number, ~~location~~Location, and ~~depth~~ Depth of ~~exploration~~ Exploration ~~points~~ Points for Structures (adapted from AASHTO)

Application	Number and Location of Exploration Points	Depth of Exploration
Shallow Foundations	• Minimum of one exploration point per substructure.	• Depth should extend to a depth such that from a Boussinesq (or similar) analysis the increase in pressure is 10% of the contact pressure, i.e., the boring depth should be 1.5 to 2 times the anticipated width of the footing. • Depth should extend below any soft, compressible soils into competent bearing material. • Minimum of 10-ft ~~(3.05m)penetration~~3.05m) penetration into competent rock if encountered prior to meeting other depth criteria.
Deep Foundations	• Minimum of one exploration point per substructure.	• Minimum penetration into competent rock should be: a. 10 ft (3.05m) for piles tipped on rock. b. G~~g~~reater of 10 ft (3.05m), or three times the shaft diameter for individual drilled shafts below the anticipated tip elevation for drilled shafts.

Retaining Walls	• Minimum of one exploration point • Exploration points every 100-500 ft.(30.5-152.4 m). • Additional exploration points behind walls for anchored structures and where settlement or global stability may be an issue.	• Minimum depth is greater of: a. Ddepth where inducesd vertical stress is less than 10 percent of applied stress at base of embankment, b. Oor depth equal to twice wall height below base of embankment unless competent hard stratum is encountered at shallower depth. • Depth should extend below any soft, compressible soils into competent bearing material.
Culverts	• Mminimum of one exploration point at each end of the culvert. • Mminimum of one boring location at each culvert extension.	• MMinimiminimum depth is greater of: a. Ddepth where induced vertical stress is less than 10 percent of applied stress at base of embankment, b. Oor depth equal to twice embankment height below culvert flowline unless competent hard stratum is encountered at shallower depth. • Depth should extend below any soft, compressible soils into competent bearing material. • .If rock is encountered above planned culvert flowline, core rock to a minimum depth of 10 feet (3.05m) below the planned flowline.

22.3.4.2 Embankments

All embankments shall have geotechnical borings performed along the planned embankments at a spacing suitable to characterize the subsurface materials and meet specific railroad requirements. All exploratory locations shall be performed to a depth of at least twice the height of the embankment beneath the anticipated bearing elevation (i.e., to a depth sufficient to characterize settlement and stability issues) or to auger refusal, whichever is shallower. Additional exploration points should be performed where settlement or global stability may be an issue.

22.3.4.3 Cut Excavations

All cut excavations shall have one or more exploratory location performed along the proposed crest and toe of the cut area and meet specific railroad requirements. All exploratory borings shall be performed to a depth of at least the height of the ~~cut beneath~~cut beneath the anticipated bottom depth of the cut or to auger refusal, whichever is shallower. In addition, undisturbed and composite bulk sample should be collected from the area of the cut excavations to be used for global stability and borrow source evaluations. If rock is encountered above the toe of the cut, rock coring should be performed to characterize the rock materials. Additional exploration points should be performed where global stability may be an issue.

~~22.3.5 INVESTIGATION PROCEDURES (2022)~~

~~Perform investigation in accordance with procedures outlined in the FHWA Geotechnical Engineering Circular No. 5 - Geotechnical Site Characterization 2nd edition (2017), and appropriate ASTM standards.~~

22.3.~~6 5~~ GROUNDWATER5 GROUNDWATER LEVEL OBSERVATIONS (2022~~2~~3)

a. Groundwater levels shall be observed and recorded at the time of investigation. It is preferable to record the groundwater level once it has stabilized; however, depending on the subsurface conditions, this may not be possible at the time of investigation.

b. If long-term observations of the groundwater are desired, a monitoring well shall be installed in accordance with applicable ASTM standards. If the boring is located where the groundwater level may be influenced by a tidal body of water, a record of the exact stage and direction of the tide at the time of taking the elevation of the groundwater shall also be made.

~~22.3.6 BACKFILLING~~22.3.6 BACKFILLING EXPLORATORY LOCATIONS (2023)

~~a.~~ Exploratory bore holes, test pits, or other intrusive exploration excavations can be a safety hazard and shall be backfilled when they are no longer required. All exploratory locations shall be backfilled in accordance with local, state, or federal regulations as appropriate.

22.3.7 CLEANING SITE (2023)

After completion of the work, all equipment should be removed and the site restored to its original condition as directed by the Engineer.

SECTION 22.4 RECORDS

22.4.1 SCOPE (2022~~2~~3)

Full and complete records of all pertinent data shall be kept for the following typical exploration methods and all other exploration methods. All items listed in Article 22.4.2, Article 22.4.3, and Article 22.4.4 shall be included for the typical exploration methods. For other exploration methods, items to be included should be determined by the Engineer.

22.4.2 GENERAL (2022~~2~~3)

The following information shall be recorded:

a. Name of railroad, site, and weather conditions.

b. Location and identifying number of test boring and reference to permanent survey data.

c. Method of investigation.

d. Date and time of start and completion of boring.

e. Name of contractor, names and titles of all boring crew members, inspectors, and engineer.

f. Ground surface elevation at each boring and datum used, preferably United States Geodetic Survey datum.

g. Elevation of groundwater or surface of waterway and time of observation after boring completion.

22.4.3 SOIL BORING (2022~~2~~3)

The following information shall be recorded:

a. Diameter and description of casing (when used).

b. Weight, drop, and efficiency of hammer and number of blows used to drive the casing (when required) for each successive foot of penetration.

c. Depths at which major changes in the character of the soil take place.

d. Method and total force used to push undisturbed sampler into soil.

e. If sampler is driven, height and weight of drop hammer used to drive sampler and number of blows required to drive the sampler in ~~it~~ each ~~6 inch~~6-inch (152 mm) interval~~es for each sample~~.

f. Elevation of bottom of sampler at the start of taking each sample.

g. Elevation to which sampler was forced into the soil.

h. The length of the sample obtained.

i. The stratum represented by the sample.

j. Detailed description of the soil in each major stratum, to include:

   i. United Soil Classification: GC, CL, GP-GM, etc.

   ii. Kind: topsoil, fill, clay, sand, gravel, etc.

   iii. Color: Light, dark blue, red, etc.

   iv. Moisture: Dry, moist, wet, very wet, etc.

k. Consistency: Loose, soft, dense, stiff, etc.

l. Depth and details of refusal, if applicable.

22.4.4 ROCK CORING (2022~~2~~3)

The following information shall be recorded:

a. Elevation of bottom of casing when seated.

b. Type of core drill, including size of core.

c. Length of core recovered for each 5 feet (1.52 m) length of core run drilled, with resulting percentage of recovery, and RQD at each stratum.

d. Elevation of each change in type of rock.

e. Elevation of bottom of core hole.

f. The rock shall be described in accordance with the following classifications:

   i. Type: Shale, slate, limestone, sandstone, granite, etc.

   ii. Condition: Broken, fissured, laminated, solid, etc.

   iii. Hardness: Soft, medium hard, very hard, etc.

g. Rate at which each core run section was cored in minutes per foot.

h. Depth of loss of drilling water and depth at which it returns.

SECTION 22.5 INSPECTION (2022~~2~~3)

No investigation shall be done except in the presence of the Professional Engineer, Geologist or their representative (inspector). No more than two drilling crews working in the same vicinity at the same time shall be covered by one

inspector. The Engineer or inspector shall identify benchmarks for the determination of the required elevations, check the log of the boring to determine that the information designated in Section 22.4, Records is being obtained, and to establish its accuracy and see that all soil samples and rock cores are properly handled and stored in a suitable place or shipped to their designated destinations.