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NEW ##DJ

Section 19-8. Use for ground movement and vibration monitoring during geotechnical related construction, such as construction of embankment, earth retaining system, ground improvement.

Replace section 19-18 with:

19-18 GROUND MOVEMENT AND VIBRATION MONITORING

## 19-18.01 GENERAL

### 19-18.01A Summary

1

Section 19-18 includes specifications for ground movement and vibration monitoring. Ground movement and vibration monitoring consists of:

1. Installing a ground movement and vibration monitoring system at locations shown, data acquisition systems for processing and storing data, a wireless network and web service for transmission of monitoring data

2. Monitoring ground movement and vibration

2. Enter the construction job component, start date, which may be the start or completing the construction of the job component, and end of monitoring period in the construction stage as provided in the geotechnical report. Edit the first sentence to clearly identify the start and end dates of monitoring period for the job component.

Monitoring period for the construction of \_\_\_\_\_ is from the \_\_\_ of constructing the job component to \_\_ days after completing construction of the job component. Do not start construction of the job component before acceptance of installation report, system verification report, baseline readings, and commission of installed monitoring system.

### 19-18.01B Definitions

3

Not Used

### 19-18.01C Submittals

#### 19-18.01C(1) General

4

Submit:

1. Shop drawings, including:

1.1. Plan sheets showing the layout of instruments, sensors, wires, tubes, conduits, gateways, and dataloggers.

1.2. Conceptual installation and monitoring schedules that show controlling construction activities that affect system installation, monitoring, and salvage or abandonment of equipment.

1.3. Equipment data sheet.

1.4. Manufacturer’s calibration certificates that are traceable to the U.S. National Institute of Standards and Technology, if applicable.

2. Installation report after the installation, including:

2.1. Plan sheets showing layout, locations, coordinates, and elevations of sensors, instruments, wires, tubes, conduits, gateways, and dataloggers.

2.2. Identification of sensors, wires, tubes, conduits, gateways, and dataloggers.

2.3. Drill logs with geological profiles and water levels if applicable.

3. System verification report.

4. Baseline readings.

#### 19-18.01C(2) Baseline Vibration Level Report

5

Include:

1. Date of existing baseline condition for each monitoring location

2. Description of each facility location

3. Maximum single-component and resultant peak particle velocities for 1-minute intervals

#### 19-18.01C(3) Monitoring Data

6

Transmit real time monitoring data electronically by wireless network or cellular data transmission. Furnish software or web service that processes, analyzes, displays, and provides warning of threshold exceedance settings of the monitored data with a secure login method.

7

For Automated Motorized Total Station (AMTS) ground surface movement monitoring data, evaluate weather, site, and traffic conditions to set the time period and frequency of readings to obtain complete data coverage in each monitoring cycle.

#### 19-18.01C(4) Reusable Equipment

8

Salvage and submit reusable equipment to the Engineer after completion of ground movement and vibration monitoring.

9

Reusable equipment includes settlement profile and movement profile monitoring systems, data loggers, data transmitters, cellular gateway systems, solar panel assemblies, battery packs, electricity assemblies, protective boxes, and software developed and paid for by the project.

### 19-18.01D Quality Assurance

#### 19-18.01D(1) General

10

Not Used

#### 19-18.01D(2) Survey Data

11

AMTS movement monitoring data and survey data must comply with quality requirements described in the Department’s Survey Manual and supplemental guidance.

## 19-18.02 MATERIALS

### 19-18.02A General

12

Not Used

### 19-18.02B Wireless Network, Software and Web Service

#### 19-18.02B(1) Wireless Network

13

Wireless network includes:

1. Wireless sensor nodes that can transmit data acquired from data acquisition systems to a cellular gateway or network. Each wireless sensor node must be able to:

1.1. Continuously transmit real-time data to the cellular gateway.

1.2. Transmit an immediate warning if a threshold is exceeded.

2. Cellular gateways that can receive data from wireless sensor nodes and transmit the data through cellular service to the cloud or local network system so that the Contractor and the Engineer and the Engineer’s representatives can monitor the data.

3. Solar panel assembly, battery packs, or electrical supply that can power the cellular gateway system for the duration of the monitoring period.

4. Protective enclosure with security lock for the wireless network system.

5. Surge and lighting protection for the wireless network system.

14

The wireless network must be IP68 rated and with operating temperature range between -40°C and 85°C.

#### 19-18.02B(2) Data Process and Display Software or Web Service

15

Furnish access to the data process, analysis, display, and threshold warning values via local software or a web service that is available to the Engineer and the Engineer’s representatives.

### 19-18.02C Monitoring System

#### 19-18.02C(1) Settlement Gauge Monitoring System

16

Settlement gauge monitoring system must include:

1. Settlement gauges with a semiconductor, vibrating wire, or fiber optic pressure transducer type including a thermistor. Each settlement gauge must include:

1.1 Factory-attached signal cables of sufficient length to route to data logger without splicing.

1.2 Designated reservoir or reservoirs for each settlement gauge placed in the protective enclosure.

2. Protective conduits for cables and tubes.

3. Data acquisition system that can:

3.1. Continuously and simultaneously process and store monitoring data.

3.2. Be programmed to transmit an immediate warning through the wireless network if a threshold is exceeded.

4. Solar panel assembly, battery packs, or electrical assembly that can power data logger and wireless sensor node that transmit readings for the duration of the monitoring period.

5. Protective enclosure with security lock for data logger, reservoir, and data transmission equipment.

6. Surge and lighting protection for the monitoring system.

17

The settlement gauge must comply with the requirements shown in the following table:

|  |  |
| --- | --- |
| **Settlement Gauge** | |
| Quality characteristic | Requirement |
| Range (feet) | 6 |
| Resolution (max, % full scale) | ±0.025 |
| Accuracy (max, % full scale) | ±0.1 |
| Fluid Type | Antifreeze solution |
| Temperature Range (ºC) | -20–80 |
| Thermal drift (max, % full scale / ºC) | ±0.1 |
| Corrosion Resistance | Yes |

#### 19-18.02C(2) Movement Profile Monitoring System

18

Movement profile monitoring system must include:

1. In-place inclinometers (IPI) with MEMS sensors that can monitor the direction and magnitude of movement in the vertical and horizontal plane

2. Casing for IPI MEMS sensors:

2.1. Casing for IPI MEMS must be grooved ABS pipe with load rating of at least 1500 lb and collapse rating of at least 190 psi

2.2. Casing for Shape Array must be bell-end style PVC pipe with inside diameter of 2 ± 0.01 inches and outside diameter of 2.38 ± 0.01 inches or grooved ABS pipe with a load rating of at least 1500 lb and collapse rating of at least 190 psi

3. Signal cables from the same manufacturer of instruments with sufficient length to route to data logger. Use manufacture’s recommended splice kit if splicing is required.

4. Conduits for signal cables.

5. Data acquisition system that can:

5.1. Continuously and simultaneously process and store monitoring data.

5.2. Be programmed to transmit an immediate warning through the wireless network if a threshold is exceeded.

6. Solar panel assembly, battery packs, and electrical assembly that can power for data logger and data transmitter with daily readings for the duration of the monitoring period.

7. Protective enclosure with security lock for data logger, and data transmission equipment.

8. Surge and lighting protection for the monitoring system.

**19**

Movement profile monitoring system must comply with the requirements shown in the following table:

|  |  |
| --- | --- |
| **Movement profile monitoring system** | |
| Quality characteristic | Requirement |
| Reading interval along profile (max, feet) | 3 |
| Resolution (arc seconds) | ±4 |
| Accuracy (arc seconds) | ±10 |
| Temperature Range (ºC) | −20–80 |

20

Movement profile monitoring system must be able to be configured and installed horizontally to monitor settlement profile or vertically to monitor movement profile.

#### 19-18.02C(3) AMTS Ground Surface Movement Monitoring System

21. AMTS mostly is paid for as a monthly rental for the duration of monitoring period.

Enter the number of benchmark prisms for the monitoring area. The default value is 8.

The practical range of current AMTS is 500 feet

AMTS ground surface movement monitoring system must include:

1. AMTS installed at locations shown and be able to automatically target designated control points and settlement monitoring points.

2. At least 5 control prism points for each AMTS. Place the control prisms:

2.1. Outside the zone of influence

2.2. In the light of sight of the AMTS throughout the duration of the monitoring period

2.3. Evenly distributed around 360 degrees of the AMTS

2.4. With varying distances from the AMTS

3. At least \_\_ benchmark prisms installed at locations evenly distributed in the monitoring coverage area of the AMTS.

4. Instrument tower and brackets for AMTS:

4.1. Height of the instrument tower and brackets must provide clearance and scanning angles so that the AMTS can scan prisms and reference points in the designated coverage area and provide required accuracy with consistency.

4.2. Instrument location must include safety measures that protect workers while attaching and learning the AMTS and prisms.

5. Data acquisition system that can:

5.1. Continuously and simultaneously process and store monitoring data.

5.2. Be programmed to transmit an immediate warning through the wireless network if a threshold is exceeded.

6. Solar panel assembly, battery packs, and electrical assembly that can power for data acquisition system and data transmitter with daily readings for the duration of the monitoring period.

7. Protective enclosure with security lock and security measures for the system to prevent vandalism and theft of the equipment.

8. Surge and lighting protection for the monitoring system.

22

AMTS ground surface movement monitoring system must comply with the requirements shown in the following table:

|  |  |
| --- | --- |
| **AMTS Ground Surface Movement Monitoring System** | |
| Quality characteristic | Requirement |
| Range with no-prism target surface (min, feet) | 500 |
| Angle accuracy (max, seconds) | 0.5 |
| Accuracy with prism (max, inches) | 0.04 + 1 ppm |
| Accuracy with no-prism surface (max, inches) | 0.08 + 2 ppm |
| Elevation accuracy with prism (max, inches) | 0.1 |
| Elevation accuracy with no-prism surface (max, inches) | 0.2 |
| Temperature range (ºC) | −20–50 |

#### 19-18.02C(4) Vibration Monitoring System

**23**

Vibration monitoring system must include:

1. Data acquisition system and data transmitter that can:

1.1. Continuously and simultaneously process, store, and transmit real-time vibration data to a wireless sensor node

1.2. Transmit immediate waring if threshold particle velocity is exceeded

2. 3-axis velocity transducer that:

2.1. Can be factory calibrated annually by the manufacturer and in the field via onboard calibration and level checks

2.2. Comply with the requirements shown in the following table:

|  |  |
| --- | --- |
| **3-Axis Velocity Transducer** | |
| Quality characteristic | Requirement |
| Range (in/sec) | 0.01–4 |
| Resolution (max, in/sec) | 0.0025 |
| Accuracy (max, %) | 5 |
| Frequency response range (Hz) | 2–250 |

3. Signal cables from the same manufacturer of the instrument and with sufficient length to route to data logger. Use manufacture’s recommended splice kit If splicing or connection cables are required.

4. Conduits for signal cables.

5. Solar panel assembly, battery packs, and electrical assembly that can power the data acquisition system and data transmitter for the duration of the monitoring period.

6. Protective enclosure with security lock and security measures for the system to prevent vandalism and theft of the equipment.

7. Surge and lighting protection for the monitoring system.

#### 19-18.02C(5) Tilt Sensing System

24

Tilt sensing system must include tilt sensors that:

1. Are battery powered and transmit data using radio frequency spectrum to a cellular gateway

2. Can transmit data via waterproof antennae or connectors if the sensor is under continuous immersed condition

3. Can detect and alert on tilt motion greater than 1 degree/second

4. Can be operational at any angle

5. Comply with the requirements shown in the following table:

|  |  |
| --- | --- |
| **Tilt sensor** | |
| Quality characteristic | Requirement |
| Range (min, degrees) | ±90 |
| Resolution (max, degrees) | 0.0001 |
| Repeatability (max, degrees) | ±0.0005 |
| Reporting frequency (max, seconds) | 5 |
| International Protection (IP) rating | 68 |
| Operating temperature range (ºC) | −40–85 |

### 19-18.03 CONSTRUCTION

#### 19-18.03A General

25

Protect monitoring systems, conduits, and exposed cables. Use hand operated compactor to compact the first 3-foot backfill over the instruments, conduits, and exposed cables. Do not operate construction equipment over the instruments and conduits before placement of hand-compacted backfill.

26

Notify the Engineer if the monitoring systems or the data transmission systems are damaged or no longer functioning. Replace and recalibrate monitoring systems within 3 days of discovery of the damage.

### 19-18.03B Installation

27

Install ground movement and vibration monitoring systems at locations and elevations shown.

28

Install IPI head assemblies casing under manufacturer’s instructions.

29

Install 3-axis velocity transducer as follows:

1. Firmly attach on the surface of the object to be monitored, or firmly set in undisturbed soil

2. Align transducer longitudinal direction of measurement parallel to the alignment of the object

3. Align transducer transverse direction of measurement perpendicular to the alignment of the object

30

Route cables through the conduits and establish data transmission links between monitoring devices and data logger and data transmission station.

31

Mark sensors, wires, tubes, conduits, gateways, and dataloggers to allow identification on the site.

### 19-18.03C System Calibration and Verification

32

Calibrate and verify the installed systems meet the requirements. Submit system calibration and verification report within 5 days of system installation. Commission equipment and instruments in the presence of the Engineer.

### 19-18.03D Monitor Baseline Vibration Levels

33

Before construction, monitor and record vibration at least two nonconsecutive workdays, spanning the hours during which construction activities will take place to establish baseline vibration levels.

### 19-18.03E Salvage Reusable Equipment

34. Remove if the entire ground movement and vibration monitoring system is paid as monthly rental.

Salvage reusable equipment after completion of settlement or movement monitoring and submit to the Engineer.

## 19-18.04 PAYMENT

35. 1. Remove this paragraph if there is no equipment is paid as monthly rental, and all reusable equipment must be salvaged.

2. Edit if part of the monitoring system is paid as monthly rental, such as AMTS ground surface movement monitoring system.

The ground movement and vibration monitoring system are paid as monthly rental for the duration of the monitoring period.