SP-150218a
(Replaces SP-150218)

SPECIAL PROVISIONS
FOR
STRUCTURAL HEALTH MONITORING AND INSTRUMENTATION

Scott County
IM-NHS-074-1(198)5--03-82

Effective Date
April 25, 2017

THE STANDARD SPECIFICATIONS, SERIES 2015, ARE AMENDED BY THE FOLLOWING MODIFICATIONS AND ADDITIONS. THESE ARE SPECIAL PROVISIONS AND THEY SHALL PREVAIL OVER THOSE PUBLISHED IN THE STANDARD SPECIFICATIONS.

150218a.01 DESCRIPTION.

A. A program to collect scientific measurements of predetermined design and maintenance parameters is to be implemented for the arch and approach bridges over the Mississippi River. These measurements will begin during construction and continue into the service life of the bridges. In order to collect the measurements, a dedicated on-site monitoring system will be installed during construction. The system will consist of various (electronic transducers), cabling, conduits, pull boxes, junction boxes, cabinets and data acquisition equipment. The Structural Health Monitoring and Instrumentation (SHM) work includes work on the arch bridges, Project IM-NHS-074-1(198)5--03-82, and the approach bridges, Project IM-NHS-074-1(197)5--03-82. The SHM contractor is responsible for the acquisition and installation of the necessary components as detailed in the plans and this special provision.

B. This Special Provision describes the sensor types and locations to be installed, and the data acquisition equipment to be installed. Before bidding, the SHM contractor may request from Iowa DOT Project IM-NHS-074-1(197)5--03-82 documents, which contain bridge and “N” plans for SHM components not part of this project.

C. The specified locations of the sensors provided in this Special Provision are based upon the designer’s anticipated erection methods. The Engineer will review the effects of the Contractor’s proposed erection manual on the assumptions used to locate the sensors. After this review, the Engineer may recommend the relocation of some of the sensors to better capture the bridge behavior.

150218a.02 CONTRACTOR QUALIFICATIONS

A. The SHM system installation and deployment work, including collection of data during bridge construction, must be performed by a contractor qualified for this specialty work (the SHM

contractor). It is anticipated that the Project IM-NHS-074-1(198)5--03-82 Contractor will engage a subcontractor for the SHM work.

B. The following contractors have been pre-approved for the SHM work of this project:

1. BDI
1995 57th Court North Suite 100
Boulder, CO 80301-2810
Contact: Scott Aschermann, P.E.
(303) 494-3230 X: 115
scotta@bridgetest.com

2. Geocomp Corporation
1390 Busch Parkway
Buffalo Grove, IL 60089
Contact: Thomas Weinmann, Vice President
224-676-1371
tweinmann@geocomp.com

3. MISTRAS Group, Inc.
195 Clarksville Rd
Princeton Junction, NJ 08550
Contact: Terry Tamutus
609-468-5737
terry.tamutus@mistrasgroup.com

C. Qualifications of any other contractor proposed to perform the SHM work of this project shall be submitted for review along with the bid for Project IM-NHS-074-1(198)5--03-82, as follows:

1. Details of at least four projects similar to this one (SHM for a major bridge), completed within the last 15 years, including:
a. Description of structure(s).
b. Construction cost.
c. Structure owner, with contact information including name, phone number and email address of responsible person familiar with the SHM system.
d. Approximate number and types of sensors, gages, etc., installed.
e. Approximate date work was completed.

2. Name(s) and qualifications of lead technician(s) who will install the system, including: brief descriptions of four projects similar to this one, with this contractor or others, completed within the last 15 years, including technician's role

D. Applicants will be informed of qualification status within 70 calendar days of the project letting. Should a proposed subcontractor not be approved by the Iowa DOT, the letting of Project IM-NHS-074-1(198)5--03-82 will not be affected, but the Project IM-NHS-074-1(198)5--03-82 Contractor shall engage a qualified SHM contractor within 140 calendar days of the letting date.

150218a.03 REQUIREMENTS FOR NOTIFICATION DURING CONSTRUCTION.

A. During this project, the SHM contractor will be responsible for gage installation. This will require members of the SHM contractor to be on the Project IM-NHS-074-1(197)5--03-82 and Project IM-NHS-074-1(198)5--03-82 site at various times. It is the SHM contractor's responsibility to inform the Engineer and the Contractor when gages are installed.

B. The SHM contractor shall notify both the Engineer and the Contractor at least 5 working days prior to the installation of any sensors.

C. The SHM contractor shall notify the Engineer of any incidents that may have damaged any part of the SHM system. The SHM contractor shall supply the Engineer and the Contractor with the time of the incident and a description of the incident.

150218a.04 PROTECTION OF SENSORS, CABLING, AND DATA ACQUISITION EQUIPMENT.

A. The SHM contractor shall take all necessary steps to protect sensors, cabling and data acquisition equipment from disturbance or damage during construction of the bridges. The following minimum precautions shall be taken during installation of sensors and data acquisition equipment.

1. Wiring shall be tied off to the rebar cage and routed in a manner to minimize risk of damage due to casting and vibrating of concrete.

2. All data acquisition equipment shall be secured to the structure and resistant to vandalism yet accessible by the Engineer.

3. After installation, the SHM contractor shall not move, dislodge, disturb, disconnect, reconnect, cut or relocate wires, instruments or related instrumentation controls or recorders; or remove any labeling of the instruments, wires, or related instrumentation controls or recorders without the approval of Iowa DOT and the Contractor. The Engineer shall be notified in order to be on site to observe any work listed above.

B. Any operational data acquisition equipment that needs to be moved or adjusted shall be coordinated with the appropriate bridge Contractor. The SHM contractor shall notify the Engineer and the Contractor at least 24 hours before any item has to be relocated.

150218a.05 MATERIALS AND EQUIPMENT.

The SHM system will consist of various sensors located throughout the bridge connected to a data collection system with remote access capabilities. The materials and equipment required for this system are described in this section.

To the extent possible, all sensors and data collection systems shall be supplied by the same manufacturer to assure compatibility. The SHM contractor shall prove compatibility of any equipment that deviates from this requirement.

A. Sensors.

For the instrumentation of this structure, numerous types of sensors are to be included throughout the bridge. See “N” plans for instrumentation layout and numbers of each sensor required. Following is a brief description of each type of sensor, appropriate catalog number, and a description of the installation technique:

1. Vibrating Wire Surface Mounted Strain Gages: The gage contains a steel wire that is tensioned between two mounting blocks that are arc welded to the steel member. A removable electromagnetic coil assembly attached to the outer steel tube plucks the wire causing it to vibrate. The frequency of the wire vibration is read as an electric signal and converted to a corresponding strain. The electromagnetic coil assembly also contains a thermistor for the temperature measurement at the gage location. The gage can be easily removed from the mounting blocks at any time after installation allowing for replacement of the gage. This gage is used for slow speed, long-term strain measurements. The vibrating wire surface mounted strain gages must meet the following requirements:

- Range: 3000 $\mu\varepsilon$
- Accuracy: ±0.5% maximum

- Resolution: 1με minimum
- Temperature Range: -20°C to +80°C

2. Strain Transducers: The transducer consists of full Wheatstone bridge circuit with four active foil gages, all pre-wired in a rugged housing. The foil gages use the relationship between electrical resistance and conductor length to measure changes in strain. As the foil is stretched, its length is increased, which results in minute increases in resistance. To accurately measure these small changes in resistance, additional signal conditioning in the form of a Wheatstone bridge resistance network is necessary. Strain transducer is used to measure short-term live load responses applied to the structure. The effective gage length shall be 3.0 inches. The strain Transducers must meet the following requirements:

- Range: ±2000 με
- Accuracy: ±2% maximum
- Sensitivity: 500me/mV/V
- Temperature Range: -50°C to +120°C

3. Embedded Corrosion Sensors: The sensor is specifically designed for direct embedment in concrete at the level of the top reinforcing steel mat. It monitors five factors in corrosion; linear polarization resistance, open circuit potential, resistivity, chloride ion concentration, and temperature. The sensor is tied to a small cage of No. 3 bars. The cage is directly attached to the reinforcement mat and holds the sensor at the appropriate level. The embedded corrosion sensors must meet the following requirements:

- Enclosure Material: VALOX plastic, epoxy coated, water tight seal
- Chloride indicator range: ±1.3 Volts electrode
- Resistivity Measurements: 1000-19000 Ohm-cm
- Temperature Range: -40°C to +70°C

4. Leaf Wetness Sensors: The sensor is designed to determine the percentage of time a surface is wet versus the time it is dry. The sensor consists of circuit board with interlacing gold plated fingers. The resistance between the fingers is lowered when condensation on the sensor occurs. The sensors will be placed inside the arch ribs to detect the presence of moisture. The leaf wetness sensors must meet the following requirements:

- Resistance at wet/dry condition: 50 and 200kohm (uncoated)
- Resistance at dry condition: 20 and 1000kohm (coated)
- Temperature Range:-40°C to +60°C

5. Temperature and Relative Humidity Probe: The probe is used to measure temperature and relative humidity inside the arch ribs. The probe shall be able to measure temperature for the range of -40° to 60°C with a temperature accuracy of ± 0.6°C, and relative humidity for the range of 0 to 100% RH with the following accuracy:

- Accuracy at 0° to +40°C:
  - ±3% RH (0 to 90% Relative Humidity)
  - ±5% RH (90 to 100% Relative Humidity)
- Accuracy at -40°C to 0°C and +40°C to +60°C:
  - ±5% RH (0 to 90% Relative Humidity)
  - ±7% RH (90 to 100% Relative Humidity)

This unit requires a custom bracket to mount the probe to the inside surface of the arch rib.

6. Vibrating Wire Tilt Meter: The gage is used for measuring changes in rotation of an element. This particular model has a pendulous mass that can move in one direction with gravity. A vibrating wire gage is used to restrain movement on the elastic hinge and is calibrated with regards to degree of rotation. This unit requires a custom bracket to mount the gage to a concrete surface with steel drop-in anchors for vertical orientation. This gage is used to

measure low speed, long-term changes. The vibrating wire tilt meter shall meet the following requirements:

- Range: ±10 degrees
- Accuracy: ±2% maximum
- Resolution: 10 arc seconds minimum
- Temperature Range: -20°C to +70°C

7. Vibrating Wire Displacement Transducer: The displacement transducer is used to measure displacement at expansion joint locations and relative movement between stiffening girders and pier cross beam as shown in plans. The transducer consists of vibrating wire in series with a tension spring. The tension spring is stretched as displacement occurs. The wire and spring are connected to a free-sliding rod located inside a protective tube. The outer tube shall be sealed such that water will not enter inside the tube. The displacement transducers shall be capable of measuring the following displacement ranges at expansion joints at the following locations:

- Abutment 1 (EB Structure): 4.0”
- Pier 2 (EB Structure): 7.0”
- Pier 3 (WB Structure): 7.0”
- Pier 7 (EB Structure): 15.0”
- Approach Span Girder and Pier 12 Cross Beam (EB & WB Structures): 8.5”
- Stiffening Girder and Approach Span Girder at Pier 12 (EB & WB Structures): 25.0”
- Approach Span Bike Trail Girder and Pier 13 Cross Beam (EB Structure): 6.0”
- Bike Trail Stringer and Approach Span Bike Trail Girder at Pier 13 (EB Structure): 7.0”
- Pier 16 (EB Structure): 11.0”
- Pier 16 (WB Structure): 9.0”

The vibrating wire displacement transducer must meet the following requirements:

- Range: 25, 50, 100mm
- Accuracy: ±0.25% maximum
- Resolution: 0.025% minimum
- Temperature Range: -20°C to +80°C

8. Wheatstone Bridge Load Cell: The load cell is used to measure hanger forces due to permanent and live loads. The load cell consists of a cylinder of high strength steel or aluminum with three to six electrical resistance strain gages located around the circumference of the cell and connected together in a Wheatstone bridge circuit. Loads applied to the cell are measured by the strain gages. The effects of uneven and eccentric loading are minimized by averaging the output of all individual gages’ reading. Bearing plates and centralizer bushings are required to minimize eccentric and uneven loading. The bearing plates should be machined flat and large enough to completely cover the load bearing surface of the load cell. The Wheatstone bridge load cell must meet the following requirements:

- Rated capacities: 100 -5000kN
- Accuracy: ±0.5% maximum
- Resolution: 0.025% minimum
- Temperature Range: -20°C to +80°C

9. Accelerometers: Accelerometers are used for measuring acceleration at the edge of the deck. The accelerometers shall be capable of measuring accelerations along the three axes of the member (3-axis accelerometer). Accelerometer shall be working at a temperature range of –35°C to +50°C, measurement range of ± 1.0g and resolution of ±0.0005g. The 3-axis accelerometer must meet the following requirements:

- Type: 3-axis MEMS
- Range: ±1.5 g
- Accuracy: ±0.5% maximum
- Resolution: 0.0005g minimum

- Accelerometer sample rate: 2000sample/second minimum
- Temperature Range: -20°C to +80°C

10. Thermocouples: Thermocouples are used to measure temperature gradient along the gradient profile. They are metal resistance thermometers that change their electrical resistance dependent on temperature. The change in electrical resistance under temperature influence is caused by the conduction mechanism of the metals. In thermocouples, two dissimilar metals are joined together at the point of measurement. When the junction of the two metals is heated or cooled a voltage is produced that can be correlated back to the temperature. Thermocouples shall be able to measure temperature for the range of -50°C to 80°C with measurement resolution of 0.2°C and shall be insensitive to corrosion and vibrations. Thermocouples must meet the following requirements:

- Accuracy: ±0.1% maximum
- Resolution: 0.2°C minimum
- Temperature Range: -50°C to +80°C

B. Data Acquisition System.

The purpose of the data acquisition system is to measure the responses from the various sensors located throughout the bridge, store the data, and provide remote access to the data to Iowa DOT. The following is a description of the required equipment:

1. Multiplexers (mux): This hardware allows up to 16 vibrating wire gages to be operated with only a few cables. The number of cables is decreased by sequentially multiplexing sensor leads into common leads. The individual common leads are connected to datalogger analog inputs, excitation channels, or ground as required by the sensor. The datalogger controls the multiplexer using two control ports or one control port and one excitation channel, such that several multiplexers can also be daisy-chained together to even further reduce the cabling involved. Multiplexers must meet the following requirements:

- Temperature Range: -40°C to +60°C

2. Data Loggers: This system is a programmable datalogger and controller that is housed within a sealed module. The system is relegated to use for long-term slow speed measurements because it can be expanded in 16 channel increments using multiplexers. A maximum of six multiplexers can be added to each datalogger, however, custom vibrating wire interface (discussed below) will be used and will provide digital signal processing to remove noise for only two multiplexers. Data loggers shall have GPS-based time stamping. Data readings are stored in the module's memory and must be periodically downloaded to a laptop computer. Software is used to program the system and the module can be disconnected from the computer until the recorded data must be downloaded. Two different types of data logger will be required; one for slow sampling rate data collection and the other is for fast sampling rate data collection. Fast sampling rate data loggers will be used to collect data from strain transducers and Wheatstone bridge load cells ~~and shall be Campbell Scientific CR 9000X or an equivalent approved by the Engineer~~. The loggers shall have minimum scan rates that are able to continuously collect data from strain transducers and bridge load cells and are capable of working in the temperature range of --25°C to +50°C. Slow sampling rate data loggers will be used to collect data from all other sensors except strain transducers and Wheatstone bridge load cells. Data Loggers must meet the following requirements:

- Maximum Scan rate: 100 Hz
- Analog Voltage Accuracy: ±0.12% maximum
- Analog Resolution: 0.33 µV minimum
- Temperature Range: -25°C to +50°C

3. Vibrating Wire Interfaces (VWI): This hardware is an interface between dataloggers and vibrating-wire sensors. It applies a spectral analysis process to distinguish the sensor's

response from noise in order to provide cleaner data. The VWI must meet the following requirements:

- Measurement speed: 2 seconds per measurement (maximum)
- Basic Resolution: 24 bit minimum
- Measurement Resolution: 0.005 Hz minimum
- Accuracy: ±0.013%
- Temperature Range: -40°C to +70°C

4. Power Supply: This hardware provides a 12-Vdc, 7-Ahr rechargeable power supply for the dataloggers and peripherals. The rechargeable battery will be trickle-charged from an AC power in the permanent installation and requires the purchase of the optional wall charger. For data collection during construction, the battery will be replaced by the SHM contractor as needed. Hence, every logger requires two power supplies: one to power the logger and one to recharge a spare battery. The power supply must meet the following requirements:

- Temperature Range: -40°C to +60°C

5. Ethernet Interface: This equipment is a module that attaches directly to the datalogger and provides the ethernet port. This port allows the datalogger to communicate over a local network or dedicated Internet connection. Ethernet interface must meet the following requirements:

- Power Requirements: 12V
- Ethernet Speed: 10Mbps minimum

6. Handheld Vibrating Wire Gage Reader: This equipment is a portable, low power, handheld unit that can read one vibrating wire gage at a time and display the measurement immediately upon its LCD screen. Handheld vibrating wire gage reader must meet the following requirements:

- Excitation range: 400 Hz to 6000 Hz
- Measurement Resolution: 0.1 Hz minimum
- Measurement Accuracy: ±0.025% maximum
- Temperature Range: -20°C to +50°C

7. Fiber Optic Communications Network Connection: The SHM contractor shall be responsible for connecting the SHM equipment to the configured fiber optic communications network via ethernet switches provided in the ITS Fiber Optic Project ITS-074-1(222)5—05-82.

C. Cabling.

At locations where the factory installed sensor cables are not long enough to reach the multiplexers or data loggers, cabling shall be used to extend the factory sensor cabling to the data acquisition system. Following is a description of the types of cabling to be used for installation of health monitoring system:

1. All installations are to be in accordance with all applicable requirements and codes. ~~See Article 2525.03, D of the Standard Specifications~~.

a. Install all cabling runs so they are continuous from sensor connections to data acquisition system. Cabling between data acquisition system components shall also be continuous. Splicing will not be allowed.

b. Pull cabling through conduit by means of a cable grip designed to provide a firm hold upon the exterior covering of cabling, with a minimum of dragging on the ground or structural components. Use reels mounted on jacks or other suitable devices. Use frame mounted pulleys or other suitable devices to pull the cable out of conduit into pull boxes. Use lubricants which are approved for cable lubrication to facilitate the pulling of cable. Provide slack for each cable by the use of a 1 foot loop in each pull box.

2. The cables consist of four wires as two twisted and shielded pairs with an AWG of 20 (e.g., Belden #9402, Alpha #2465C, or equivalent). Cabling shall comply with Article 4189.01, C of the Standard Specifications.

D. Cable Labels.
All cables shall be labeled within 12 inches of the terminus.

1. Sensor cables shall be clearly labeled with the sensor ID.

2. Cabling shall be clearly labeled to identify the equipment they are connected to on either end (i.e. Mux 2-1 to VWI#15).

3. The labels shall be pre-prepared type written utilizing a minimum of 10 point font.

4. The labels shall be weatherproof and protected with clear shrink wrap tubing.

E. Contact Information.
The products described herein are available through multiple manufacturers, including the following:

1. Geokon, Inc.: 48 Spencer Street, Lebanon, New Hampshire, 03766, Phone # (603) 448-1562, or see their website at http://www.geokon.com.

2. Roctest, Inc.: 665 Pine Avenue, Saint-Lambert, Quebec, Canada, J49 2P4, Phone # (450) 465-1114, or see their website http://www.roctest-group.com

3. Vishay Micro-Measurements Group, Inc.: 951 Wendell Blvd., Wendell, NC, 27591, Phone # (919) 365-3800, or see their website http://www.vishaypg.com/micro-measurements.

4. Campbell Scientific, Inc.: 815 W. 1800 N., Logan, Utah, 84321-1748, Phone # (435) 753-2342, or see their website http://www.campbellscientific.com

5. Datataker, Inc.: 8588 Mayfield Road, Chesterland, Ohio, 44026, Phone # (440) 729-2570, or see their website http://www.datataker.com

6. Belden, Inc.: 220 US27, South Richmond, IN, 47374, Phone # (765) 983-5200, or see their website http://www.belden.com

7. Alpha Wire, Inc.: 71 Lidgerwood Avenue, Elizabeth, NJ, 07207, Phone # (800) 522-5742, or see their website http://www.alphawire.com

8. Cooper B-Line, Inc.: 509 W. Monroe St., Highland, IL, Phone # (618) 654-2184, or see their website http://www.cooperbline.com

9. Soltec, Inc.: 12977 Arroyo Street, San Fernando, CA, 91340-1548, Phone # (800) 423-2344, or see their website http://www.solteccorp.com

10. Virginia Technologies, Inc.: 660 Hunters Place, Suite 102, Charlottesville, VA 22903, Phone # (434) 970-2200, or see their website http://www.vatechnologies.com

11. SENSR, LLC.: P.O. Box 158, Elkader, IA 52043, Phone # (563) 245-3750, or see their website http://www.monitoringstructures.com/

12. Flowline: 10500 Humbolt Street, Los Alamitos, CA 90720, Phone # (562) 598-3015, or see their website http://www.flowline.com/

150218a.06 INSTRUMENTATION LAYOUT.
This section details the installation requirements for the SHM system. The SHM contractor will have the responsibility of the installation of the entire SHM system. The following details the SHM contractor's requirements for installation of the SHM system:

A. Approval of Structural Health Monitoring System.

Prior to purchasing any sensors or data acquisition equipment, the SHM contractor shall submit to the Engineer for review and approval of a structural health monitoring system plan. This plan shall, at minimum, include the following:

1. A complete listing of all proposed sensors along with manufacturer specifications and manuals.

2. A complete listing of all proposed data collection equipment along with the manufacturer specification and manuals.

3. Schematic drawings showing proposed installation procedures for each sensor type, including sensor orientation.

4. Schematic drawings and or narratives describing how and when each sensor will be installed into the data collection system, and a timeline of sensor and data collection equipment installation relative to the bridge construction.

5. Plan for protecting the equipment before, during and after installation.

6. Schematic drawing of final Structural Health Monitoring system configuration.

B. B. Handling of Health Monitoring System.

The SHM contractor shall store all sensors and data acquisition equipment in a climate controlled facility prior to installation. The equipment shall not be exposed to environmental conditions beyond the manufacturer recommendations. Any equipment that is improperly stored will be rejected by Iowa DOT and the SHM contractor will be responsible to replace at no additional cost to the project.

C. Installation of Sensors.

The SHM contractor will be responsible for installation of sensors and all necessary cabling as described in this Special Provision. Installation includes running attached wiring from the sensor to the appropriate multiplexer in the appropriate junction box. No field drilling will be allowed in any of the steel plates. Sensors shall be installed utilizing manufacturer supplied mounting brackets. Tilt meters shall be installed utilizing stainless steel concrete anchors. Care shall be taken to route cabling in a manner that will protect it from ongoing construction activity. Exposed wiring shall be protected in a conduit. It is the SHM contractor's responsibility to coordinate with the Contractor to incorporate the installation of any sensor attached to the structure.

1. Orientation of Sensors: Strain gages and LVDTs shall be installed with their axes parallel to the longitudinal axis of the gaged member. Questions concerning the orientation of sensors shall be directed to the Engineer.

2. Acceptance of Instrumentation: The SHM contractor must prove that the installed sensors are in good working order and functioning prior to acceptance and payment for instrumentation. For vibrating wire sensors, SHM contractor shall verify that the transducer and wiring are operational through the uses of a handheld vibrating wire gage reader or ohmmeter. Readings in terms of microstrain, ohms, and/or temperature as appropriate for each gage shall be recorded and provided to the Engineer. After the sensors are connected into the data loggers and after installed in their final configuration, the Engineer will download the data and verify that each sensor is providing reasonable data and data is being properly collected by the logger.

3. Repair of Defective Sensors: The SHM contractor shall be required to repair or replace any sensors determined to be defective after initial installation. If sensors or instrumentation are damaged after being cast in concrete, the following procedures shall be utilized:

a. Any sensor that does not function after initial installation and prior to being cast into concrete shall be replaced with a new sensor and cable at no cost to the Iowa DOT.

b. Any sensor that is damaged during or after concrete placement shall be brought to the attention of the Engineer and the Contractor. The SHM contractor is to review the cause of the damage and provide recommendation to the Engineer as to whether the sensor is to be repaired, replaced, or abandoned. The Contractor is responsible for the repair or replacement of the sensor at no additional cost to the project. The Engineer may require that any abandoned sensors be supplemented by additional sensors in adjacent locations at no additional cost to the Iowa DOT.

c. The SHM contractor shall notify the Engineer and Contractor of any damage that is caused to sensors or cabling after the sensors have been installed and are functioning. Any damaged sensors shall be replaced by the Contractor at no additional cost to the Iowa DOT. Any damaged cabling shall be repaired per manufacturer recommendations.

4. Documentation of Sensors: The SHM contractor shall provide documentation to the Engineer of the final location of all installed sensors. The SHM contractor may use surveyors to locate the locations of the instrumentation providing the Engineer with x, y, and z coordinates of the final gage locations. Alternatively, the SHM contractor may provide the Engineer with marked up sketches clearly showing the final locations of all gages providing stationing, offset from centerline, and depth of embedment. In either case, the final locations shall clearly document all sensor numbers with associated final locations.

a. Name of Sensor as shown in this special provision

b. Sensor location as noted above

c. Orientation of sensor axis

d. Serial number of sensor

e. Any calibration sheets provided by the vendor

f. Photo of installed sensor. Embedded sensors shall be photographed prior to casting concrete. To identify the sensor in the photo, the contractor shall include a 3 x 5 card with the sensor ID clearly printed on the card and shall be included in the frame of each sensor photo. Orientation of sensor shall be clearly discernable in the photo.

g. Initial readings immediately after installation, and after concrete is cast

D. Photo and Video Documentation.

The Engineer shall be provided access during all the phases of construction for the purposes of photo and video documentation.

E. Installation of Data Acquisition System.

1. Multiplexers: Multiplexers shall be located in junction boxes or cabinets throughout the bridge as shown in the plans.

2. Data Loggers: Data loggers shall be located in junction boxes or cabinets throughout the bridge as shown in the plans.

3. Vibrating Wire Interfaces: Vibrating wire interfaces shall be located in junction boxes or cabinets throughout the bridge as shown in the plans.

4. Power Supply: Power supplies and wall chargers shall be located in the equipment cabinets where data loggers are located. The power supplies will provide power along with a battery backup to the data loggers and ethernet interface. Wall chargers will convert the 115V AC power to appropriate DC power for the power supplies.

F. Coordination Meetings.

The SHM contractor shall be advised of and allowed to attend coordination meetings. As necessary, the SHM contractor will attend the regular construction meetings with the Contractor in

order to coordinate the performance of all work and material needed for the instrumentation of the bridge during the various stages of its construction.

150218a.07 METHOD OF MEASUREMENT.

Measurement will be made for specific items furnished and installed in place, completed and accepted in accordance with the following items:

A. Vibrating Wire Surface Mounted Strain Gage: is to include the gage, gage cable, materials, labor and equipment necessary for the installation of sensor as detailed in this special provision.

B. Strain Transducer: is to include the gage, gage cable, materials, labor and equipment necessary for the installation of sensor as detailed in this special provision.

C. Embedded Corrosion Sensor*:* is to include the sensors, sensors cable, materials, labor and equipment necessary for the installation of sensor as detailed in this special provision.

D. Temperature and Relative Humidity Probe: is to include the probes, probes cable, mounting brackets, materials, labor and equipment necessary for the installation of probe as detailed in this special provision.

E. Leaf Wetness Sensor: is to include the sensors, sensors cable, materials, labor and equipment necessary for the installation of sensor as detailed in this special provision.

F. Vibrating Wire Tilt Meter: is to include the gage, mounting bracket, stainless steel anchor, gage cable, conduit, materials, labor and equipment necessary for the installation of gage as detailed in this special provision.

G. Vibrating Wire Displacement Transducer: is to include the gage, mounting brackets, gage cable, conduit, materials, labor and equipment necessary for the installation of gage as detailed in this special provision.

H. Wheatstone Bridge Load Cell: is to include the load cell, load cell cable, bearing plates, bushings, conduit, materials, labor and equipment necessary for the installation of load cell as detailed in this special provision.

I. Thermocouple: is to include the gage, gage cable, materials, labor and equipment necessary for the installation of gage as detailed in this special provision.

J. Accelerometer: is to include the sensors, sensor cable, materials, labor and equipment necessary for the installation of sensor as detailed in this special provision.

K. Multiplexer: is to include all materials, labor and equipment necessary for the permanent installation of multiplexers and connections to sensors as detailed in this special provision.

L. Data Logger: is to include all materials, labor and equipment necessary for the permanent installation of data loggers as detailed in this special provision. The following items shall be included in the unit price for each data logger: all component-interconnects between the data logger, vibrating wire interfaces, power supplies; cost of power supply and related components; cost of ethernet interface and related components; cost of multidrop interface and related components; cost of completing connection to fiber optic communication network; and all other materials necessary to complete the installation of the permanent SHM system.

M. Vibrating Wire Interface: is to include all materials, labor and equipment necessary for the permanent installation of each vibrating wire interface as detailed in this special provision. All cabling required for connection between vibrating wire interface and multiplexers shall be included in the unit price.

N. Power Supply: shall be incidental to data logger installation, and will not be paid for separately.

O. Ethernet Interface: shall be incidental to data logger installation, and will not be paid for separately.

P. Handheld Vibrating Wire Gage Reader: shall be incidental to the work described, and will not be paid for separately.

Q. Cabling: shall be incidental to sensor installation, and will not be paid for separately.

R. Cabling Labels: shall be incidental to sensor installation, and will not be paid for separately.

150218a.08 BASIS OF PAYMENT.
Payment will be made under:

PAY ITEM	**PAY UNIT**
Vibrating Wire Surface Mounted Strain Gage	Each
Strain Transducer	Each
Embedded Corrosion Sensor	Each
Leaf Wetness Sensor	Each
Temperature and Relative Humidity Probe	Each
Vibrating Wire Tilt Meter	Each
Vibrating Wire Displacement Transducer	Each
Wheatstone Bridge Load Cell	Each
Accelerometer	Each
Thermocouple	Each
Multiplexer	Each
Data Logger	Each
Vibrating Wire Interface	Each