DECEMBER 23, 2019
STRUCTURAL MONITORING SYSEM PEARL HARBOR MEMORIAL BRIDGE
FEDERAL AID PROJECT NO. 0951(374)
STATE PROJECT NO. 0092-0676
CITY OF NEW HAVEN

ADDENDUM NO. 2

This Addendum addresses the following questions and answers contained on the "CT DOT QUESTIONS AND ANSWERS WEBSITE FOR ADVERTISED CONSTRUCTION PROJECTS":

Question and Answer Nos. 2, 15, 36, 39, & 41

SPECIAL PROVISIONS

NEW SPECIAL PROVISION

The following Special Provision is hereby added to the Contract:

- NOTICE TO CONTRACTOR – DRILLING AND CORING

REVISED SPECIAL PROVISIONS

The following Special Provisions are hereby deleted in their entirety and replaced with the attached like-named Special Provisions:

- CONTRACT TIME AND LIQUIDATED DAMAGES
- ITEM NO. 0601900A – STRUCTURAL MONITORING SYSTEM

PLANS

REVISED PLANS

The following Plan Sheets are hereby deleted and replaced with the like-numbered Plan Sheets:

02.001.A2
03.004.A2
03.006.A2

The Bid Proposal Form and Detailed Estimate Sheets are not affected by these changes.

There will be no change in the number of calendar days due to this Addendum.

The foregoing is hereby made a part of the contract.

NOTICE TO CONTRACTOR – DRILLING AND CORING

The Contractor is hereby notified that the maximum allowable drilling depth for concrete surfaces shall be 2-inches. All locations of proposed drilling shall be submitted for review and approval prior to conducting work. Coring or thru-drilling of any concrete members shall not be allowed.

CONTRACT TIME AND LIQUIDATED DAMAGES

In order to minimize the hazard, cost and inconvenience to the traveling public, pollution of the environment and the detriment to the business area, it is necessary to limit the time of system installation which interferes with traffic as specified in Article 1.08.04 of the Special Provisions.

A total of One thousand sixteen (1,016) calendar days will be allowed for completion of all work on this Contract.

There will be assessments for liquidated damages that will be addressed in the following manner:

Phase 1 – SMS Installation and Acceptance

Two hundred twenty-three (223) calendar days will be allowed for completion of the Phase 1 work on this Contract and the liquidated damages charge to apply will be One-thousand Five Hundred Dollars ($1,500) per calendar day.

Phase 2 – Monitoring Data Collection and Delivery

Seven hundred ninety (790) calendar days will be allowed for completion of the Phase 2 work on this Contract and the liquidated damages charge to apply will be One-thousand Dollars ($1,000) per calendar day.

Phase 3 – SMS Removal and Project Completion

Sixty-five (65) calendar days will be allowed for completion of the Phase 3 work on this Contract and the liquidated damages charge to apply will be One-thousand Five Hundred Dollars ($1,500) per calendar day.

LIQUIDATED DAMAGES PER HOUR

Project No. 0092-0676

Route I-95 Northbound Western Limit to On-Ramp from I-91 Southbound 3 Lane Section		
If Working Periods Extends Into	A.M. 1 Lane Closure	A.M. 2 Lane Closure
1st Hour of Restrictive Period	$ 500	$ 500
2nd Hour of Restrictive Period	$ 500	$ 25,000
3rd Hour or any Subsequent Hour of Restrictive Period	$ 1,000	$ 70,000

Route I-95 Northbound On-Ramp from I-91 Southbound to Eastern Limit 3 Lane Section		
If Working Periods Extends Into	A.M. 1 Lane Closure	A.M. 2 Lane Closure
1st Hour of Restrictive Period	$ 500	$ 6,000
2nd Hour of Restrictive Period	$ 500	$ 25,000
3rd Hour or any Subsequent Hour of Restrictive Period	$ 500	$ 50,000

The above liquidated damages apply to those hours shown on the Limitation of Operations charts designated with a “3” or “E”.

For those hours on the Limitation of Operations charts designated with a "2", the liquidated damages shown above for "1 Lane Closure" shall apply when only one lane is open to traffic.

For each hour shown on the Limitation of Operations charts designated with an “E”, liquidated damages of $500 shall apply for each hour, or part thereof, if all available shoulder widths are not available to traffic.

Liquidated damages in the amount of $500 shall apply for each hour, or part thereof, that the Contractor interferes with existing traffic operations on any ramps or turning roadways during the non-allowable hours.

LIQUIDATED DAMAGES PER HOUR

Project No. 0092-676

Route I-95 Southbound Western Limit to On-Ramp from Woodward Ave. 3 Lane Section		
If Working Periods Extends Into	A.M. 1 Lane Closure	A.M. 2 Lane Closure
1st Hour of Restrictive Period	$ 10,000	$ 50,000
2nd Hour of Restrictive Period	$ 45,000	$ 100,000
3rd Hour or any Subsequent Hour of Restrictive Period	$ 50,000	$ 100,000

Route I-95 Southbound On-Ramp from Woodward Ave. to Eastern Limit 3 Lane Section		
If Working Periods Extends Into	A.M. 1 Lane Closure	A.M. 2 Lane Closure
1st Hour of Restrictive Period	$ 500	$ 15,000
2nd Hour of Restrictive Period	$ 3,000	$ 60,000
3rd Hour or any Subsequent Hour of Restrictive Period	$ 1,000	$ 90,000

The above liquidated damages apply to those hours shown on the Limitation of Operations charts designated with a “3” or “E”.

For those hours on the Limitation of Operations charts designated with a "2", the liquidated damages shown above for "1 Lane Closure" shall apply when only one lane is open to traffic.

For each hour shown on the Limitation of Operations charts designated with an “E”, liquidated damages of $500 shall apply for each hour, or part thereof, if all available shoulder widths are not available to traffic.

Liquidated damages in the amount of $500 shall apply for each hour, or part thereof, that the Contractor interferes with existing traffic operations on any ramps or turning roadways during the non-allowable hours.

ITEM #0601900A – STRUCTURAL MONITORING SYSTEM

1.0 DESCRIPTION:

Under this item, the Contractor shall complete the following Tasks:

- **A.** Structural Monitoring System Installation and Commissioning
- **B.** Data Collection and Delivery
- **C.** Live Load Tests
- **D.** Cable Plucking Tests
- **E.** Structural Monitoring System Removal and Restoration

Each Task shall be as described in detail below.

A.1 Description of Task A – Structural Monitoring System (SMS) Installation and Commissioning:

A. 1.1 General

A Structural Monitoring System (SMS) shall be installed on the Pearl Harbor Memorial Bridge (PHMB) to monitor and assess its structural performance. The expected time period for continuous monitoring data collection from the SMS is twenty-four (24) months.

The Contractor shall furnish, install, operate, and maintain full functionality of the SMS continuously for a time period of twenty-four (24) months. The Contractor shall also collect and deliver the monitoring data to a remote, designated server to be maintained by CTDOT's Design Consultant (see Task B). The Contractor shall be required to provide 24-hour emergency contact numbers of qualified employees. Additionally, the Contractor shall be responsible for performing three (3) live load tests and three (3) cable plucking tests during the monitoring period (see Tasks C and D). At the end of the monitoring period, the Contractor shall remove all data acquisition equipment as well as all sensors and wiring. All removed monitoring equipment shall become property of the Contractor.

Work shall also include testing and commissioning the SMS per the requirements as specified herein. Sensor locations of the SMS, as well as access details and power availability across the PHMB, are provided in the plans.

The SMS will be comprised of the following major components with sensor quantities in the parentheses:

1) Accelerometers (biaxial) for cable vibrations (8)
2) Anemometer for wind characteristics (1)
3) Crackmeters for activeness of existing concrete cracks (42)
4) Displacement transducers for expansion bearing movements (12)
5) Strain gages on concrete elements for stresses due to in-situ loads (152)

6) Strain rosettes on steel elements for stresses due to in-situ loads (4)
7) Temperature sensors on concrete and steel surfaces and in the air (17)
8) Tiltmeters (biaxial) for tilting movements of bridge tower legs (6)
9) Reference, or dummy, sensors for baseline responses to ambient environment (10)
10) Data acquisition and transmission network

All data and information generated by the SMS shall become the sole property of CTDOT to use for any purpose and to distribute as desired. CTDOT's Design Consultant will validate and analyze the monitoring data for the purpose of assessing the structural performance of the PHMB.

A. 1.2 Objectives

The general objective of the SMS is to provide continuous monitoring data from high precision sensors for the Engineer to assess the structural performance of the PHMB.

The Contractor shall install and maintain the SMS to continuously monitor the physical and environmental parameters of the structure as shown in the SMS plans. This specification provides measurement and performance requirements for all the sensors and data collection systems to be deployed.

A. 1.3 SMS Functional Requirements

The Contractor shall develop, operate, and maintain the SMS to meet the following functional requirements:

1) Assure full functionality for twenty-four (24) months of continuous monitoring, including three (3) load tests with controlled vehicles (see TASK C) and three (3) cable plucking tests (see TASK D)
2) Deliver monitoring data remotely to a specified destination on a daily basis (see Task B)
3) Assure data quality to be free of noise induced spikes and temperature compensated as per sensor manufacturer's recommendations
4) Provide data backup and system redundancy for uninterrupted data collection under unexpected circumstances including weather, accidents, etc.
5) Provide sufficient robustness for regular bridge operation, maintenance, and inspection activities
6) Provide easy access to key components of SMS with the existing bridge access system

A. 1.4 General System Requirements

The SMS, comprised of sensors, data acquisition and storage equipment, as well as wireless communication devices, shall meet the following general system requirements:

A. 1.4.1 Minimum Outdoor Protection Rating

The outdoor equipment and/or their enclosures shall have the following characteristics:

1) Resistant to UV light
2) Water and moisture proof

3) Ingress protection rating for enclosures: IP66
4) NEMA Type 4X for all enclosures
5) Considerations for vandalism

A. 1.4.2 Durability
Appropriately designed and installed cabinets shall be provided for all data-loggers and hardware. The on-structure hardware and cabinets shall be of robust construction capable of resisting damage. Cabinets shall be secured to the structure in areas with no public access. Cabinets shall be fitted where possible with anti-tamper fixings and shall be provided with locks to prevent theft or vandalism. All data and power cables shall have appropriately designed and installed cable ducts and cable-trays.

A. 1.4.3 Vibrations
Bridges are dynamic structures that experience continuous vibrations due to wind, traffic, etc. All components (e.g. sensors, data loggers, other hardware, all cabling, interfaces, seals, glands, cabinets, ducts, fixings, connections, etc.) shall be designed and installed with due consideration for continuous structural vibrations including:

- low frequency large amplitude vibration of the whole bridge
- high frequency small amplitude vibration of the local structural element

In particular all components shall function as specified in the following sections, for vibration levels up to 2g (g is the acceleration due to gravity at the Earth's surface). This requirement shall be verified by reviewing information provided by sensor and data acquisition system manufacturers.

A. 1.4.4 Protection from Birds
Where practical, all external sensors shall be provided with protection against interference from birds including direct contact and bird droppings. Protection that is provided shall not interfere with the operation and readings of the sensors, nor shall it interfere with structural behavior or services provided on the structure (e.g. gantries).

A. 1.4.5 Electrical Protection
All components shall be provided with sufficient protection against electrical surge from power fluctuations, Electro-Magnetic Interference (EMI), lightning strike, and Electro-Magnetic Pulses (LEMP) generated by lightning strike. Protection may be, but shall not be limited to, grounding system power-surge fuse circuits.

All data loggers and hardware shall be provided with power-surge fuse circuits.

A. 1.4.6 Power Supply
AC power shall be supplied to the SMS from dedicated 120V power outlets as shown in the plans. Local backup batteries with a minimum operation capacity of 96 hours shall be provided to avoid interruptions to continuous monitoring.

A. 1.4.7 Fixing to Main Structure

The attachment of any component to the structure shall not damage the structure or protective system (e.g. paint system or similar). If the removal of the protective system is necessary for installation, for example for the installation of strain sensors, any exposed steel areas surrounding the sensor equipment shall be protected from corrosion for the duration that the sensors are in place. The Contractor shall submit in writing a proposed removal and protective coating method to the Engineer for acceptance.

The maximum allowable drilling depth for concrete surfaces shall be 2-inches. All locations of proposed drilling shall be submitted for review and approval prior to conducting work. Coring or thru-drilling of any concrete members shall not be allowed.

A. 1.4.8 Corrosion Protection of the SMS Components

All electrical and mechanical components of the SMS shall be protected against corrosion and shall be able to withstand the climatic conditions and road salt for that equipment within the spray zone.

A. 1.4.9 Visual Impact

All exterior sensors and wiring shall have minimal visual impact to the public in daytime and for possible shadows under the LED lighting in nighttime. Exterior sensors include, but are not limited to, accelerometers on stay cables, crackmeters on the outer face of tower legs, crackmeters on the cable anchorages, and thermal couples.

A. 1.4.10 Spare Parts

The Contractor shall be responsible for stocking proper amounts of spare parts for SMS components in order to minimize disruptions to continuous data delivery due to component failures over the entire monitoring period.

B.1 Description of Task B – Data Collection and Delivery

B. 1.1 General

Work includes maintaining the full functionality of the Structural Monitoring System (SMS) and delivering monitoring data continuously for twenty-four (24) monitoring months per the requirements as specified herein.

For the purpose of this specification, a "monitoring month" shall be defined as an uninterrupted period of not more than 31 consecutive calendar days.

The start date and end date for each monitoring month shall be proposed by the Contractor and subject to review and approval by the Engineer.

B. 1.2 Commissioning Date

Data collection and delivery begins upon the Engineer's written acceptance of the Contractor's installation and functionality of the SMS, to be known as the SMS Commissioning Date.

The effective start date for each monitoring month shall be re-established whenever the data collection period is interrupted and corrective action is required.

C.1 Description of Task C – Live Load Tests

C. 1.1 General

Work includes performing three (3) live load tests under the direction of CTDOT's Design Consultant (Engineer) using controlled vehicles of known weights while collecting and delivering monitoring data from the Structural Monitoring System (SMS) per the requirements as specified herein.

C. 1.2 Schedule

The expected scheduling of the three (3) live load tests are:

1) Live Load Test No.1 – Upon completion of installation and before commissioning of the SMS.
2) Live Load Test No.2 – End of 12 months of the monitoring period.
3) Live Load Test No.3 – End of 24 months of the monitoring period.

Each live load test shall entail conducting multiple test runs on each of the I-95 NB and I-95 SB bridges using five (5) test vehicles as specified under Materials for TASK C.

D.1 Description of Task D – Cable Plucking Tests

D. 1.1 General

Work under this Task includes performing three (3) cable plucking tests under the direction of CTDOT's Design Consultant (Engineer) while collecting and delivering monitoring data from the Structural Monitoring System (SMS) per the requirements as specified herein.

D. 1.2 Schedule

The expected scheduling of the three (3) cable plucking tests are:

1) Cable Plucking Test No.1 – Upon completion of installation and before commissioning of the SMS.
2) Cable Plucking Test No.2 – End of 12 months of the monitoring period.
3) Cable Plucking Test No.3 – End of 24 months of the monitoring period.

E.1 Description of Task E – Structural Monitoring System Removal And Restoration

A.1 General:

Work under this Task includes removing the entire Structural Monitoring System (SMS) upon completion of the twenty-four (24) month monitoring period and restoring bridge surfaces after removal of SMS components. Work to restore the bridge surfaces shall include containment, protective coating removal, collection and disposal of associated debris, surface preparation and field painting.

2.0 MATERIALS:

All materials shall be as shown on the plans and shall be as specified for each Task as described in detail below.

A.2 Materials for Task A – SMS Installation and Commissioning:

A. 2.1 System Component Requirements

The Contractor shall propose the type(s) of technology for the sensors and data acquisition equipment of the SMS that meets all the functional and system requirements to accomplish the Project objectives as described above. Possible technologies shall include, but not be limited to, electrical resistance (ER), fiber optical (FO), micro electro-mechanical systems (MEMS), piezoelectric (PE), and vibrating wire (VW).

Primary components of the SMS shall include, but are not limited to, the following:

- Sensors
- Cables and conduits
- Mounting and protection appurtenances
- Data acquisition equipment
- Wireless communication devices
- Control cabinets and enclosures

The Contractor shall submit product data or catalog cuts for the proposed SMS components indicating that said components meet or exceed the following requirements in consideration of the local environmental conditions at the bridge Site.

A. 2.2 Sensors

Contract plans provide a Sensor Summary Table that lists the types and quantities of sensors required for the SMS. The Sensor Summary Table also lists the quantities of reference (dummy) sensors for select sensor types which shall be used to evaluate the sensors' long-term stability and sensitivity to the ambient environment.

All sensors shall be ordered with the required lengths of instrumentation cable from the approved manufacturers. All cables shall be installed with sufficient slack so that they do not pick-up load or break during the 24-month monitoring period. This is of particular importance where the SMS cables cross expansion joints, if any.

All sensors of each type shall meet or exceed the performance requirements as specified below. Monitoring data will be collected at the sampling rates as specified in the performance requirements below as well as in the Sensor Summary Table in the contract plans. The Contractor needs to be aware that the sampling rates may be modified (but not to exceed the specified values) by the Engineer as deemed necessary during the required monitoring period.

A. 2.2.1 Accelerometers

A total of eight (8) bi-axial accelerometers shall be provided as shown in the plans, one on each of the stay cables. These sensors are to measure accelerations in two directions perpendicular to the cable axis.

Table A. 2.2.1 – Accelerometer Performance Requirements

Acceleration Measurement Range	±64.34 feet/sec^2 (±2g)
Frequency Measurement Range	0.01 to 20 Hz
Sensor Sampling Rate	100 Hz or less
Resolution	100 micro-g
Accuracy	±100 micro-g
Environmental Requirements	Suitable for exposure in marine environments
Operating Temperature	-10 to +140°F
Storage Temperature Range	-10 to +140°F
Operating Humidity Range	0 to 100 %
Precipitation	Operation maintained to 1 foot/hour
Power Supply	12 VDC

Other requirements:

1) Each accelerometer shall be secured directly and firmly to the stay cable for truthful measurement of cable vibrations.
2) The accelerometers and cabling shall be protected from corrosion, tampering, and vibration under wind.
3) The accelerometer cabling shall run down to the deck level spirally along the stay cable and enter the box girder through existing access holes in the deck overhang.
4) The accelerometer cabling shall be mechanically fastened to the deck overhang.
5) At locations of the existing holes where the accelerometer cabling enters the box girder, proper sealant shall be applied to prevent water from leaking through the holes.

A. 2.2.2 Anemometer

An anemometer, as listed in the Sensor Summary Table on the plans, shall be used to measure and record wind speed and directions at the bridge Site. The anemometer must be secured firmly to its supporting mast and located a minimum of 10 feet above the top of the tower leg. Wind speed data shall be provided in feet per second (fps) or miles per hour (mph). Axis X shall lie in the horizontal plane and follow the structure centerline towards I-95 NB traffic; axis Y is also in the horizontal plane, orthogonal to X. Axis Z is to be vertical.

Table A. 2.2.2 – Anemometer Performance Requirements

Sensor Sampling Rate	10 Hz or less
Measuring Parameters	Measurement in three orthogonal directions: x, y, and z as described below
Plan Wind Speed Range	0 to 213 fps
Vertical Wind Speed Range	-82 to 82 fps
Wind Speed Resolution	0.33 fps
Wind Speed Accuracy	<±1 fps or 1% of the reading
Plan Wind Direction Range	Full 3D: 0 to 360 degrees in plane, -90 to 90 degrees vertically
Plan Wind Direction Resolution	1 degree
Plan Wind Direction Accuracy	<±3 degrees
Gust Survival Wind Speed	328 fps
Environmental Requirements	Suitable for exposure in marine environments
Operating Temperature Range	-10 to +140°F
Storage Temperature Range	-10 to +140°F
Operating Humidity Range	0 to 100%
Precipitation	Operation maintained to 1 foot/hour
Power Supply	12 VDC

Other requirements:

1) The supporting mast and ancillaries shall be designed and installed to minimize interference with the free-flow wind field being measured.
2) The anemometer and mast shall be designed for an ultimate limit state condition of 328 fps factored wind speed.
3) The mast shall have a lowering mechanism for access to the anemometer without climbing, such as telescopic.
4) Cables shall be placed inside the tower where possible.
5) Power and data cable arrangement are subject to the approval of the Engineer.

A. 2.2.3 Crackmeters

Forty-two (42) crackmeters are listed in the Sensor Summary Table in the plans which shall be used to measure the opening and closing movements of select existing cracks at the following locations:

1) Eight (8) crackmeters to monitor the diagonal and transverse cracks at cable anchorages in the deck overhang topside in Spans 1 and 2 around Tower Pier No. 2.
2) Twenty-four (24) crackmeters to monitor longitudinal cracks inside box girder in the closure pour near mid-span.
3) Eight (8) crackmeters to monitor existing horizontal cracks on the outer face of the exterior tower legs just above the cross girder of Tower Piers 2 and 3, two (2) on each tower leg.
4) Two (2) crackmeters to monitor existing vertical concrete cracks on the inner face of the south tower leg of Tower Pier 2 opposing the strain rosettes inside the cable anchor box.

Additionally, three (3) reference or dummy crackmeters are specified for evaluating the sensor's long-term stability and sensitivity to the ambient environment. As listed in the Sensor Summary Table in the plans, a dummy crackmeter shall be installed at each location type at the deck overhang area, inside the box girder, and exterior surface of the tower leg.

Table A. 2.2.3 – Crackmeter Performance Requirements

Measurement Range	1 inch (25 mm)
Sensor Sampling Rate	10 Hz or less
Accuracy	±0.10% Full Scale (F.S.)
Resolution	<0.025% F.S.
Thermistor	3 kilo ohms (kΩ)
Environmental Requirements	Suitable for exposure in marine environments
Operating Temperature	-10 to +140°F
Storage Temperature Range	-10 to +140°F
Operating Humidity Range	0 to 100 %
Precipitation	Operation maintained to 1 foot/hour
Power Supply	12 volts direct current (VDC)

Other requirements:

1) The exact locations of crackmeters over existing cracks are to be determined in the field as directed by the Engineer.
2) Dummy crackmeters shall serve to establish baseline measurements for factors other than opening and closing movements of existing cracks, including, thermal expansion and contraction of concrete, and sensor responses to ambient environment.
3) Dummy crackmeters shall be placed on the same or similar concrete surface free of cracking and subject to the same ambient environment as the crackmeters over existing cracks.
4) Locations of dummy crackmeters are to be determined in the field as directed by the Engineer.

A. 2.2.4 Displacement Transducers

Twelve (12) displacement transducers are listed in the Sensor Summary Table in the plans which shall be used to monitor the longitudinal and vertical movements of each of the expansion bearings at Anchor Pier 1, Tower Pier 2, and Anchor Pier 4. Additionally, one (1) reference or dummy displacement transducer is specified for evaluating the sensor's long-term stability and sensitivity to the ambient environment.

Table A. 2.2.4 – Displacement Transducer Performance Requirements

Measurement Range	8 inches (200 mm) longitudinal; 1 inch (25 mm) vertical
Sensor Sampling Rate	10 Hz or less
Accuracy	±0.10% F.S.
Resolution	<0.025% F.S.
Thermistor	3 kΩ
Environmental Requirements	Suitable for exposure in marine environments
Operating Temperature	-10 to +140°F
Storage Temperature Range	-10 to +140°F
Operating Humidity Range	0 to 100 %
Precipitation	Operation maintained to 1 foot/hour
Power Supply	VDC

Other requirements:

1) Displacement transducers of different ranges may be used for measurement of the longitudinal and vertical movements of expansion bearings.
2) Displacement transducers shall be properly mounted and protected for possible forces during the twenty-four (24) month monitoring period including wind, birds, and debris build-up.
3) Displacement transducers, especially those for longitudinal movements of expansion bearings, shall be made clearly visible to bridge inspection and maintenance personnel.
4) The dummy displacement transducer shall be subject to no external displacement and securely placed at a location subject to the same ambient environment as other displacement transducers.

A. 2.2.5 Strain Gages for Concrete Stresses

One hundred and fifty-two (152) strain gages are listed in the Sensor Summary Table in the plans which shall be used for long-term monitoring of dynamic concrete stresses at the following locations:

1) Eight (8) strain gages to measure vertical concrete strains on the inner face of the outer tower legs just above the cross girder of Tower Piers 2 and 3, two (2) on each tower leg opposing the two crackmeters on the outer surface of the same tower leg.
2) Forty-eight (48) strain gages to measure longitudinal concrete strains in the top and bottom flanges of a box girder across section in Span 1.
3) Forty-eight (48) strain gages to measure longitudinal concrete strains in the top and bottom flanges of a box girder across section in Span 2.
4) Forty-eight (48) strain gages to measure longitudinal concrete strains in the top and bottom flanges of a box girder across section in Span 3.

Additionally, four (4) reference or dummy strain gages are specified for evaluating the sensor's long-term stability, sensitivity to the ambient environment, as well as

measurement of stress induced strain versus thermal deformation induced strain. General locations of the dummy strain gages are specified in the Sensor Summary Table in the plans.

Table A. 2.2.5 – Strain Gage Performance Requirements

Measurement Range	2000 micro strain
Sensor Sampling Rate	50 Hz or less
Accuracy	±0.10% to ±0.5% F.S.
Resolution	1 micro strain
Nonlinearity	< 0.5% F.S.
Environmental Requirements	Suitable for exposure in marine environments
Operating Temperature	-4 to +176 degrees F
Storage Temperature Range	-20 °C to 80 °C (-4 °F to +140 °F)
Operating Humidity Range	0 to 100 %
Precipitation	Operation maintained to 1 foot/hour
Power Supply	12 VDC

Other Requirements:

1) The strain gages shall be equipped with an integral thermistor or equivalent for simultaneous measurement of temperature to allow temperature compensation as per manufacturer's recommendations.
2) The strain gages shall be manufactured from corrosion-resistant material and be fully waterproof.
3) Each strain gage shall be supplied with an appropriate length and size of attached cable, waterproofed and sealed as an integral part of the assembly.
4) The dummy strain gages shall not be subject to load induced strains but shall be subject to the thermal expansions and contractions of concrete and the same ambient environment as the active strain gages.

A. 2.2.6 Strain Rosettes for Steel Stresses in Cable Anchor Box

Four tri-axial strain rosettes suitable for long term monitoring are listed in the Sensor Summary Table in the plans which shall be used to monitor stress variations in the steel anchor box in the south tower leg of Tower Pier 2 due to cable forces from live load and temperature effects. One (1) reference or dummy strain rosette shall be installed to evaluate the sensor's long-term stability, sensitivity to the ambient environment, as well as to measure stress induced strain vs. thermal deformation induced strain.

Table A. 2.2.6 – Strain Rosette Performance Requirements

Sensor Type	Strain Gage
Measurement Range	2000 micro strain
Sensor Sampling Rate	50 Hz or less
Accuracy	±0.10% to ±0.5% F.S.
Resolution	1 micro strain
Nonlinearity	< 0.5% F.S.
Environmental Requirements	Suitable for exposure in marine environments
Operating Temperature	-4 to +176 degrees F
Sensor Temperature Range	-20 °C to 80 °C (-4 °F to +140 °F)
Operating Humidity Range	0 to 100 %
Precipitation	Operation maintained to 1 foot/hour
Power Supply	12 VDC

Other Requirements:

1) Strain rosettes shall be bonded or soldered to the surface of the structural steel in accordance with the sensor manufacturer's recommendations.
2) In order to ensure a complete bond between the sensor and the base steel, the steel surface shall be prepared by grinding to expose bare metal, if recommended by the sensor manufacturer. The area of paint removal by grinding shall be minimized. The sensor shall be installed within 24 hours of the grinding to expose bare metal process.
3) The locations of paint removal shall be submitted in writing to the Engineer for review and approval prior to physical work. Such acceptance by the Engineer does not relieve the Contractor of his responsibility for complying with applicable OSHA and DEEP regulations.
4) All sensors shall be protected per the manufacturer's requirements for long-term performance in the outdoor environment.
5) Upon completion of sensor installation, any exposed steel areas surrounding the sensors or mounting blocks/devices shall be protected from corrosion. The Contractor shall be required to submit their proposed protective coating system for review and approval by the Engineer a minimum of twenty (20) calendar days prior to sensor installation. The proposed protective coating system shall be suitable for a marine environment and acceptable to the sensor manufacturer. Once approved, the protective coating shall be applied per the manufacturer's recommendation within 24 hours of the installation and acceptance of the sensor. The Contractor shall be responsible for maintaining the coating including any reapplication as necessary or at the discretion of the Engineer for the duration that the sensors are in place.
6) Application shall be performed by brush or roller methods only.
7) The Contractor shall supply clean tarps for the purpose of containing and collecting debris generated from paint removal. The tarps shall not be measured for payment but shall be included in the general cost of the work.
8) The Contractor shall be responsible for disposing of all removed materials, including tarps.

A. 2.2.7 Temperature Sensors

A total of seventeen (17) temperature sensors shall be installed across the bridge to measure the air, concrete and steel surface temperatures as listed in the Sensor Summary Table in the plans. Temperature sensors may be installed over the painted surface if acceptable to manufacturer's recommendations. These sensors and their wiring shall be robust to withstand environmental conditions during the monitoring period.

Table A. 2.2.7 – Temperature Sensor Performance Requirements

Measurement Range	-40°C to 80°C (-40°F to +140°F)
Sensor Sampling Rate	1/minute or less
Accuracy	±0.2°C (0.36°F)
Resolution	0.1°C (0.18°F)
Power Supply	12 VDC

Other Requirements:

1) Should removal of paint be required to ensure a sufficient bond, the locations of paint removal shall be submitted in writing to the Engineer for review and approval prior to physical work. Such acceptance by the Engineer does not relieve the Contractor of his responsibility for complying with applicable OSHA and DEEP regulations.
2) The area of paint removal, if required, shall be prepared by grinding to expose bare metal, if recommended by the sensor manufacturer. The area of paint removal by grinding shall be minimized. The sensor shall be installed within 24 hours of the grinding to expose bare metal process.
3) All sensors shall be protected per the manufacturer's requirements for long-term performance in the outdoor environment.
4) Upon completion of sensor installation, any exposed steel areas surrounding the sensors and associated equipment shall be protected from corrosion. The Contractor shall be required to submit their proposed protective coating system for review and approval by the Engineer a minimum of twenty (20) calendar days prior to sensor installation. The proposed protective coating system shall be suitable for a marine environment and acceptable to the sensor manufacturer. Once approved, the coating shall be applied within 24 hours of the installation and acceptance of the sensor. The Contractor shall be responsible for maintaining the coating including any reapplication as necessary or at the discretion of the Engineer for the duration that the sensors are in place.
5) Application shall be performed by brush or roller methods only.
6) The Contractor shall supply clean tarps for the purpose of containing and collecting debris generated from paint removal. The tarps shall not be measured for payment but shall be included in the general cost of the work.
7) The Contractor shall be responsible for disposing of all removed materials, including tarps.

A. 2.2.8 Biaxial Tiltmeters

A total of six (6) biaxial tiltmeters are listed in the Sensor Summary Table in the plans which shall be used to monitor the tilting movements at the top of each tower leg at Tower Pier 2 and Tower Pier 3 as shown in the plans. Additionally, two (2) reference or dummy tiltmeters shall be installed to evaluate the sensor's long-term stability and sensitivity to the ambient environment. The dummy sensors shall be mounted at the base of each tower pier where tilt movements are expected to be near zero.

Table A. 2.2.8 – Biaxial Tiltmeter Performance Requirements

Sensor Type	2D Inclinometer
Measurement Range	±10 degrees
Sensor Sampling Rate	10 Hz or less
Accuracy	±0.10% F.S.
Resolution	0.00005 degrees (8 arc seconds)
Nonlinearity	< 0.3% F.S.
Operating Frequency	1400-3500 Hz
Operating Temperature	-20°C to 80°C (-4°F to +140°F)
Power Supply	12 VDC

A. 2.3 Cabling

All data cables shall be properly sized, insulated, and braided-shielded for optimal noise reduction. All connections to sensors and data acquisition equipment must be solid, properly insulated, and well protected against the environment. Splice connections of data cables shall be avoided. Power and sensor signal cables must be separately installed and shall not be collinear.

All cables shall be properly labeled with a complete record of the sensor to which each cable is connected.

Drain holes may be used for cable routing provided the cables or any encasement thereof do not restrict the opening by greater than 75% of the existing diameter.

All Cables shall be neatly fastened and secured to the structure.

A. 2.4 Data Acquisition Equipment and Software

Data acquisition units shall be provided and configured to collect measurements from all the sensors at the required sampling rates as specified above. In accordance with Article 1.05.02 of the standard specifications, the Contractor shall submit temporary work plans and product data for the proposed design, configuration, and layout of, as well as communications among, all the data acquisition units for the entire SMS.

Monitoring data for all sensor measurements shall be delivered wirelessly to a designated server on a daily basis in the format specified in Construction Methods for TASK B - DATA COLLECTION AND DELIVERY.

The data acquisition equipment shall have an internal storage capacity of at least 30 days of monitoring data.

Receptacles for 120V AC power supply are available throughout the bridge as shown in the plans. Local backup batteries with a minimum operating capacity of 96 hours shall be provided to prevent interruptions to continuous monitoring. Power protection must meet or exceed UL60950 Standard for Safety of Information Technology Equipment.

All data logger components shall be housed in appropriately sized NEMA 4X enclosures with thermostatically controlled vents or heaters to maintain the operating environment within the enclosures.

The data acquisition software shall have the capabilities for measurement control, data collection and manipulations, data display, as well as data transmission. The software shall also have the flexibility for remote adjustments to meet the Engineer's needs for data management during the monitoring period.

A. 2.5 Wireless Communication Devices

The Contractor shall continuously provide all wireless communication necessary for delivering monitoring data remotely to a server specified by the Engineer, as well as for any local communications among various data acquisition units as required.

B.2 Materials for Task B – Data Collection and Delivery

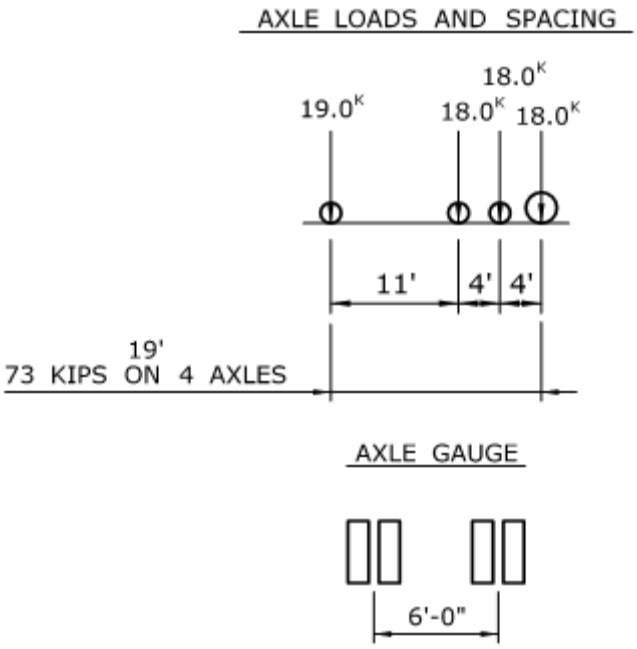
B. 2.1 Equipment and Wireless Service

Materials for this Task shall include those relevant to data collection and delivery such as computer(s), data modems and wireless service plan. The Contractor shall propose data collection equipment compatible with the proposed SMS components for the Engineer's approval.

C.2 Materials for Task C – Live Load Tests

C. 2.1 Test Vehicles

The Contractor shall arrange for the use of five (5) test vehicles and appropriately licensed operators, with Gross Vehicle Weight (GVW) and axle weights within 5% of the CTDOT CT LEGAL LOAD CT-L73.0 Plate ID: LL-CL.1.



VEHICLE CLASSIFICATION	
RATING LEVEL	LEGAL
VEHICLE CLASS	SPECIAL HAULING VEHICLE
VEHICLE TYPE	SINGLE UNIT
	4-AXLE
GVW	36.5 TON

Figure C. 2.1 CTDOT BLRM, CT Legal Load CT-L73.0, Plate ID: LL-CL.1

D.2 Materials for Task D - Cable Plucking Tests

D. 2.1 Equipment

The Contractor shall furnish equipment and any necessary materials for conducting the cable plucking tests including cable excitation tools, access equipment, lighting, etc. All proposed equipment and materials shall be subject to the Engineer's review and approval.

E.2 Materials for Task E - Structural Monitoring System Removal and Restoration

E. 2.1 Surface Repairs

The Contractor shall furnish equipment and materials required to remove the SMS components and restore bridge surface conditions, including, access equipment, lighting, bridge surface repair materials, paint systems, etc. All proposed equipment and materials shall be subject to the Engineer's review and approval.

For restoration of structural steel surfaces which require painting, the proposed paint shall be one of the following 2-coat systems:

Carbomastic 15

Carbothane 133 LV, manufactured by:	Carboline 2150 Schuetz Road St. Louis, MO 63146 (800) 848-4645
Epoxy Mastic Aluminum II HS Poly 250, manufactured by:	Sherwin Williams 425 Benton Street Stratford, CT 06615 (203) 377-1711 (800) 474-3794
Carbomastic 90 Carbothane 133 LV, manufactured by:	Carboline 2150 Schuetz Road St. Louis, MO 63146 (800) 848-4645

All materials for the complete coating system shall be furnished by the same coating material manufacturer with no subcontracted manufacturing allowed. Intermixing of materials within and between coating systems will not be permitted. Thinning of paint shall conform to the manufacturer's written recommendations. The coating thickness shall be in accordance with the Manufacturer's printed instructions. All components of the coating system and the mixed paint shall comply with the Volatile Organic Compounds (VOC) Content Limits and Emission Standards stated in the Connecticut Department of Energy and Environmental Protection's Administration Regulation for the Abatement of Air Pollution, Sections 22a-174-41 through 41a and 22a-174-20(s), respectively.

A Materials Certificate will be required for the selected paint system in accordance with Article 1.06.07, confirming the conformance of the paint to the requirements set forth in the specifications. The selected Topcoat shall conform (as close as possible) in color to the existing topcoat.

3.0 CONSTRUCTION METHODS:

All construction methods shall be as shown on the plans and shall be as specified for each Task described below.

A.3 Construction Methods for Task A – SMS Installation and Commissioning:

A. 3.1 Submissions for Review and Approval:

A. 3.1.1 Experience Verification of Instrumentation Supervisor

The Contractor shall submit the resume of the Instrumentation Supervisor (IS) who will lead the field installation of the SMS and shall be on site during all field activities including installation, acceptance tests, system commissioning, live load tests, cable

plucking tests, system removal, etc., or as required by the Engineer. The submission shall address the following requirements:

1) The IS must have performed sensor installation, data collection, and wireless data transmission for at least one bridge monitoring project in the U.S.
2) The project(s) must have started within the last 8 years.
3) The project(s) must have a monitoring period of at least 12 months.
4) The project(s) must have employed wireless data transmission.
5) The project(s) must have used strain gages plus one other sensor type as listed in the Sensor Summary Table in the plans.

The Contractor shall not start work until the proposed Instrumentation Supervisor has been reviewed and approved by the Engineer. The IS shall not be changed without prior written notification to the Engineer.

A. 3.1.2 Drawings, Technical Specifications, and Work Plans

The following documents shall be submitted to CTDOT for review and approval by the Engineer prior to mobilization for field work:

1) Descriptions and drawings of proposed Structural Monitoring System (SMS) meeting all specified functional and system requirements including, sensor types, data acquisition system layout, and wireless communication plans for data collection and transmission.
2) Technical specifications of all components of proposed SMS.
3) Proposed locations of all the reference/dummy sensors.
4) Power and storage backup plans including mitigation measures to ensure continuous data collection and delivery during unexpected events.
5) Detailed work plans and schedules for system installation per manufacturers' recommendations, acceptance tests, and commissioning, including access methods and lane closure needs as required.
6) Quality Control (QC) procedures for delivery and storage of components, system installation, field validation tests for sensor measurements, and functionality assurance over the 24-month monitoring period.

A. 3.1.3 Pre-Installation and Post-Installation Condition Reports

Prior to any surface preparation for sensor installation, the Contractor shall prepare a Pre-Installation Condition Report to record the existing bridge surface condition of all the areas where sensors will be installed. This report shall include clearly labeled and noted digital photographs at each sensor location.

Upon completion of system installation, the contractor shall prepare a Post-Installation Condition Report to record the completed condition of all the sensors, data collection equipment, as well as wiring, cables, or conduits, including all the fasteners or anchors installed onto the bridge. This report shall be in a similar format to the Pre-Installation Condition Report for easy comparisons including clearly labeled and noted digital photographs at all locations where any components of the SMS are attached to the bridge.

For any unexpected conditions encountered during surface preparation and sensor installation, the Contractor shall immediately report to the Engineer. The Contractor shall submit the Pre-Installation and Post-Installation Condition Reports to the Engineer within two weeks after completion of system installation.

A. 3.1.4 As-Built Plans and Field Calibration Records

After completion of the installation and successful commissioning of the SMS, the Contractor shall submit As-Built plans of the entire SMS as well as field calibration records of sensors.

The As-Built plans shall document the final locations of all components of the SMS after completion of installation including active and reference/dummy sensors, wiring, data acquisition equipment, power backup batteries, wireless communication plans, etc.

For each type of sensor in the completed condition, the Contractor shall provide field calibration records to verify accurate measurements of the physical parameter specified for the sensor, such as strain, displacement, acceleration, etc. The field calibration method may be physical or electronic subject to the approval of the Engineer.

A. 3.2 Quality Inspection, Acceptance Tests, and System Commissioning

A. 3.2.1 Inspections for Work Quality

All sensor installations must be inspected for correct location and alignment, complete bonding, and sufficient protection. All cabling must be inspected for correct labeling and proper anchorages along their entire lengths. All data acquisition devices must be inspected for the security of anchorages and soundness of weather enclosures.

The Contractor shall implement internal Quality Control (QC) procedures and submit documentation to the Engineer for approval. The Engineer will inspect part or all of the Contractor's work.

A. 3.2.2 Acceptance Tests

Immediately following full system installation, the Contractor shall test the SMS operations for the Engineer's acceptance. The acceptance tests shall consist of three parts:

1) An operation test for a minimum of ten (10) continuous days of monitoring data collection and delivery as specified in TASK B - DATA COLLECTION AND DELIVERY.
2) A bridge live load test as specified in TASK C - LIVE LOAD TEST.
3) A cable plucking test as specified in TASK (D) CABLE PLUCKING TEST.

The operation test shall demonstrate that the SMS runs continuously without the development of any errors. The test shall consist of continuous operation of the SMS, including performing data processing, and remote display on a designated server. The test shall be performed for a minimum of ten (10) continuous days. If an error is discovered, it shall be corrected immediately. The duration of the test may be extended as determined necessary by the Engineer.

A. 3.2.3 System Corrections

Based upon findings from the field inspections and acceptance tests, the Contractor shall be responsible for making adjustments to the installed system per the preset requirements to the satisfaction of the Engineer.

A. 3.2.4 System Commissioning

Upon satisfactory acceptance of the SMS in writing from the Engineer (after the inspections, acceptance tests, and system adjustments as described above), a SMS Commissioning Date will be established as the beginning of the twenty-four (24) month monitoring period.

B.3 Construction Methods for Task B – Data Collection and Delivery:

B. 3.1 General

Over the twenty-four (24) month monitoring period, the Contractor shall continuously collect and wirelessly deliver monitoring data from the SMS to a remote, designated server. The designated server will be provided and maintained by CTDOT's Design Consultant. Data delivery will be evaluated and accepted on a daily basis.

The monitoring data from all the sensors of the SMS shall be collected at the required sampling rates as specified in the Sensor Summary Table in the plans. The Contractor is hereby informed that the sampling rates may be reduced by the Engineer during the monitoring period.

B. 3.2 Data Format

The monitoring data shall be delivered in time history form, with the specific electronic format (e.g., ".dat" files, ".txt" files, or data streams) to be determined after the Project begins, in accordance with the following requirements:

1) Each data delivery unit is for a 24-hour day with the time stamp ranging from 00:00:00 to 23:59:99 after the date.
2) Data may be delivered in different divisions or groupings, each for a part or all of the sensors of the same type at a specific sampling rate.
3) All data and/or files must be explicitly labeled with consistent names for sensors and data divisions/groupings throughout the entire monitoring period.

The following is a sample data file for four (4) displacement transducers at a sampling rate of 20Hz (0.05 second time interval) over a time period of 1.00 second including 21 records. The names of the four sensors are "D1_C_NW", "D2_C_SW", "D3_C_NW", and "D4_C_NE".

"TIMESTAMP","RECORD","D1_C_NW","D2_C_SW","D3_C_NW","D4_C_NE"
"TS","RN","inches","inches","inches","inches"

"2017-06-20 18:00:00",91830,2.864177,2.846374,0.9357423,6.637329
"2017-06-20 18:00:00.05",91831,2.864104,2.863018,0.9393985,6.635016
"2017-06-20 18:00:00.1",91832,2.870385,2.855161,0.9424356,6.643025
"2017-06-20 18:00:00.15",91833,2.867249,2.846511,0.9363592,6.630674
"2017-06-20 18:00:00.2",91834,2.866039,2.855021,0.9344152,6.633711
"2017-06-20 18:00:00.25",91835,2.873425,2.8602,0.929633,6.643477
"2017-06-20 18:00:00.3",91836,2.862581,2.84888,0.9312826,6.627229
"2017-06-20 18:00:00.35",91837,2.865549,2.854213,0.9345191,6.636378
"2017-06-20 18:00:00.4",91838,2.867173,2.859032,0.9305261,6.639971
"2017-06-20 18:00:00.45",91839,2.86226,2.852898,0.9225762,6.635644
"2017-06-20 18:00:00.5",91840,2.866654,2.852461,0.9303972,6.636617
"2017-06-20 18:00:00.55",91841,2.867652,2.855954,0.9350054,6.635026
"2017-06-20 18:00:00.6",91842,2.873713,2.856197,0.9182903,6.633779
"2017-06-20 18:00:00.65",91843,2.867337,2.854764,0.9140036,6.639677
"2017-06-20 18:00:00.7",91844,2.87761,2.848283,0.9199077,6.640744,
"2017-06-20 18:00:00.75",91845,2.868293,2.851979,0.9253747,6.639903
"2017-06-20 18:00:00.8",91846,2.866004,2.858789,0.9266227,6.632388
"2017-06-20 18:00:00.85",91847,2.865339,2.852957,0.9308509,6.631148
"2017-06-20 18:00:00.9",91848,2.861262,2.85212,0.9334728,6.630547,
"2017-06-20 18:00:00.95",91849,2.870265,2.855795,0.9254977,6.650356
"2017-06-20 18:00:01",91850,2.873418,2.857176,0.9401094,6.647738

B. 3.3 Review of Data:

The data receiving portal of the designated server will check the quantity and quality of the monitoring data to be delivered by the Contractor on a daily basis.

CTDOT's Design Consultant (Engineer) will analyze the monitoring data and establish response envelopes of all the sensors over time. The Engineer will also use the reference/dummy sensors to evaluate the stability of the active sensors over time and assess their drifts due to temperature changes.

The Engineer will notify the Contractor when invalid data is identified from the receiving server. Examples of such instances may include but be not limited to unusual or significant noise levels, unusual or significant drifting of sensor response(s), abnormal responses due to possible disconnection of sensor(s) or cable(s), etc. The Contractor shall take investigative or corrective actions within three (3) days upon receiving such notification from the Engineer.

C.3 Construction Methods for Task C – Live Load Tests

C. 3.1 General:

Under the direction of the Engineer, the Contractor shall conduct multiple test runs on each of the I-95 NB and I-95 SB bridges using the test vehicles while the bridge is closed to traffic intermittently. The Contractor shall obtain and record all the wheel weights of all the test vehicles on Site using portable scales prior to the load test on the same day.

C. 3.2 Road Closures:

Each load test will be conducted during nighttime hours to reduce traffic disruptions on a date and time period that has been approved by the Engineer. The Contractor shall coordinate with CTDOT to schedule the Connecticut State Police (CSP) to conduct ramp closures and intermittent rolling closures to bridge traffic during each live load test. CTDOT will be responsible for contacting the CSP.

C. 3.3 Test Runs:

Table C.3.1 lists all the test truck crossing patterns and test speeds to be conducted on each of the NB and SB bridges. For each bridge (I-95 NB and I-95 SB), there are 12 test runs at slow speed (5 MPH) and 5 test runs at a 50 MPH travel speed. The 5 MPH and 50 MPH test runs of the same crossing pattern are for measuring and assessing the effects of vehicle loading dynamic impact. For each pair of those test runs, the same test vehicle must be used and must maintain the same lateral position while crossing the bridge. Test runs are subject to modifications by the Engineer and may need to be repeated as deemed necessary by the Engineer based on field operation conditions.

Table C.3.1 Crossing Patterns of Test Vehicles

Pattern	Bridge	Descriptions	Speed
1NB/1SB	I-95 NB/SB	Single truck crossing Right Shoulder	5 MPH
2NB/2SB	I-95 NB/SB	Single truck crossing Lane 1	5 MPH & 50 MPH
3NB/3SB	I-95 NB/SB	Single truck crossing Lane 2	5 MPH & 50 MPH
4NB/4SB	I-95 NB/SB	Single truck crossing Lane 3	5 MPH & 50 MPH
5NB/5SB	I-95 NB/SB	Single truck crossing Lane 4	5 MPH & 50 MPH
6NB/6SB	I-95 NB/SB	Single truck crossing Lane 5	5 MPH & 50 MPH
7NB/7SB	I-95 NB/SB	Single truck crossing Left Shoulder	5 MPH
8NB/8SB	I-95 NB/SB	Two trucks crossing side-by-side Lanes 1 and 2	5 MPH
9NB/9SB	I-95 NB/SB	Two trucks crossing side-by-side Lanes 2 and 3	5 MPH
10NB/10SB	I-95 NB/SB	Two trucks crossing side-by-side Lanes 3 and 4	5 MPH
11NB/11SB	I-95 NB/SB	Two trucks crossing side-by-side Lanes 4 and 5	5 MPH
12NB/12SB	I-95 NB/SB	Five trucks crossing side-by-side Lanes 1 to 5	5 MPH

C. 3.4 Operation Plan:

Each rolling closure of I-95 NB or I-95 SB is expected to be approximately 15 minutes. Multiple test runs may be completed during each closure. The limits of the PHMB are easy to identify by the pylons on each end of the bridge. After a test vehicle clears the bridge limit, it should adjust its speed and proceed at the posted advisory speed limit.

The right shoulder and the right lane of the bridge may be closed to traffic during allowable times as specified to serve as a staging area for the test trucks during the live load tests. The closure of the right shoulder and the right lane of the I-95 NB Bridge in the proximity of Tower Pier No. 2 may also serve as the work area for the cable plucking test as described in the TASK D - CABLE PLUCKING TESTS.

The Contractor shall propose a detailed operation plan to execute all the live load test runs while meeting all the requirements of Section 1.08 – Prosecution and Progress and Item #0971001A – Maintenance and Protection of Traffic. The Contractor shall submit their operation plan for the Department's review and approval in advance of each live load test.

C. 3.5 Logs:

The Contractor shall collect measurements from all sensors of the SMS for all the test runs of each live load test.

Upon completion of each live load test, the Contractor shall submit detailed logs for documenting all the test runs performed as well as monitoring data to CTDOT. The logs shall include the start and finish times, test truck(s) crossing pattern and speed, as well as clearly labeled and noted digital photos of all the test runs.

D.3 Construction Methods for Task D – Cable Plucking Tests

D. 3.1 General:

A cable plucking test involves manually exciting a cable for free vibration for a minimum of 30 seconds while recording its vibration time histories using accelerometers. The

acceleration time histories are then used to derive the natural vibration frequencies of, and assess the tension in, the cable.

Each existing cable features a damper located adjacent to the base at road level. Said dampers consists of an arm attached to a collar.

D. 3.2 Test Method and Reporting:

For the PHMB, each cable plucking test requires manually exciting each of the eight (8) instrumented cables on the south tower leg of Tower Pier No. 2 in Span 2 as shown in the SMS plans. Each cable shall be excited under two conditions as explained below. Manual excitation of the cables may be performed by hanging ropes or by hitting with a rubber hammer at a proper elevation to obtain reasonable amplitudes of cable vibration.

The Contractor shall perform the cable plucking test, record the acceleration time histories of each cable, and submit to the Engineer for analysis upon completion of each cable plucking test. The Engineer will be on Site during the cable plucking test and will derive vibration frequencies of each cable using a Fast Fourier Transform (FFT) algorithm. Cable plucking test shall be repeated for some or all of the cables as deemed necessary by the Engineer based on field operation conditions.

Each cable shall first be excited with the damper engaged. Upon completion of testing all engaged cables, the Contractor shall disengage the damper and re-excite each cable. Upon completion of testing the disengaged cables, the Contractor shall re-engage the damper at each cable. The Contractor shall maintain and protect all components of the damper while disengaged. At no point in time shall the Contractor leave the site with dampers disengaged.

The Contractor shall ensure that data collected while the dampers are engaged is clearly identified from that collected while the dampers are disengaged.

D. 3.3 Scheduling:

Cable plucking tests will be conducted during nighttime hours to reduce traffic disruptions. The right shoulder and the right lane of the I-95 NB Bridge in the proximity of Tower Pier No. 2 shall be closed to traffic to serve as the work area during the cable plucking test. This closure should be coordinated with the live load test as described in the Construction Methods for TASK C - LIVE LOAD TEST.

D. 3.4 Logs:

Upon completion of each cable plucking test for the eight (8) instrumented cables, the Contractor shall submit detailed logs for documenting all the tests performed as well as measured acceleration time history data to CTDOT. The logs shall include the start and finish times, cable identification, excitation method, sensor locations as well as clearly labeled and noted digital photos of all tests.

E.3 Construction Methods for Task E – Structural Monitoring System Removal and Restoration

E. 3.1 General:

The Contractor shall remove all the components of the SMS after receiving the Notice for Successful Completion of 24 Months of Monitoring from CTDOT. All removed monitoring equipment shall become property of the Contractor.

Upon removal of the SMS, the Contractor shall repair any bridge surface to the condition documented in the Pre-Installation Condition Report, or as directed by the Engineer. Possible repairs may include but are not limited to patching of local concrete spalls left by mechanical anchorages of sensors or cables, and recoating of structural steel surfaces in locations where the existing coating was damaged or removed.

The Contractor shall restore all steel areas where paint was previously disturbed by removing the protective coating and field painting the area as specified elsewhere within this document.

Containment(s) for paint removal and collection of debris shall be designed and erected to contain, as well as facilitate the collection of debris from the paint removal operations. Description of the containment(s) shall be submitted to the Engineer for review and comments prior to any paint removal. Review of the containment means by the Engineer shall in no way relieve the Contractor of his responsibility for the containment.

In preparation of any paint removal and/or removal of protective coating, the structural steel shall be power tool cleaned according to SSPC-SP 15 "Commercial Grade Power Tool Cleaning." The power tools (needle guns, grinders, etc.) shall be equipped with HEPA vacuum attachments. Before the power tool cleaning, all dissolvable foreign matter, such as oil, grease, and dust shall be removed by wiping or scrubbing the surface with rags or brushes wetted with solvent in accordance with the provisions of SSPC-SP 1 "Solvent Cleaning." Clean solvent and clean rags or brushes shall be used for the final wiping. The cleaned surface shall be accepted by the Engineer. If the surface is determined to meet the requirements of SSPC-SP 15, painting operations can commence. **Note:** Chemical stripping and abrasive blast cleaning will not be permitted.

After the designated areas of paint removal and/or removal of protective coating have been inspected and accepted according to the surface preparation specification, SSPC SP 15, the steel surfaces which are to receive the field touch-up paint shall be cleaned immediately prior to coating operations by wiping or scrubbing the surface with rags or brushes wetted with solvent. Use clean solvent and clean rags for the final wiping.

- Solvent must be compatible with the specified coatings. Solvent cleaned surfaces shall be primed before any detrimental recontamination or corrosion occurs. Follow manufacturer's safety recommendations when using any solvent.
- All foreign materials such as dirt, dust, loose rust scale, sand, bird droppings, and all materials loosened or deposited on the steel surface by cleaning operations

shall also be completely removed by vacuuming before any painting operations commence.

- Failure by the Contractor to properly prepare and clean surfaces to be painted in accordance with the specifications shall be cause for rejection by the Engineer. All surfaces that are rejected shall be cleaned and painted to the satisfaction of the Engineer in accordance with the specifications, at no additional cost to the State.

The method for coating application shall be by brush and roller equipment. The containment for paint application shall consist of drop cloths and a solid platform bottom. Storage, opening, mixing, thinning and application of the paint shall be accomplished in strict accordance with the specified Contract requirements and procedures published by the paint manufacturer and supplier. The Contractor shall have at the Project site, at all times, the current copies of all technical data, recommendations and procedures published by the paint manufacturer. All coatings shall be supplied in sealed containers bearing the manufacturers name, product designation, batch number and mixing/thinning instructions. Leaking containers shall not be used. Paint shall be furnished in the manufacturer's original sealed and undamaged containers. For multiple component paints, only complete kits shall be mixed and used. Partial mixing is not allowed. The paint shall be applied to produce a uniform smooth coat without runs, streaks sags, wrinkles, or other defects. The Contractor shall provide a suitable facility for the storage of paint, which is in accordance with the latest Federal and State regulations. This facility must provide protection from the elements and insure that the paint is not subjected to temperatures outside the manufacturer's recommended extremes. The Engineer shall be provided access to the stored paint at any time, for inspection and to witness removal of the materials. The Contractor's facility for the storage of paint is subject to the approval of the Engineer.

Solvent cleaning just prior to coating application or coating application work shall be performed when the conditions are as follows:

- The relative humidity is at or below 80% and when there is no falling rain or dew present, or anticipated, before a prepared surface can be coated.
- The substrate is not damp or covered by frost or ice.
- The surface temperature and air temperature are between 50°F and 100°F.
- The surface temperatures of the steel and air are more than 5°F above the dew point temperature, as determined by a surface temperature thermometer and electric or sling psychrometer.

If the requirements of the coating manufacturer differ from the ranges provided above, comply with the most restrictive requirements unless directed otherwise by the Engineer in writing.

For any unexpected conditions encountered during sensor removal and restoration, the Contractor shall immediately report to the Engineer.

E. 3.2 Submittal:

The Contractor shall submit proposed repair methods and procedures to the Department for review and approval prior to start of removal and restoration work.

For restoration of areas where paint was removed, a minimum of 20 calendar days before associated surface preparation and coating application work, the painting Contractor shall submit the following for acceptance:

1. A copy of the Contractor's written procedures to be used to control the quality of surface preparation and coating application including monitoring of ambient conditions, surface cleanliness and profile, coating mixing, dry film thickness and final film continuity.
2. A copy of the written surface preparation and application procedures. This written program must contain a description of the equipment that will be used for surface preparation, including the remediation of soluble salts, and for paint mixing and application. Coating repair procedures shall be included.
3. Containment method (paint removal/collection of debris, surface preparation, coating applications, coating applications with heat, etc.).
4. If the application of heat is proposed for coating application purposes, provide information on the heat containment and procedures that will be used, with data sheets for the equipment. Note: If heat is used for coating operations, the heat and containment must be maintained to provide the required temperatures for the duration of the cure period.
5. Proof of SSPC-QP1 qualifications and CAS-certification(s), as applicable.
6. Proof that the finish coat complies with the color and gloss retention performance criteria of SSPC Paint 36, Level 3, for accelerated weathering.
7. Coating product information, including coating manufacturer, product name, application instructions, technical data, MSDS and color chips.

The Contractor shall not begin any existing protective coating removal work until the Engineer has accepted the submittals. The Contractor shall not construe Engineer acceptance of the submittals to imply approval of any particular method or sequence for conducting the Work, or for addressing health and safety concerns. Acceptance of the submittals does not relieve the Contractor from the responsibility to conduct the work in strict accordance with the requirements of Federal, State, or local regulations, this specification, or to adequately protect the health and safety of all workers involved in the Project and any members of the public who may be affected by the Project. The Contractor remains solely responsible for the adequacy and completeness of their procedures and work practices, and adherence to them.

E. 3.3 Scheduling:

The Contractor shall coordinate with CTDOT to determine suitable time windows for removing the SMS and restoring bridge surface conditions based on the work needs identified during removal of the SMS. The Contractor shall also be responsible for

determining the needs for access equipment and traffic control for safe operation of this work in accordance with relevant regulations and standards.

E. 3.4 Final Condition Report:

The Contractor shall prepare a Final Condition Report after system removal and bridge surface restoration. This report shall include clearly labeled and noted digital photographs at each sensor location and shall be in a similar format to the Pre-Installation and Post-Installation Condition Reports for easy comparisons.

The Contractor shall submit the Final Condition Report to the Engineer within two weeks after completion of system removal and restoration.

E. 3.5 Walk Through:

Upon receipt and review of the Final Condition Report the Engineer shall schedule a walk-through to be conducted by representatives of CTDOT and the Contractor. The purpose of the walk-through is to identify and document any bridge surfaces that were not completely repaired by the restoration work to the level in the Pre-Installation Condition Report or as directed by the Engineer.

E. 3.6 Punch List and Addendum to Final Condition Report:

As a result of the walk-through, a punch list shall be prepared by the Contractor to document outstanding repairs, if any, to completely restore the bridge surface condition. The Contractor shall complete these outstanding repairs within one week, or as directed by the Engineer, and submit an Addendum to Final Condition Report.

E. 3.7 Notice for Satisfactory Completion of SMS Removal and Restoration:

A Notice for Satisfactory Completion of SMS Removal and Restoration will be issued by CTDOT upon satisfactory completion of the punch list and review of the Addendum to Final Condition Report.

4.0 METHOD OF MEASUREMENT GENERAL:

This item, being paid on a lump sum basis, will not be measured for payment; a Schedule of Values is required for the Engineer's review. The Schedule of Values shall address the following Tasks and components (with estimated quantities):

Task A - Structural Monitoring System Installation

Accelerometers (biaxial) (8 each)

Anemometer (1 each)

Crackmeters (for concrete) (42 each)

Displacement Transducers (12 each)

Stain Gages (for concrete) (152 each)

Strain Rosettes (tri-axial for steel) (4 each)

Temperature Sensors (17 each)

Tiltmeters (bi-axial) (6 each)

Reference/Dummy) Sensors (10 each)

Cabling (entire system) (1 lump sum)

Data Acquisition Equipment/Software (entire system) (1 lump sum)

Wireless Communication Devices (entire system) (1 lump sum)

As-built Plans, Technical Specifications, and Field Calibration Records (entire system) (1 lump sum)

Materials and Labor for Maintaining 24-Month Full Functionality (spare parts, power backup batteries, data backup devices, etc.) (1 lump sum)

Note: All costs associated with protective coatings as required per this special provision will not be measured for payment and shall be included in the cost for the sensor type, as applicable.

Task B - Data Collection and Delivery

Data Collection and Wireless Delivery from all Sensors (per month, excluding live load or cable plucking test data) (24 months)

Note: The monitoring month is measured from the SMS Commissioning Date or effective start date following the restoration of any data collection interruptions which may or may not be the first day of the calendar month. In developing the Schedule of Values, the value for this task shall be no less than 15% of the total lump sum bid price for Item No. 0601900A Structural Monitoring System.

Task C - Live Load Tests

Live Load Test Including Test Data and Logs (3 each)

Task D - Cable Plucking Tests

Cable Plucking Test Including Test Data and Logs (3 each)

Task E – Structural Monitoring System Removal and Restoration

Structural Monitoring System Removal (1 lump sum)

Bridge Surface Condition Restoration and Work Logs (1 lump sum)

Note: All costs associated removal of protective coatings and field painting of structural steel as required per this special provision will not be measured for payment and shall be included in the cost for the sensor type, as applicable.

Note: In developing the Schedule of Values, the value for this task shall be no less than 2% of the total lump sum bid price for Item No. 0601900A Structural Monitoring System.

5.0 BASIS OF PAYMENT:

General

This item will be paid for at the Contract lump sum price for "Structural Monitoring System" accepted in place which shall include all materials, labor, equipment, and tools incidental thereto.

Task B – Data Collection and Delivery

The Engineer will evaluate the quantity and quality of the monitoring data at the designated remote server on a daily basis. The Contractor is required to monitor the system and maintain 100% output functionality for each sensor type for the duration of the monitoring period. If missing data is identified, the Contractor shall be required to investigate the cause and take corrective action within five calendar days. The Contractor shall submit their proposed repair procedure(s) and anticipated timeframe to restore the system to 100% functionality to the Engineer for review and approval. Should the Contractor fail to restore the system to 100% functionality within the approved period, the Engineer shall reserve the right to reject the data, and if rejected, refuse payment(s) for the affected month(s). Should the data be rejected, the Engineer shall extend the total duration of the monitoring period to ensure the required quantity of data is collected as specified within these contract documents.

Within each monitoring month, in order to be eligible for payment, the Contractor is required to maintain 90% output functionality for each sensor type. During each monitoring month, if more than 10% of monitoring data is missing for any sensor type, the Engineer shall reserve the right to reject the data and refuse payment(s) for the affected month(s). Should the data be rejected, the Engineer shall extend the total duration of the monitoring period to ensure the required quantity of data is collected as specified within these contract documents.

Requests for time extensions will be reviewed on a case by case basis, per Article 1.08.08. Liquidated Damages shall apply if the Contractor fails to restore the system to the Engineer's satisfaction, within the approved period. The Contractor shall demonstrate they are actively engaged/pursuing to repair the system to 100% functionality. Once the system is restored to the Engineer's satisfaction, an effective start date for a new monitoring month shall be established. In no case will a new monitoring month be established if the system is not performing at 100% functionality.

Pay Item	Pay Unit
Structural Monitoring System	L.S.