

The particular technical specification given here-in-under is added at the end of the chapter 11 "Drilling" of Annexure 4.03 of Volume IV.

12 Instrumentation and Monitoring

12.1 Scope of Work

General

- i) The Contractor shall supply, install, calibrate, test, survey and maintain instrumentation as specified in this section or as directed by the Employer. The Contractor shall supply and install all measuring equipment and construct terminal structures, protective surrounds for instruments, excavate pits and trenches, drill holes, install pipes and fittings, and cast concrete where required.
- ii) The extent, type, and location of the individual instruments shall be as specified herein and as per design required. The number and location of the instruments may be altered by during the construction period, according to the requirements.
- iii) The Contract Documents give only the number, general type, and general arrangement of the instruments to be supplied by the Contractor.
- iv) The design and drawings indicate the detail arrangement of the instruments to be provided by the Contractor.
- v) Instruments shall be preferably vibrating wire type. All instrumentation operating on electrical or hydraulic systems shall be accompanied by individual test certificates, and shall be tested prior to installation, unless specifically stated otherwise.
- vi) All instruments shall be installed to the lines and elevations shown on the Drawings as the work progresses during construction.
- vii) The installation of instruments may interface with the overall construction progress. The Contractor shall make provision for any such interface in his construction planning. He will not be entitled to any compensation or extension of the Time for Completion by reason of any such delays, including repair and replacement of damaged instruments.
- viii) No instruments or any of their components shall be purchased prior to design approval. However, approval of the Contractor's proposals and drawings or data shall not relieve the Contractor from his sole responsibility to meet all the requirements under the Contract.
- ix) All instruments shall be guaranteed against defect in installation/manufacturing for at least 18 months from the date of supply or 12 months from the date of embedment/installation, whichever is later. All defective instruments during the period of guarantee shall be replaced by the Contractor at no cost to the Employer. However, the buried defective instruments shall not be returned to the Contractor.
- x) All the instruments shall be supplied with at least 3 copies of instruction manuals explaining installation procedures, guidelines, necessary protection measures, maintenance requirements, etc., complete in all respects.

- xi) All instrument shall be procured from reputed original/primary manufacturer or their authorised agent. Instruments procured from secondary manufacturer or assembling agencies shall not be accepted.

Measuring Devices

- i) Instrumentation and monitoring for underground works include the following:

- Rock bolt Load cells
- Base Load cells
- Load cells
- Single and multiple point borehole extensometers
- V.W Pore pressure meters (piezometers)
- Bi-Reflex Targets
- Convergence Hooks
- Tape Extensometer with calibration frame
- Concrete/total pressure cells
- Arc Weldable Strain Gage, Re bar strain meter, Group strain meter
- Switchbox/Readout units
- Field and laboratory tests.
- Radar type Automatic water level recorder
- Automatic weather station,
- Strong Motion Equipment

12.2 Submittals

- i) The Contractor shall submit with his bid general information on the instrumentation they proposes to install, as brand and type, including peripherals, read out units or probes, which may be necessary for the instruments proposed to be used.
- ii) Within 112 days after the date of the letter of Acceptance, the Contractor shall submit details of the instruments proposed for the installation. These shall be consistent with the general information on the instrumentation submitted by the Contractor with his bid as well as with any modifications subsequently agreed to by the Engineer-in-Charge and the Contractor, and shall include:
- Names of instrument vendors mentioning their credential, status i.e. original or secondary manufacturer, etc. which shall have to be approved by the Owner.
 - Detailed description of all instrumentation, cabling and accessories including any ancillary measuring equipment he proposes to install.
 - Evidence of the successful performance of the instrumentation proposed for installation.

- Manufacturer's instructions for the installation, testing and operation of the instruments.
- Schedule of monitoring of instruments.

iii) During the execution of the Works, the Contractor shall submit any further details regarding the instrumentation required by the Employer. The Contractor shall prepare surveys and furnish "as-built" drawings for all installed instruments.

12.3 Skilled Personnel

- i) The whole of the instrumentation work shall be carried out under the direct supervision of a senior supervisor, accepted by the Employer and employed by the Contractor, who is well experienced in all types of instrumentation and installation work and who understands the purpose and function of all instruments being installed.
- ii) Installation and calibration of the instruments shall be carried out by skilled technicians, acceptable to the Employer, well experienced in the installation of instruments and who have a thorough understanding of the purpose and function of the particular instruments being installed.

12.4 Installation

- i) The Contractor shall install and calibrate all instrumentation conforming to the suppliers' instructions and shall, where necessary, expose all partially installed instruments, cables and tubes to continue their installation, including carrying out all survey work required to locate such instruments. A representative of instrument's manufacturer shall be present during the entire process of installation. The Contractor shall submit to the Employer a certificate issued by the manufacturer regarding the installation of the instruments, as per the instrument's manual. The Contractor shall tag all cables and tubes with identification tags approved by the Engineer-in-Charge to provide continuous identification.
- ii) Cables and tubes shall be installed to the maximum lengths practicable. Splicing and coupling, if essential, shall be performed in accordance with the manufacturer's recommendations. Calibration readings shall be taken prior to and immediately after splicing. Open ends of all incomplete lines of tubing and casing shall be kept plugged or sealed and the Contractor shall at all times during installation keep the insides of casings and tubes free from foreign matter. Cables and tubes shall be protected from mechanical damage.

12.5 Care of Instrumentation

- i) The Contractor shall protect all instruments and connections from damage and displacement during the progress of the work. If damage or displacement of the instruments or connections occurs during the progress of the work, they shall be repaired or replaced immediately by the Contractor.

- ii) The Contractor shall be fully responsible for the maintenance and repair of all instrumentation for the duration of the contract period.
- iii) The Contractor shall recalibrate instruments at the frequency/ period as specified by manufacturer.

12.6 Reading of the Instruments

- i) An initial set of readings on all instruments installed at any particular elevation shall be taken immediately after their installation, and the Contractor shall not place concrete over the instruments or tubes or cables at this location until these readings have been taken.
- ii) The Contractor, after consultation with the Employer, shall programme his work and make all necessary arrangements to record the reading of instruments as soon as possible after their installation. Such arrangements shall include, where necessary, the provision of temporary read out points.

12.7 Instrumentation and Monitoring for Underground and surface Works

12.7.1. General

- i) The Contractor shall supply and install the measuring devices, carry out additional excavation, drilling, construct concrete or mortar pads, grouting, backfilling with concrete, perform the measurement, and record the readings at frequency/period specified in design document for all the Instrument.
- ii) The Contractor shall take utmost care in the recording and analysis of the readings and prevent mixing of readings from different instruments.
- iii) During execution of the Works, the Contractor shall observe, record and submit readings of all the instruments in specified format along with analysis of observed data and at specified frequency/ period to the Employer.
- iv) The Contractor shall make provisions in his planned excavation activities to enable the performance of the rock mechanics testing to be carried out whenever required concurrently with the underground excavation without disruption or delay. No extension of time of Completion of works will be granted to the Contractor due to the performance of such testing.
- v)

12.7.2. Load Cells

Load cells of electronic type shall be installed to monitor the behaviour of rock bolts installed. The load cells shall have the following characteristics:

Capacity:	100 KN to 300 kN
Overload capacity:	50% of Full scale

Accuracy:	0.5% of Full scale
Material of Element	Stainless steel
Welding	Hermetically sealed by welding with vacuum inside
Suitable for 25, 32 and 36 mm diameter rock bolts	
Remote electrical read out	

Each load cell shall be supplied with a cable of minimum 20 m length for the electrical type cells.

At the beginning, the readings shall be taken daily. Later, weekly readings shall be taken till the cessation of any movement or until the Employer permits termination

12.7.3. Base Load Cells

Base load cells shall be used to monitor changes in stress in the rib in very poor rock.

12.7.4. Single and Multipoint Bore-Hole Extensometers

These extensometers shall be installed in underground excavation to measure displacements in the rock mass surrounding the excavation.

The extensometers shall be installed in the boreholes drilled radially on a plane perpendicular to the centreline of the underground structure. The exact location of each measuring section will be determined by the Engineer-in-Charge.

The extensometers to be installed shall be of single point or three-point type. The borehole diameter shall be 76mm or as recommended by the supplier of the extensometers. The measuring heads shall be installed in recesses excavated around the collar prior to the drilling of the hole and shall be protected from damage by a cover plate.

Single point extensometers will have a length of 6 to 18m with 3(three) or 4(four) point extensometers.

Reading of the extensometers shall be done with a digital gauge of 0.01mm scale division. At the beginning, the readings shall be taken daily. Later, weekly readings shall be taken till the cessation of any movement or until the Employer permits termination but latest when the placing of the concrete lining commences.

12.7.5. V.W Pore Pressure Meters (Piezometers), Uplift pressure gauge

Water pressure transducers shall be installed in drilled holes, behind shotcrete, concrete lining, Raft etc. for measuring pore pressure / uplift pressure.

At the beginning, the readings shall be taken daily. Later, weekly readings shall be taken till the cessation of any movement or until the Employer permits termination.

12.7.6. Bi-Reflex Targets

Bireflex targets shall be installed to enable monitoring of surface displacements by means of a total station.

12.7.7. Convergence Hooks

Convergence measurement shall be performed in underground excavation works to determine the relative displacement of opposite measuring points placed around the excavation perimeter.

The measuring points shall consist of the convergence bolts made of stainless-steel pins mounted on a short reinforcing bar grouted into predrilled hole.

Distance changes between the opposite convergences bolts shall be measured by means of tape extensometer connected to the bolts and tensioned between them. Change of length shall be read on a digital gauge. Accuracy of the measurement shall be 1 mm.

The convergence bolts shall be installed within the heading zone after the installation of supports. At the beginning, the measurement shall be carried out daily. Later, weekly readings shall be taken for several months up to the cessation of any movement but latest when the placing of the concrete lining commences.

The convergence measuring tape and the digital gauge shall be calibrated on their corresponding calibration devices before and after each measurement. Digital readout shall be in metric unit.

12.7.8. Concrete/Total Pressure Cells

- Total pressure cells shall measure the pressure normal to the back face of linings.

12.7.9. Arc Weldable Strain Gauge, Re bar strain meter, Group strain meter

These strain gauges shall be used to measure strain in various structural components.

12.7.10. Automatic Weather Station

Feature	Value
Air Temperature sensor	
Sensor Type	SHT35
Range	-40 °C to +60 °C
Resolution	0.01 °C or better
Accuracy	Within ± 0.2 °C or better for complete measuring range.
Relative Humidity Sensor	
Sensor Type	Capacitive/Solid State Humidity Sensor
Range	0 to 100% RH
Accuracy	$\pm 2\%$ RH or better @ 25 °C
Resolution	0.1% or better
Response Time	20 sec or better
Wind Speed Sensor	
Sensor type	Ultrasonic
Range (Operation)	0 to 60 m/s or better
Accuracy	+/- 2% @ 12m/s or better
Resolution	0.1 m/s
Threshold	0.5 m/s or less
Response time	1sec or better
Wind Direction	
Sensor type	Ultrasonic
Range	0 to 360 Degrees
Accuracy	+/- 3 degrees 0 to 35 m/s and +/- 5 degrees 35 to 60 m/s
Resolution	1 deg.
Threshold	0.5 m/s or better
Response time	250 milli sec or better
General	
Self-aspirated	To ensure continuous supply of air. Free from turbulence, water droplets and radiation.
Accessories	All accessories for mounting the instrument at ~1.5mts height above the ground level. e.g. special cross arm clamps or flag, if any, shall be provided.
Automatic Rain Gauge	

ADDENDUM/CORRIGENDUM TO ANNEXURE 4.03(VOL-IV): PARTICULAR TECHNICAL SPECIFICATION
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Sensor	
Sensor Type	Tipping Bucket type with Hall Effect / Reed switch Pickup
Orifice diameter	Shall be 200 mm (approx.)
Range	0 to 200 mm/h
Resolution	0.1 mm
Accuracy	±2% or better at 25.4 cm/hr.
General	
Power Supply	To be powered by Solar Panel provided by bidder with DCP.
Internal Parts	Stainless steel, Anodized aluminium, or UV-stabilized plastic
Levelling	Suitable levelling adjustment screws and circular spirit level must be provided on the base of Tipping Bucket Rain Gauge (TBRG) for levelling the Tipping bucket Mechanism.
Enclosure	NEMA 4 X or better (vertical installation) or IP66 rated housing.
Certification	IMD/WMO certification shall be provided.
Note: Bidder shall provide spout filter and bird cage to prevent ingress of insects and debris.	

12.7.10.1. Solar Panel and Battery for AWS

Mono crystalline Solar panel of rated capacity 50W, Short Circuit Current: 2.5 A or better, Open Circuit Voltage 21 V or better, and Sealed Maintenance Free (SMF) rechargeable battery of minimum 65 AH (12 V) of reputed national brand with enclosure for weather protection, shall be used to power the system. In no sun condition the AWS should operate for at least 15 days. Bidder/vendor should provide a calculation sheet to demonstrate the same.

The system shall have a battery charger of proper rating to charge the battery through the solar panel.

The system shall have photovoltaic battery charge controller for protection of battery from over charging, Under-voltage protection. Short circuit protection and Protection from the lightning strike.

All fixing devices required to fix the solar panel to the tower/mast shall be provided by the vendor.

12.7.10.2. Enclosure

- Minimum 12" x 14" enclosure suitable for data logger with a power supply and one or more peripherals.
- NEMA 4X or better Enclosures.

- Non-Corrosive, UV stabilized material.
- Should have cable entry options and one sealable conduit.
- Fully water proof for heavy precipitation area.
- All connectors must be clearly labelled as to their function.
- The enclosure shall be properly vented with a device, which will not allow humidity to enter in the enclosure.

12.7.10.3. Accessories

- All sensors should be supplied with cables (as required) that are UV proof to ensure good performance for years.
- All support arms holding sensors should be manufactured from anodized aluminium or galvanized steel and fitted to the tower-scaffold by means of stainless steel and/or hot galvanized clamps and stock of screws.
- The sensors provided should come calibrated from the factory with Certificates of Calibration.
- Users and technical service manuals (in English) be included.
- Tools for installation and maintenance must be included.
- One sensor tester; handheld calibration kit.

12.7.10.4. Instrument Tripod Stand/Mast Assembly

The tripod stand/mast for fixing data logger, battery, solar panel etc. should be of Stainless Steel (SS) with minimum 3.0m height. The mast diameter should be minimum 50mm. All accessories/tools for mast mounting must be able to resist a wind speed of 150km/hour.

12.7.10.5. Lightning Protection

The entire unit has to be adequately protected against lightning and build of static charges. The lightning rod should protrude 1 m above the highest point (Antenna) and should be placed in the centre of the pole. The mast should be electrically grounded by following as per CPWD earthing procedures.

12.7.10.6. Earthing for Equipment

The electrical grounding for all other electronic and electrical equipment should be done by following standard CPWD procedure. The earthing for the equipment's should be done separately and should have a minimum distance of 2.5 meter from the earthing done for lightning rod. In no case both the earths should be done in the same earthing rod.

12.7.11. Strong Motion Equipment

12.7.11.1. General

- **Operating Temperature:** -40°C to +60°C or better
- **Humidity Range:** 0% to 100% (non-condensing)
- **Ingress Protection:** IP67 or better
- **Shock Resistance:** Designed to withstand high-shock events ($\geq 5000g$).
- **Standards:** Must comply with international standards such as CE, ISO, IEC, or IEEE standards for seismic instrumentation.
- **Warranty:** At least 3 years of warranty for both hardware and software.

12.7.11.2. Sensor

- **Type:** Tri-axial, Mechanical force balance transducer in a single sealed module with output for one vertical (Z) and two horizontal components N-S and E-W orthogonal to each other.
- **Frequency Range:** 0.1 Hz to 100 Hz.
- **Full-Scale Acceleration Range:** $\pm 2g$, $\pm 4g$, $\pm 8g$ (selectable).
- **Dynamic Range:** ≥ 140 dB or more.
- **Accuracy:** $\pm 0.5\%$ or better.
- **Resolution:** 24-bit or higher (ADC).
- **Linearity:** $< 1\%$ of full scale.
- **Cross-axis Sensitivity:** $< 1\%$ of full scale.

12.7.11.3. Data Logger

- **Sampling Rate:** Configurable from 1 Hz to 500 Hz (typical range).
- **Memory:** Internal memory with minimum 16 GB (expandable up to 128 GB or more).
- **Recording Format:** Must support commonly used seismic data formats (e.g., SEED, miniSEED, or ASCII).
- **Triggering:** Threshold, STA/LTA (Short-Term Average / Long-Term Average), and event- based triggering.
- **Real-Time Monitoring:** Capability to transmit real-time data to remote locations via Ethernet, GSM, or satellite communication.
- **Data Download:** USB, Ethernet, or wireless (Wi-Fi/Bluetooth) capability.
- **Power Consumption:** $\leq 5W$ in continuous mode
- **Backup Power:** Integrated rechargeable battery with a minimum of 72 hours of operation during power outages.
- **Power Supply:** Standard AC mains.

12.7.11.4. Software Requirements

- **Configuration Software:** User-friendly software for configuring accelerographs, adjusting sensitivity, and real-time monitoring.
- **Data Analysis Tools:** Integrated software for post-processing, filtering, and exporting seismic data.
- **Compatibility:** Cross-platform (Windows, Mac, Linux)

12.7.11.5. Additional Features

- **GPS Synchronization:** For precise time stamping of data (± 1 ms accuracy).
- **Self-Diagnostics:** Automatic self-check of key parameters (power, sensor integrity).
- **Expandability:** Support for external sensors and additional channels if needed.

12.7.12. Data Logger

- a) It should have menu driven status monitoring and settings to enable:
- i) View connected sensor data onsite.
 - ii) View real time data and past records onsite.
 - iii) Take data backup in USB drives onsite.
 - iv) View station ID, System Health, etc.
 - v) View system clock onsite.
 - vi) Sensor Measurement/Auto Transmission as scheduled by User.
- b) It should have multiple communication facility including RS-232, SDI-12, USB, and/ or Ethernet (Compact flash), etc.
- c) One or more numbers of SDI-12 Interface ports.
- d) 24 Bit or Better Analog to Digital Converter.
- e) Conversion Accuracy ± 1 LSB
- f) Measuring Interval: 1 min to 24hrs
- g) Should support individual recording intervals for different sensor/parameter connected.
- h) The Data logger should have watchdog timer to reset the system and restore the previous set-up in case of microprocessor resets and power glitch.
- i) Firmware Operating System: Multi-tasking operating system - must log data and transmit at same time.
- j) Internal memory of the data logger should be sufficient to store minimum 10,00,000 readings, expandable to 100,00,00,000 readings or more than 16 GB via internal SDHC card.
- k) If internal memory is full, it should overwrite the data. While overwriting, it

- should delete the oldest data and store the current data.
- l) Power supply: 12V DC, low current drain (quiescent $\leq 10.0\text{mA}$).
 - m) Internal battery backup for clock: Lithium-ion Battery with storage: 3 years.
 - n) Charge Controller: Internal or External.
 - o) User Permissions: System of user rights / passwords, access restricted to authorised personnel.
 - p) Shall receive time synchronization with NAVIC/GPS time (UTC/GMT time) through a NAVIC/GPS receiver connected to the data logger. The time synchronization should happen automatically, at least once in 6 hours.
 - q) Should have a LED Display with Graphical dot matrix of minimum 122×32 pixels or LCD Display of minimum 16×2 Alphanumeric display.
 - r) Should have separate key for navigation of menu and for other functions.
 - s) Should have at least one USB Compatible host for data back-up.
 - t) Sensor Interface: $8 \times$ Sensor Channels, $4 \times$ Sensor Power Control.
 - u) Operating Temperature Range: -40°C to $+60^\circ\text{C}$.
 - v) Battery-Backed SRAM: Minimum 4 MB.
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- w) The data logger software shall be compatible to Microsoft Windows 10 operating system or updated version with all required licenses.
 - x) Necessary accessories: Serial cable + adaptor for notebook connection. All accessories (fixing units, etc.) as required.
 - y) Tools: Complete tool kit for installation and routine maintenance giving full detail (number of pieces and type).
 - z) Manuals: Full documentation and maintenance instructions in English (1 copy per station).

12.8 Switchbox/Readout Unit, Automatic data acquisition & monitoring

The Contractor shall supply Switchbox/readout unit for all instruments for taking reading at convenient points at construction stage and terminating the terminals at Barrage and Power house control room, Valve house and Surge shaft in respect of the Instruments installed at the respective sites. These instruments are intended to be used throughout the O&M of the project where automatic data acquisition & monitoring system shall be provided. Use of Instruments installed in the HRT and Penstock shall be discontinued on completion of construction.

Cables from individual instruments at different locations shall be routed with required peripheral, switch box etc. to fulfill the above stated requirement.

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The switchbox/read out unit shall be portable, battery-operated, designed to read vibrating wire gauge/resistance gauges/thermistors.

The LCD display shall present maximum information including output signal period, linear or frequency reading, gauge temperature, thermistor's Ohm value, gauge factor and type.

The unit shall be able to log data having minimum 128 kb of static RAM. Power supply shall be through rechargeable battery.

- 12.9** Specification of any other instrument specifically not mentioned herein shall be as per the standard requirement and specification of the approved vendor for the item which shall have to fulfil the intended use.