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4 **ROCK SUPPORT**


4.1 **SCOPE OF WORK**

The Specifications described in this Chapter relate to the Work which includes all labour, plant, materials, equipment and services required for the supply, fabrication, installation, testing and maintenance of underground and surface rock support, including rock bolts and grouted anchor bars (rock dowels), of wire mesh and, of structural steel rib supports and steel or precast R.C.C. lagging as specified herein and/or as shown on the drawings and as required by the Project Manager.

4.2 **DEFINITIONS**

- i) For the sake of convenience, the terms used in this Chapter are defined as follows:
 - a) REINFORCEMENT ELEMENT / ANCHOR BOLT is a general term for rock bolts, grouted anchor bars and rock anchors (tendons),
 - b) ROCK BOLT is a stressed/unstressed reinforcement element consisting of a tor steel rod, a grouted anchorage, and an anchor plate. The bolt – which is bonded to the rock over most of its length – may be tensioned after setting of the grout to ensure effective load transfer between bolt and anchor plate,
 - c) GROUTED ANCHOR BAR is an un-tensioned reinforcement element consisting of a rod embedded in a mortar or grout filled hole. It is synonymous with “rock dowel”,
 - d) ROCK ANCHOR is a stressed reinforcement element consisting of a rod or tendon, a mechanical or grouted anchorage, and an anchor plate. The anchor is tensioned between the anchorage and the anchor plate before grouting,
 - e) PRESTRESSED CABLE ANCHOR is a bundle of cables of 15.2 mm □ strands formed of high strength steel wires inserted into PVC sheathing pipes, installed in blind end or through type holes.

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- f) INDIVIDUAL ROCK BOLTING refers to the installation of reinforcement elements in localized areas of instability or weakness as determined during excavation. It is synonymous with “spot bolting”,
- g) PATTERN ROCK BOLTING refers to the installation of reinforcement elements in a regular pattern over the excavation surface.
- h) WIRE MESH is a general term for welded wire mesh fabric and chain link fabric.

4.3 **ROCK BOLTS**


Variations of typical layouts of rock bolting are expected including modifications in the quantities, type, location, pattern, spacing and length of rock bolts and in the rock bolt accessories. Such variations will be determined by the Project Manager as the excavation proceeds, to suit field conditions and shall not be a cause for variation in the unit prices tendered.

4.3.1 **STANDARDS**

The rock bolts shall conform to the latest editions of the following Indian Standards or, where not covered by these Standards, to their equivalent International Standards, subject to the approval by the Project Manager.

IS: 1786	Specifications for high strength deformed-steel bars and wires for concrete reinforcement.
IS: 2062	Steel for general structural purposes.
IS: 10270	Guidelines for design and construction of prestressed rock anchors.
IS: 11309	Method of conducting pull out test on anchor bars and rock bolts.
IS: 13219	Rock bolts for mines (cement grouted) - general requirements.

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4.3.2 SUBMITTALS

- i) At least 30 days prior to the commencement of excavation works, the Contractor shall submit, to the Project Manager, the details of his proposed bolt and anchor systems' equipment to be used for testing and installation of rock bolts.
- ii) The Project Manager reserves the right to require any additional information deemed necessary to be included in the submitted documents.

4.3.3 MATERIALS

- i) Rock bolts shall be either:
 - a) Threaded solid bar type grouted over their full length with suitable resin or cement grouts, and shall be fabricated from high strength deformed bars conforming to IS: 1786 with a diameter of 25 mm and requiring a hole diameter of about 38 mm with a minimum load carrying capacity of 100 kN (10 tonnes) per bolt,
 - b) Standard Swellex type expanding shell anchors with a minimum load carrying capacity of 100 kN (10 tonnes) per bolt.
- ii) Rock bolts shall be provided with all necessary accessories such as resin cartridges or grouting pipes, hard steel washers, nuts and bearing plates and all necessary equipment needed for installation, tensioning, grouting and testing.
- iii) Bearing plates shall be steel plates of a dish shape of minimum dimensions 150 x 150 x 10 mm conforming to IS: 2062 and shall have a hemispherical seating with centralised slot to suit the dimensions of the bolts and allow the bolts to be installed at angles other than perpendicular to the rock face.
- iv) If directed or approved by the Project Manager, the Contractor shall supply and install enlarged flat steel plates or rolled steel U-sections to complement the plate anchors or connect together two or more rock bolts.
- v) Rock bolts may be required to be tapered at the upper end for ease of insertion in a drill hole and equipped at the lower end with a welded ring

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flange to hold a roof plate. Bearing plates which will be permanently exposed, shall be coated before installation with an anti-corrosion protective coating compound. Any defects in the coating shall be adequately recoated after installation. The outer ends of the rock bolts, nuts and washers shall also be coated with anti-corrosion compound after installation and tensioning. The remaining portions of all rock bolts shall be clean and free of all deleterious materials, including dirt, paint and grease.

- vi) The contractor shall maintain on site a reserve supply of all rock bolt types and extensions in lengths, all complete with accessories.

4.3.4 INSTALLATION OF ROCK BOLTS

- i) All rock bolts shall be installed in accordance to the manufacturers recommendations.
- ii) All resins and grouts shall be used in accordance to the manufacturers recommendations.
- iii) The procedure and equipment used for drilling in rock and for installing and tensioning the bolts shall be in accordance with these specifications and subject to review and approval by Project Manager.
- iv) Holes for rock bolts shall be drilled to the exact depths required by the lengths of the bolt at locations shown on the drawings, or as required by Project Manager. The Contractor shall provide access to the face for this purpose as soon as possible after the completion of the excavation of each round or bench.
- v) Holes which are drilled out of place or alignment shall be replaced as required by the Project Manager at no additional cost to OWNER
- vi) The diameter of holes for the installation of rock bolts shall be according to the diameter of resin cartridges or mechanical shells. 25 mm ribbed bolts are normally used in holes \varnothing 38 mm using resin capsules \varnothing 32 mm.
- vii) The rock surface around the drilled holes to receive the bearing plate shall be chipped smooth or be covered with a smooth quick-set cement pad supplied by the contractor.

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- viii) Immediately prior to installation of the bolt, the hole shall be flushed and cleaned of all drill cuttings, debris and water, by inserting a rigid tube to the bottom of the hole and blowing compressed air through the tube as it is slowly withdrawn.
- ix) Unless instructed otherwise, rock bolts shall be installed and tensioned prior to the excavation of the next bench or round excavation. The tension force shall be determined by the Project Manager after completion of the initial testing program.
- x) The Contractor shall provide torque wrenches of a type acceptable to Project Manager. All impact and torque wrenches shall be calibrated once every month..
- xi) All bolts within 10 m of a blasting operation shall be retightened to the approved torque within 4 hours after each blast. If it is found that any bolt will not take the required torque without anchorage slip, a new bolt shall be installed in the immediate vicinity of the unsatisfactory bolt. If at any subsequent time prior to placement of concrete lining, either the Project Manager or the Contractor finds that rock bolts have become loose, then the Contractor shall re-tension any such bolts by applying the specified torque.

4.3.5 TESTING AND MONITORING OF ROCK BOLTS

- i) Bolts shall be tested to the minimum load carrying capacity of 100 kN (10 tonnes) per bolt
- ii) The Contractor shall furnish at least one set of testing equipment including hydraulic jacks, fixing device, hydraulic pump with manometer, extensometer and all necessary accessories. The testing equipment shall be capable of stressing the largest diameter rock bolt to the yield stress of the bolt.
- iii) Prior to the installation of rock bolts in the Works, a series of pull-out tests shall be carried out in different rock types designated by the Project Manager, and which will be representative of the rock expected to be encountered during the excavation, to prove the suitability of the rock bolts.

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During the pull-out test, both the load applied and movement undergone shall be measured. As directed by the Project Manager, qualification tests shall be required for each combination of the rock type/ installation condition to be able to assess the suitability of the rock bolt. The pull-out tests shall be carried out sufficiently in advance of the installation of the rock bolts in the Works so that, in the event that the proposed rock bolts do not meet load-strain requirements, the Contractor shall have time to furnish and test rock bolts of a different type as directed by the Project Manager. The Contractor shall maintain detailed records of the pull-out tests, the result of which will be used to establish relationships between rock quality, type of rock bolts and tensioning.

- iv) During progress of the Work, the Contractor shall perform pull-out tests; stressing up to yield point or 1.5 times the design value, whichever is less, in the presence of the Project Manager, on at least 1 per 50 rock bolts installed. The Project Manager will determine the bolts to be tested.
- v) If any rock bolt fails due to improper workmanship or defect in materials, the Project Manager may order a test on all adjacent rock bolts and all rock bolts so failing shall be rejected, replaced and retested at no additional costs.

4.4 FORE-POLING WITH GROUTED ANCHOR BARS/SELF DRILLING HOLLOW CORE ANCHORS

- i) Where necessary and when authorised by the Project Manager, grouted anchor bars or self-drilling hollow core anchors shall be used for fore-poling as shown on the drawings.
- ii) Material and installation of grouted anchor bars shall be in accordance with clause 4.6.
- iii) Self-drilling hollow core anchors shall be of ϕ 32/36 mm hollow core bars with a lost drill bit at the end. The bars shall be capable of being injected with cement grout and capable of bonding with rock.
- iv) The spacing of the anchors is variable and shall be determined by the Project Manager in response to the geological conditions encountered.

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- v) The anchors shall be installed between the arches in such a fashion that they are supported on the foremost arch and pass under the rear arch. The amount of overlap shall be determined by the Project Manager.


4.5 ROCK BOLTS AS MICRO-PILES


- i) Where necessary and when authorised by the Project Manager, rock bolts shall be used as micro piles to underpin the base of the arch supports.
- ii) The micro piles shall be ϕ 32 mm threaded solid bar type grouted over their full length with suitable cement grouts, and shall be fabricated from high strength deformed bars conforming to IS: 1786.
- iii) The bars shall be installed in ϕ 150 mm cased boreholes of the required length. The holes shall be equipped with grout tubes to enable them to be grouted at their base. The hole shall be filled with grout prior to removal of the casing. After the initial set of the grout the piles shall be injected through the base tubes with a minimum pressure of 2 kg/cm². The actual value shall be determined by the Project Manager.

4.6 GROUTED ANCHOR BARS

- i) The grouted anchor bars will not be stressed. The rods shall be fully grouted with cement mortar grout. Hooks will be welded to the grouted anchor bars and are covered under the Chapter "Steel Reinforcement".
- ii) The rod shall be manufactured from reinforcing bars with a yield stress of not less than 400 MPa. The bars shall comply with IS: 1786. The diameter of bars shall generally be 20 to 36 mm and the length and position shall be as shown on the Drawings or as directed by the Project Manager. For grouted anchor bars, the hole diameter shall be 1.5 times the reinforcing element diameter.
- iii) The surface of the anchor bars shall be clean of rust, scale, dirt or other foreign matter.
- iv) Holes drilled for anchor bars shall be kept plugged until just prior to commencement of grouting operations. Before grouting, each hole shall be thoroughly flushed with water and cleaned with compressed air.

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<div> <div>v)</div> <div>Water shall be removed from the hole before grouting. If the hole cannot be kept dry during grouting, the grout shall be introduced into the end of the hole through a pipe, which shall be gradually withdrawn as the hole is filled.</div> </div> <div> <div>vi)</div> <div>Grout shall have a water to cement ratio of between 0.4 and 0.6 by weight, and a sand to cement ratio of 3:1 by weight, unless otherwise specified by the Project Manager. Admixtures shall be subject to approval by the Project Manager.</div> </div> <div> <div>vii)</div> <div>Anchor bars shall have suitable spacers attached to it to centre the bar in the grout hole and then the anchor bar shall be forced into the grout-filled hole before the initial set of the grout. The bar shall be vibrated or tapped in order to ensure good contact between the steel surface and the grout.</div> </div> <div> <div>viii)</div> <div>Bar ends to be embedded in the concrete structure shall be provided with hooks welded to the bar to provide a good anchorage. In order to facilitate the inserting of the bars into the holes, the hooks can be welded to the anchor bar after installing. The welding and the overlap of the bar end with the hook(s) shall be as approved by the Project Manager.</div> </div> <div> <div>ix)</div> <div>Anchors bars shall be protected after installations in such a manner as to prevent any movement until the grout has hardened. The Contractor shall replace any bars found to be loose after the grout has set.</div> </div> <div> <div>x)</div> <div>The depth of holes indicated on the Drawings or as directed by the Project Manager shall be measured from the effective excavation surface. Should the anchor bars be connected to the reinforcement steel of the concrete structure to be anchored, longer bars shall be provided in case of over excavation, to maintain the required position in the structure.</div> </div> <div> <div>xi)</div> <div>Testing of grouted anchor bars shall be as specified for rock bolts.</div> </div> <div> <div>4.7</div> <div><u>PRESTRESSED CABLE ANCHORS(WHEREVER REQUIRED)</u></div> </div> <div> <div>4.7.1</div> <div><u>GENERAL</u></div> </div> <div> <div>i)</div> <div>Prestressed cable anchors are also proposed to be provided to support the vertical rock faces of the power house machine hall/erection bay along B-</div> </div>		
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line and D-line. Pre-stressed cable anchors comprise a bundle of cables of 15.2mm diameter strands formed of high strength steel wires conforming to IS:6006(latest revision) inserted into PVC sheathing pipes, installed in blind end or through type holes. The D-line wall will be supported by blind end type anchors, where as B-line wall will be supported by through type anchors installed in through holes drilled into the draft tube gate shafts or by blind type anchors.

- ii) Each prestressed anchor shall be tensioned to a prestressing force of about 100 Tonne and is designed to resist a force of 120 Tonne without plastic deformation. The fabrication and installation of anchors shall be done as per the drawings furnished and directions of the Project Manager.
- iii) The fabrication and installation of prestressed anchors shall include the following activities:
 - Drilling the bore holes of 100-105 mm dia;
 - Fabrication of prestressed anchors and their delivery to the place of installation;
 - Arrangement of support pads;
 - Installation of prestressed anchor in the bore hole;
 - Primary grouting;
 - Fabrication, erection and concreting of bearing plate;
 - Tensioning of the prestressed anchors;
 - Secondary grouting and rust protection of anchors;
- iv) Not less than 90 days before the Contractor intends to begin fabrication of the prestressed anchors, he shall submit to the Project Manager for approval complete details of methods, materials and equipment that he proposes to use. Such details shall show the method of fabrication, tensioning, grouting procedures and such other information as may be required by the Project Manager.

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4.7.2 DRILLING OF HOLES

- i) Direction of drilling shall be as specified in the drawings. Specially high accuracy shall be achieved for the “through-hole” anchors.
- ii) The permissible deviation of these holes at the point of coming out of the draft tube gate shaft shall not exceed 0.5 m in any direction. The boreholes for the blind type anchors shall be drilled with accuracy of 1 degree in respect of the specified angle of inclination. The boreholes shall be adequately cleaned before the installation of anchors in them.

4.7.3 FABRICATION OF PRESTRESSED ANCHORS

- i) The anchors shall be assembled of 6 high-strength cables of 15.2 mm diameter each. Slotted spacers made of approved plastic or other type of materials shall be installed between the cables. The assembly of the anchors shall be performed on a special roller table.
- ii) The roller table shall be installed in a shed. Special storage area shall be provided to protect the cables against corrosion and the PVC pipes against solar heat.
- iii) The steel wires shall be cleaned of all rust so as to obtain shining metallic surface. The cleaned wire shall be protected from corrosion by applying epoxy or any other anti corrosion paint. The samples of cable formed of high strength steel wires shall be subjected to testing as directed by the Project Manager.
- iv) Every prestressed anchor shall be marked as directed by the Project Manager. The Project Manager shall keep a regular supervision over the fabrication of pre-stressed anchors and if a prestressed anchor does not meet the requirement specified by the Project Manager, the contractor shall refabricate the prestressed anchor at his own cost.

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4.7.4 ANCHOR BEARING PADS

- i) Prior to insertion of anchors in the boreholes, bearing pads shall be provided at the back of bore holes for transfer of loads from the anchors. The bearing pads on the surface machine hall/erection bay, and in the draft tube gate shafts will be in the form of reinforced concrete pads.
- ii) The anchor pads shall be deep-set in the rock as specified in the drawings. The shuttering of the anchor pads shall be made of steel plates and shall be properly secured in place. The concrete in anchor pads shall be placed with extreme care to avoid any voids while compacting through dense reinforcement bars and places adjacent to the embedded pieces.


4.7.5 INSTALLATION OF ANCHORS IN HOLES

Immediately before an anchor is to be installed in any drill hole, the hole shall be thoroughly cleaned by flushing with water under pressure until the water returns clear and blowing out with air to remove the water. The insertion of anchors in the 'through holes' shall be performed from the draft tube gate shafts. The insertion of the anchors to the blind holes shall be performed from the machine hall/erection bay. The insertion will be performed manually taking necessary precautions not to damage the PVC pipes. On completion of the installation work, the cable ends coming out from the borehole shall be such as required for their fastening (blocking) and jacking. Excess length of the cable shall not be permitted.

4.7.6 PRIMARY GROUTING

- i) Grouting shall be accomplished by means of movable grout unit which shall be capable of:
 - Pumping of dense cement grout with w/c = 0.35-0.40;
 - Grouting at low injection speed of 0.8 to 1.0 cum/hr.
 - Grouting at pressure upto 10 kg/sq.cm.
- ii) Grout injection shall be performed from the lower to the upper end of the anchor. Flushing of bore holes shall be carried out prior to grout injection.

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The grouting shall be carried out as specified in the drawings to be furnished by the Project Manager.

- iii) The cement grout composition shall be such as to develop strength of 30 MPa. Sodium nitrite in the amount of 2.5% of the cement weight shall be added to the grout as rust-prevention admixture.


4.7.7 FABRICATION, ASSEMBLY AND CONCRETING OF BEARING PLATES FOR PRESTRESSED ANCHORS

- i) The bearing plates shall be fabricated by the contractor as shown in the drawings furnished or as directed by the Project Manager. Concrete of grade M-25 shall be used.
- ii) The work specified here-in-above shall be carried out under constant supervision of the Project Manager.

4.7.8 TENSIONING OF PRESTRESSED ANCHORS

- i) The Contractor shall tension the prestressed anchors, using his own equipment for this purpose, as specified hereinafter and under constant supervision of the Project Manager. The tensioning of prestressed anchors shall be done gradually as decided by the Project Manager. Any prestressed anchor which cannot be stressed to the design load shall be replaced by a new one, and at the expense of the contractor.
- ii) Tensioning shall be performed by means of special movable three action hydraulic jack unit. Except and otherwise specified, tension procedures shall be as recommended by the manufacturer of the prestressing anchors and approved by the Project Manager. The anchors shall be tensioned by means of hydraulic jack of a type approved by the Project Manager and equipped with pressure gauges having accurately calibrated dials at least 150mm in diameter which can be read accurately to the nearest 50 kgs of applied load. Each jack and its gauge shall be accompanied by a certified calibration chart showing the relationship between the gauge readings and load being applied to the anchor for both the loading and unloading

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movement of the jack. Equipment shall be provided for measuring the elongations of the anchors during tensioning to an accuracy of 1/100.

- iii) The procedure shall provide smooth tensioning of the cables. Tensioning shall be subjected to the following control parameters:
- The cable elongation under the load of 120 Tonne upto the specified value shall not exceed 1 mm.
 - Return movement of the cables after pressing the cone by the same jack shall not exceed 8 mm.
- iv) The anchors tested less than 120 Tonne load shall be fixed to withstand the force as specified in the design depending on their location over the height of the walls to be anchored.

4.7.9 SECONDARY GROUTING AND RUST PREVENTION MEASURES

- i) After completion of initial stressing and prior to secondary grouting, contractor shall check the load in selected prestressed anchors when required by the Project Manager. All anchors which show a loss of prestress in excess of 5 % shall be retensioned to the original tensioning force.
- ii) On completion of tensioning, the prestressed anchors shall be subjected to secondary grouting in a manner to be specified by the Project Manager. Secondary grouting of these anchors shall be performed after walls movements are stabilized.
- iii) Rust prevention measures shall be taken to protect the reinforcing cables inside the PVC pipes and all their lengths outside the borehole against corrosion.
- iv) These measures shall include pumping of a water solution of sodium nitrate and sodium carbonate through the anchor. All slots in the fastening headings shall be water sealed to protect the cables.

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4.7.10 MONITORING THE PERFORMANCE

The tension in prestressed anchors shall be monitored by means of dynamometers installed on about 10 % of anchors.

4.8 WIRE MESH

4.8.1 GENERAL

- i) Welded wire mesh fabric shall be installed in surface or underground construction sites with or without shotcrete as directed by Project Manager.
- ii) Chain link fabric shall only be used in surface applications. Welded wire mesh fabric shall be used for all underground work.

4.8.2 STANDARDS


The wire mesh shall conform to the latest revisions of the following Indian Standards.

- | | |
|----------|--|
| IS: 1566 | Hard drawn steel wire fabric for concrete reinforcement. |
| IS: 2721 | Galvanised steel chain link fence fabric. |
| IS: 4948 | Welded steel wire fabric for general use. |

4.8.3 MATERIALS

- i) Chain link fabric shall conform to the requirements of IS: 2721 and shall have a mesh size of approximately ϕ 3 mm x 50 mm x 50 mm as shown in the drawings or as required by Project Manager.
- ii) Welded wire mesh fabric shall conform to the requirements of IS: 4948 and shall have a mesh size of ϕ 5 mm x 100 mm x 100 mm as shown in the drawings or as required by Project Manager.

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4.8.4 INSTALLATION


- i) The fabric shall be cleaned of mud, grease, oil or other foreign matters, if shotcrete is to be applied. Wire mesh should be fixed after placing a 1st layer of shotcrete.
- ii) The fabric shall be placed against excavated surfaces and fastened to rock bolts, if present, with extra steel plates (bearing plates) of adequate size but not less than 100 x 100 x 5 mm and nuts. The fabric shall be securely fastened to the rock at intermediate points between the rock bolts with steel pins of 450 mm minimum length. Sufficient pins shall be provided to ensure that the fabric is held tightly to the rock surface. It shall be ensured that the fabric is drawn close to the excavated surface so that when shotcrete is applied subsequently, the mesh shall be firmly stretched between the rock reinforcement and other fastening attachments, and shall neither sag nor vibrate excessively and impair the effectiveness of the shotcrete.
- iii) Usage of wooden pegs or pins for fastening of the wire mesh to the rock surface -is not permitted.
- iv) Overlap in the wire mesh shall not be less than 250 mm and shall be tied with wire.


4.9 STEEL RIBS (IF APPLICABLE)

4.9.1 GENERAL

- i) Structural steel supports shall be installed in underground work as immediate supports after excavation in the heading zone in excavation class 4.
- ii) Steel ribs shall only be installed to support the heading of underground excavations in all areas where, in the opinion of Project Manager, alternative methods of rock reinforcement shall not provide adequate support either for construction safety or for permanent stability.

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<div><div><div>iii)</div><div>The exact requirement for steel ribs in any area shall depend on actual rock conditions encountered as excavation progresses, and as assessed by the Project Manager.</div></div><div><div>iv)</div><div>The gap between the steel ribs shall be filled with shotcrete or by cast in-situ concrete with suitable precast concrete or steel lagging as formwork.</div></div></div> <div><div>4.9.2</div><div><u>STANDARDS</u></div><div><p>The fabrication and installation of structural steel support shall conform to the latest edition of the following Indian Standards or, where not covered by these Standards, to the equivalent International Standards:</p><div><div>IS: 800</div><div>Code of practice for general construction in steel.</div></div><div><div>IS: 816</div><div>Code of practice for use of metal arc welding for general construction in mild steel.</div></div><div><div>IS: 2062</div><div>Steel for general structural purposes.</div></div><div><div>IS: 5878</div><div>Code of practice for construction of tunnel conveying water.</div></div></div></div> <div><div>4.9.3</div><div><u>SUBMITTALS</u></div><div><div>i)</div><div>30 days prior to the commencement of excavation works, the Contractor shall submit, to the Project Manager, the details of his proposed steel ribs system including provision for fore-poling wherever required and proposed filling method (shotcrete or lagging and backfill with cast in-situ concrete).</div></div><div><div>ii)</div><div>The Project Manager reserves the right to require any additional information deemed necessary to be included in the submitted documents.</div></div></div> <div><div>4.9.4</div><div><u>MATERIAL</u></div><div><div>i)</div><div>The steel ribs shall comprise I sections or any other section as shown on the drawings or as approved by the Project Manager.</div></div><div><div>ii)</div><div>OWNER will provide steel sections from which the Contractor will fabricate ribs as required by the Project Manager. Steel sections and plates shall be</div></div></div> <div><div>ISSUE</div><div>P0</div></div>		

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cut, welded, bolted or otherwise proposed to the shapes and dimensions indicated on the drawings or as directed by the Project Manager.


- iii) Rib splices shall be welded or made of bolted plates in such a manner as not to reduce the section moment of resistance. Where possible all shop connections shall be welded and all field connections shall be bolted.
- iv) Material used in splices shall conform to the specifications of the material being spliced.
- v) Only one section size of steel rib profile shall be used for each portion of the Underground Works and the Structural Requirements due to rock conditions encountered shall be met by varying the spacing of the ribs as directed by the Project Manager.
- vi) Steel support accessories shall include, but not be limited to collar braces, tie rods, spreaders, liner plates, cribbing, blocking wedges, foot blocks, sills and invert struts which are fabricated from steel plates or sections or other steel products. Steel support accessories shall be used usually in conjunction with the steel ribs in the underground excavations and shall be used elsewhere when required by Project Manager.
- vii) Steel ribs shall be cold bent only with an allowance of one percent to the shape as shown on the drawings. Reshaping of the bent ribs at the place of installation may only be undertaken with the Project Manager's consent and only if the material properties are not unduly impaired.
- viii) If backfilled lagging is used, lagging shall be precast M20 concrete or proprietary steel lagging. The approval of the Project Manager is required before any lagging is used.

4.9.5 INSTALLATION

- i) Excavation of the underground works shall be completed true to the lines shown on the drawings before installation of steel ribs. The steel ribs shall be placed at the minimum excavation line and at a spacing as shown on the drawings or as determined by the Project Manager.

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<div> <div>ii)</div> <div>Concrete blocks or steel profiles shall be provided as footings for the steel ribs. Use of timber as foot blocks shall be strictly prohibited. The footplates shall be of sufficient size and rigidity. If required, the legs of the ribs shall be anchored to the rock by rock bolts.</div> </div> <div> <div>iii)</div> <div>Immediately after placing the ribs in a correct position, they shall be interconnected and braced by means of steel bars or beams in order to prevent any displacement and to maintain spacing. Use of timber spreaders shall be strictly prohibited.</div> </div> <div> <div>iv)</div> <div>The space remaining between the outer flange of the steel ribs and the rock surface shall be backfilled immediately after the rib has been placed – and before further excavation takes place – with M-20 concrete and precast RCC or steel lagging or M-25 shotcrete over the entire circumference of the steel rib in order to provide uniform load distribution. If required, shotcrete shall be applied before the erection of steel ribs as a protective measure as directed by the Project Manager.</div> </div> <div> <div>v)</div> <div>The Contractor shall survey and record the position of all steel ribs installed in order to facilitate drilling operations. Their position shall be marked on the finished concrete lining surface and reported to the Project Manager periodically.</div> </div> <div> <div>vi)</div> <div>Blocking and wedges used to set the steel ribs may be baked clay or cement bricks, steel or concrete blocks. Timber shall not be used.</div> </div> <div> <div>vii)</div> <div>Structural steel supports shall be maintained in position after installation. Any steel rib installed improperly or damaged shall be adjusted, repaired or replaced by the Contractor as appropriate and without delay but after duly informing the Project Manager.</div> </div> <div> <div>viii)</div> <div>Backfilling between rock and lagging with rock spoils, bracing with timber and timber lagging shall be strictly prohibited.</div> </div> <div> <div>ix)</div> <div>The steel arch ribs shall be set in haunches excavated from the tunnel at spring line as shown on the drawings. In the event that subsequent removal of the bench endangers the stability of the haunch, the contractor shall</div> </div>		
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install steel posts to support the ribs and extend the steel posts to final invert elevation as soon as practicable after excavation of the bench.

- x) During the course of work, the contractor shall maintain a sufficient reserve of steel ribs complete with accessories at each work site.

4.10 MEASUREMENT AND PAYMENT

The Unit Rates entered in the Bill of Quantities shall be applied regardless of the excavation method or the classification of the excavation.


4.10.1 ROCK BOLTS

- i) Measurement of rock bolts will be of the actual length in metres of rock bolts installed, along with base plate and other accessories as shown on drawings or as required by Project Manager.
- ii) Payment will be made at the unit prices per metre stated in the Bill of Quantities for providing, drilling and installing rock bolts and accessories complete in every respect and as specified herein.
- iii) Payment for cement, resin and additives for grout mixes, quick-set cement for bearing plates, pads and rust protection materials and all other ancillary works or accessories is deemed to be included in the unit price for providing and installing rock bolts.
- iv) Payment for testing of the bolts as specified above is deemed to be included in the unit price for providing and installing rock bolts.

4.10.2 FORE-POLING WITH GROUTED ANCHOR BARS/SELF DRILLING HOLLOW CORE ANCHORS

- i) Measurement for grouted anchor bars and self-drilling hollow core anchors as fore-poling shall be of the actual length in metres of anchors installed and approved by the Project Manager.
- ii) Payment will be made at the Unit Price per metre entered in the Bill of Quantities, which shall include the entire cost of all material, labour, drilling,

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grouting, plant and equipment necessary for the supply and installation of the grouted anchor bars/self-drilling hollow core anchors.

4.10.3 ROCK BOLTS AS MICRO-PILES (IF APPLICABLE)

- i) Measurement for rock bolts used as micro piles shall be of the actual length in metres of bolts and the total number of piles installed, along with all accessories and cement grouting as shown in the drawings or approved by the Project Manager.
- ii) Payment will be made at the Unit Price metre entered in the Bill of Quantities, which shall include the entire cost of all material, labour, drilling, plant and equipment necessary for the supply and installation of the rock bolt micro piles.


4.10.4 GROUTED ANCHOR BARS

- i) Measurement for grouted anchor bars will be of the total length of the bars installed and approved by the Project Manager.
- ii) Payment will be made at the Unit Price per metre entered in the Bill of Quantities, which shall include the entire cost of:
 - a) Drilling of the holes,
 - b) Washing and cleaning of the holes,
 - c) Furnishing, cutting, and installing steel anchor bars,
 - d) Furnishing of cement mortar and filling the drillholes,
 - e) Testing.

4.10.5 PRESTRESSED CABLE ANCHORS

- i) Payment for drilling of bore holes shall be made separately as defined in Chapter "Drilling".
- ii) Measurement and payment for furnishing, fabrication, installation including grouting and monitoring of prestressed anchors shall be in the running meters of length of anchors measured between the outside faces of the

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bearing plates, with no allowance for jacking length. The rate shall be inclusive of all materials, labour, plant and monitoring by dynamometers complete in all respect.


4.10.6 WIRE MESH

- i) Measurement of wire mesh shall be of the net area (without overlaps) actually installed.
- ii) Payment will be made for chain link fabric at the Unit Rate per square meter (net area without overlap) entered in the bill of Quantities, which shall include the entire cost of supply and installation of chain link fabric including overlaps, and the provision of all necessary accessories for fixing, such as steel pins, extra plates, nuts etc. for fastening to rock bolts.
- iii) Payment will be made for welded mesh fabric at the Unit Rate per square meter (net area without overlap) entered in the bill of Quantities, which shall include the entire cost of supply and installation of mesh including overlaps, and the provision of all necessary accessories for fixing, such as steel pins, extra plates, nuts etc. for fastening to rock bolts.

4.10.7 STEEL RIBS

- i) Measurement for payment for providing, handling, fabrication and installation of the steel ribs will be of the weight of steel ribs actually installed and approved by the Project Manager.
- ii) Payment will be made at the Unit Rates per metric tonne entered in the Bill of Quantities (up to two decimal places), which shall include the entire cost of:
 - a) Providing, handling, fabrication, transportation to the place of installation and installation of steel ribs, all foot plates, foot blocks, tie rods, bolts, nuts, cross-bracing and all other accessories,
 - b) Manufacture, supply and installation of precast concrete or steel lagging. The rates quoted shall include cost of preparation of casting yard, formwork, concrete, reinforcement and the casting

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<div style="text-align: center;"> <p>finishing, filling of gaps between adjacent precast concrete units with concrete, curing, handling, erection group, welding, preparation of supporting surface, and testing, etc.</p> <p>c) Surveying and marking the position of ribs on the finished concrete surfaces.</p> <p>For measurement and payment purposes, the weight of the steel ribs will be based on the unit weight of the steel profile per linear metre (without any accessories) as stated on the certified copies of manufacturer's reports, or by direct weighing on the Site.</p> <p>iii) Measurement and payment for backfilling with shotcrete or concrete if lagging is used shall be as per the relevant Chapters "Concrete" and "Shotcrete".</p> <p>End of Chapter</p> </div> <div style="text-align: right; border: 1px solid black; padding: 5px; width: fit-content; margin: 0 auto;"> ISSUE P0 </div>		