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### **3      UNDERGROUND EXCAVATION**


#### **3.1      SCOPE OF WORK**

- i) This Chapter covers all excavation work for underground structures to be carried out by the Contractor under this Contract and shall include all labour, materials, plant and equipment, all survey and setting out, all excavation, loading, transportation and disposal of materials to disposal or stockpile areas as well as the cleaning of excavated surfaces.
- ii) Based on surface geological investigations, a geological report was prepared in March 2016. This report is included in “Information to Bidders” of the bid documents. Contractor shall be expected to have made himself fully conversant with the geological and geotechnical features of the project area. The information is however of an indicative nature only and is based on limited data available at the time of tender. It does not relieve the Contractor of his sole responsibility to make his own assessment of the geological conditions prevalent in the Project Area – before tender and during construction – and to ensure that he has sufficient resources to cope with all conditions likely to be encountered.
- iii) Contractor shall comply with all safety procedures and requirements as stipulated in Part I Chapter “Safety Precautions”.
- iv) Contractor may be required by the Project Manager to perform exploratory drilling (including core recovery, if necessary) during excavation of the tunnel.
- v) The approval given by the Project Manager, to the Contractor’s methods and equipment, shall not relieve the Contractor of his full responsibility for a proper and safe execution of underground excavations, of liability for injuries or deaths, or of any other obligations under this Contract.

#### **3.2      DEFINITIONS**

- i) **HEADING AND BENCH EXCAVATION** is carried out in two steps, the **HEADING** is defined as the crown portion of underground tunnel excavation.

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The BENCH excavation is defined as the excavation of platform left after the 'Heading' excavation.

- ii) **HEADING FACE:** The advance end or wall of a tunnel, at which the work is progressing.
- iii) **HEADING ZONE:** Heading zone refers to a zone between the newly established face and a cross-section one tunnel or shaft diameter behind that face measured along the tunnel centreline.
- iv) **REAR ZONE:** Rear zone is the whole length of tunnel between the heading zone and the portal.

### 3.3 **STANDARDS**

The methods and practices for surface excavation shall conform to the latest editions of the following Indian Standards or, where not covered by these Standards, to the equivalent International Standards subject to the approval of the Project Manager:


- IS: 3764              Excavation work – code of safety.
- IS: 4081              Safety code for blasting and related drilling operations.
- IS: 4756              Safety code for tunnelling work.
- IS: 5878              Code of practice for construction of tunnels conveying water.


Indian Explosives Act 1940, as updated.

### 3.4 **SUBMITTALS**

- i) At least 30 days prior to the commencement of underground excavation, the Contractor shall submit details of his excavating methods and sequences for all underground works, including plant and equipment to be used, ventilation, rock support, details of methods for drilling probe holes and safety measures.
- ii) The description shall in particular include the following:
  - a) Details of all mechanical plant to be used, including back up equipment in the event of breakdowns,


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<div> <div> <div>b)</div> <div>Sequence of various activities of the excavation work in different headings with an indication of corresponding time requirement in a time-progress diagram similar to that shown in the drawings,</div> </div> <div> <div>c)</div> <div>Detailed sequencing of excavation cycles (excavation, mucking, support),</div> </div> <div> <div>d)</div> <div>Description and purpose of any special methods to be adopted by the Contractor,</div> </div> <div> <div>e)</div> <div>Details of his proposals for deploying and maintaining backup Diesel generating sets at various work faces,</div> </div> <div> <div>f)</div> <div>Details of his proposed survey and setting out procedures,</div> </div> <div> <div>g)</div> <div>Details of his proposed convergence measuring system.</div> </div> </div> <div> <div>iii)</div> <div>The description of drilling and blasting procedures shall include the following:</div> <div> <div>a)</div> <div>Diameter, spacing, depth, pattern and orientation of blast holes,</div> </div> <div> <div>b)</div> <div>Type, strength, amount, and distribution of explosives to be used per hole, per delay and per blast,</div> </div> <div> <div>c)</div> <div>Type of detonators, powder factor and sequence and pattern of delays to be used per blast.</div> </div> </div> <div> <div>iv)</div> <div>At least 28 days prior to dumping or stockpiling of any material, the Contractor shall submit the layout of the spoil and stockpile areas, which shall be within the areas designated on the bidding drawings. All pertinent data of working methods and provisions for the security, stability, and temporary and permanent drainage of the areas shall be included, and details of volumes, material types, heights and grades provided.</div> </div> <div> <div>v)</div> <div>To enable the Project Manager to verify all necessary setting out and elevations carried out by the Contractor, the latter shall notify the Project Manager in writing, giving at least 14 days notice, of his intention to start excavation.</div> </div> <div> <div>vi)</div> <div>During the advance of underground excavations, the Contractor shall record and submit weekly to the Project Manager 3 copies of the following:</div> </div>		
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- a) General items, regardless of the method of excavation:
- Theoretical volume of solid material excavated according to typical sections shown on the drawings,
  - Classification of the excavation as agreed and signed off by the Project Manager,
  - Amount, location, spacing, and type of steel ribs, and lagging installed in the various zones, as defined hereafter,
  - Surface of shotcrete, and wire-mesh, installed in the various zones,
  - Shotcreting thickness, batching volumes, rebound data and mix for shotcreting,
  - Number, length, types and pattern of rock bolting, installed in the various zones together with the length of drilled holes and quantity and type of resins and grouts used in each hole,
  - Results of pullout tests performed,
  - Geology encountered, competence of the rock formations, rock falls, zones of instability, and information obtained from Probe/Pilot holes,
  - Graphical representation of the locations, lengths and orientation of the Probe/Pilot holes,
  - Occurrence of gas, if any,
  - Water inflows at the heading face, and the rate of discharge of water from the dewatering system and temperature of the water,
  - Convergence measurements indicating the chainages in the rear zone performed by optical measuring devices specified in Chapter "Instrumentation",
  - Personnel employed during various stages of the operation and their qualification,
  - Time required and details for each activity in all the cycles performed during the week,

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<div> <ul style="list-style-type: none"> <li>- Unusual occurrences, all delays and the reasons for delays,</li> <li>- Flow of fresh air in the heading zone,</li> <li>- Advance of each heading face and the chainage of heading face before the excavation/blasting of each round.</li> </ul> <p>b) Special items referring to drill and blast excavation:</p> <ul style="list-style-type: none"> <li>- Type and number of drill holes, and length of each round,</li> <li>- Pattern of drill holes, their diameters and length,</li> <li>- Type, quality and location of explosives in each drill hole, and blasting scheme (direct or retarded).</li> </ul> <p>vii) The Project Manager reserves the right to require any additional information deemed necessary to be included in the submitted documents.</p> <p><b>3.5 <u>EXCAVATION LINES AND TOLERANCES</u></b></p> <p><b>3.5.1 <u>GENERAL</u></b></p> <p>i) Excavation shall be made to the lines, grades and dimensions shown on the drawings or as otherwise directed by the Project Manager. Typical cross sections, excavation lines, and dimensions of excavations are shown on the drawings.</p> <p>ii) The minimum excavation line (A-line), as shown on the drawings, is the line within which no rock material will be permitted to remain.</p> <p>iii) The pay line (B-line), as shown on the drawings, is the line beyond minimum excavation line, at which the payment for excavation will be made, even if the actual excavation is between the minimum excavation line and the pay line. Unless specifically mentioned otherwise, the pay line for tunnel shall be taken as 150 mm from the A-line for all types of rocks and excavation methods.</p> <p>iv) Contractor shall take into account of the exactness his excavating equipment and any deformations of the excavated rock perimeter in determining the size, grade and alignment of the excavation and shall</p> </div>		
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guarantee that the theoretical thickness of the shotcrete lining, the internal diameter of the finished lining and the thickness of the final concrete lining is never reduced. Immediately behind the heading face, the contractor shall measure the excavated profile by means of a profile template or any other method approved by the Project Manager. All out-of-line excavation shall be rectified so that the minimum excavation line as defined above is maintained. The minimum inner lining thickness for the tunnel shall be maintained throughout the excavation. Contractor at his own cost shall correct any deviations.


- v) Deformations of the excavated rock perimeter are deemed to be included in the 150 mm pay line (B-line) allowance.
- vi) Contractor shall ensure the correctness of alignment and shall carryout all necessary setting out/survey works required for this purpose.

### 3.5.2 OVERBREAK

- i) Contractor is required to perform the excavation works in such a way that the final excavation surface is located between the pay line and the minimum excavation line. Excavation beyond the pay line is defined as overbreak. The "Overbreak line" is a line outside the pay line (B line), determined by measurement. No overbreak or concrete beyond the pay line will be measured for payment, except when included as part of an accepted geological overbreak as described hereafter.
- ii) Overbreak is accepted as accepted geological overbreak when each of the following four conditions are simultaneously fulfilled:
  - a) Overbreak extends beyond the pay line,
  - b) The overbreak occurs above the overt of the tunnel,
  - c) The Project Manager is immediately informed and given an opportunity for inspection while both the cause and the extent of the overbreak are clearly visible,
  - d) It did not occur while, in the opinion of the Project Manager, the contractor was using improper working methods or was otherwise

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negligent, and could not have been prevented by prompt and appropriate installation of supports and in view of the Project Manager is solely due to geological reasons.


- iii) Prior to the commencement of the final lining, the voids created by overbreak extending beyond the minimum excavation line for Rock Class I and II shall be filled-up to the minimum excavation line with concrete of same grade of lining and for Rock class III and IV shall be filled-up with concrete M15 grade.
- iv) Contractor shall survey and plot cross sections at sufficient intervals to allow for a reasonably accurate estimate of the volume of overbreak, which he claims to be due to geological conditions.
- v) If for any reason other than accepted geological reasons, excavation is carried out beyond the pay line (i.e. Contractor's careless blasting etc.), the Contractor shall remove the excess material and backfill the voids as described above, at his own cost.
- vi) The maximum amount of accepted geological overbreak is 4% of the pay line (B-line) quantity. Any overbreak in excess of this amount will not be accepted as geological overbreak.
- vii) The decision taken by the Project Manager regarding the admissibility or otherwise of overbreak shall be final and binding on the Contractor.

### **3.6 EXCAVATION**

#### **3.6.1 GENERAL**

- i) The excavation of the tunnels commences from the excavations for the intakes and outlets as shown in the drawings. Details of the actual portal construction shall be determined by the Project Manager in consultation with the Contractor prior to the commencement of underground excavations for tunnels.
- ii) Excavation not shown on the drawings, and not included in the Bill of Quantities, but which the Contractor considers necessary for his own


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purposes, such as excavation for train switches or stations, rail foundations, mucking pits, pump sumps, drain ditches other than those shown on the drawings, spaces for supply facilities, may only be carried out with the prior approval of the Project Manager. All such excavations shall be backfilled with concrete of M-20 grade up to the minimum excavation line prior to the commencement of the final tunnel lining.

- iii) Excavation of adits, other than those shown in the drawings, by the Contractor for his own convenience shall be subject to the prior approval of the Project Manager. Such adits - when no longer required - shall be plugged as directed by the Project Manager.
- iv) Drainage measures must be applied as close to the heading faces as possible. Where excessive inflows of water occur, the Contractor shall take all appropriate measures to execute the excavation work safely and in a professional manner. In rocks that tend to soften or swell in the presence of water the Contractor shall take measures to minimise contact between the water and rock.
- v) In the event that the invert of excavations can be damaged or eroded by the construction traffic, the Contractor shall take adequate measures to protect the invert by providing suitable road surfacing underground.
- vi) After excavating, the Contractor shall adequately protect the tunnel invert surface from damage caused by the construction traffic. Should small grain or broken excavation material be used for such protection it shall be removed prior to placing the final tunnel lining. No vehicular traffic will be permitted over tunnel invert after removal of the protective material.
- vii) Wherever shear zones and poor rock bands are encountered along the tunnels, adequate methods of rock support as shown in the drawings or as directed by the Project Manager shall be applied at once by the Contractor to avoid any cavity formation.

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### 3.6.2 SURVEY AND SETTING OUT

Contractor shall be responsible for all survey and setting out during construction. On commencing work on site he will be advised of the fixed survey network on site by the Project Manager. Contractor shall then be solely responsible for ensuring that the works are correctly set out. At the request of the Project Manager he shall make available the co-ordinates of any of his control points for the Project Manager to check. Any checking of the control points by the Project Manager does not relieve the Contractor of his responsibility to ensure that the tunnel is constructed to the specified tolerances.


### 3.6.3 METHOD OF EXCAVATION


- i) The tunnels shall be excavated using full face or heading and bench method with excavation performed by drill and blast, by mechanical methods or in exceptional cases by manual means, as shown in the drawings or as per instructions given by Project Manager.
- ii) The shafts shall be excavated using a full face method with excavation performed by drill and blast or by raise drilling, as shown in the drawings or as per instructions given by Project Manager.
- iii) All blasting must be performed using controlled blasting techniques. If incorrect blasting techniques, in the opinion of the Project Manager, lead to the use of more support than would be necessary with controlled blasting techniques, the additional support will not be paid and the excavation shall be classified as the class that would have resulted from controlled blasting techniques.
- iv) Contractor may propose his own sequence of excavation, which may be adopted subject to approval of Project Manager.

### 3.6.4 EXCAVATION BY DRILLING AND BLASTING

- i) Drilling shall be done in accordance with the requirements of Chapter "Drilling".


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<div><div><div>ii)</div><div>Contractor shall establish by trial blast and use drilling and blasting techniques which will produce a smooth final profile, a minimum of overbreak and a minimum of fracturing of the rock beyond the required excavation lines. The techniques used shall be, at all times, subject to the Project Manager’s approval, who may direct several blasting tests to be undertaken by the Contractor to substantiate his proposed methods of blasting.</div></div><div><div>iii)</div><div>During the progress of excavation, the drilling and blasting pattern, specifically the number and depth of holes, quantity, quality and distribution of explosives, shall be varied as necessary to suit the rock conditions encountered, taking into consideration the information obtained from the probe holes, the actual drilling Work (velocity, colour of rinsing water, etc.), as well as the previous blasting results.</div></div><div><div>iv)</div><div>All conventional excavation shall be performed by controlled blasting techniques as described below:<div><div>a)</div><div>Presplitting: Consists of drilling a single row of closely spaced holes, drilled deeper than the depth of the round, along the final excavation perimeter. These holes are lightly charged and detonated before the main blast, to produce a presplit crack, which limits the propagation of cracks from the subsequent main blast, and in such a way, which reduces damage in the rock beyond it.</div></div><div><div>b)</div><div>Smooth Blasting: Consists of drilling a number of closely spaced holes along the final excavation perimeter, placing light charges in the holes and detonating the charges simultaneously after the main blast. The outer line of drill holes for the main blast is set at an approved distance inside the final perimeter leaving an annulus of rock to be peeled off the damaged final excavation perimeter by the smooth blast. The smooth blast holes are drilled, charged and blasted in the same tunnelling cycle as the main blast.</div></div></div></div></div>		
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- c) Cushion Blasting: A special case of blasting in which considerable air space or stemming surrounds charges in the holes and serves to reduce undesired blast effect on the final excavation perimeter.
- d) Line-drilling: Line-drilling shall be used where control perimeter blasting may cause excessive damage to the surrounding rock or where there are structures adjacent to the excavation. Line-drilling is defined as a single row of unloaded holes drilled along the neat excavation line, spaced no more than two to four times the hole diameter on centres. These will form a surface of weakness to which the primary blast can break. Light blasting with well-distributed charges fired after the main excavation is removed may be permitted in the holes. If, however, in the opinion of the Project Manager the blasting may injure the rock, the use of explosives shall be discontinued and the excavation shall be completed by mechanical or manual means.
- v) In general only wet drilling will be permitted in order to reduce dust in the underground excavations. In exceptional circumstances, or when wet drilling has deleterious effects on the ground, compressed air drilling may be used subject to the use of adequate precautions such as sufficient ventilation and the use of protective masks.
- vi) Perimeter drill holes shall be placed such that the over excavation beyond the minimum excavation line is minimized. The spacing of holes shall not exceed 50 cm. Contractor shall pay utmost attention to obtain a smooth and uniform excavated surface.
- vii) Should the entire length of most of the perimeter drill holes not be visible after each round of blasting, the Contractor shall make an adequate adaptation in the blasting pattern used and submit it to the Project Manager for approval.
- viii) The depth of a new round shall never exceed that which was determined and approved prior to commencement of blasting. The Project Manager may

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<p>order a reduction of the adopted round depth if the actual rock condition requires it.</p> <p>ix) Blasting of a new round will not be permitted if insufficient personnel are available to perform the mucking and subsequent support work afterwards. In particular, this applies to work before holidays, non-working weekends, etc.</p> <p>x) Blasting that may damage the rock beyond the required excavation lines or the tunnel installations will not be permitted. Any damage to or displacement of the supports, and any damage to any part of the Works caused by blasting or any other of the Contractor's operations shall be repaired by the Contractor in a manner satisfactory to the Project Manager.</p> <p>xi) No new round shall be blasted until the supports required within or behind the heading zone have been installed.</p> <p>xii) All loosened material that is likely to fall shall be removed immediately following blasting, at frequent intervals during the progress of the Work, and finally during the clean-up prior to placing the final tunnel lining.</p> <p>xiii) Blasting within 25 m of concrete or grout will be permitted only after concrete or grout is seven days old and only after the submission by Contractor and approval by Project Manager of a plan showing the relative positions of structures of grouted areas and the areas to be blasted, Contractor's proposed drilling and blasting plan, together with an outline of precautions to be taken.</p> <p>3.6.5 <u>EXCAVATION BY MECHANICAL MEANS</u></p> <p>i) Continuous adequate ventilation shall be provided during excavation by mechanical means. Contractor shall ensure that the level of dust and silicates remains at a safe level by using a suitable extraction system and by ensuring that the duct inlets are positioned as close to the face as possible. All personnel in the heading zone shall be equipped with adequate safety masks. Personnel shall not enter the cutting area. The machine shall be</p> <div data-bbox="1398 2033 1485 2123" style="border: 1px solid black; padding: 5px; text-align: center;"> ISSUE P0 </div>		

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<p>equipped with appropriate warning devices/sirens to signal when the cutter head is about to start or when the machine is about to move.</p> <p>ii) Road headers if used, shall have adequate total power and cutter-head power and be equipped with appropriate types and numbers of picks, cutters, disks and/or teeth, to excavate the rock efficiently. Worn tools shall be replaced immediately. Road headers shall possess a low centre of gravity and be stable under all conditions.</p> <p>iii) Contractor is responsible for ensuring that he has adequate electrical power at the required voltage for all electrical powered plant.</p> <p>iv) All diesel-powered plant shall be fitted with suitable particle filters.</p> <p>v) The cutter head boom shall be capable of a full range of movement – both transversely and vertically – and in conjunction with the mobility of the machine shall be able to excavate the face to a neat profile with minimum overbreak. Contractor shall ensure that he has adequate plant and equipment to excavate inaccessible corners of the heading and the tunnel invert. The equipment should be capable of leaving a core of material to support the face in poor ground.</p> <p>vi) Contractor shall establish techniques by trial, which will produce a smooth final profile, a minimum of overbreak and a minimum of fracturing of the rock beyond the required excavation lines. The techniques used shall be, at all times, subject to the Project Manager's approval.</p> <p>vii) Preliminary excavation lengths of each round have been given on the drawings. The final excavation lengths shall be determined by the Project Manager in consultation with the Contractor. The length of each excavation stage shall never exceed that which was determined and approved prior to commencement of excavation. The Project Manager may order a reduction of the excavation length if the actual rock condition requires it.</p> <p>viii) Excavation of the next length will only be permitted if sufficient personnel are available to perform the mucking and subsequent support work. In particular, this applies to work before holidays, non-working weekends, etc.</p>		
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- ix) Excavation that may damage the rock beyond the required excavation lines or damage the tunnel installations will not be permitted. Any damage to or displacement of the supports, and any damage to any part of the Works caused by the excavation work or any other of the Contractor's operations shall be repaired by the Contractor in a manner satisfactory to the Project Manager.
- x) No new excavation length shall be excavated until the supports required within or behind the heading zone have been installed.
- xi) All loosened material that is likely to fall shall be removed immediately, at frequent intervals during the progress of the Work, and finally during the clean-up prior to placing the final tunnel lining.

#### 3.6.6 CLEANING OF EXCAVATED SURFACES


- i) Even prior to the removal of the bulk of the material loosened by blasting, the Contractor shall clean the newly exposed rock surface from rock fragments, dust and debris to permit, if required, the application of the first layer of shotcrete.
- ii) Cleaning shall be done by directing a jet of water or air on the rock face. Compact, washable rock shall be cleaned with compressed air-water jets. Rock which is prone to quick disintegration, swelling, heaving, or is interspersed with clay filled fissures shall be cleaned with compressed air only. The cleaning shall be done to the satisfaction of the Project Manager.
- iii) The cleaning is separate from the clean up of excavated surfaces required immediately prior to placing of the final tunnel lining described further under Chapter "Concrete".

#### 3.6.7 ADDITIONAL EXCAVATION

- i) Contractor may be directed by the Project Manager to enlarge or change the section or carry out excavation beyond the minimum excavation line in parts of the Underground Works where excavation has already been completed. Such excavation shall be defined as additional excavation.

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- ii) Additional excavation may be carried out for, but not be limited to, the following purposes:
  - a) To enlarge the excavated cross section in the rear zones to enable the insertion of new or additional steel ribs for support,
  - b) To enable the Project Manager to carry out rock mechanics tests associated with the determination of rock properties,
  - c) To enlarge the tunnel cross section in the rear zones to accommodate the increased thickness of the concrete lining for structural reasons.
- iii) Contractor shall make the necessary provisions in his planned excavation activities to enable such additional excavation to be carried out concurrently with the main excavation without disruption or delay.

#### 3.6.8 DISPOSAL OF EXCAVATED MATERIALS

- i) All materials from underground excavation suitable for use as fill, concrete aggregates or for other purposes shall be stockpiled on the Site within the radial distance of 3.0 km from the nearest portal as directed or approved by the Project Manager, if the immediate placement in the final location in Permanent Works is not possible.
- ii) Excavated materials, which are not suitable for or are in excess of the permanent construction requirements, shall be disposed off within 5.0 km from tunnel/adit portal in areas designated by the Project Manager in the course of the Work.
- iii) Contractor shall shape and trim the disposal areas and stockpiles to the lines and grades as directed or approved by the Project Manager, and shall provide for adequate diversion of existing water courses. The area where the excavated material is to be disposed shall be stripped of all vegetation and topsoil and the topsoil shall be stockpiled nearby. If the area is steeply dipping, precautions shall be taken to ensure stability of the material in the area, including base drainage and surface protection against erosion. The material dumped shall be compacted, by movement of the dumping

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vehicles, and grading as necessary, in layers not exceeding 0.5 m in depth. It shall be the responsibility of the Contractor to remove any material from any slide that may occur in the disposal dump or its base and re-dispose the removed material properly to the satisfaction of the Project Manager. Prior to the commencement of excavation Work, the Contractor shall have prepared the disposal area to the satisfaction of the Project Manager and the methods proposed for disposal shall also have received approval of the Project Manager.

- iv) Contractor shall be liable for any damage to Temporary or Permanent Works or to the property of third parties caused by poor drainage or poor dumping in the waste disposal or stockpile areas.
- v) If additional areas are required for disposal of the excavated materials, the Contractor shall propose such areas for approval of the Project Manager.
- vi) Contractor shall ensure that no excavated materials are disposed off in the streams or at locations where in the opinion of the Project Manager, these are liable to be washed away by the floods.
- vii) On completion of the disposal or removal of the stockpiles, the contractor shall replace the topsoil and seed the area with an approved grass mixture.

### **3.7 UNDERGROUND SERVICES DURING CONSTRUCTION**


#### **3.7.1 EVACUATION OF WATER**

Contractor shall carry out all works required to capture and drain service and infiltrated groundwater during the construction as stipulated under Chapter “Control of Water, Construction Drainage and Dewatering”.

#### **3.7.2 ILLUMINATION**

Contractor shall install an adequate illumination system in the underground works as stipulated under Part I, Chapters “Site Installations, Services and Environmental Obligations” and “Safety Precautions”.

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### 3.7.3 VENTILATION, CONTROL OF DUST, SILICA AND NOXIOUS GASES IN UNDERGROUND WORKS

Contractor shall install and operate equipment and carry out all works required for the ventilation as stipulated under Part I, Chapter “Safety Precautions” and shall install and operate equipment for the control of dust, silica and noxious gases in Underground Works.

### 3.7.4 COMMUNICATION SYSTEM


Contractor shall install and operate the communication system between the heading faces and entrances to the tunnel, as stipulated in Part I, Chapter “Site Installations, Services and Environmental Obligations”

## 3.8 CLASSIFICATION OF UNDERGROUND EXCAVATION

### 3.8.1 GENERAL


- i) Underground excavation is divided into different classes in order to differentiate between the difficulties and hindrances resulting from the varying material properties of the ground encountered during excavation work.
- ii) The classification of the excavation will be determined by the Project Manager in consultation with the Contractor. The decision of Project Manager in all such matters shall be final and binding. This does not relieve the Contractor of his responsibility for a proper and safe execution of underground excavations.
- iii) The class of excavation is defined by the hindrance to the progress of the excavation works caused by the type and amount of rock support installed in the heading zone during excavation.
- iv) Subsequent or supplementary installation of support behind the heading zone shall have no influence on the classification of the excavation classes.


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<div><div><div>v)</div><div>vi)</div><div>vii)</div><div>viii)</div></div><div><p>The definition of each excavation class is based only on the supporting measures installed and shall be valid irrespective of the excavation method used.</p><p>The weathering of the rock, the jointing of the rock and the inflow of groundwater during excavation shall not be taken as direct criteria for the assignment of excavation classes, rather as qualitative criteria in assigning support. Difficulties caused by ingress of excessive water during the excavation are covered in Chapter “Construction Drainage and Dewatering”. Collection and drainage of normal seepage water (up to 2 litres/second per 100 m tunnel) in suitable drainage systems subject to approval of Project Manager is included in the excavation.</p><p>The assignment of an individual excavation class shall always apply to the whole of the theoretical excavation cross section as defined by the "B"-line, even if the partial excavation method is being used.</p><p>The Project Manager will map the geology along the tunnel. This information in conjunction with the results of the convergence measurements carried out by the Contractor shall be used to confirm the classification of the excavation and the support installed.</p></div></div>		
<div><div>3.8.2</div><div><div><div><div>CLASSIFICATION OF TUNNEL EXCAVATION</div></div></div></div><div><p>The underground excavation classes for the main tunnels are specified as follows and as shown on the drawings:</p><div><div><div>Class 1</div><div>Definition: The rock is essentially self-supporting.</div><div>Measures: The excavated section remains basically unsupported apart from a light overhead protection of anchors over 90°. Individual rock bolts and shotcreting that may be required in localised areas of the bench will not be taken into consideration for classification purposes.</div></div><div><div>Class 2</div><div>Definition: Systematic support required in the heading and benching.</div></div></div></div></div>		
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<div> <div>Class 3</div> <div> <p>Measures: Support system consists of light shotcrete and anchors in the heading. Individual rock bolts and shotcreting that may be required in localised areas of the bench will not be taken into consideration for classification purposes.</p> <p>Definition: Systematic support required in both the heading and the bench.</p> <p>Measures: Support system consists of medium thickness shotcrete, mesh and anchors in the heading and medium shotcrete, mesh and anchors in the bench.</p> </div> </div> <div> <p><b>3.8.3    <u>GEOLOGICAL MAPPING</u></b></p> <p>i) Concurrently with excavation, the Project Manager will map the geological conditions along the entire tunnel. This mapping and related information will be used to confirm the classification of the rock, the choice of rock support and in the design of the final lining for the tunnel.</p> <p>ii) Contractor shall provide adequate lighting, ventilation, and reasonable access for mapping and shall at the request of the Project Manager clean and wash off the walls, face and crown of the excavations if necessary for mapping.</p> <p><b>3.8.4    <u>INSTRUMENTATION AND MONITORING</u></b></p> <p>i) Concurrently with excavation, the Contractor shall in the presence of Project Manager monitor the convergence of the rock support and tunnel lining with an approved optical convergence measuring system as specified in Chapter “Instrumentation and Monitoring”.</p> <p>ii) Contractor will provide the Project Manager with the results of the convergence measurement, which the Project Manager shall use to confirm the classification of the rock, the choice of rock support and in the design of the final lining for the tunnels.</p> </div>		
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### 3.8.5 PILOT HOLES

- i) Pilot holes shall be drilled ahead of the tunnel excavation, wherever required by the Project Manager, to determine in advance, the nature of the material to be excavated and the presence of any water and gases.
- ii) The drilling of pilot holes in drill and blast methods, shall be included in the normal pattern of drilling the blast holes. The diameter of each hole shall not be less than 38 mm. The length of pilot hole shall be decided by the Project Manager.
- iii) Based on the pilot hole information, the Contractor shall, without delay, provide to the Project Manager, in writing, his assessment of the expected material to be encountered.
- iv) Should pilot holes indicate the presence of excessive water ahead of the excavation face, the Contractor shall take appropriate precautions such as grouting, draining, or adopt such suitable measures as necessary to facilitate excavation. Similarly, the Contractor shall adopt suitable measures to deal with any gases or zones or weakened rock, which may be encountered. All measures deemed necessary by the Contractor shall be subject to approval by the Project Manager.
- v) Contractor may also be required to perform exploratory drilling with core recovery if required by the Project Manager.

### 3.9 SUPPORTS FOR UNDERGROUND EXCAVATION

- i) The provisional or permanent supports for the underground excavation shall be as shown in the drawings. The support consists principally of shotcrete with wire mesh or steel fibre reinforcement, individual or pattern rock-bolts and if required structural steel supports in portal. In certain circumstances additional grouting may be required during excavation and should be performed in accordance with Chapter "Grouting".
- ii) The Project Manager, in consultation with the Contractor, shall classify the excavation on the basis of rock conditions encountered or predicted during the Work and will determine the rock support that shall be used during the


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excavation advance. The decision of Project Manager in all such matters shall be final and binding. This does not relieve the Contractor of his responsibility for a proper and safe execution of underground excavations.

- iii) Contractor shall employ supervising engineers, who by their schooling and knowledge are experienced in supporting work. These supervisors shall examine the rock conditions after each excavation advance and shall verify that the rock support system is installed as ordered. They shall carry sufficient authority to be able to order installation of additional supports or to stop further advance if, in their opinion, the conditions are unsafe. However, they shall have no right to cancel the type or amount of rock supports previously ordered by the Project Manager. These supervisors shall be continuously present and inspect each face throughout the duration of underground excavation work.
- iv) The required supports shall be installed without delay during the process of excavation within the heading zone. In the rear zones additional supports shall be installed immediately after it is observed that the supporting system previously installed is insufficient to prevent further loosening of the material surrounding the excavation or when the convergence of the lining is not stabilising with time.
- v) Shotcrete, with or without steel wire mesh fibre reinforcement of approved quality shall be applied to excavated surfaces in accordance with the provisions illustrated separately in Chapter "Shotcrete". Contractor shall take into account, in his construction planning, that placing of shotcrete protection will be required immediately after blasting or excavation.
- vi) Rock-bolts wire mesh and steel supports shall be installed in accordance with the provisions in Chapter "Rock Support".
- vii) The use of timber will not be permitted for tunnel supports in any form, not even for temporary purpose. All wedge blocks used shall be sand/cement or baked clay bricks of an approved standard.

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- viii) Contractor shall keep on the Site, all necessary construction plant and equipment for installing the rock support, ready for operation in the excavation heading during the entire excavation period.
- ix) Even though it is the Project Manager who determines the type and amount of rock supports to be installed, it is the Contractor who shall bear the whole responsibility for the proper and safe excavation including the provision of extra supports and special protection for the personnel when the conditions so require.


### **3.10 MEASUREMENT AND PAYMENT**


#### **3.10.1 GENERAL**


- i) Measurement and payment for underground excavation will be made according to the classification system specified above. Separate quantities and Unit Rates for the various excavation classes in different portions of the Works are provided in the Bill of Quantities. The definitions of the excavation classes are only relevant for the measurement and payment of the excavation volumes. The estimated quantities for each excavation class given in the Bill of Quantities are not to be considered as an accurate indication of the quantity of work in each class since the predicted and the actual length of each excavation class may differ due to geotechnical conditions encountered during in the course of work. Contractor shall not be entitled to any extra payment over and above the Unit Rates entered in the Bill of Quantities by reason of changes in the actual quantities of the various excavation classes.
- ii) Measurement of excavation in tunnel shall be by volume (m<sup>3</sup>) and shall be obtained by multiplying the theoretical cross-sectional area defined by the pay line (B-Line) shown on the drawings, by the length measured along the centreline (intersection of horizontal and vertical centrelines) of the tunnel.
- iii) Payment for excavation in tunnel will be made at the applicable unit bid rate per cubic metre as indicated in the Bill of Quantities and shall include the entire cost of – but not be limited to – the following:

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	<p>a) Provision of all labour, equipment and materials required for the excavation in all rocks by any tunnelling methods including drilling for pilot holes and holes for blasting; developing and improving controlled blasting methods, blasting tests and performance of blasting; cleaning, washing, protection, and maintaining excavated surfaces in satisfactory conditions, and protection of tunnel invert until the concrete lining is placed; all enlargements and additional excavations required by the Contractor for his construction methods; all temporary supports required for the safety of working crews,</p> <p>b) Provisions for and the operation of vehicular as well as train traffic; loading, hauling, and dumping the excavated material on stockpiles, spoil tips, or points of incorporation into the Permanent Works up to 3.0 km radial distance from the nearest portal for tunnels; clearing, shaping, trimming and maintenance of the disposal areas as specified; clearing, shaping, trimming and maintenance of the stockpile areas, re-cultivation of disposal and stockpile areas; re-handling of suitable materials including segregating, grading, drainage and drying of materials suitable for use in other construction or as backfill,</p> <p>c) All delays during excavation work resulting from installation of rock supports required by the geotechnical conditions of the material encountered, irrespective of the distance from the face,</p> <p>d) Complying with all requirements of statutory laws and regulations relating to underground works and any restrictions resulting there from; obtaining all necessary permits and licences for the use, storage, and transport of explosives and other materials,</p> <p>e) Surveying, setting-out, checking of excavated profile and alignment, and any subsequent rectification works resulting from undue or incorrect surveys; provision of suitable equipment for, and delays due, to carrying out this work,</p>	<div data-bbox="1398 2033 1485 2123" style="border: 1px solid black; padding: 5px; text-align: center;"> <b>ISSUE P0</b> </div>

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<div> <div>f)</div> <div>Furnishing, installation, operation, maintenance, and removal of communication, illumination, and ventilating systems; safety precautions and measurement of dust, silica, and noxious and flammable gases,</div> </div> <div> <div>g)</div> <div>Recording and preparation of reports related to excavation progress and procedures,</div> </div> <div> <div>h)</div> <div>All work involved with, and any partial or short interruptions or inconveniences caused by, the check surveys and performance of rock mechanics test, where no separate payment is provided elsewhere in these Specifications,</div> </div> <div> <div>i)</div> <div>Convergence measurements as specified in Chapter “Instrumentation and Monitoring”.</div> </div> <div> <div>iv)</div> <div> <p>Extra payment will be made for handling the excavated material beyond 3.0 km from the portal/working site as applicable. Payment for handling of excavated material will be made at the Unit Price per cubic metre per km and the same will be applicable for all leads beyond initial 3.0 km. Measurement will be based on the hauled volume. The volume of the material will be measured during hauling operations by counting the number of return truck loads, and will be calculated by applying the following bulking factors:</p> <div> <div>a)</div> <div>For common excavation material: 1.2</div> </div> <div> <div>b)</div> <div>For excavated rock: 1.4</div> </div> <div> <div>c)</div> <div>And using the formula:</div> <div> <div>-</div> <div>Total volume = Number of truck loads x truck capacity/bulking factor</div> </div> <div> <div>-</div> <div>Payment for the resulting calculated volume will be made at the Unit Price per cubic meter and entered in the Bill of Quantities. No payment will be made for any trips by empty trucks.</div> </div> </div> </div> </div>		
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### 3.10.2 ASSIGNMENT OF EXCAVATION CLASSES


- i) For the practical determination of the excavation classes, the actual length of tunnel will be divided into unit portions of 5 m each, along the centreline, starting from points to be defined by the Project Manager at the Site.
- ii) For assigning Classes 1, 2 and 3 (tunnel), the whole unit length of 5 m shall be considered and the average amount of support installed in the heading zone of the header during excavation determined. Where steel arches have been installed, the length between the outermost ribs shall be taken.
- iii) Support installed in excess of that for the assigned class will not be taken into consideration.
- iv) Number, length, type and diameter of installed rock-bolts will not be considered as criteria for classification purposes.
- v) Steel wire mesh placed either as reinforcement of shotcrete, or as protective netting, including short bolts for mesh fixation, shall have no influence on classification of excavation.
- vi) Localised application of shotcrete shall have no influence on classification of excavation.

### 3.10.3 OVERBREAK AND BACKFILLING

- i) No payment will be made for excavation, removal of material or backfilling beyond the pay line (B-line) except in case of an accepted geological overbreak.
- ii) Measurement for the removal of material and backfilling of voids arising from overbreak accepted by the Project Manager as occurring entirely for geological reasons, will only be entertained if the Contractor makes a request directly after excavation, or within such time that the overbreak can clearly be determined as being due to adverse geological conditions. Measurement shall be based on the actual in situ solid volume of all excavated material outside the pay line (B-line) based on cross sections at 1.5 m intervals.

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<div> <div>iii)</div> <div>No payment will be made for excavation, but measurement and payment will be made both for the removal of excavated material, including cleaning of surfaces, and for the additional concrete required.</div> </div> <div> <div>iv)</div> <div>Payment will only be made for accepted overbreak up to a maximum extent of 4% of the theoretical pay line (B-line) area. Any accepted overbreak beyond the above limits of 4% of the pay line area shall be removed and filled at the Contractor's own cost.</div> </div> <div> <div>v)</div> <div>Payment for the removal of excavated material will be made at the unit rate per cubic meter entered in the Bill of Quantities for loading, hauling and dumping of material and cleaning of the surface created by the overbreak.</div> </div> <div> <div>vi)</div> <div>Payment for backfilling of voids created by an approved geological overbreak with concrete, shotcrete or grout will be made at the applicable unit rates entered in the Bill of Quantities.</div> </div> <div> <div>vii)</div> <div>No measurement or payment will be made for voids outside the "B"-line, which are not accepted by the Project Manager as being due to geological reasons.</div> </div> <div> <div>3.10.4</div> <div><b><u>ADDITIONAL EXCAVATION</u></b></div> <div>Payment for additional excavation shall be regulated by taking measurement of the actual excavation carried out as per the line, grade and dimension given by the Project Manager, in writing. In all such cases no consideration of B-line shall be made for payment purpose.</div> </div> <div> <div>3.10.5</div> <div><b><u>EXCLUSIONS</u></b></div> <div> <div>i)</div> <div>All costs for dewatering of underground sites and overcoming difficulties due to the ingress of water shall be covered by the applicable unit rates specified in the Chapter "Control of Water, Construction Drainage and Dewatering". Construction of drainage trenches in the tunnel inverts is included in the measurement for underground excavation. No separate measurement and payment will be made for them.</div> </div> </div>		
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- ii) All costs for exploratory drilling except Pilot Holes will be covered by the applicable Unit Rates as specified in Chapter “Drilling”.
- iii) All costs for supply and installation of rock support will be covered by the applicable Unit Rates as specified in the Chapter “Rock Support”.
- iv) Rock support required due to the Contractor's not adhering to approved drilling and blasting or excavation techniques will not be included for payment.
- v) No extra payment will be made for the following:
  - a) Over-excavation, removal of material beyond the pay line, or backfilling with concrete, shotcrete or grout beyond the pay line (B-line), except that due to geologically accepted overbreak (up to a limit of 4% of the pay line area as specified above). This applies also to any rectification works resulting from incorrect surveys and/or blasting,
  - b) Additional work of removing material and backfilling voids with approved material where overbreak due to adverse geological conditions coincides with that due to Contractor's poor working methods or negligence,
  - c) Over-excavation and filling required for Contractor's convenience,
  - d) Extra work or material required to repair damage to the tunnel invert caused by the construction equipment,
  - e) Clearing, grubbing and maintaining in the disposal and stockpile areas,
  - f) Draining, shaping and trimming of the dumped material in disposal areas to the lines and grades as directed or approved by the Project Manager,
  - g) Excavation of adits carried out by the Contractor for his own convenience and plugging thereof.

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