

18.1.11 The Contractor shall refer to Clause 18.1.12 on the sampling and testing from the additional boreholes in order to assess soil properties relevant to tunnelling operation, to identify potential risks such as clogging, abrasivity, high permeability soil and to plan and optimize the soil conditioning strategy to the acceptance of the Engineer. The Contractor shall note the requirements in **Clause 15** of the Particular Specification on the preparation of the soil investigation report. All costs associated with additional Site Investigation are deemed included in the Contract Price.

18.1.12 The Contractor shall review the Factual Geotechnical report provided by the Authority and propose additional boreholes to ensure sufficient sampling and testing representative of the various ground condition is available at tunnel horizon.

For each of the additional boreholes carried out, the Contractor shall carryout permeability test and collect minimum of three samples at (centre, crown and invert levels of the tunnel) to determine the following parameters:

a) Soil Strata;

1. Plasticity (Atterberg Limits) and Moisture Content
2. Bulk Density and Dry Density
3. Particle Size distribution (PSD)
4. Quartz content, grain shape angularity of pebbles to be described
5. Abrasivity test (Tests shall be carried out at 200m intervals and if the ground condition varies, additional tests will be required. The location of tests shall subject to the Engineer's acceptance.)

b) Rock Strata;

1. Bulk Density and Dry Density;
2. Slake durability test at least 2-3 samples from each borehole;
3. UCS test and Point Load Index test; and
4. Abrasivity test

The Contractor shall produce a test report for all additional boreholes before commencement of tunnelling works. The report shall also include PSD plots within tunnel horizon. The cost of all works stated above shall be deemed included in the Contract Price.

- 18.1.13 The Contractor shall note that the commencement of the TBM main drive with full backup duly installed and commissioned fully inside the bored tunnel is defined as the completion of tunnel initial drive.
- 18.1.14 The Contractor shall ensure that the security measures and design of the tunnels incorporate all the necessary security requirements in accordance with the Security Protection Plan (SPP) / Final Security Protection Plan (FSPP) and other security requirements imposed by the Authority.
- 18.1.15 The Contractor shall liaise with the, QP(S), AC and AC(Geo) and eAC provide the access, information and documentation required to allow them to carry out their duties in relation to the tunnelling.

18.2 Bored Tunnels Works

- 18.2.1 The Contractor shall use one (1) TBM for the bored tunnelling works. It is envisaged that Earth Pressure Balance (EPB) type TBMs will be used.
- 18.2.2 It is envisaged that the Contractor shall launch the TBM from the launching shaft towards CR205 station.
- 18.2.3 The ground improvement for TBM dock in at CR205 interface is under the scope of CR206 contractor. The Contractor has to co-ordinate with the relevant parties to ensure the necessary works are completed before the TBM reaches the CR205 interface. The Contractor shall refer to **Clause 7** of the Particular Specification for the details of the interface requirements with CR206 and CR205 contractors.
- 18.2.4 No provision has been made for the retrieval of the TBM at the CR205 interface. The Contractor shall dismantle the TBM underground and retrieve it back to CR206 via the completed tunnels. The shield skins shall be left underground at the interface with station of CR205 and fully grouted by the Contractor to stabilize the ground. Cast in-situ or segmental permanent lining shall be constructed from the last segmental lining ring built within the shield skins to the interface with the CR205 headwall to form the permanent tunnels. The Contractor shall hack and subsequently prepare the interface wall such that the surface is suitable for the installation of hydrophilic strip and ensure water tightness has been achieved.

- 18.2.11 The bored tunnel may under-cross existing roads, old railway corridor and run along existing road reserve corridors. The Contractor shall investigate road structures and undertake all necessary measures to ensure the tunnelling works beneath these roads do not affect the stability / safety of these road operations. Engagement and coordination with relevant authorities shall be carried out to ensure that mitigation works are in place, should road diversion or temporary road closure be required. The Contractor shall take responsibility to ensure both road operation and tunnelling works are not compromised. Details of construction method, protection measures and real-time monitoring shall be submitted to the Engineer for acceptance.
- 18.2.12 Volume Loss Limits:
- The Contractor shall ensure that his tunnelling operations are within the limits of the LTA Civil Design Criteria (CDC) notwithstanding the requirement for tighter limits as identified by the Contractor's impact assessment report.
- 18.2.13 Any information including the foundation types and depth shown in the Authority's Drawings are indicative only.
- 18.2.14 If required, Contractor shall carry out the strengthening work, diversion of road, temporary traffic management, removal of the piles prior to the tunnelling work and reinstatement of the affected structures.
- 18.2.15 The Contractor shall design, construct, maintain and subsequently remove the full noise enclosures with roof, including provisions for mechanical and electrical services, for the whole of the launch shaft and gantry crane working area and muck pit to shield the noise generated from the tunnelling works. The full noise enclosure shall be installed before the start of the initial drive of the TBM, and to be designed for multiple dismantling and reassembling of the TBM for the subsequent tunnel drive. The Contractor shall refer to **Appendix A** of the General Specification for full noise enclosure requirements for the launch shaft. The full acoustic enclosure shall be completed prior the commencement of the first initial drive.

- 18.2.15A Prior to the second launch, the Contractor and the TBM supplier shall jointly carry out a Site Acceptance Test (SAT) to demonstrate the TBM is fit to commence the second drive. The SAT includes but not limited to full examination of all TBM and backup equipment and components, main bearing, shield, tail seals and cutterhead body with wear detection. This TBM inspection, maintenance and refurbishing works shall be considered in the programme. Both the TBM supplier and the Contractor shall submit reports to the Authority to confirm that the condition of TBM is fit for the second drive.
- 18.2.16 **Storage of Segments on Site**
- 18.2.16.1 The Contractor shall stockpile tunnel segment rings prior to the commencement of his tunnelling works. He shall propose to stockpile minimally at Site, two (2) months-worth of complete tunnel segment rings ("Minimum Number") based on his main drive tunneling programme, subject to the acceptance of the Engineer. In the event that the Site area is insufficient for the storage of the above quantities of tunnel segment rings, the Contractor shall propose location of other storage site/premises within Singapore for Engineer's approval. The Temporary Occupation License (TOL) and all associated cost of the storage areas shall be deemed included in the Contract Price.
- 18.2.16.2 The **Option Module A** specified in the Appendix to the Form of Tender shall apply for stockpiles stored at storage areas. The Contractor shall also comply with the requirements specified in the following Clauses.
- 18.2.16.3 The Contractor shall ensure that the Minimum Number of complete tunnel segment rings at the storage areas and requirements are met, before he can include this item in his one-time claim.
- 18.2.16.4 The Minimum Number of stockpile tunnel segment rings shall be maintained throughout the tunnelling works and only to be utilized for the last section of the tunnel. The Contractor shall seek the approval of the Engineer in the event he requires to draw down from the stockpile.
- 18.2.16.5 The Contractor shall propose and implement a tamper proof and non-removable tagging system to track the movement of segments from production to installation, subject to the Engineer's approval. The Contractor shall be responsible to provide, maintain and/or replace the scanner and associated equipment and software at his own expense.
- 18.2.16.6 Pavement for storage areas shall be designed by a Professional Engineer (PE), registered under the Singapore's Professional Engineer Board (PEB) to ensure safe storage of tunnel segment rings.

- 18.2.16.7 The Contractor shall at his own expense arrange for the Engineer and his appointed representatives to carry out inspection and audit for:
- (a) the storage areas and/or other premises; and
 - (b) the tunnel segment rings stored.
- 18.2.16.8 The Contractor shall optimise the land use and secure the land provision to implement the storage, subject to the relevant authorities' approval. The location of storage is subjected to the Engineer's acceptance. Where the stockpile (or part thereof) proposed is not at the Site, the Contractor shall minimise the number of storage sites/premises for the stockpile.
- 18.2.16.9 The Contractor shall ensure sufficient protection and security for the tunnel segment rings stockpile to prevent damage and loss.
- 18.2.16.10 Damage occurring to tunnel segment rings at any stage prior to erection shall be repaired promptly in accordance with the guidelines provided in **Appendix 16.1** of Materials & Workmanship Specification for Civil & Structural Works. Tunnel segment rings to which damage has occurred and which cannot be repaired shall be rejected, indelibly marked on the inner (concave) face and permanently removed from the storage areas. The amount of such tunnel segment rings shall be deducted from the interim payment in accordance with the **Option Module A** specified in the Appendix to the Form of Tender.
- 18.2.16.11 The Contractor shall submit the proposed team including but not limiting to, lifting supervisor and safety personnel. The Contractor shall appoint a supervisor who will inspect and ensure that the tunnel segments are properly secured prior to leaving the storage site/premises for delivery to Site.

18.3 Tunnelling Design

- 18.3.1 The Contractor shall complete the tunnel segment design, developing the Authority's notional design to suit the rail alignment. The segment design shall be submitted to the Engineer and any other relevant authority for approval.
- 18.3.2 The Contractor shall engage qualified person Design (QPD) to calculate TBM face pressure and other key tunnelling parameters to meet the most onerous of the volume losses indicated in this Particular Specification and as determined by the Contractor for the safe completion of the tunnelling works, or as may be required by the Authority, AC, QP(S), BCA or any other relevant authority.

- 18.7.6 The Contractor shall coordinate and ensure that his Professional Engineer (PE) is engaged at the design stage to review the TBM design. The Contractor shall liaise with the TBM Supplier and ensure that the TBM is designed to suit the envisaged site conditions. All lifting points shall be endorsed by the Contractor PE prior to usage on-site.
- 18.7.7 Each of the Contractor's proposed TBM shall have a thrust output of not less than 46,000kN, or as required to achieve the contract requirements, whichever is higher. This force shall be provided from a series of hydraulic cylinders in a double thrust jack configuration located around the shield circumference.
- 18.7.8 The cutterhead shall be driven by variable speed electric drive system with an installed minimum power of 1,200kW.
- 18.7.9 The Contractor shall note that sections of the tunnelling drive may encounter rocks of Bukit Timah Granite Formation (GIV or better) hence the TBM shall be designed to suit this particular condition.
- 18.7.10 The TBM is to be designed and operated to ensure the groundwater pressure is maintained at all times, thus controlling consolidation settlement along the drive.
- 18.7.11 The TBM shall allow replacement of the main bearing and tail brush seals and other parts from within the tunnel. The bearing shall be removable rearward with the minimum of disturbance to the other components, in the event of the need for replacement. The Contractor shall submit a method statement and programme demonstrating that the design will facilitate main bearing removal and replacement in the event of bearing failure during tunnelling operations to the Engineer for acceptance.
- 18.8 Supply and Support of Tunnel Boring Machine**
- 18.8.1 In addition to the requirements of the General Specification **Appendix P2** and **O2**, each belt conveyor shall be provided with at least two (2) belt weighting device (for cross-checking) as part of an automatic monitoring system for the material discharge per ring of advance.
- 18.8.2 The Contractor shall ensure that thermal insulation is provided for the chilled water pipes when there is a possibility of condensation within TBM and backup.
- 18.8.3 The Contractor shall ensure that drift eliminators are provided for the cooling towers serving the TBMs.

- 18.8.4 Electricity supply for the TBM shall be 6.6kV or 11kV. The use of 22kV distribution is not permitted in the tunnels/launching shafts. All TBM's transformer proposed shall be of Silicon oil type with Air Natural (KNAN) configuration. Secondary winding of all transformers shall have a solidly earthed star-point.
- 18.8.5 Dry type transformers are not allowed in tunnels/launch shafts.
- 18.8.6 The segment erector shall be of vacuum type. It shall permit the safe handling and placement of the tunnel lining within the specified performance rates and provide adequate facility for the insertion and tightening of the segment bolts. When the erector is in operation, the TBM Excavation mode shall be automatically on standby as a safety requirement.
- 18.8.7 Segment retainer system shall be provided to hold the second last assembled segmental ring in position at the tail skin prior to next advance.
- 18.8.8 A probe drilling and ground treatment system shall be provided with the capability to drill and grout ahead of and around the TBM via use of the horizontal and inclined ground consolidation tubes. The drilling and grouting forward shall be done via the shield, bulkhead and cutterhead. This shall be done in accordance with LTA's specifications. The Contractor shall design the TBM such that it maximises the free working space in and around the TBM for the purpose of probe drilling and ground treatment. Probe drilling and grouting system shall be suitable for all types of geology as stated in the GIBR.
- 18.8.9 The Contractor shall ensure that all probing and grouting equipment, inclusive of drive unit, manipulator, extension rods and drill bits, as a minimum, are stored and available within the Backup for immediate deployment.
- 18.8.10 The probe drilling and ground treatment unit shall have independent power source. Drill diameter shall be 60 mm and the probe unit shall permit both drilling and coring for a "B" size core. The drilling equipment shall be capable of drilling a distance of 20 meters in the geological conditions foreseen.

- 18.8.11 The probe drilling and ground treatment unit shall allow drilling and grouting to be carried out ahead of the TBM face to cover a full 360 degrees annulus at a distance of 20 meters ahead. Each grout port shall be fitted with a valve, and shall be designed so that a blow-out preventer can be fitted to control the loss of ground and groundwater during drilling. The proposed system shall comprise regularly spaced grout sleeve pipes built into the shield skin for grouting the ground ahead of the tunnel axis. The location and number of ports shall be adequate to facilitate full coverage of the ground in front of the cutterhead and fully around the shield for ground stabilization in all ground conditions. The design shall be submitted to the Engineer for acceptance. The drilling ports shall be readily accessible and be fitted with suitable non-return valves and located such that there is space for the use of blowout preventers.
- 18.8.12 The Contractor shall design a suitable hydraulic manipulator for the probe drill and ground treatment unit. This shall be permanently located within the front zone of the Backup such that the equipment is always available for set up within 2 hours. A high degree of wear is to be expected for the material transport system. All components designed to transport the excavated material shall be manufactured to provide an abrasion resistant surface to minimise replacement and /or maintenance.
- 18.8.13 The design and capacity of the rolling stock muck skip arrangement shall consider the EPB TBM's maximum advance speed (mm/min), muck density, excavation diameter of tunnel, etc. The contractor shall operate with minimum 16m³ capacity muck skips as a part of the rolling stock logistics.
- 18.8.14 Locomotives shall be provided with Colour CCTV cameras mounted at both sides of the rolling stock and a monitor shall be placed inside locomotive operator's cabin to assist the operator's visibility.
- 18.8.15 The Contractor shall demonstrate the dimensions/volume of the skip is capable to meet the required tunnelling rates.
- 18.8.16 For the purposes of minimising spillage, each muck skips shall be marked with a line, 150mm below the top surface of the skip. The Contractor is to ensure that the skips are filled below this line, for accurate accounting in terms of volume as well to maintain the quality and safety standards within the tunnel.

18.9 Tunnel Construction Staff and Personnel

- 18.9.1 The Contractor is to ensure that key staff proposed at tender, or suitable alternate staff (with the same level of qualification, experience, and capability as those originally proposed) expressly accepted by the Engineer in writing, are available on Site as required from the programmed start of TBM design until structural completion of all the tunnel drives. Each of the key staff shall have a designated deputy capable of covering the duties during agreed absences from site.
- 18.9.2 As a minimum requirement, the Contractor shall ensure that the Tunnel Manager and the Tunnel E&M Manager are available during TBM design, manufacturing and full time on site from three (3) months after Contract award until structural completion of all tunnel drives. Alternatives will not be acceptable unless to the acceptance of the Engineer. Each of the key staff shall have a designated deputy capable of covering the duties during agreed absences from site. Amount to be deducted for each period of absence from Site, except where the agreed deputy is covering the duties on the Site:
- (a) TBM Tunnel Manager \$40,000 per month; and
 - (b) TBM E&M Manager \$40,000 per month.
- 18.9.3 The absence for parts of a month for personnel mentioned in **Clause 18.10.2**, shall be assessed pro rata.
- 18.9.4 The Building and Construction Authority, Ministry of Manpower or the Qualified Persons may deem the absence of any of the key staff as unacceptable and immediately stop work at their sole discretion. In this case the Contractor is required to satisfy the relevant authority such that the work may be resumed. This is in addition to compliance with any requirements by the Engineer. All delays, stoppages, loss, and expense arising from the absence of any of the key staff shall be the Contractor's responsibility.
- 18.9.5 The Contractor shall deploy one tunnel team for each concurrent tunnel drive. Where the Contractor undertakes multiple drives concurrently, they shall ensure they provide one team per drive to ensure that the tunnelling works can be carried out on a 24-hour basis.

18.10 TBM Operation, Management and Control

- 18.10.1 The Contractor shall upload TBM operating parameters to the Authority's designated server in accordance to **Clauses 7 and 14** of the Particular Specification.

- 18.11.4 The Contractor shall allow for adequate cutterhead interventions in his construction requirements and programme for cutting tools check and replacement based on his TBM design for the baseline activity specified in the GIBR. All costs shall be borne by the Contractor and deemed to be included in the Contract Price.
- 18.11.5 Prior to crossing beneath any sensitive structures, the Contractor shall carry out joint inspection with QP(S)/SRE(T) or Qualified Site Supervisors (QSS) for the condition of cutter head tools in consultation with the TBM manufacturer to ensure safe tunnelling under these structures. The Contractor shall submit plan for cutterhead intervention for cutter tools check and replacement for Engineer's acceptance to be undertaken before entering the influence zone of the sensitive structure.
- 18.11.6 From the experiences gained during the demonstration of the changing of the cutting tools, the tunnelling machine manufacturer and Contractor should develop a safe working procedure for the changing of the cutting tools for inclusion in the TBM manual.
- 18.11.7 The initial inspection made before entering the excavation chamber shall be done under compressed air as per BCA requirements.
- 18.12 Tunnel Lining**
- 18.12.1 In addition to **Chapter 16** of Materials & Workmanship Specification for Civil & Structural works, the Contractor shall make reference to this Clause and **Clause 25** of the Particular Specification for the requirements on the segmental precast lining.
- 18.12.2 The Authority has made effort to standardize the segmental mould design as shown in the Authority's Drawings for the possible sharing of segments amongst the various civil contracts. The Contractor shall work with the Engineer's team upon award of contract to develop standard segment details not limiting to position of segment identification stamp and shear cones, the details of dowel system, the composite gasket, etc. prior to the confirmation of segmental mould design and casting of segments.
- 18.12.3 The foam strip to be provided along radial joints of segments to prevent grout from by-passing the shield tail skin seal. The foam strip shall be compressible, and no load shall be exerted by the foam strip on the segments when they displace underground loading.

- 18.12.4 The bolting system for connecting the segmental lining across radial joints shall be a proprietary spear bolt connection system. The bolting system comprises a bolt and an accompanying cast-in bolt socket. The bolt shall be a minimum M24 steel bolt Grade 8.8 or to an equivalent as approved by the Engineer.

18.14 On-Board Weighing System (OBMWS)

- 18.14.1 In addition to the requirement to the **Appendix O2** of the General Specification, the Contractor shall design, supply, install, programme, test, and commission the “On-board muck Weighing System” (OBMWS) which comprises load cells installed on each flat car of the rolling stock with connected hardware and software accessories to enable real-time weight measurements and monitoring for soil reconciliation during the mining operations for the duration of the tunnelling works. The accuracy of the weighing system shall be $\pm 0.5\%$ of the load weighed.
- 18.14.2 The Contractor shall design the OBMWS taking into consideration the tunnel operating environment and safety considerations related to maintenance, handling and operations.
- 18.14.3 The OBMWS with the load cells are preferred to be built-in within the flat car taking into consideration the tunnel operating conditions. They may also be retro- fitted on existing flat car. In either options, the Contractor has to submit the detailed design and specification to the Engineer for acceptance prior to fabrication. The Contractor shall also include in his submission the detailed drawings and load calculation depending on the expected skip volume.
- 18.14.4 The Contractor shall ensure that all the hardware (load cells, data loggers and data transmitter device within the tunnel) used for the OBMWS shall be of a suitable grade (minimum IP 67 rated) and shall meet the standards for underground applications in respect of fire and toxicity. The Contractor shall also select robust durable components that can withstand a high degree of wear due to harsh tunnel environment and must last for the entire tunnel operation. The hardware’s designed and installed must be easily replaceable in the event there is any damage, and the system must be back in operation within the next shift (12-hours).
- 18.14.5 The OBMWS shall be synchronized with the excavation cycle when spoil is being removed and collected on the skips. The measured weight shall be displayed on the operator’s console and in the Authority’s Office. The monitoring system shall be designed to provide continuous information on the ratio of the actual to theoretical measurement of the material excavated throughout each advance, after allowing for the weight of conditioner injected.

CONTINUED ON PAGE PS-2-23B

- 18.14.6 The Contractor shall integrate the OBMWS to the existing TBM PLC system in accordance with **Clause 4.27(j)** of the General Specifications **Appendix P2**, which includes the TBM parameters and the belt conveyor operation parameters. This system shall display on computer screens most of operation data, parameters, all alarms and faults. This information shall be displayed on the same control room screen as a part of the excavation management system to control the over/under excavation arising from the tunnelling works.
- 18.14.7 This system shall display real time data and allow recording of the information related to
- a) Soil net weights for each skip against time
 - b) The standard TBM excavation information with the over/under excavation results as and when the skip is being weighed (real time)
 - c) The final summary of the excavation record after each tunnel ring
- Details of the proposed system and the accuracy of its measurements shall be submitted to the Engineer for his acceptance
- 18.14.8 Upon the integration and completion of the OBMWS onto the flat cars of the locomotives and integration with the TBM PLC, the Contractor shall conduct Functionality Acceptance Tests (FAT) on the system to the satisfaction of the Engineer. These tests shall be conducted at the surface ground level and endorsed by the professional engineer. All the relevant certification and details shall be submitted to the Engineer.
- 18.14.9 The Contractor shall provide regular maintenance of the OBMWS and carry out regular re-calibration as necessary to maintain the accuracy of the OBMWS throughout the duration of the tunnelling operation.

CONTINUED ON PAGE PS-2-24

18.15 Tunnel Drainage

The Contractor shall seek approval from relevant enforcement authorities (such as PUB and NEA) prior to the discharge of trade effluent generated from the construction and the tunnelling works into sewer, watercourse, Clementi stream or controlled watercourse. The Contractor shall treat and monitor the trade effluent to meet the respective allowable discharge limits before it is discharged into any sewer, watercourse, Clementi stream or controlled watercourse as approved by the relevant authorities. The Contractor shall note that Earth Control Measures (ECM) are meant for the containment and treatment of silty rainwater runoff only, and , not meant for the treatment of process water, such as oil, grease, cement, and bentonite from tunnelling activities. Such process water should be handled and treated separately to comply with regulatory requirements.

18.16 Method Statements

- 18.16.1 The Contractor shall comply with the requirements of **Appendix O1** of the General Specification.
- 18.16.2 In addition to the requirements of the General Specification and **Clause 12** of the Particular Specification the Contractor shall provide the method statement for achieving the required volume loss under sensitive structures.