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- Proposed groundwater control system and its efficiency;
- Locations of any elements of systems for recharge wells and proposed locations of piezometers/water standpipes inside and outside the excavation or cofferdams;
- Impact assessment and protective measures for any building, structure, infrastructure or utilities due to groundwater control;
- Redundancy in the system to cater for breakdown or failure of any element of the groundwater control system;
- Maintenance regime of the groundwater control system to sustain the optimum functioning of the system; and
- Proposed contingency measures for ground water control.

- 14.7.6 To ensure stability of excavations and to limit groundwater drawdown during excavation to not more than 1m below the existing groundwater levels, the Contractor shall propose and implement mitigation measures to control groundwater drawdown to the acceptance of the Engineer.
- 14.7.7 Installation of relief wells inside the excavation are discouraged and the Contractor is encouraged to design the Earth Retaining Stabilising Structure (ERSS) without having to install relief wells.
- 14.7.8 Notwithstanding the requirements to provide an essentially watertight retaining wall structure in the vicinity of compressible soils, in particular Kallang Formation soils, groundwater control measures are to be implemented. The measures shall control seepage where the Contractor predicts that groundwater drawdown or seepage related consolidation settlements would occur.
- 14.7.9 In the event that excessive drawdown of ground water occurs and fails to stabilise, the Contractor shall be responsible for all measures to ensure the stability of the excavation, adjacent structures, facilities and services.
- 14.7.10 Where recharge systems are proposed, the Contractor shall take into account of the following requirements:

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- Recharge wells shall be periodically maintained, cleansed and back-flushed using a submersible pump to clean out the well screen section to ensure the well efficiency.

14.7.10.5 Deep Recharge Wells with Pressure Pumps

- Where required, the Contractor shall install a deep recharge well at depths of more than 25m to recharge with a pressure pump. Before proposing such system, the Contractor shall evaluate the impact of high water pressure on surrounding ground and foundation system of adjacent buildings. The long term effects on surrounding foundation system to be carefully evaluated and submitted to the Engineer's acceptance before implementation of deep recharge well system.

14.7.11 The Contractor shall submit the recharge well maintenance strategy report. Any recharge well that is not functioning as per the design or faulty shall be replaced.

14.7.12 The decommissioning of the recharge well system shall also be subjected to the acceptance of QP(S) and Engineer.

14.7.13 The provisions of groundwater control systems including the design, supply, installation, operation, monitoring, maintenance and removal costs shall be deemed included in the Contract Price. For the avoidance of doubt, the costs for all water usage and/or utilities charges shall be the Contractor's responsibility and shall be borne by the Contractor.

14.8 **Earth Retaining Stabilising Structure (ERSS) and Ground Improvement**

14.8.1 Fissure Grouting

14.8.1.1 The Contractor shall carry out fissure grouting to minimise the groundwater drawdown in the fractured rocks. The minimum width of fissure grouting shall be 3m as shown in Figure 14.1 and Figure 14.2 below. The fissure grouting shall be carried out in accordance with the following:

(a) For rock head above formation level:

- Diaphragm wall: Fissure grouting shall be from formation level (refer to Figure 14.1)

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- (ii) Other wall types: Fissure grouting shall be from the rock level (refer to Figure 14.2)
- (b) For rock head below the formation level (<10m depth): Fissure grouting shall be from the rock level for all wall types (refer to Figure 14.2)

The fissure grouting shall be carried out to the level where the coefficient of permeability of the rock is not higher than $1.0E-7$ m/s or to a minimum depth of 10m below the formation level, whichever is deeper. The Contractor shall assess the ground condition and propose extent and depth of fissure grouting required for the control of water drawdown for the acceptance of the Engineer. The fissure grouting shall achieve a coefficient of permeability of not higher than $5.0E-8$ m/s. The Contractor shall refer to **Appendix BJ** of the Particular Specification for the fissure rock grouting.

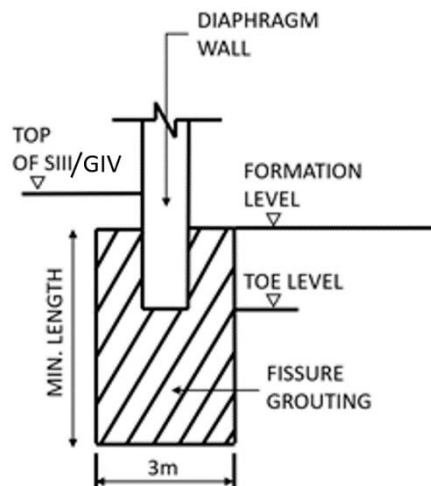


Figure 14.1

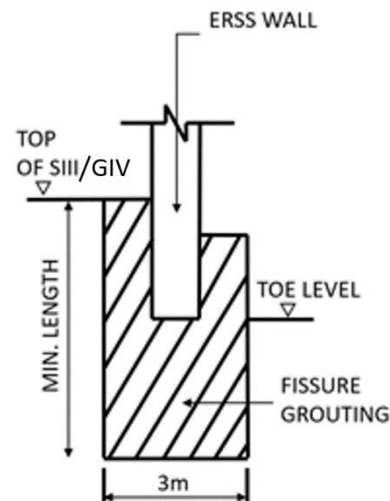


Figure 14.2

14.8.1.2

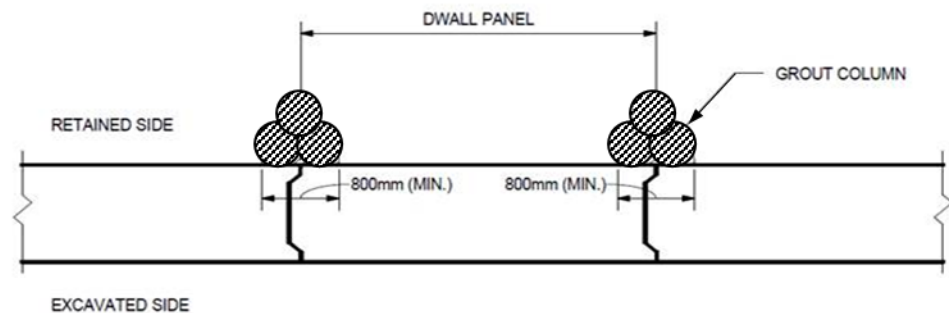
Where the rock level is expected to be encountered below the formation level and the permeability of the soil between the ERSS toe and 10m below the toe is higher than $1.0E-7$ m/s, curtain grouting in soil shall be carried out to provide a total cut off depth of at least 10m below the formation level. The curtain grouting shall achieve a coefficient of permeability of less than $5.0E-8$ m/s.

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14.8.2 Joint Grouting

Where fluvial sand and other permeable soils exist, the joints behind the diaphragm wall panel shall be grouted minimum 1m into Bukit Timah Residual Soil or Jurong Residual Soil or ground with permeability of $1.0\text{E-}8\text{m/s}$, or to the acceptance of the Engineer, as shown below.

**JOINT GROUTING DETAIL**

Minimum Number of Grout Columns at Joints of Diaphragm Wall Panels

At joint locations between two (2) types of ERSS walls where the end of one of the ERSS wall abuts perpendicularly or at an angle with the other ERSS wall, the joint shall be sealed with grout columns (minimum three columns) on the outer side of the excavation from ground level to the toe level of the ERSS wall, subject to the acceptance of the Engineer and QP(S). The minimum requirement for grouting permeability at the joints shall be $K=1\text{E-}8\text{m/s}$.

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14.9 Ground Treatment

- 14.9.1 Ground treatment where required to improve soil conditions, control wall deflections and ground movements or control the flow of water into the excavation, the following clauses shall apply.
- 14.9.2 The specialist contractor for ground improvement works shall have proven track record of ground improvement in similar ground conditions and scale of works.
- 14.9.3 The method of treatment is to be proposed and designed by the Contractor and submitted to the Engineer and QP(S) for acceptance, and where necessary, the design shall be submitted by the Contractor's PE to BCA or other relevant authorities for approval.
- 14.9.4 The Contractor shall carry out a trial section of ground treatment with the appropriate instrumentation and monitoring works to demonstrate with tests as agreed with the Engineer and QP(S) to prove that the treatment has achieved or will achieve, the required results.
- 14.9.5 Prior to starting work, all sub-surface utilities shall be located and supported/protected or diverted to the satisfaction of the appropriate authorities and the Engineer.
- 14.9.6 Drilling and treatment shall be carried out with the utmost care to prevent disturbance to the nearby services and properties. Care shall be taken to prevent undesirable ground movements.
- 14.9.7 The Contractor shall establish suitable temporary survey benchmarks for the purposes of monitoring ground movements during ground treatment. Such benchmarks shall be located outside the zone of influence of the ground treatment works.
- 14.9.8 The Contractor shall continuously monitor buildings/structures/utilities movements due to the ground treatment works at intervals acceptable to the Engineer. The monitoring results shall be made available for the Engineer's review within 12 hours of the measurements being taken.