CONTENTS

Clause Description Page PS-14-

14. STRUCTURAL IMPACT ASSESSMENT, SETTLEMENT CONTROL AND MONITORING

14.1 General

14.1.1 The Contractor is solely responsible for ensuring that his design and construction does not cause damage to surrounding infrastructure, buildings, and complies with all statutory obligations and requirements of the Authority and other authorities.

14.1.2 The Contractor shall indemnify the Authority for any costs arising from settlement or ground movements caused by the Works.

14.1.3 The Contractor shall view available as-built structural and foundation drawings at the Authority's office. The Contractor shall note that the reports and as-built drawings may not contain building/foundation information for every building/structure that is likely to be affected by the Works. In the event that the as-built structural and foundation drawings are incomplete or not available, the Contractor shall be responsible for seeking and ascertaining the relevant information including the purchase of as-built drawings necessary for his design and impact assessment with all such costs deemed included in the Contract Price.

14.2 Buildings/Structures to be Assessed

14.2.1 All buildings and structures likely to be affected by the Works shall be assessed based on the LTA Civil Design Criteria (CDC) and BCA requirements for the likelihood of damage. Based on the Contractor's detailed construction methodology and predicted ground movements, he shall determine the zone of influence of the Works. The minimum zone of influence for the Works is specified in **Appendix E** of the Particular Specification. The Contractor shall carry out pre-condition surveys of the buildings or structures for the purpose of building impact assessment study.

14.2.2 For buildings and structures that are along the mined linkway or tunnel alignment where applicable, notwithstanding the documentation and drawings provided by the Authority, the Contractor shall carry out his own investigation to verify the presence of foundations at the structure horizon and assess the implications. Should the foundations be found to be encroaching into the structure horizon, the Contractor shall remove all obstructions within the alignment in advance at his own cost.

14.2.3 The Contractor shall consider the findings from the pre-construction survey in his impact assessment of the existing buildings/structures within the zone of influence.

14.2.4 The Contractor shall take into consideration the combined effects due to the construction of the Works in adjacent civil contracts in his impact assessment studies. The Contractor shall coordinate with the adjacent contractors to obtain the relevant information.

14.2.5 Prior to completion of his design, the Contractor shall carry out a serviceability performance review for all structures to assess the extent of disturbance that these structures can accommodate. Factors that shall be taken more closely into account in the serviceability performance review shall include, but not be limited to, the following:

- Basement configuration and waterproofing system;
- Cladding system;
- Foundation systems;
- Previous movements;
- Soil-structure interaction; and
- Structural integrity.

Detailed analysis taking into account of the above factors shall be carried out.

14.2.6 The Contractor shall propose a suitable protective works scheme to be included in his Damage Assessment Report, to all buildings and structures for which the predicted damage category is “Slight” and above. After the acceptance of the protective works scheme by the Engineer, the Contractor shall design and install the protective works.

14.3 Pre-Construction and Post-Construction Condition Survey

14.3.1 The purpose of the pre-construction and post-construction condition surveys is to provide a record of the condition of the structures within the survey area of the Works, before commencement and after completion of the Works.

14.3.2 The Contractor shall carry out comprehensive pre-construction and post-construction condition survey as per requirements specified in **Appendix U** of the Particular Specification of all existing buildings, structures, infrastructure and utilities within the zone of influence of his works as a minimum as shown in **Appendix E** of Particular Specification.

14.3.3 The Contractor shall also note and comply with the latest BCA Guidelines on Pre-Construction Survey and comply with statutory requirements.

14.3.4 The Contractor shall also carry out pre-construction and post-construction condition survey of existing drains and sewers (including Closed Circuit Television (CCTV) surveys where necessary) within the Contract Limits, and up to the summit of the drains, canals and box culverts. The exact extent of drains, canals and box culverts to be surveyed shall be subject to the acceptance of PUB and the Engineer. The Contractor shall also carry out joint site inspections with PUB to review any defects observed during the inspection and to determine with PUB the drains or sewers that will need to be rectified by PUB prior to commencement of the Works. Any protection measures for the drains and sewers, if required, shall be carried out at the Contractor’s cost and time.

14.3.5 The Contactor shall carry out pre-construction condition survey prior to the commencement of the Works as required by the Building Control Regulations and submit his reports with Professional Engineer (PE) endorsement to the Engineer for acceptance. Upon acceptance, the Contractor shall submit the report to the stakeholders for record. The pre-construction condition survey on all buildings and structures shall be thorough and shall include, but not be limited to show the conditions of pavement, car porch, driveway, ponds, landscape, hardscape, fixed furniture, small reinforcement concrete shed, letter box structure, gates fencing, existing ground/ pavement level around the houses, compound drains with invert level taken including cope level, etc. Conditions of all walls, ceilings and floor for each unit/room as well as roof structure including picture of roof trusses, etc. shall be recorded with pictures. All external walls of premises shall have pictures as part of the pre-condition survey report for each property.

14.3.6 Photographs of defects and measurements of representative cracks of structural members shall be taken when necessary and submitted to the Engineer in hard and soft copy. All existing cracks shall be monitored with a crack meter.

14.3.7 In the course of the Works, the Contractor shall carry out additional condition surveys to existing buildings, structures and utilities within the zone of influence where required to record the changes after the pre-construction conditions surveys and prior to the commencement of works at the location of vicinity. In all cases, the Contractor shall be responsible for all protection measures necessary to ensure that the buildings adjacent to the Contractor’s worksite will not be adversely affected by his works.

14.3.8 For structures that are under construction or are to be demolished, the necessity to carry out these surveys depends on when these structures are completed or to be demolished. The Contractor shall submit his proposed course of action to the Engineer for acceptance.

14.3.9 The Contractor shall be responsible to seek permission from the building owners for access to carry out his surveys. In cases where the owners refuse or are un-contactable, the Contractor shall adopt all reasonable measures to contact the owners and these shall be recorded in detailed chronological order in a format acceptable to the Engineer. The records shall be forwarded to the Engineer in one (1) hardcopy and softcopy on 3-monthly basis or as requested by the Engineer.

14.3.10 The Contractor shall note that there could be sensitive structures which may lie beyond the limits of the zone of influence. In this case the Contractor is to ensure that his design and pre-construction condition surveys shall take into account of these structures and that his construction work do not cause distress to these structures.

14.3.11 The Contractor shall engage a PE for the preparation of the survey reports who shall not represent any property owner who is filing a claim for property damage against the Authority or under the LTA Act in respect of or in connection with the Works. The pre-construction condition survey shall be completed prior to the commencement of any works and the post-construction condition survey shall be completed within six (6) months after Basic Structure Completion.

14.3.12 The Contractor shall carry out post-construction condition survey upon completion of the Works as necessitated by the Building Control Regulations and submit his reports to the Engineer for acceptance and upon acceptance submit to the stakeholders for record.

14.3.13 The Contractor shall take full ownership of the Pre-construction and Post-construction Condition Survey Report and shall be solely responsible for the accuracy and completeness of the Report. The Contractor shall be responsible for the timely submission of pre-construction and post-construction reports to the Engineer. Both reports shall be endorsed by PE. The reports shall be submitted to the Engineer for acceptance in the format as described under **Clause 14.3.15** below.

14.3.14 Requirements

14.3.14.1 The Contractor shall prepare a programme for carrying out the pre-construction and post-construction condition surveys. The programme shall be sufficiently flexible to allow for any additional condition surveys that may become necessary as work progresses. Close liaison with the Engineer shall be maintained to ensure that the pre-construction and post-construction condition surveys are completed in a satisfactory manner and within the required time frame.

14.3.14.2 The Contractor shall notify the Engineer in writing of his intention to carry out a condition survey of any building at least six (6) weeks prior to the date when he requires access to that building. All notices to property owners for permission to carry out the pre-construction and post-construction condition surveys shall be issued by the Engineer after receiving the Contractor's prior notification. The Contractor shall obtain all necessary information, including the name and address of the property owners, to enable the Engineer to issue notices to enter the premises.

14.3.14.3 The Contractor shall ensure that the dates shown on the descriptive and visual records of structure conditions submitted to the Engineer and/or stakeholders are clear and verifiable.

14.3.14.4 The Contractor shall ensure he allows sufficient time for pre-construction condition surveys of any sensitive facilities such as existing Maju Camp, SPPG substations, Old Jurong Railway tunnel, etc including the application processing time for security clearance for his personnel as well as accounting for the limited working time within the identified structures.

14.3.14.5 The Contractor shall note the strict requirements for taking photographs at sensitive high security areas and must allow sufficient time and resources to get the necessary permissions and equipment in order to comply with security requirements of those premises.

14.3.15 Reports

14.3.15.1 A written report shall be prepared for every surveyed structure or group of structures (if they are linked).

14.3.15.2 The Schedule of Condition shall include, but not be limited to, the following:

- Name of the structure (where applicable);
- Postal address;
- Use of structure, e.g., residential, commercial, etc.;
- Type of construction, foundation(s) and structural frame system, e.g., number of storeys, steel frame building, etc.;
- Cladding and its supporting framework;

- Condition of structure - detailed description together with photographs including particulars such as the type or quality of finishes in the areas likely to be affected by Works, existing defects with detailed measurements, observation of cracks, verticality, history of previous repair, location and type of strengthening measures adopted;

- Location plan to identify areas described; and

- Proposed types and locations of instrumentation and monitoring.

14.3.15.3 The Contractor shall submit a proposed format for the condition surveys for the acceptance of the Engineer before finalising his reports. The Contractor shall submit the reports duly signed by the PE within four (4) weeks of completing the surveys.

14.3.15.4 The Contractor shall propose appropriate monitoring systems for structures based on the findings of the surveys.

14.3.15.5 Photographs taken by the Contractor and/or his PE for all condition surveys shall be as follows:-

- Each photograph shall clearly show all the necessary details intended to be shown and as described in the report;

- Details of cracks/defects shown in the photographs shall contain a graduated scale;

- For pre-construction condition survey, matt colour prints (dated and size 4R) shall be presented, annotated and submitted in bound volumes together with negatives/soft copies; and

- For post-construction condition survey, digital photographs (high quality, minimum seven (7) mega-pixel, size 4R and dated) shall be presented, annotated and submitted in bound volumes with negatives/soft copies.

14.3.15.6 A sketch plan shall be included in each individual structure report to show the location and orientation of each photograph. In the event that the photographs are of a quality unacceptable to the Authority, they shall be retaken at the Contractor’s own cost.

14.3.15.7 Once the reports are accepted by the Engineer, one (1) original and one (1) bound copy, all duly signed by the Contractor's PE upon completion of the survey of that structure or building together with one (1) soft copy of the report and photographs, shall be submitted to the Engineer. The letter with these reports to the Engineer shall include a qualitative description on the susceptibility to damage due to the Works based on the pre-construction survey and impact assessment, and any protection measures required. The reports shall be submitted within two (2) weeks following the completion of the survey works.

14.3.15.8 The information on the pre-construction condition survey and post-construction condition survey reports shall be taken in digital format and stored in suitable digital storage media. It shall be submitted to the Engineer at the time of report submission. The information and colour photographs shall be retrievable via Microsoft Windows PC or compatible system.

14.3.15.9 In addition, the Contractor shall also develop and provide the Engineer with a computerized tabulation of the following details for ease of retrieval of the reports:

- Section No.;
- Property Ref No.;
- Type of Property;
- Property Name;
- Property Address; and
- Report No.

14.3.15.10 The Contractor shall give a presentation on the findings of the condition surveys to the Engineer within two (2) weeks of submitting the report. The format of the presentation shall be similar to that in the report submission. The presentation shall be conducted using Microsoft PowerPoint or any other software acceptable to the Engineer. Models shall be used, if necessary. A question and answer session shall be included at the end of the presentation to answer queries posed by agencies and the Engineer.

14.3.15.11 In the vicinity of the contract interface with any ongoing development, the Contractor shall coordinate and share the building condition survey reports with the adjacent contractor.

14.3.15.12 The Contractor shall monitor within his Contract boundary any new developments or construction activities by others and keep track of the impact cause by these works.

14.4 Settlement Analysis Report

14.4.1 For all temporary and permanent Works to be designed and constructed by the Contractor, the Contractor shall submit a Settlement Analysis Report to document the assessment of anticipated ground movements and the response of the adjacent buildings, structures and utilities due to the execution of his Works.

14.4.2 The Settlement Analysis Report shall include, but not be limited to the following:

- Geotechnical characteristics of the ground considering additional soil investigation by the Contractor and any other information obtained;
- The proposed methods and sequencing of construction and types of equipment to be used;
- Type of structures including the existing conditions of the structures and foundations together with allowable total settlement, differential settlement, angular distortion and/or strains. These values shall not result in a damage category that exceeds the requirements as defined in the LTA CDC and/or the performance requirements set by respective agencies/stakeholders;
- Set review levels (Alert Levels (AL) and Work Suspension Levels (WSL) as defined in the LTA CDC) for each stage of the works together with contingency plans and actions when review levels are breached;
- Assumptions and calculations on which the assessments of the ground movements, movement of structures, etc., were made;
- Anticipated ground movements (both horizontal and vertical) during the execution of the Works, including drawings showing predicted settlement and settlement contours. The drawings are to show predicted green field settlement due to the construction of Temporary and Permanent Works. The assumptions made in respect of the temporary works schemes are to be shown in the drawings;

- The Contractor's proposal for additional site investigation where required for finalisation of settlement and protective works design;
- The risks of predicted settlements being exceeded and mitigation measures to reduce these risks;
- Contingency proposals for protective works, if predicted settlements are exceeded; and
- Assessment of the effects of the predicted short and long term ground and structural movements on all adjacent buildings, structures and infrastructures, and identification of any which requires protection works.

14.4.3 The Contractor's Settlement Analysis Report, prepared and endorsed by his QP(D) shall follow the format of a Preliminary, Pre-final and Final Settlement Analysis Report, taking on any additional soil investigations or other information obtained. Each report (preliminary, pre-final and final) should highlight any changes with full justification for the modifications. Protective works designs for all structures shall be fully developed. The Final Settlement Analysis Report shall be submitted prior to the commencement of Works on site and no Works will be allowed until the Final Settlement Analysis Report is accepted by the Engineer and QP(S).

14.5 Protective and Corrective Measures

14.5.1 The protective works designs for all structures must be fully developed and duly endorsed by the Contractor's PE. Based on his assessment, the Contractor shall propose and install any protective works, subject to the acceptance of the Engineer and QP(S). Protective works shall be in the form of modification to support systems and foundations, ground improvements, compensation grouting, jacking or structural strengthening, groundwater control systems, propping, shoring or other methods proposed by the Contractor. Care shall be taken to ensure that the selected method of preventive and/or protective measures does not have adverse effects on the buildings/structures/utilities and has a proven record for this type of construction in similar ground conditions. The protection works shall not impede any access unless alternatives are provided by the Contractor. For protective works which shall be removed upon completion of the Contractor's works, the Contractor shall include in his proposal the method statement for its safe removal.

14.5.2 Prior to commencing work, the Contractor shall also propose contingency plans subject to acceptance of the Engineer and QP(S). All preventive measures to minimise ground movement or structural movement shall be designed and installed by the Contractor. The Contractor shall implement these and any other necessary measures in the event that the measured movements exceed the accepted review levels or indicate that final long term movement will exceed the allowable values established in the Final Settlement Analysis Report.

14.5.3 The design shall undertake a comparative risk assessment to demonstrate that the risks associated with installation/implementation of any intrusive protection measures are no worse than the risks associated with the initial conditions.

14.5.4 In case where the proposed protective measures are planned to be installed/implemented directly on the building/structure or within its premises, the Contractor shall obtain the building/structure owner's approval for carrying out the protective works.

14.5.5 For every building/structure/infrastructure within the worksite identified as requiring protective works, the Contractor shall submit design calculations, working drawings, method of working and programme at least four (4) weeks before the commencement of any work (including the protective measures) in the area of the building or structure. No work shall be carried out prior to the acceptance of the proposal by the Engineer and the QP(S).

14.6 Rectification and Strengthening to Adjacent Buildings and Structures

14.6.1 For buildings and structures identified in the impact assessment as being adversely affected, the Contractor shall design and implement full rectification and strengthening works prior to commencement of his Works.

14.6.2 For structures identified as sensitive structures, temporary supports and rectification measures shall be implemented immediately by the Contractor at his cost upon the Engineer's direction, failing which the Engineer may appoint his own Contractor to carry out such works and recover all costs from the Contractor.

14.6.3 Whenever any defects or damages are reported or identified on adjacent buildings and structures within the zone of influence during the construction period, the Contractor shall carry out the necessary rectification works at his cost to ensure safety to the properties immediately upon the Engineer's direction. This work shall be completed within a reasonable period as agreed with the Engineer.

14.6.4 The Contractor shall submit his proposed rectification and strengthening method statements endorsed by his QP(D) for the Engineer's, relevant authority's, QP(S)'s and the owner's approval prior to its implementation.

14.7 Groundwater Control Systems

14.7.1 Recharge Well

14.7.2 The Contractor shall propose a comprehensive groundwater control system to suit his design and construction method of the temporary works scheme to ensure safety of the excavation and minimal impact to surrounding structures and utilities, subject to the acceptance of the Engineer and the QP(S).

14.7.3 The Contractor's QP(D) shall prepare a detailed design of the ground water control system for the acceptance of the Engineer. It is recommended that Construction Industry Research and Information Association (CIRIA) C750 shall be referred for the design of recharge well system. A detailed description of the proposed ground water control system and programme for the monitoring shall be submitted to the Engineer for acceptance before the commencement of construction works. The details specified in this section are for reference and the Contractor is responsible for the performance of ground water control system to meet his design requirements.

14.7.4 The Contractor shall also take into consideration ongoing works carried out by the adjacent contractors and coordinate with them on feasible groundwater control systems. The Contractor shall ensure that the groundwater regime is controlled to limit associated ground movements and impacts on adjacent structures. This assessment shall be included in the Settlement Analysis Report and Damage Assessment Report respectively.

14.7.5 The provision of groundwater control systems shall include, but not be limited to the following:

- Predicted groundwater drawdown extent relating to Contractor's sequence and method of construction;

- 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 Control of groundwater may be used in order to ensure stability of excavations and to limit groundwater drawdown during excavation to not more than 2m below the existing groundwater levels. However, if in the opinion of the Engineer these activities would have an adverse impact on any slope, roads, structure or utility, such operations will not be implemented, and the Contractor shall propose alternative mitigation measures 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:

14.7.10.1 Diameter and Spacing of Recharge Wells

- The minimum diameter of recharge well shall be at least 200mm. The UPVC perforated pipe shall be provided at a minimum diameter of 100mm.

- Recharge wells shall not be installed at a spacing of more than 5m, subjected to the acceptance of the Engineer.

14.7.10.2 Filter Pack and Well Screen

- The grading curve of the filter material shall roughly follow the same shape as the grading curve of the natural soil surrounding the filter. Where the natural soil surrounding the filter contains a large proportion of gravel or coarser material, the filter shall be designed based on the grading of the proportion of the natural soil finer than the 19mm sieve.

- The filter shall extend above the level of the well screen to allow for some loss or compaction of the filter material during placing and well development.

- Well screens that are installed must be durable over the duration of the project.

- The well screens shall be wrapped in double layer of approved geotextile or nylon mesh with minimum opening of 2mm and have minimum 6% of open area to minimize the head loss and entrance velocity.

14.7.10.3 Water Supply and Pressure Head

- Water used for recharge shall be chemically compatible with groundwater to limit precipitation. Suspended solids that may cause clogging are to be avoided. The Contractor shall as far as practicable, use non-potable water such as NEWater for recharging wells, subject to acceptance of the Engineer. The Contractor shall consult PUB on the availability of NEWater at the worksite.

- The design head to be maintained during the normal operation of the recharge well shall be at least 2m of water head. Pressure head shall be adjusted if the performance of the well does not meet the design requirement. The design injection pressure shall ensure that the wells and surrounding ground remain stable and do not heave at surface.

14.7.10.4 Installation and Testing of Recharge wells

- The well system shall be arranged to ensure that recharge occurs relatively uniformly where wells are assumed to be normally operational for 90% of the time, but not including contingency well pump/ well failure.

- Flow meters and pressure gauges compatible with the pipe fittings to riser shall be provided for routine monitoring of flow rates and water pressure. The calibration and working condition of all flow meters and pressure gauges shall be demonstrated to the satisfaction of the Engineer prior to commencement of monitoring and shall be checked thereafter every two (2) months. Any defective equipment shall be repaired or replaced at the request of the Engineer.

- Zone of recharge shall be targeted for permeable (with permeability of more than 1.0E-7m/s) like F1, permeable Bukit Timah Residual Soil, soil rock interface, fractured rock, etc., with sufficient screen area to achieve the required recharge capacity. Recharging of Fill layer shall be avoided.

- The entire recharge system is to be installed, tested and operationally ready for commission prior to commencing bulk excavation, and activated before the excavation commences, unless otherwise accepted by the Engineer.

- After completion of installation of recharge wells, functioning test for all recharge wells shall be conducted to confirm its effectiveness.

- The Contractor shall install a monitoring system of piezometer/water standpipe to test the effectiveness of recharge wells on ground water table to the acceptance of the Engineer.

- The Contractor shall submit the report on the testing results, including his assessment of his results immediately after the test.

- 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 also carry out fissure grouting to minimise the head loss in the fractured rocks. The minimum width of fissure grouting shall be 3m as shown below. The fissure grouting shall be carried out from the rock head level 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. The grout shall achieve a coefficient of permeability of not higher than 5.0E-8 m/s. **Appendix BJ** of the Particular Specification shall be referred to for the Specification of the fissure rock grouting.

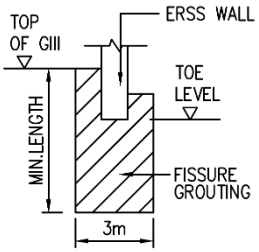
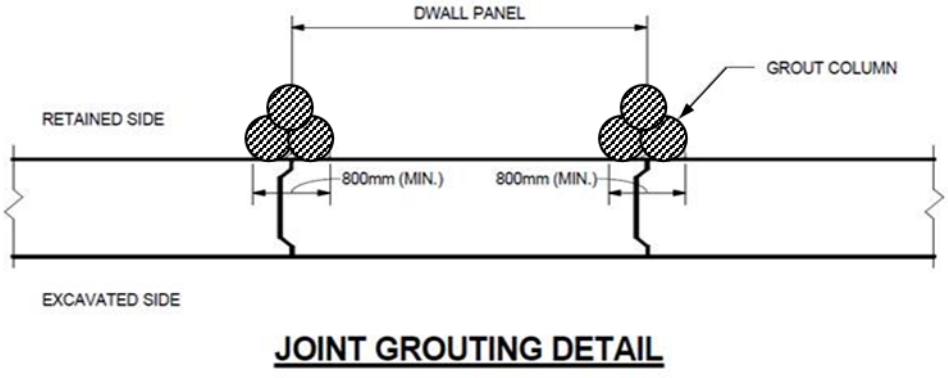


Figure 14.1 – Minimum Width of Fissure Grouting

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.

14.8.2 Joint Grouting

14.8.2.1 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 ground with permeability of 1.0E-8m/s, or to the acceptance of the Engineer, as shown below.



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=1E-8m/s.

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.

14.9.9 In the event that surface subsidence or heave due to ground treatment is excessive in the opinion of the Engineer and QP(S), the Contractor shall immediately stop treatment works and propose alternative treatment methods, for acceptance by the Engineer and QP(S).

14.9.10 The Contractor shall submit to the Engineer daily records of the previous day's works duly endorsed by QP(S). Records are to be submitted for each drilled hole and shall include the following:

- Depth and diameter of drilling;
- Size, type and depth of casing used;
- Details of diameter, sleeved length and unsleeved length of any grout tubes installed in the drill holes;
- Quantity of sleeve grout used (if any); and
- Quantity, type, pressure and gel time of grout injected at each injection point, or per meter length in the case of continuous grouting.

14.9.11 Testing of the ground treatment area shall be in accordance with Materials and Workmanship Specification for Civil and Structural Works and LTA CDC. Failure to meet the required parameters will warrant re-grouting at the Contractor’s cost and time;

14.9.12 Details of the toxicity of all grouts shall be submitted to the Engineer and QP(S) for acceptance before they are used. Only environmentally friendly grouts will be accepted for use; and

14.9.13 During any injection grouting, the Contractor shall, with the permission of the relevant authorities, carry out inspections of all manholes and inspection pits for services within 20m of any area where injections are being carried out. Such inspections shall take place not less than once every two weeks, or at closer intervals if necessary, during the period of injection. Should grout material be found in any manhole, inspection pit, duct, pipe or other installations, the Contractor shall, under the direction of the Engineer and QP(S) and with the permission of the relevant authorities, remove all of the grout material. The Contractor shall also propose for the acceptance of the Engineer and QP(S) the changes to his method of working to prevent further grout ingress to adjacent serv

14.10 Instrumentation and Monitoring

14.10.1 The Authority will engage an Instrumentation and Monitoring Specialist Contractor (IMC) to carry out instrumentation and monitoring works. The IMC's scope includes installation, monitoring, and removal of instruments.

14.10.2 Instrumentation and Monitoring Drawings

14.10.2.1 The Contractor shall produce instrumentation and monitoring drawings to be coordinated and agreed with the Authority's appointed Accredited Checker (AC), the Engineer and QP(S), and in full compliance with the most onerous requirements of the CDC and the requirements of any relevant authorities.

14.10.2.2 The Contractor shall note that the instrumentation and monitoring works shown in the Authority's Drawings are the minimum requirements for the reference schemes of the proposed ERSS for the Works. The minimum zone of monitoring shall be in accordance with LTA CDC, or the zone of influence as per **Appendix E** of the Particular Specification, whichever is maximum.

14.10.2.3 The Contractor shall review the Authority's reference instrumentation and monitoring plans; further develop and submit his instrumentation and monitoring proposal to the QP(S), AC, and the Engineer for acceptance where required for the safe completion of the works, to suit the Contractor's construction method, sequence and temporary works, or to meet requirements of the Authority or other authorities.

14.10.2.4 If the Contractor requires additional or different types of instruments or requests to increase the frequency of the monitoring after the Contractor's ST submission to BCA is approved, including design checks as required by the Authority's AC and other regulatory agencies, the Authority upon receiving the endorsed instrumentation drawings from the Contractor's QP(D), will instruct the IMC to complete the additional instrumentation and monitoring. The Authority will recover all cost incurred (with administrative charges) from the Contractor.

14.10.2.5 The Contractor shall be responsible to review and analyse the instrumentation data provided by the Authority's IMC on a daily basis, when required, in order to verify his QP(D)'s design.

14.10.2.6 The Contractor shall consider the practicality of installing and monitoring works to be carried out by the IMC when proposing the instruments to be installed and monitored including the necessary reinstatement works and safe access for IMC.

14.11 Track Monitoring and Track Gauge Survey

14.11.1 During the Works, the Contractor shall carry out the track monitoring or any such monitoring of existing rail infrastructures, as requested by the Public Transport Operator (PTO), authorities, or the Engineer, at his own cost.

14.11.2 The Contractor shall conduct track gauge survey to monitor against the allowable limits for track distortions as specified in the Code of Practice for Railway Protection for the existing MRT tracks within the influence zone of construction works.

14.11.3 The track gauge survey shall comprise of an initial track gauge survey prior to the construction works by the Contractor, a final track gauge survey after the construction works, periodical checks and any numbers of track gauge survey during the construction works when anomalies are detected in the monitoring instrument or as and when requested by the Engineer.

14.11.4 Each trip of the track gauge survey shall come with a report including endorsement by Registered Surveyor.

14.11.5 The Contractor is to submit detailed method statement for carrying out the track gauge survey and obtain approval from LTA DBC and the PTO prior to carrying out such survey.

14.11.6 The Contractor is to note that such track gauge survey can only be carried out upon the PTO’s approval and only during engineering hours.

14.12 Attendance and Assistance to the Instrumentation and Monitoring Specialist Contractor (IMC)

14.12.1 The Contractor shall coordinate and provide the IMC all necessary provisions, protection and safe access for him to carry out installation and monitoring of instruments and allow for the monitoring of the works in a timely and safe manner.

14.12.2 The Contractor shall be responsible for the safeguarding of all installed instruments within the worksite during the construction activities. The Contractor shall reimburse the Authority's IMC for the replacement cost of all damaged instruments within the contract boundary regardless of the level of protection provided to the instruments by the Authority's IMC. Should the Contractor deem that the level of protection provided by the Authority's IMC is inadequate, the Contractor shall provide additional protection to the instruments at his own cost. Any failure to reimburse the Authority's IMC for the replacement costs of damaged instruments shall be recoverable from the Contractor by the Authority. The cost shall be recovered by the Authority from the Contractor through back charging, inclusive of administrative fees.

14.12.3 The Contractor shall coordinate closely with the IMC to ensure sufficient time is allowed between installation of instruments and commencement of relevant site activities to enable a reliable set of base readings to be established. These timescales are to be accommodated in his work programme and shall be agreed with the Engineer and QP(S).

14.12.4 The Contractor, his QP(D) and other required persons shall attend meetings called by BCA or other relevant authorities on matters relating to Temporary and Permanent Works designed by the Contractor, including submitting reports to BCA and other relevant authorities through the QP(S) on instrumentation. The Contractor shall also avail himself to attend to all matters pertaining to works on instrumentation and monitoring when requested by the Engineer or QP(S).

14.12.5 Where the IMC conducts stakeholder engagement, the Contractor shall provide all attendance and actively participate in the engagement.

14.12.6 The Contractor shall provide temporary lighting, power and water supplies for the instrumentation works at his cost. The Contractor shall coordinate with the IMC on these requirements.

14.12.7 The Contractor shall allow the IMC to connect the electricity supply from the Contractor's power source to the IMC's office(s). The Contractor shall be responsible for the maintenance cost of the IMC's office(s).

14.12.8 Extensive instrumentation monitoring of the ground and structures between the Interfacing Contractors are expected. The Contractor shall work in close co-ordination with the Interfacing Contractors to obtain, transfer and exchange monitoring and site investigation data and encountered ground conditions. When the results of the investigations of the Interfacing Contractors does not agree on the ground conditions or monitoring data, the Contractor shall immediately inform the Engineer and carry out all the necessary additional works to clearly determine the correct values of the monitored data and the ground conditions and he shall send a report including all the investigations, their final results and the reasons of the discrepancies to the Engineer.

14.12.9 Where real-time monitoring works are made by the Contractor, the real-time monitoring data shall be made available to the Authority concurrently and uploaded to the Data Management System in the format as required by the Tunnelling and Excavation Monitoring System (TEMS) and at a frequency as determined by the Engineer.

14.12.10 The Contractor's QP(D)/QPD(Geo) shall propose locations for vibration monitoring devices (at six (6) monthly interval calibration) for any ground vibration or structure vibration induced due to the construction or equipment, at his own cost. This includes vibration caused by piling, demolition, excavation or any construction activities that pose a nuisance to the public.

14.13 Web-Based Instrumentation and Monitoring Data Management System

14.13.1 The Contractor shall liaise with the Authority appointed contractors and upload the following data to the server:

(a) Layout and sections in both longitudinal and cross sections;

(b) Layout and sections of the recharge well system; and

(c) Alignment layout plans, site layout plans and excavation layout plans,

(d) Pre-determined values of ERSS wall deflection along depth at each critical stage of the excavation, and

(e) Additional site investigation borehole data in Association of Geotechnical and Geoenvironmental Specialists (AGS) format.

14.13.2 All construction activities and related reports in shift/daily/weekly/monthly reports shall be uploaded to the server including but not limited to the following:

- Installation of ERSS;
- Excavation, strutting, ground anchor;
- Permanent works construction progress;
- Any other site construction works;
- Site progress and incident photos; and
- Recharge well system

14.13.3 For all other monitoring works conducted separately by the Contractor, the Contractor shall upload all construction reports and construction related data including construction status update and photos to the Authority's designated server at a frequency as determined by the Engineer.

14.13.4 The Contractor shall work with and cooperate with IMC and any Authority appointed web-based instrumentation and monitoring data management system contractors (TEMS operator) to determine the format of data upload and the network connectivity to ensure data could be uploaded without manual intervention. The activities shall include the following:

- Connectivity tests;
- Data integrity tests
- Exception tests; and
- Other tests deemed required to validate the data transferred.

14.13.5 The Contractor shall provide the network connection and upload the data to the Authority's designated server and/or PC in a machine readable data format (e.g. Comma-separated values (CSV)) via a secure file transfer mechanism (e.g. Secure File Transfer Protocol (SFTP)), which will be subjected to the Engineer's acceptance.

14.13.6 The Contractor shall ensure that the access to TEMS and any transfer of data to TEMS shall be only from within Singapore. No access will be provided to IP addresses that are outside of Singapore. TEMS application does not support whitelisting of IP addresses that are outside Singapore.

14.13.7 A logical reference system to the acceptance of the Engineer shall be established in accordance to the requirements in **Appendix P** of the Particular Specification for all instruments prior to installation.

14.14 **Instrumentation and Monitoring Requirements**

14.14.1 The Contractor shall install the load cells (supplied by the IMC) on temporary struts and anchors in accordance with the manufacturer's recommendation. The Contractor shall coordinate with the IMC on the requirements for the design of the bearing plates and housing for the load cells. The Contractor shall design, supply and install the bearing plates on the temporary struts / anchors. Upon decommissioning of the load cells, the Contractor shall remove and return the load cells to the IMC.

14.14.2 The Contractor shall supply and install necessary pipe sleeves for installation of in wall inclinometers by the IMC. The Contractor shall protect the inclinometer pipe sleeves during installation of retaining walls, excavation and concreting operations. Any pipe sleeve damaged or filled with concrete shall be rectified by the Contractor at his own cost to facilitate the inclinometer installation by the IMC. The Contractor shall grout the pipe sleeves upon completion of the monitoring works.

14.14.3 Galvanized Iron (GI) pipe with minimum 125mm inner diameter for installing inclinometers in structural retaining walls and deep foundation elements shall be provided and installed by the Contractor. The GI pipes shall be securely capped at both ends. Any pipe sleeve damaged or filled with concrete shall be rectified by the Contractor at his own cost.

14.14.4 The Contractor shall coordinate with the IMC and agree the locations of instruments and shall submit the coordinated locations of the monitoring instruments for the Engineer's acceptance before proceeding with the installation works. A copy of the installation records sign-off by IMC and the contractor shall be submitted to the Engineer for record.

14.15 Review Levels for Works

14.15.1 Prior to the commencement of construction works, the Contractor's QP(D) shall assign predetermined review levels: AL and WSL for his design of ERSS based on the analysis and design assessments. The assigned values shall be submitted to BCA for approval and the Engineer for acceptance prior to commencing his works. Predetermined Levels (PDL) shall also be provided for every excavation stage; excavation for guide walls, ERSS, bulk excavation, for control of the Works.

14.15.2 The Contractor's QP(D) shall be responsible for submitting the predetermined review levels for the instruments at the interface with the adjacent contract to BCA and the Engineer for acceptance prior to the Works. The Contractor's QP(D) shall proactively coordinate with adjacent contracts on apportioning of review limit at the interfacing area. Where additional instruments at the contract interface are proposed by the Contractor, the Contractor shall allow sufficient time and provide safe access for the IMC to install these instruments.

14.15.3 During construction, the Contractor may propose changes to the values selected as review levels. Changes to review levels will have to be justified on the basis of observed performance, and shall be submitted for the acceptance of BCA, the QP(S) and the Engineer.

14.15.4 If the reading on any instrument approaches the AL, the Contractor shall meet with the Engineer, the QP(S) and where relevant, the adjacent contractors to review the data obtained from that instrument. If as a result of the review, it is considered that the suspension level is likely to be exceeded, the Contractor shall reassess the construction methodology together with the QP(S) and the Engineer and propose enhancement measures.

14.15.5 If the reading on any instrument is expected to breach the suspension levels, the Contractor shall inform QP(S) and the Engineer immediately. The Contractor shall implement immediate measures to make the related part of the Works safe, and then cease work in that part of the Works until remedial measures have been submitted and accepted by QP(S) for implementation.

14.16 Review and Reporting of Instrumentation Data

14.16.1 The Contractor's QP(D) shall check the instrumentation readings and verify that the performance of the Works, adjacent existing structures and ground are in accordance with the design and confirm this in writing to the Engineer.

14.16.2 The Contractor shall hold regular monitoring review meetings, as required by the Engineer, to review the readings and identify trends of concern. The Contractor's relevant personnel shall attend this meeting. The Contractor shall inform the Engineer and QP(S) immediately should there be erroneous or unfavourable readings or trends on the instrumentation readings. The Contractor shall make provisions in his program for such incidents and time extensions will not be granted if the reasons for such lapses are attributed to negligence by him during construction.

14.16.3 The Contractor shall attend weekly instrumentation and monitoring meetings with the relevant parties to review the readings, observations, comments and issues etc.

14.16.4 The Contractor shall submit the Interpretative Monitoring Report to the Engineer and the QP(S) on a weekly basis (minimum), in a format to be agreed with the Engineer and QP(S). Based on the instrumentation and monitoring results received from the IMC, the Contractor shall carry out the following:

- Verify the design assumptions and whether design levels could be exceeded;
- Provide confirmation of the predicted behaviour of the temporary earth retaining system during excavation;
- Assess the effect of the Works on buildings, structures and utilities;
- Provide a record of trend and performance of the results;
- Implement appropriate contingency measures, where required; and
- Present the weekly monitoring results using Powerpoint at a weekly instrumentation meeting held with the QP(S).

14.16.5 The report shall summarise the results of the monitoring, including any review levels that have been exceeded. Where necessary, the report shall include recommendations for altering the design of the Works, or the method or sequence of construction. The report shall also include cross sections which summarise instrumentation readings at each highly instrumented section e.g. array type B and C.

14.16.6 The frequency of the report may be increased at the discretion of the Engineer and QP(S) should there be any area of particular concern.

14.16.7 The Interpretative Monitoring Reports shall be endorsed by the Contractor's QP(D), and are to be submitted within seven (7) days of the last reading.

14.16.8 One (1) hard copy and one (1) CD submission of all reports shall be submitted to the Engineer for acceptance. A separate copy of the reports shall be provided for the QP(S), LTA's Development and Building Control Department and other relevant authorities, if required.

14.16.9 PDF copies for all records, reports and other hardcopy submissions shall be submitted to the Engineer for acceptance.

14.17 **Permit to Proceed with Excavation System**

14.17.1 The Contractor shall comply with the "Permit to Proceed with Excavation" system (Refer to BCA Annex C and D for Site Inspection and Approval Records and Ground Movement Assessment Record) which is mandatory for any excavation or digging activities. All relevant permits, approvals and utility plans shall be attached to the permit.

14.17.2 The Contractor shall be fully responsible for and shall make all necessary provisions in his programme and Contract Price for the implementation of the "Permit to Proceed with Excavation" system. Notwithstanding the provisions in the Conditions of Contract, the Contractor shall not be entitled to claim for delays, for extension of time and or additional payment whatsoever arising from the implementation of this system.