SPECIFICATION FOR DYNAMIC CONSOLIDATION / DYNAMIC REPLACEMENT

1.0 SOIL IMPROVEMENT

1.1 General

Soil Investigation Information are provided in Part B1 annex as a guide to the Contractor for his consideration of the Soil Improvement Methodology.

1.1.1 Description Of Work

The Contractor shall analyse by pre-engineering testing using approved type Pressuremeter test (PMT), Cone Penetration Test (CPT) and other additional methods if required the in-situ soils to determine the bearing capacity and the potential for settlement due to the various loading as specified in Section 5.3.

The approximate limits of work are shown on the ground improvement drawings. The exact limits of work shall be determined jointly by the Superintending Officer and the Contractor upon completion of the pre-engineering testing performed.

The Superintending Officer may also direct the Contractor to perform ground improvement in other areas deemed necessary.

The Contractor shall design and carry out appropriate methods of soil improvement required depths to ensure the bearing capacity and the settlement of soils within the site limits be improved to the criteria specified in Section 5.3. All design proposals shall have the endorsement of a registered Professional Engineer in Singapore.

The following soil improvement methods may be used individually, or in combination to achieve the desired results. This listing is not necessarily all-inclusive and Contractor may elect to use other methods with prior approval of the Superintending Officer.

1. Dynamic consolidation
2. Dynamic replacement
3. Surcharging
4. Vertical drains
5. Excavation and soil replacement

The Contractor shall carry out surface monitoring to control the ground improvement works to establish compliance with the Criteria of Acceptance.

The Contractor shall submit drawings to the Superintending Officer for approval prior to commencement of the ground improvement work, showing the limits of each proposed soil improvement method.

The Contractor shall integrate the scheduling of infrastructure construction with the ground improvement work to ensure that damage to completed infrastructure does not occur and to minimise delays of work.

1.1.2 Contractor Qualifications

The ground improvement work shall be performed by a qualified company, or companies, each having a minimum of fifteen years experience in ground improvement techniques and shall be subject to the approval of the Superintending Officer. Company or companies shall have successfully completed not less than 10 major projects involving ground improvement using the approved techniques, of which at least ten projects shall have been large scale ground improvement projects of a minimum of 100,000 sq. meters each, and at least five projects of similar nature shall have been performed in Singapore. Contractor shall be able to deliver compaction energy from 300 ton meter to at least 1,000 ton meter energy per blow. The Contractor shall prove his capability of having delivered such compaction energies in his previous projects. Contractor shall also have the site services of a competent and experienced geotechnical engineer who is capable of analyzing existing soil data, obtaining and interpreting additional data as required, performing field testing prior to, during and after ground improvement and designing the ground improvement program best suited to the site conditions of this projects.

1.1.3 Quality Assurance

All testing procedures shall be performed in accordance with the indicated standards:-

Standard	Number	Title
ASTM	D-422	Particle Size Analysis of Soils
ASTM	D-423	Liquid Limit of Soils
ASTM	D-424	Plastic Limit and Plasticity Index of Soils
ASTM	D-854	Specific Gravity of Soils
ASTM	D-1140	Amount of Material in Soils Finer than the no. 200 Sieve
ASTM	D-2216	Laboratory Determination of Moisture Content of Soil
ASTM	D-2435	One Dimensional Consolidation Properties of Soils
ASTM	D-2487	Classification of Soils for Engineering Purposes
ASTM	D-2850	Unconsolidated, Undrained Strength Of Cohesive Soils in Triaxial Compression
Ponts & Chaussees Manual Test Procedure NMSIS2		Pressuremeter Testing for In-situ Soil & Rock
ASTM	D-3441	Deep, Quasi-static, Cone and Friction Cone Penetration Tests of Soils

1.1.3.1 Pressuremeter Testing

The Pressuremeter consists of 2 main elements i.e. a radially expandable cylindrical probe which consists of 3 independent cells and a monitoring unit which remains on the ground surface. The recommended type shall be the Pressuremeter type GC. and approved by the

Superintending Officer. The probe shall be protected by a steel casing with longitudinal slits which allow radial expansion. The monitoring device is connected to the probe by two tubes one inside the other. The inner tube carries the water to the central cell and space between the two tubings allows the gas to reach the guard cells to prevent possible expansion of the inner tubing which would lead to erroneous readings of the amount of water injected.

The installation of the probe shall be driven to the required elevation either by driving as in the case of the Standard Penetration Test or by static pressure such as in the case of Dutch Cone Penetration Test. The preferred manner shall be the one that employ the driving method using a D9000 Pressuremeter Installation rig. Pre-drilled or pre-bored boreholes using rotary wash boring is not acceptable due to disturbance of the borehole walls, the circulation of water under pressure between the walls of the borehole and the cone barrel and the risk of alteration of the soil due to water absorption if left exposed for more than 24 hours.

The test must be carried out systematically, meter by meter in order to record accurately the variation of strength parameters as a function of depth. Discontinuities in the test spacing are not allowed. Emphasis is placed on the necessity for continuous Pressuremeter testing from the ground level to the required depth. The test should be carried out with ten equal loading increments up to the point of failure. Readings of deformations with respect to time are taken for each pressure increment of 15 seconds, 30 seconds and one minute after the application of this increment. To obtain a complete deformation curve, the measured volume should reach 700 cm^3 if P1<8 bars and 600 cm^3 if 8 bars <P1<15 bars.

1.1.3.2 Pre-Engineering Testings

(i) Contractor shall undertake soil testing prior to commencement of Soil Improvement works to provide data for the purpose of refining the preliminary design to comply with the acceptance criteria as specified. The field testing shall include the following:

(a) Pressuremeter tests shall be performed at every meter vertical intervals and at changes in strata in accordance with the method outlined in Ponts an Chaussees Manual Test Procedures NMSIS2.

(b) Dutch-Cone Static Penetration Tests shall be performed in accordance with the ASTM Tentative Method of Deep, Quasi-Static, Cone and Friction Cone Penetration Tests of Soil (ASTM D3441-79).

(ii) The Contractor shall determine the total number and locations of pre-engineering tests necessary to analyse the soil conditions and to delineate the areas requiring Dynamic Consolidation/Replacement works. Pre-engineering testing shall include the following as a minimum:-

(a) A minimum of one test location of each 2000 sq meter of area marked for improvement on the drawings.

(b) A Dutch-Cone Penetration Test with a friction sleeve static cone penetrometer shall be performed at each test location. A Pressuremeter Test shall be performed at every second test location. A comparison of test results shall be made, where more than one test is performed at a test location.

(c) Contractor shall determine locations of any additional testing that may be required in the event that conflicting test results are indicated by two adjacent tests or to delineate areas for ground improvement.

1.1.3.3 Final Acceptance Testing

(i) The Contractor shall verify the ground improvement works for compliance with the acceptance criteria by in-situ tests of the improved soils and by analysis of the test results. The final testing shall be conducted a minimum of one week after completion of the ground improvement. The final tests shall generally be at the locations of the pre-engineering test locations and shall include the following field test:

(a) Pressuremeter test shall be performed at every meter intervals and at changes in strata in accordance with the method outlined in Ponts and Chaussees Manual Test Procedure NMSIS2.

(b) Dutch Cone Penetration Tests shall be performed in accordance with the ASTM Tentative Method for Deep Quasi-Static, Cone and Friction cone Penetration Tests of Soil (ASTM-3441-757).

(ii) Final testing shall include the following as a minimum:-

(a) A minimum of one final test location of each 2000sq meters of improved area.

(b) A Dutch Cone Penetration Test with a friction sleeve static cone penetrometer shall be performed at each test location. A Pressuremeter Test shall be performed at every second test location. A comparison of test results shall be made where more than one test is performed at test location.

(c) Locations for Pressuremeter and Dutch-Cone tests shall not be separate by more than 3 meters at a test location.

(d) Areas in which the specified criteria are not met shall be reworked by the Contractor until the specified requirements are met. The Engineer, at its option, may check the Contractors test results by conducting additional and independent testing.

1.1.4 Submittals

The Contractor shall submit the following data to the Superintending Officer for review and approval:-

(i) Method Statement for execution of works

(ii) Pre-engineering testing Proposal : A plan and schedule for pre-engineering testing shall be submitted at least 7 days before the pre-engineering testing is scheduled to begin.

(iii) Pre-engineering testing Report : Not later than 14 days after completion of pre-engineering testing, Contractor shall submit a report for each Area or other approved area, stating the pre-engineering testing plan, including the pre-test data, after test data, field instrumentation plan and results.

(iv) Daily Activities Report : Narrative report in a format approved by the Engineers, detailing the day to day activities of the work.

(v) Interim Progress Report : Report on densification operations, including pre-engineering testing, final acceptance testing, instrumentation and monitoring record and elevation measurements, quantities completed during month and cumulative quantities to date and a forecast of remaining work.

(vi) Final Technical Report : This report shall be submitted at the completion of the works. The Final Report shall contain graphical presentation of all parameters used by the Contractor to accomplish the acceptance criteria including all pre-engineering test and final test parameters. All related pre-test and final test results including instrumentation records shall be shown graphically. The Final Report shall also include calculations

verifying the maximum bearing capacity of the soil and predicted settlements.

(vii) The Contractor shall submit in five copies for each stage of reports which shall be endorsed by a Professional Engineer before submitting to the Superintending Officer.

(viii) Engineering Calculations : Engineering calculations for bearing capacity and settlement as required in the Final Technical Report shall be based on the following as applicable:-

- Standard interpretation and application of Pressuremeter test results
- Standard methods for the interpretation and use of static cone penetrometer test results.

(a) Calculations shall be submitted for review and approval by the Engineers.

(b) Where computer programs are used, the Contractor shall submit to the Engineer for approval the listing with explanations, user manual and sample problems.

(c) Calculation Methods : Calculations shall be based on the following methods:-

1. Bearing Capacity shall be computed using:

   (i) Norm D60 AN Procedure and PMT date (Limit Pressure)

   (ii) Schmertmann Equations and CPT data

2. Settlements

   (i) Total settlement may be computed based on PMT data using procedures outlined in Norm D60 AN 'Interpretation and Application of Pressuremeter Test Results to Foundation Design'.

   (ii) Total settlement shall include immediate and consolidation settlement.

   (iii) For granular soils, settlement shall be computed based on CPT data sing Schmertmann's method.

   (iv) Self bearing settlements shall be computed based on D60.

1.2 Monitoring and Control of the Works

(i) The Contractor shall submit monitoring and control data as specified, together with recommendations. Such data shall include but not limited to

(a) Measurement of Consolidation of Compressible Clayey Subsoil (if any present). The degree of consolidation shall be measured using settlement records of both surface settlement marker and deep settlement plates.

(b) Measurement of Compaction of Loose Sandy Subsoil and Fill : The degree of compaction shall be measured using Pressuremeter tests and Dutch-cone test results.

(ii) During the compaction operations Contractors shall monitor surface particle velocity and acceleration generated by dynamic processes at locations close to existing pavement, structures or utility lines. The Contractor shall make appropriate arrangements to ensure that safety of any existing structure or utility from dynamic processes.

Contractor shall develop and submit for approval of the Engineers, limiting values of particle

velocity and acceleration which will avoid damage to completed infrastructure.

(iii) Vibration shall not exceed approved levels in surrounding structures and pavements. Where acceptable particle velocity or acceleration are likely to be exceeded, cut off trenches or other protective measures shall be taken Contractor shall demonstrate to the satisfaction of the Engineers, by trails, that his proposal will reduce the maximum particle velocity or acceleration to acceptance values.

(iv) The degree of settlement shall be determined from surface settlement markers and deep settlement plates. In situ settlement measurement shall be used in the Asaoka Method to predict total settlement.

(v) The Contractor shall advise the Engineer as to the means of protection, reading and maintenance of all monitoring equipment such that the Engineers will be able to continue to monitor the works.

(vi) Contractor shall assign a Resident Geotechnical Engineer approved by the Engineers to be present at the job site at all times for the duration of the ground improvement work. The Resident Geotechnical Engineer shall provide coordination with the Engineers and be available for review meeting.

(vii) Progress Reports : Contractor shall submit progress reports as described in Section 1.1.4

1.3 Acceptance Criteria

1.3.1 Bearing capacity is defined as net allowable bearing capacity.

1.3.2 Differential settlement and settlement are defined as:-

- settlement of loose hydraulic fill under its own weight (self bearing)
- settlement of loose hydraulic fill under static load
- settlement of loose hydraulic fill under dynamic load
- settlement of natural soft clay under fill load and future load
- differential settlement due to variation of fill thickness and soft clay thickness

Tree different loading conditions are identified on the drawings with different acceptance criteria.

Area type A (roads, sewers and drains)

1 Bearing Capacity exceeding 60 kN/m^2 over the upper 6 meters

2 Self bearing conditions over the entire fill thickness

3 Differential settlement not exceeding 1/750

4 Harmonic mean of the pressure meter moduli exceeding 4500 kN/m^2 in the upper 6 meters

Area type B (heavy traffic area)

1 Bearing capacity exceeding 100 kN/m^2 over the upper 6 meters

2 Self bearing conditions over the entire fill thickness

3 Differential settlement not exceeding 1/750

4 Harmonic mean of the pressure meter moduli exceeding 9000 kN/m^2 in the upper 5 meters of sand fill

5 Harmonic mean of the pressure meter moduli exceeding 6000 kN/m^2 in the upper 10 meters of sand fill

Area type C – Structures

1 Bearing capacity exceeding 240 kN/m^2 for isolated footings constructed 50 cm below ground surface

2 Self bearing conditions over the entire fill thickness

3 Differential settlement not exceeding 1/1000

4 Total settlement of the single footings and structures not exceeding the reinforced concrete norms.

The Contractor shall provide professional indemnity to warrantee the performance of the structures erected on improved grounds

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