

SECTION 03500 - SOFT SOIL IMPROVEMENT MEASURE

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SECTION 03500 - SOFT SOIL IMPROVEMENT MEASURE

1. DESCRIPTION

This work consists of supply of materials and instruments, installation of devices for vertical drainage, construction of vertical drains, monitoring of settlements, and implementation of all necessary measures to improve the existing mechanical conditions of the underground soft soil layers, in accordance with the requirements for stabilization and pre-consolidation determined on the Drawings.

The requirements herein specified refer to the following types classified by case and method applied for the purpose of improving the underground soft soil layers on which the roadway embankment will be constructed. The combined improvement measures to be applied for all the referred types consist of the replacement of at least 1.0 m thick layer of natural ground by soil material A1 or A3 (AASHTO), a layer of “Coarse Sand Blanket (CSB)” and an additional layer of “Pre-Loading Embankment (PL)”, as shown on the Drawings:

- (a) **Type 1:** Improvement by pre-consolidation of the soft soil layer by installing Sand drains (SD);
- (b) **Type 2:** Improvement by pre-consolidation of the soft soil layer by installing Sand Compaction Piles (SCP);
- (c) **Type 3:** Improvement by pre-consolidation of the soft soil layer only by the effect of the roadway embankment weight.

1.1 Vertical Drainage System

- (a) This Specification Section addresses the implementation of construction methods and practices, and supply and installation of specific materials shown on the Drawings and herein specified to stabilise by pre-consolidation the soft soil layers underlying some sections of the roadway embankment.
- (b) These items include the construction of “Coarse Sand Blankets (CSB)” with a separation geotextile membrane, horizontal drainages, installation of Sand Drains (SD), Sand Compaction Piles (SCP), construction of Pre-Loading Embankment (PL) and monitoring of settlements during specified prior to subgrade preparation.
- (c) At the locations shown on the Drawings, the various settlement treatments for stabilisation by pre-consolidation shall include:
 - i) Staged construction of embankment;
 - ii) Waiting up after a part of embankment to the time specified on the Drawings before remaining part of embankment (subgrade layer) and paving is

permitted based on the Reference Section (refer to Sub-section 3.9) test results and the Engineer's approval; and

1.2 Soil Replacement

Soil replacement work shall include excavation to remove soft soil, hauling to disposal areas, re-fill by soil material and compaction of specified materials to the required density as indicated on the Drawings or as instructed by the Engineer.

1.3 Pre-Loading Embankment (PL)

The roadway embankment shall be constructed in two stages so as to ensure the roadway embankment reaching the allowable final residual settlement estimated in the detailed design, before pavement construction.

- (a) **1st Stage:** The embankment shall be constructed to its total height including an over-height approximately equal to the foreseen height of settlement of embankment at the end of the period considered for stabilization, hereafter referred to as “Pre-Loading Embankment”(PL).

The embankment finishing at this stage shall be constructed to its elevation up to the top of the Pre-Loading Embankment in conformity with the design. The following parts of the embankment shall be constructed completely and in conformity with the design:

- i) Backfilling after topsoil removal;
- ii) Coarse sand blanket;
- iii) Pre-Loading Embankment up to height of settlement compensation;

The subgrade layer shall not be constructed in this stage.

- (b) **2nd Stage:** Once the embankment has reached the scheduled stability, or after the Engineer has authorized the construction of the subgrade layer on the stabilized embankment, embankment formation shall be prepared to the lines and levels specified on the Drawings by removing the exceeding height of embankment provided by the PL, or adding material in case the settlement exceeds the expected height of PL.

1.4 Embankment Instrumentation and Monitoring

This section mainly describes the specifications and methods for supply of instruments, installation, data recording/monitoring of embankment settlements and horizontal deformations related to the applied soft soil improvement measures.

1.5 Subsoil Investigation

This section mainly describes the specifications for the subsoil investigation required to confirm the composition of the soil layers underlying the embankment where the soft soil improvement measures are applied.

1.6 Sub-Drainage System

This work consists of the construction of water protection dikes, pumping wells, and drain hoses necessary for sub-drainage under the drainage composed of the "Coarse Sand Blanket", in accordance with the lines, levels, grades, sizes, dimensions and types shown on the Drawings.

2. MATERIAL REQUIREMENTS

2.1 Reference Standards

The most recent editions of the following standards shall apply to the materials covered in this Section:

AASHTO M288	Geotextile Specification for Highway Applications
ASTM D420	Standard Guide to Site Characterization for Engineering, Design, and Construction Purposes
ASTM D1452	Standard Practice for Soil Investigation and Sampling by Auger Borings
ASTM D1586	Penetration Test and Split-Barrel Sampling of Soils
ASTM D3776	Mass Per Unit Area (Weight) of Fabric
ASTM D4595	Tensile Properties of Geotextile by the Wide-Width Strip Method
ASTM D4632	Grab Breaking Load and Elongation of Geotextile
ASTM D4716	(In-plane) Flow Rate per Unit Width and Hydraulic Transmissivity of a Geosynthetic Using a Constant Head
ASTM D4751	Apparent Opening Size of a Geotextile
ASTM D4833	Index Puncture Resistance of Geotextiles, Geomembranes, and Related Products
ASTM D6241	Static Puncture Strength of Geotextiles and Geotextile Related Products Using a 50mm Probe
22TCN262-2000	Procedure for Surveying and Design Embankments on Soft Ground.
TCVN 7305:2008	(ISO 4427:2007) Plastic Piping System – Polyetylen (PE) Pipes and Fitting for Water Supply.

2.2 Submittals

2.2.1 Shop and Working Drawings and Schedules

- (a) In accordance with the requirements stipulated in Specification Section 01150 “Contractor’s Submittals”, the Contractor shall submit complete sets of Drawings and Schedules for the soft soil improvement works, to the Engineer for review and approval.
- (b) The Contractor shall obtain the Engineer’s approval of the submitted drawings and schedules at least 28 days before commencement of the corresponding works.

2.2.2 Other Submittals

Other submittals shall include, but not be limited to, the following:

- i) **General:** Samples and all the information related to the materials requiring approval. This information might include all the pertinent certificates, testing results, and any other document that could prove that the material is suitable for the respective work.
- ii) **Documents from Manufacturers:** All the information related to instruments, method of installation, etc. provided by the manufacturers proposed by the Contractor.
- iii) **Sands:** Samples of the sand proposed to be used for construction of the Coarse Sand Blanket, the Sand drains, and the Sand Compaction Piles. The samples shall be tested as specified to confirm their compliance with the requirements herein specified.
- iv) **Surface Settlement Plates (SSP):** One set of SSP devices composed of the plate, PVC pipe and caps, and steel pipe with respective couplers.
- v) **Observation Wells:** One set of observation well devices composed of PVC pipe piles and caps.
- vi) **Natural Ground Protection Measures:** The Contractor shall propose necessary measures for natural ground protection when construction plants come into working area and execute soft soil improvement works: in concerning to the coarse sand blanket under the plant, projective measures of chocking and bedding shall be applied in order to avoid the natural ground runs to a plastic yield whenever the plant shakes;
- vii) **Vehicles and plant:** Information of vehicles and plant for soft soil improvement construction shall also be submitted: type of plant, vehicles, weight, number of axial and route of material transportation, which can be concerned to natural ground damage.

2.3 General Requirement for Materials and Instruments

- (a) Materials used for the soft soil improvement measures shall comply with the minimum requirements described in this Specification Section.
- (b) The Contractor shall use for the soft soil improvement works only the instruments previously approved by the Engineer.

2.4 Materials for the Soft Soil Treatment Method

2.4.1 Coarse Sand Blanket (CSB)

- (a) The sand material to be used for CSB shall be free from clay, wood, bark, or other extraneous material.
- (b) The material for CSB shall meet the following requirements:
 - Sand shall be medium and/or coarse sand
 - Particles with diameter >0.25mm: Min 50%;
 - Particles with diameter <0.075mm: Max 3%;
 - Content of organic material: Max 5%;
 - Permeability: Min 5×10^{-3} cm/sec.

2.4.2 Horizontal Drainages

- (a) Horizontal drainages could be constructed to avoid delay of consolidation and to facilitate discharging of consolidation water during consolidation.
- (b) Horizontal drainages consist of perforated drain pipe and catch basin.
- (c) Pipe for horizontal drain shall be HDPE pipe (type PE 100) in accordance with TCVN 7305:2008 or equivalent international standards, shall meet the following basic requirements as shown on the below TABLE 1A, perforated 20cm diameter as shown on drawing or equivalent, shall have a wall thickness of at least 10mm, shall be wrapped with two layers of geotextile filter fabric as shown on drawing and shall have adequate bearing capacity for filling load.

TABLE 1A: Basic Requirements of Horizontal Drainage Pipe

No.	Characteristic	Requirement	Test parameters		Test method (s)
			Parameter	Value	
I.	Mechanical Characteristic				
1.	Hydrostatic Strength at 20°C	No failure of any test piece during test period	End caps Conditioning period Number of test pieces	Type A According to TCVN 6149-1 3 Water-in-water	TCVN 6149-1; TCVN 6149-2

			Type of test Test temperature Test period Circumferential (hoop) stress for PE 100	20°C 100 h 12,4 MPa	
2.	Hydrostatic Strength at 80°C	No failure of any test piece during test period	End caps Conditioning period Number of test pieces Type of test Test temperature Test period Circumferential (hoop) stress for PE 100	Type A According to TCVN 6149-1 3 Water-in-water 80°C 165 h 5,4 MPa	TCVN 6149-1; TCVN 6149-2
3.	Hydrostatic Strength at 80°C	No failure of any test piece during test period	End caps Conditioning period Number of test pieces Type of test Test temperature Test period Circumferential (hoop) stress for PE 100	Type A According to TCVN 6149-1 3 Water-in-water 80°C 1000 h 5,0 MPa	TCVN 6149-1; TCVN 6149-2
II. Physical Characteristic					
4.	Elongation at break for $10 \leq e \leq 12$ mm (e: thickness of pipe)	$\geq 350\%$	Test piece shape Test speed Number of test pieces	Type 1 50 mm/minute According to TCVN 7434	TCVN 7434-1; TCVN 7434-3
5.	Elongation at break for $e > 12$ mm (e: thickness of pipe)	$\geq 350\%$	Test piece shape Test speed Number of test pieces	Type 1 25 mm/minute According to TCVN 7434	TCVN 7434-1; TCVN 7434-3
		Or	Test piece shape Test speed Number of test pieces	Type 3 10 mm/minute According to TCVN 7434	

- (d) Catch basin shall be 60cm diameter spiral corrugated steel pipe and the below part of catch basin connected to coarse sand blanket shall be perforated and wrapped with two layers of geotextile filter fabric as shown on drawing.

- (e) Submerged motor pump shall use more than 1.0kW and has automatic control unit to drain from day to night continuously without congestion of pore water which occurs during soft soil treatment.

2.4.3 Sand Drains (SD)

- (a) This work consists of the installation of a system of Sand drains (SD) and horizontal drainage layers in areas of soft ground as shown on the Drawings or directed by the Engineer. The work shall be carried out in close conformity with the requirements which will be established by the Engineer after the execution of the necessary subsoil investigations by the Contractor.
- (b) The work shall include installation of SDs at the required spacing and depth, the supply and installation of a woven geotextile material over the sand drain and under the drainage layer, and the placing of a granular drainage layer over the area intended to be drained.
- (c) The sand material to be used for SDs shall be free from lumps of dirt, organic matter or any other deleterious matter.
- (d) The material for SDs shall meet the following requirements:
 - i) Sand shall be medium and/or coarse sand
 - ii) Particles with diameter >0.25mm: Min 50%;
 - iii) Particles with diameter <0.075mm: Max 3%;
 - iv) Content of organic material: Max 5%;
 - v) Permeability: Min 5×10^{-3} cm/sec.

2.4.4 Sand Compaction Piles (SCP)

- (a) This work consists of the installation of a system of Sand Compaction Piles (SCPs) and horizontal drainage layers in areas of soft ground as shown on the Drawings or directed by the Engineer. The work shall be carried out in close conformity with the requirements which will be established by the Engineer after the execution of the necessary subsoil investigations by the Contractor.
- (b) The work shall include installation of SCPs at the required spacing and depth, the supply and installation of a reinforcement geotextile material over the sand drain and under the drainage layer, and the placing of a granular drainage layer over the area intended to be drained.
- (c) The sand material to be used for SCPs shall be free from lumps of dirt, organic matter or any other deleterious matter.
- (d) The material for SCPs shall meet the following requirements:
 - Sand shall be medium and/or coarse sand

- Particles with diameter >0.25mm: Min 50%;
- Particles with diameter <0.075mm: Max 3%;
- Content of organic material: Max 5%;
- Permeability: Min 5×10^{-3} cm/sec.

2.4.5 Separation-Geotextile Filter Fabric

- Where required, as directed by the Engineer, the geotextile filter fabric for separating the "Coarse Sand Blanket" material from the existing soils shall conform to TCN248-98 for high survivability fabric specifically used for highway separation applications.
- The fabric shall be non-woven, needle punched, of continuous filament type and manufactured from polypropylene, with weight $\geq 160 \text{ g/m}^2$ and thickness $\geq 1.6 \text{ mm}$. It shall have a permeability rate greater than surrounding soils and have the minimum physical properties shown in Table 2.

Table 2. Minimum Requirements for Separation-Geotextile Filter Fabric

Property	Required Values	Test Method
Apparent Opening Size O_{95} , mm	≤ 0.15	ASTM D4751
Strip Tensile Strength, kN/m	≥ 12	ASTM D4595
Elongation at Failure, %	≤ 65	ASTM D4595
CBR Puncture Strength, N	$\geq 1,500$	ASTM D6241

- The filter fabric shall be procured from a reputable manufacturer and shall be approved by the Engineer.
- The Contractor shall present relevant certified test results and justify that the filter fabric is suitable for the intended use.

2.4.7 Soil Replacement

Replacement fill material shall be provided from deposits found within or in the surroundings of the project area, from borrow pits or from any sources approved by the Engineer accordance with Specification Section 03400 - Embankment Construction. Materials shall be granular materials classified as A-1, A-2 and A-3 in AASHTO M 145-82 or equivalent material. Materials shall be tested according to the requirements of Vietnam current standard or AASHTO T11, T27, T87, T88, T89, T90, T146, and ASTM D1140 as applicable or as instructed by the Engineer. The Contractor shall submit attached to his method statement the information of the materials he intend to use including the sources and relevant test results for the Engineer's approval.

2.4.8 Reinforcement Geotextile Fabric

- a) This item shall consist of supplying and installing approved geotextile material as a part of the road earthworks.
- b) Unless otherwise shown on the drawings or instructed by the Engineer, the materials to be used shall be as follows:

The geo-textile sheets shall be UV-stabilized and made of polyester yarns woven in the strength of 200 kN/m and 50 kN/m for warp and weft directions respectively (ASTM D4595). Tensile elongation at break for both direction (ASTM D4595) $\leq 15\%$. The permittivity (ASTM D4491): $\geq 0.05 \text{ s}^{-1}$. UV resistance (ASTM D4355): $> 70\%$ strength retention after 3 months UV light exposed. It shall have the minimum physical properties shown in Table 3.

Table 3. Minimum Requirements for Reinforcement-Geotextile Fabric

Property	Required Values	Test Method
Min. Permittivity s^{-1}	0.05	ASTM D4491
Min. Strip Tensile Strength kN/m	200	ASTM D4595
Max. Elongation at Failure %	15	ASTM D4595
Min. UV Resistance %	70	ASTM D4355

- c) Geotextile sheet shall be measured by square meters for the net area of measurement will be made for joints or for surplus material laid outside the requirement of the Engineer.

2.5 Embankment Instrumentation

The instrument types, installation methods, and monitoring procedures shall initially be tested in the Reference Section (RS), as specified in these Specifications. The Contractor shall immediately amend or rectify any instruments which are not functioning adequately in the RS. Installation methods shall be modified as directed by the Engineer.

2.6 Observation Wells

- a) Pipes for observation wells shall be perforated 20-cm diameter PVC pipes as shown on the Drawings.
- b) Perforated PVC pipes shall have a wall thickness of at least 10 mm and shall be wrapped with two layers of geotextile filter fabric as shown on the Drawings.

3. CONSTRUCTION REQUIREMENTS

3.1 Coarse Sand Blanket (CSB)

- a) Prior to the placing and compaction of embankment material and prior to the installation of vertical drains, a "Coarse Sand Blanket" shall be placed on the prepared ground surface to ensure adequate drainage of pore water during consolidation of the underlying soils.
- b) The drainage blanket shall conform to the location and dimensional requirements of the typical cross-sections and details shown on the Drawings.
- c) The Contractor shall ensure that the clay materials rising from the PVD placement operations do not cause contamination of the working surface. The Contractor shall remove the risen clay.
- d) Surface depressions around the installations shall be filled with the same material (as for CSB) before commencing the works over the treated area.
- e) Course sand blanket shall be placed in layers not less than the thickness as shown on the relevant Drawings and compacted to a density of 90% of the maximum dry density determined according to AASHTO T180.
- f) Frequency of tests for CSB material shall be at the interval of 5000m³ sand placing at the designed position or as directed by the Engineer.

3.2 Horizontal Drainages

- a) Paving work of perforated drain pipe shall be executed after excavating more than 50cm depth from top of the coarse sand blanket.
- b) The sand shall not get into connecting point when pipe is connected.
- c) Contractor can change the distance between perforated drain pipe and the location of catch basin after Engineer's approval.
- d) Catch basin shall be installed up to at least 2.0m below from the top of the coarse sand blanket and perforated drain pipe have to stick out into catch basin to avoid separation between perforated drain pipe and catch basin by settlement.
- e) Submerged motor pump shall be installed as shown on the drawings and continuously operated by automatic operation device. If the pump malfunctions, consolidation delay will happen, therefore it is necessary to have extra pump for replacement.
- f) The voids by catch basin shall be filled with coarse sand after completion of loading embankment or as directed by the Engineer. Requirements of the coarse sand material shall be same with material of Coarse Sand Blanket. Filling and compacting works of the voids shall be carried out similar to embankment construction, but using hand tamper and to ensure that compaction density shall

be equivalent with density of the surrounding area under the Engineer's supervision and direction.

3.3 Vertical Drains (VD)

- a) The Contractor shall furnish all necessary labour, equipment and materials, and perform all operations necessary for the installation of Vertical Drains (VD) in accordance with the details shown on the Drawings and with the requirements of this Specification Section.
- b) VDs shall be staked as shown on the Drawings and installed after construction of the first "Coarse Sand Blanket" layer with thickness not less than 20cm. The latest "Coarse Sand Blanket" layer, which is 20cm-thickness at least, shall be constructed following installation of VDs and prior to embankment construction. Such, the top elevations of the VDs are always higher than the bottom level of CSB 20cm at least and the top elevations of the VDs are also always lower than the top level of CSB 20cm at least. The actual elevations of the VDs may be changed to each type of the VDs and in each route section, in accordance with the Drawings and instruction of the Engineer, but in any case, the elevations shall not violate the above mentioned requirement.
- c) The Contractor shall first satisfy the requirements for submittal of the VDs sequence and method of installation for the Engineer's approval.
- d) Contractor shall include, but not limited, followings in the installation plan
 - i) Overview of installation
 - ii) Installation management system (Real name)
 - iii) Detail work schedule (Including materials, manpower, and equipment plan)
 - iv) Quality of applied materials and result of testing thereof.
 - v) Installation method of each work stage.
 - vi) Quality management plan: quality management organization and execution plan, and treatment plan for under expected goal and so on.
 - vii) Safety management plan and environment management plan.
 - viii) Countermeasure for traffic flow and protection of environmental pollution.
 - ix) Items which shall require adjustment and change of contract document for appropriate installation.
- e) Submission time and the number of copies
 - i) Submission time : 14days before commencement of each work.
 - ii) The number of copies : 2
- f) VDs shall be installed with such equipment as to keep subsoil disturbance to the minimum

- g) VDs shall be installed vertically from the working surface to the required elevations, to ensure VDs of after installation not cutting the installed VDs and in a sequence that will not require equipment to travel over previously installed VDs. The Contractor shall provide the Engineer with a suitable means for determining the depth of the VDs at any time. The installation tolerance is as follows.

The allowance installation tolerance

VDs type	Allowance Tolerance	
	Position	Inclination
SD, SCP	20 cm	2°

- h) Where obstructions are encountered which cannot be penetrated, the Contractor shall abandon the hole. A maximum of two attempts shall be made to install a new VDs within 0.5 meter of the obstructed hole. VDs that are damaged or improperly installed, will be rejected.
- i) Installation of the VDs should consider and be coordinated with the geotechnical instrumentation shown on the drawings. Special care shall be taken when installing VDs near instruments already in place. Replacement of instruments damaged by the Contractor will be the responsibility of the Contractor.
- j) The Contractor shall demonstrate that the equipment, method, and materials can produce a satisfactory installation in accordance with these Specifications. For this purpose, the Contractor shall install trial VDs at different locations within the work area.
- k) The Contractor shall first satisfy the requirements for submittal of the detailed and dimensioned layouts of VDs locations for the Engineer's approval,
- l) Approval by the Engineer will not relieve the Contractor of the responsibility to install VDs in accordance with the Drawings, and this Specification. If at any time, the Engineer determines that the method of installation does not produce a satisfactory VDs, the Contractor shall alter the method and equipment as necessary.
- m) The Contractor shall keep daily records of the VDs placed. Copies of these shall be submitted to the Engineer within two days following the placement. The records shall show:
- date,
 - grid and area reference of each drain,
 - depth of placement of each drain below the working surface,
 - in case of SD and SCP, the quantity of sand placed in each drain and ampere of vibro-motor,
 - obstructions and delays,

- vi) number and type of tests carried out,
- vii) readings of installed instruments,

Any unforeseen conditions encountered shall be noted briefly in the records.

3.4 Sand drain (SD)

- a) If directed by the Engineer, a temporary earth dike will be formed around the work area to protect the drains, filling materials and other related works from water.
- b) During the settlement period, an additional 1 meter wide, 1 meter thick sand layer may be instructed by the Engineer to be placed at the toe of the sand embankment.
- c) The Contractor's proposed construction statement for SD installation shall be based on the following procedure:
 - i) Sand drains shall be installed by driving a pipe with a closed valve at its lower end.
 - ii) When it has penetrated to the required depth, the inside of the pipe shall filled with approved dry coarse sand and the valve at the bottom of the pipe opened.
 - iii) Once the pipe was filled up and confirmed by the Contractor's quality control supervisor, the upper end of the pipe shall be hermetically closed permitting an efficient application of compressed air.
 - iv) Compressed air shall be applied inside the pipe to raise the pipe out of the ground, simultaneously expelling the sand out of the bottom of the pipe.
 - v) On completion of all vertical drains to the spacing shown on the approved shop drawings, a suitable coarse sand mat shall be spread over the area to the depth shown on the approved shop drawings.
- d) The method of compaction by using water will definitely be rejected. In any case of disregarding of this requirement, the Contractor shall, at his expense and as directed by the Engineer, construct additional SDs to technically compensate this default.
- e) Frequency of tests for SD material shall be at the interval of 5000m³ sand placing at the designed position or as directed by the Engineer.
- f) The SD installation machine shall have devices to measure the length installed, and installing pressure and necessary measures to control the volume of sand installed.

3.5 Sand Compaction Piles (SCP)

- a) Contractor shall submit installation plan for each section and commence to installation in accordance with Engineer's approval.
- b) Contractor shall prepare changed installation plan and take approval by Engineer when installation plan is changed.
- c) Followings shall be submitted additionally

- i) Monitoring plan
- ii) Installation report
- d) Install machine for SCP shall prepare equipment to record driving length and quantity of applied materials. Also contractor shall prepare pilot installation test and take approval from Engineer for determination of depth, penetration ability, degree of automatic recorder, and capability of bucket.
- e) Replacement ratio of sand, spacing, distribution, diameter of piles, and quantity of sand shall be accordance with contract document.
- f) In the case of SCP driving, drawing height of casing and re-penetration depth shall be based on followings . If contractor gets resonable alternatives through pilot installation test, contractor shall apply it as countermeasure with Engineer's approval. Also, pullout and re-penetration of 1m shall be performed additionally 1 time at 1m depth.
 - i) Depth is lower than 3m
 - Pullout height of casing: 3m
 - Depth of re-penetration : 2m
 - ii) Ground surface to Depth 3m
 - Pullout height of casing : 1.5m
 - Depth of re-penetration : 1.0m
- g) Spacing between height of sand at inside of casing and end of casing shall maintain over than 1.5m
- h) Sand pouring at inside of casing shall follow afterwards.
 - i) Contractor shall install bench mark before installation of SCP and based on bench mark, contractor shall mark installation location to match with pitch.
 - ii) Installation location shall determine in accordance with site survey. If location mark damaged by heavy equipment or moved, it shall be re-installed immediately.
 - iii) Installation of SCP shall prepare under the Engineer's attendance. If monitoring equipment broken, installation shall be stop.
 - iv) Drainage installing casing and Leader shall be measured inclined angle for vertical direction and get approval from Engineer.
 - v) Water jet which is prepared to promoting for casing driving shall be used at upper layer of sand and get approval form Engineer before using.
 - vi) If change of Installation location, depth, spacing, and method of installation needed in accordance with additional soil investigation, contractor shall report to Engineer immediately.

- vii) When install SCP, enough sand shall be secured around installation equipment.
- i) Installation management record follows afterwards
 - i) Installation report of SCP shall submit to the Engineer with including followings.
 - Depth of casing driven
 - Applied sand quantity
 - Ground level before driving
 - Record for installation location of SCP, consumed time, length, installation of other works.
 - Record of installation management monitoring equipment
 - Driver of installing equipment and personnel who is responsible for installation.
 - ii) Depth gauge of casing, inclinometer of casing, amperemeter of vibro motor shall record continuously with automatic record equipment.
- j) Frequency of tests for SCP material shall be at the interval of 5000m³ sand placing at the designed area or as directed by the Engineer.
- k) The SCP installation machine shall have devices to measure installing pressure in addition.

3.6 Separation Geotextile Filter Fabric

- a) Where required, filter fabric shall be supplied in rolls, marked to show the length, width, type and weight of the material. Each roll shall be packed in a way to protect the geotextile from direct sunlight during transport and storage in accordance with the supplier's recommendation and as directed by the Engineer.
- b) One layer of separation geotextile filter fabric shall be placed, as directed by the Engineer, over the prepared ground surface in areas that remain soft, unstable, and muddy due to their proximity to the ground water table, before installing the "Coarse Sand Blanket". It shall be stretched out on properly levelled surfaces to obtain a continuous filter layer, without kinks and creases. Overlap for joints shall be not less than 0.50 m for transversal joints, and not less than 0.25 m for longitudinal joints.
- c) Borings and holes for pipes and rods of instruments shall be made as small as possible and without damaging the filter fabric on the sides.
- d) Vehicles or construction equipment shall not be allowed on the filter fabric unless a sufficiently thick layer of fill shall be placed carefully so as not to damage the fabric.

- e) Any damage to the filter fabric shall be repaired or replaced to the satisfaction of the Engineer by the Contractor at his expense.
- f) The Contractor shall provide all information and data applicable for the geotextile filter fabric noting all physical and chemical properties to the Engineer for approval, prior to purchasing the same.

3.7 Soil Replacement and Pre-Loading Embankment (PL)

- a) Excavation and replacement shall be executed to lines and levels shown on the Drawings or as instructed by the Engineer. The construction requirements shall be in accordance with Specification Section 03100 - Common Soil Excavation and Specification Section 03400 - Embankment.
- b) The embankment shall be placed to the lines and levels shown on the Drawings, and in accordance with requirements and procedures of Specification Section 03400 “Embankment Construction”.
- c) The PL shall be kept until the specified settlement criteria have been satisfied and approved by the Engineer.

3.8 Removal of PL

- a) The removal of PL shall be subject to the following criteria:
 - i) The estimated minimum time for settlement indicated on the Drawings has passed (this criterion can be modified by the Engineer, based on the results of the Reference Section test).
 - ii) After the settlement criteria have been satisfied, the PL shall be excavated and moved to other fill areas or stockpiled as directed by the Engineer; and the embankment surface shall be prepared for the roadway subgrade.
- b) The PL, after the approval for its removal has been issued by the Engineer, shall be excavated to the specified elevations within a tolerance of ± 5 cm. This material shall be removed and may be reused if so determined by the Engineer.
- c) Payment for the re-used material from the removed PL will be in accordance with the procedure described in Sub-section 4.1 of this Specification Section.

3.9 Reference Section (RS)

The initial section of ground improvement is designated as a Reference Section (RS). The purpose of this section is to test the Contractor's working methods, observe embankment stability, confirm staged loading sequences, evaluate the rates of settlement for the various embankment heights and vertical drain design, establish best monitoring procedures and proposed instruments, and check the tentative criteria for acceptance of improved ground. The Contractor's widening construction for other

sections shall be determined by the Engineer based on the initial tests results of the Reference Section.

RS shall have a length of approximately 100 meters, and shall be located as shown on the approved shop drawings prepared by the Contractor.

The main construction requirements for RS are as follows:

- a) RS shall be constructed based on the typical cross sections shown on the Drawings. The embankment shall in all other respects be constructed in accordance with the Drawings and Specifications for the roadway embankment.
- b) Work requirements shall be the same as specified for the relevant work items mentioned elsewhere in this Specification.
- c) The Contractor shall drill and obtain samples to a maximum depth of 40 m as shown on the Drawings or as directed by the Engineer. If required by the Engineer, samples shall be obtained and tested at a laboratory, for comparative analysis with the observation and instrumentation results obtained from RS.
- d) RS shall have more instrumentation than other parts of the works and shall be monitored on the same basis as the permanent embankment. This monitoring will be a guide in judging the stability, staged loading, consolidation periods, vertical drain design, and modifications to Pre-Loading Embankment removal criteria. Only the Engineer may adjust these requirements. In addition, from the results of the Reference Section test, the Engineer and Contractor may together discuss changes to optimize the work procedure of the Contractor.
- e) In addition to the settlement monitoring plates and stakes required for embankment monitoring throughout the alignment, observation well, inclinometer, piezometer will be installed at the locations and depths shown on the Drawings, or as directed by the Engineer.

3.10 Reinforcement Geotextile Fabric

- a) Reinforcement geotextile fabric sheets shall be installed at the specified locations in the arrangement as shown on the drawings. Prior to laying of the geotextile all preceding works shall have been completed and the ground surface shall be cleared of all sharp materials that could puncture or tear the fabric. The ground surface shall be flat and level and any unevenness shall not exceed 100mm and the inclination shall be less than 5%.
- b) Laps in the geo-textile material sheets shall be made by either overlapping each sheet by a minimum of 300mms or by stitching using a 30mm double overlocking seam.

3.11 Embankment Instrumentation and Monitoring

- a) The Contractor shall throughout the works supply, install and monitor the instruments and observation points for monitoring settlements, and horizontal deformations of the embankment.
- b) The instruments shall be placed as shown on the Drawings or as directed by the Engineer. Instrument monitoring and maintenance will be required throughout the Contract period or as directed by the Engineer.
- c) The Contractor shall take utmost care to ensure that the instrumentation is not damaged or disturbed in any way, and kept in good working order as long as it is required. He shall erect warning markers where necessary to protect them. For all those instruments which project through and above the fill, special precautions shall be taken to provide protection from vehicles and construction plant by provision of suitable barriers at a distance of minimum 0.75 m around each instrument. Heavy construction equipment shall not be used within 1.00 m distance from projecting instruments. Any instrumentation damaged or disturbed by construction operations shall be replaced or repaired by the Contractor at his expense. At the end of the observation period, the instrumentation shall be cut off below subgrade level and preserved where necessary.
- d) All instruments shall be labeled with their reference number at the location where the readings or measurements are taken. The labeling shall be in accordance with the system and method to be agreed with the Engineer.
- e) The installation of all instrumentation and observation points shall be as specified on the Drawings. All instruments shall comply with the requirements under item (c) above for each particular type.
- f) Where required, boreholes for instruments shall be drilled by a suitable method to provide a clean and stable hole of required diameter to the correct depth. Boreholes shall be cased as required. Boreholes shall be drilled using clean water. Drilling mud or polymer additives shall only be used with the approval of the Engineer.
- g) During drilling, care shall be taken to ensure that material loss from outside the casing be kept to a minimum. Surging of casing will not be allowed, and flushing of drilling water up the outside of the casing shall be kept to a minimum.
- h) For any borehole or part thereof that requires grouting during the installation of instruments, the grout shall be poured into the boreholes using a tremie pipe.

3.12.1 Surface Settlement Plates (SSP)

- a) Surface Settlement Plates (SSP) shall consist of a base plate of 800mm x 800mm connected to steel extension rods and protection pipes as shown on the Drawings. The length of each extension rod shall be exactly as shown on the Drawings.

- b) SSP shall be installed on bottom of the "Coarse Sand Blanket" (CSB) platform, on the separation geotextile (in case of non-application of CSB, the SSP shall be installed at 30 cm higher than the soil replacement level), in such a way that the top of the base plate rests horizontally. Before the placing of any embankment material, the Engineer shall inspect the complete installation and check the initial elevations on top of the base plate and on top of the rod. The rod and pipe shall be extended as the embankment construction advances.

3.12.2. Alignment Wood Stakes

- a) Alignment stakes shall consist of 5 (five) wood stakes, each 1.5 m long, penetrating to a depth of 1.0 m, and placed at 4 m intervals on each side of the embankment.
- b) The wood stakes shall as vertical as possible and be driven on the same line.
- c) Alignment nails shall be placed on the top surface of the stakes, exactly on an alignment perpendicular to the roadway alignment.

3.12.3. Inclinerometers

- a) The Contractor shall engage experienced personnel to install inclinometer tubes in the pre-drilled investigation boreholes, as shown in the drawing. The depths of the inclinometers will be determined by the engineer, but generally they shall be installed at least 2m into the underlying hard stratum. Details of a typical inclinometer installation in a drillhole are shown in the Drawing. The Contractor shall submit to the Engineer for approval details of the installation including surface protection that he proposed to adopt.
- b) Since Inclinerometers or similar approved instruments shall be used for determining the horizontal deformation of the ground. The Engineer's approval for the material and method of installation of the inclinometer tubing will be indispensable prior the commencement of installation.
- c) Drillholes shall be sunk in appropriate size subject to be approved by the Engineer.
- d) The backfilling grout shall be a bentonite cement mix with a strength comparable to that of the surrounding soil or concrete. The Contractor shall submit full details of the proposed grout mix for the approval of the Engineer.
- e) Prior to installation, the end edges and the keyways of the inclinometer tubings shall be examined and the contractor shall remove any damaged tubing and provide replacements when required to do so by the Engineer. The inclinometer tubing shall be inserted into the drillhole inside the temporary casing. The top and bottom of the inclinometer tubing shall be fitted with an end cap and all tubing couplings shall be rivetted connections. While connecting the tubings, the inserted section shall be securely clamped at ground level and the section connected to it.

All completed connections shall be sufficiently wrapped with sealing tape to prevent the ingress of grout. The tube shall be filled with water to overcome buoyancy.

- f) After insertion of the inclinometer tubing, the hole shall be backfilled by pumping grout through a tremie pipe. The grout shall be pumped initially to fill the hole to the top of the temporary casing. The casing shall then be extracted in such a manner that the level of the grout inside the hole shall be at all times higher than the bottom of the casing.
- g) The Contractor shall flush the tubings after installation to remove all solids and flush again after two days.
- h) The Contractor's licensed surveyor shall determine the level of the top of the inclinometer tubing after final trimming and the level shall be recorded on the installation record.
- i) The Contractor shall keep full details of the drilling and installation and submit a complete record to the Engineer within two working days after installation. The format of the record sheet shall be approved by the Engineer prior to commencement of work.

3.12.4 Electric Piezometers

- a) Electric piezometers to be installed in the Embankment shall be vibrating wire or vibrating strip piezometers, supplied from a reputed manufacturer. They may be either the borehole installation type, or the push-in type, and shall be complete with all necessary readout and data-logging equipment. Information on the proposed type, brand, and specifications for the proposed piezometers shall be submitted with the tender together with any other technical documentation. Lightning protection shall be provided as required.
- b) Piezometers shall be installed from the natural ground ("free-field" piezometers), or from the top of the coarse sand blanket, before proceeding with the embankment fill.
- c) Piezometers shall be installed in boreholes as shown on the Drawings, or carefully pushed to the tip elevation indicated. The installation method shall be as specified by the supplier and approved by the Engineer.
- d) Piezometer leads above ground shall be protected as required by the manufacturer.

3.12.5 Recording and Monitoring

(1) Commissioning and Base Reading

- a) After installation, the functioning of each instrument or observation/monitoring point shall be checked. As a part of the commissioning, three sets of readings shall be taken and compared. If significant differences or anomalies are found, then further readings shall be averaged to form the base readings representing conditions prior to start of the earthwork.
- b) The instrumentation records shall contain the following information:
 - i) Instrument reference number and type.
 - ii) Chainage and coordinates.
 - iii) Dates of installation.
 - iv) Initial readings.

(2) Installation Records

Installation records of each instrument shall be prepared containing the following additional information as appropriate for each instrument type:

- i) Existing ground level at the time of installation;
- ii) Weather conditions;
- iii) Length, width, diameter, orientation, and depth;
- iv) Plant and equipment used, and diameter and depth of any drill casing used;
- v) Readings required during installation to ensure that all previous steps have been followed correctly, including acceptance tests;
- vi) Simplified log of ground conditions (in drill holes);
- vii) Type of back-fill used;
- viii) Problems encountered, delays, unusual features of installation, and any events that may have a bearing on instrument behavior;
- ix) A record of commissioning information and readings.

(3) Installation Report

An installation report for each instrument section shall be prepared incorporating the following items and submitted to the Engineer for his review and approval:

- a) Text describing the work carried out and the types of instruments installed.
- b) All installation record sheets.
- c) Plan and cross-section drawings at a scale of 1:200 showing the locations, elevations and details of all instruments.
- d) Values of all base readings taken together with any subsequent readings until the time of submission.

(4) Monitoring

a) Frequency of Measurements

- i) Each instrument or observation point shall be read immediately before and after each change in loading (i.e. each layer of embankment or structural fill etc.), daily during filling operations, then at twice-weekly intervals during the first month. Thereafter, until the end of the settlement period, each instrument or observation point shall be read at intervals not greater than once a week. Monthly readings shall then be made through the end of the Contract period. Any instrument found to be faulty shall promptly be brought to the Engineer's attention and replaced by the Contractor at no additional cost.
- ii) The Contractor shall monitor piezometric pressure in the piezometers once daily for the first seven (7) days after the installation. Thereafter, water levels shall be monitored twice weekly during the first month, and thereafter-weekly intervals until the end of the settlement period, or as directed by the Engineer. Monthly readings shall then be made through the end of the Contract period. During periods of continuous rainfall, water levels shall be monitored daily for a duration to be directed by the Engineer.
- iii) Whenever sets of data are measured, they shall be compared to previous sets of data. If anomalous readings are present which may differ from the expected value or trend, then further readings shall be taken immediately and the Engineer shall be kept informed. If the anomalous values persist, then the Engineer shall be informed and an investigation shall be carried out to ascertain the reasons for the anomalous readings.

b) General Information on All Records

The records of instrumentation readings shall include the following information:

- i) Instrument or observation point reference number and type;
- ii) Location by chainage/offset or by coordinates;
- iii) Dates of installation;
- iv) Initial readings;
- v) Personnel responsible; and
- vi) Relevant comments or remarks.

c) Requirement on stability

Data of settlement observation in the vertical direction and movement observation in the horizontal direction of soft soil area at both sides of

embankment in the progress of roadbed filling and pre-loading filling must not exceed the value regulated below:

- i) Settlement rate at the bottom of embankment for roadbed center must not exceed 10mm per day
- ii) Movement rate in the horizontal direction of observation stakes at both sides of embankment must not exceed 5mm per day

(5) Monitoring Report

- a) The Contractor shall submit a graphical plot of all monitoring instrumentation readings to the Engineer on a daily basis.
- b) The Contractor shall submit to the Engineer a formal monitoring report at the end of each calendar month, in written, electronic digital and graphical format. A sample monitoring report shall be submitted to the Engineer (including all graphical presentations) for approval at least two weeks before the submission of the first monthly report.
- c) Each monthly report shall include:
 - i) A description of monitoring work performed during the previous month;
 - ii) Information on reading anomalies or corrections, and factors which may have influenced the measured data;
 - iii) Observations and remarks;
 - iv) Drawings showing installed locations of instruments (taken from installation report);
 - v) Data tabulations or plots of instrument readings as described hereafter; and
 - vi) Computer disk file copies of all records.
- d) Data tabulation or plots of instrument readings:
 - i) The Contractor shall have suitable software for generation of the required plots and tabulations. The zero time to be used in all the plots and tabulations shall be agreed with the Engineer. The time axis shall be agreed with the Engineer. The time axis shall be marked in days from "day zero" and an indication of date or month shall be included in the axis. The plots and tabulations, thereby giving a complete record starting from the time of installation, shall contain the following:

Instrument	Required Plots and Summaries
Settlement Plate	Settlement versus Time (Tabulation and plot)
Alignment Stakes	Horizontal and vertical movements of each stake with reference to a baseline survey. Position

	shall be plotted versus time and date from beginning of embankment filling operations.
Observation Well	Draining conditions of the Coarse Sand Blanket
Inclinometer	Horizontal movement versus settlement at center.
Piezometer	Piezometer pressure showing excess Piezometric pressure versus time for each piezometer and versus depth for latest set of readings (plots).

- ii) All plots, where time forms the horizontal axis, shall have same scale for the time axis. Where fill thickness, settlement and excess water head are all available at the same location, the plots shall be combined on the same sheet where possible. Final layouts, scales and details shall be agreed with the Engineer at the time of submitting the format.

3.12 Stability and Settlement Monitoring Surveys

The Contractor shall provide all personnel and equipment necessary to initiate, modify design, install and monitor instrumentation for the Reference Section and for the overall project embankment stability and settlement in accordance with these Specifications.

The Contractor can propose or the Engineer can instruct any in-situ tests such as CPTu, FVST for confirming increase of shear strength in case settlement is converged early in comparison with original plan.

3.13.1 Geotechnical Engineering Specialists

(1) Requirements

- The Contractor shall provide experienced Geotechnical Engineering Specialists, an assistant Geotechnical Engineering Specialist and a Senior Soil Technician to conduct detailed investigation of the embankment behavior, including additional explorations, testing, evaluations and modifications required, evaluation of results for reference section; review of design, installation and monitoring of ground improvement measures, piles and pile testing; confirmation of the settlement period completion; and all other geotechnical support as requested by the Engineer.
- The Assistant Geotechnical Engineering Specialist shall be a graduate engineer with at least 5-year experience, including at least one-year experience on PVD and soft ground improvement projects.
- A Senior Soil Technician with at least 5-year experience in geotechnical field investigations shall also be provided in full time during the field explorations.

- d) Prior approval for the Geotechnical Specialists is required. The Contractor shall submit names and curriculum vitae of the personnel to carry out the additional geotechnical engineering services as well as a programme of their attendance for approval by the Engineer. Any deviation from the approved programme of attendance or the requirements given in this Section shall only be permitted with the approval of the Engineer.

(2) Work Tasks of Geotechnical Engineering Specialists

Specific work tasks to be undertaken by the geotechnical engineering specialists shall include, but not be limited, to the following:

- a) Evaluate adequacy of subsurface information along the alignment;
- b) Define and conduct additional field explorations along/across alignment;
- c) Define and conduct additional laboratory tests;
- d) Review/revise design and instrumentation of Reference Section;
- e) Monitor construction and assist with installation of instrumentation for the Reference Section;
- f) Direct and co-ordinate monitoring of instrumentation in the Reference Section during the settlement period.
- g) Evaluate information obtained from Reference Section:
 - i) Embankment stability and staged loading sequences;
 - ii) PL height;
 - iii) PVD, VSD, SCP lengths and spacing
 - iv) PVD, VSD, SCP transition design
 - v) Time for completion of settlement period.
- h) Re-assess/revise engineering soil properties for design;
- i) Re-evaluate embankment stability and slope design;
- j) Re-evaluate embankment settlement estimates;
- k) Review/modify soft soil treatment design;
- l) Review/modify embankment sub-drain design;
- m) Review/modify overbuild design:
 - i) Embankment;
 - ii) Underpasses;
 - iii) Box culverts; and

- iv) Pipe culverts.
- n) Re-evaluate instrumentation/monitoring requirements for embankment construction;
- o) Confirm/modify criteria for completion of embankment settlement period and removal of PL;
- p) Re-evaluate pile foundation design for structures;
- q) Re-evaluate pile load test requirements and driving criteria; and
- r) Re-evaluate design/modify criteria for installation of embankment relief piles.

3.13.2 Soil Investigation

The Contractor shall also provide all labor, equipment and materials necessary to carry out additional soil borings, field and laboratory tests and reports as instructed by the Engineer. These are required for the Contractor to conduct detailed evaluation of soil conditions along the alignment, and for determination of material borrow sites and other routine operations in carrying out the Works.

(1) Field Equipment for Soil Investigation

- a) The Contractor shall provide to the Site and maintain during the entire Contract period a suitable and well-maintained boring rig, or rigs, and other necessary supporting equipment and spare parts. The rig(s) and equipment shall be equipped for carrying out the following types of investigation to the indicated depths, or as directed by the Engineer:
 - i) Borings, maximum depth: 70 m;
 - ii) Standard penetration tests (SPT), maximum depth: 70 m.
- b) The Contractor shall have all equipment ready to start the subsoil investigations one month after the issue of the Notice to Proceed.
- c) The equipment shall at all times be available for subsoil investigations. It can be used for other purposes such as installation of instruments only when approved by the Engineer.
- d) The Contractor shall present along with his Bid detailed information of the type and brand of the boring equipment he proposes to provide. The equipment shall be subject to the Engineer's approval.
- e) At the end of the Contract the equipment will revert to the Contractor.

(2) Subsoil Investigation and Testing:

a) Borings:

The Contractor shall investigate the subsoil by performing borings along the embankment centerline or footing area of bridges specified on the Drawings, and as

directed by the Engineer. Borings may be advanced by auger, rotary, or wash-boring methods, in accordance with ASTM Guide D420-87, ASTM Test Method D1452-80 (1990), or equivalent methods approved by the Vietnamese standards.

b) **Standard Penetration Tests (SPT):**

- i) Standard Penetration Tests with split spoon sampling shall be performed in all borings by suitable standardized equipment according to the method described in ASTM Test Method D1586-84 (1992). The number of blows shall be performed using a free drop hammer and recorded for every 15 cm of penetration of the sampler. Samples shall be placed in plastic bags and transported to the laboratory for classification and other testing as required by the Engineer. The transportation method shall be subject to the approval of the Engineer.
- ii) SPTs shall be carried out at depth intervals of 2.0 m, or as instructed by the Engineer. Results of SPTs shall be presented on boring logs as agreed with the Engineer.
- iii) One part of each STP sample shall be put into a sealed transparent jar (wider than 35 mm inside diameter) and be submitted to the Engineer.

c) **Field Records:**

The Contractor shall record all measurements and relevant observations in the field on standard logs approved by the Engineer. They shall be filled out successively and handed over to the Engineer by the end of each day in two copies. The logs shall show the following information:

- i) Date and name of Inspector/Engineer;
- ii) Boring number and location by co-ordinates;
- iii) Reference Elevation (MSL);
- iv) Name of operator;
- v) Type of boring;
- vi) Water level observed in borehole or in casing;
- vii) Description of soil strata encountered;
- viii) Depth of all soil boundaries;
- ix) Size, type and depth of samples, and sample numbers;
- x) Type, depth, and recordings of in-situ tests;
- xi) Recovery ratios of samples;
- xii) Description of samples;

- xiii) Notes on boring procedures, casing sizes and resistance to driving or coring;
 - xiv) Any irregularities found during boring or testing; and
 - xv) Specification of delays, breakdowns or standby.
- d) Unless otherwise specified as above mention, other contents of drilling, borings and sampling works shall be in accordance with requirements of the Specification Section 01950 “Additional Geotechnical Investigations”.

3.13.3 Grouting of Pipes for SSP and Observation Wells

- a) After completion of the works for soft soil improvement, and upon the approval of the Engineer for construction of the subgrade layer, all the pipes used for SSP and observation wells shall be grouted following the procedure shown in this Sub-section.
- b) Grout at the top of SSP and observation wells shall be a pumpable cement mortar grout approved by the Engineer, and placed in accordance with the following requirements:
 - i) The proportions of the mix shall be such as to conform as closely as possible to the strength or consistency of the natural soils present.
 - ii) One month prior to commencement of this work item, trials shall be conducted with different mixes to ascertain the relationship with strength.
 - iii) Specimens shall first be cured and stored, and then tested in unconfined compression at 7 days.
 - iv) On the basis of these trials, the mix design for the cement mortar grout shall be decided.
- c) The Contractor shall obtain the Engineer’s approval for the grouting procedure.

4. MEASUREMENT AND PAYMENT

4.1 Method of Measurement

- a) The Works in this Specification Section shall be measured according to the item classifications and units contained in the Bill of Quantities.
- b) “Sand Drains” (SD) will be measured by linear meters from the actual level of the bottom of Course Sand Blankets for the diameter as given in the Bill of Quantities. The Sand Drain constructed above the actual level of the bottom of Course Sand Blankets will not be measured but will be deemed to be included in the unit price for the Sand Drains.
- c) “Sand Compaction Piles” (SCP) will be measured by linear meters from the actual level of the bottom of Course Sand Blankets for the diameter as given in the Bill of Quantities. The Sand Compaction Piles constructed above the actual

level of the bottom of Course Sand Blankets will not be measured but will be deemed to be included in the unit price for the Sand Compaction Piles.

- d) "Coarse Sand Blankets" (CSB) will be paid by cubic meter for compacted material in place. The measured volume will be based on the nominal thickness shown on the Drawings and as approved by the Engineer. Any excess volume will be paid as Embankment Construction.
- e) Geotextiles will be measured and paid by square meter of ground covered by the fabric.
- f) The settlement plates (include monitoring), electric piezometers, lateral displacement observing stake (wood stake), observation well and inclinometers will be measured for payment by the actual number of set of instruments installed.
- g) "Pre-Loading Embankment" (PL) material and construction will be measured and paid in accordance with the requirements and stipulations of Specification Section 03400 "Embankment Construction".
- h) The volume of settlement compensation construction required as a result of embankment settlement shall be measured and paid through Specification Section 03400 "Embankment Construction". The means and methods of measuring this volume caused by embankment settlement will be based on settlement plate measurements and as approved by the Engineer.
- i) "Surcharge"
 - i) The quantity of preload material (surcharge embankment and removal) shall be the number of cubic meters placed to the lines and levels given on the Drawing or directed by the Engineer after the settlement period. The actual volume shall be calculated from the agreed cross sections using the profile of the top of the embankment surcharge after the settlement period as shown on the Drawings or approved shop drawings or directed by the Engineer and the profile of the bottom of K98 subgrade layer.
 - ii) Where the Engineer instructs that additional surcharge be placed, the quantity shall not be separately measured but shall be included in the quantity for 'Surcharge Embankment'.
 - iii) Payment for surcharge embankment and removal will be made through pay item 03500-09. This pay item includes the cost for both surcharge embankment and removal.
 - iv) The Contractor shall prepare and submit to the Engineer a plan for the re-use of material remaining from the removal of surcharge embankment after the settlement period. Accordingly, the unit rate of the pay items for preload material (surcharge embankment and removal) shall include the costs of setting aside material for reuse, disposing surplus or unsuitable

material on or off Site, in accordance with the Engineer's instruction. No separate pay item will be measured or paid for this work.

- j) The volume of preload material for abutment (surcharge embankment and removal) will be measured and paid by the number of cubic meters of material excavated. The actual volume shall be calculated from the agreed cross sections using the profile of the top of the embankment surcharge after the settlement period as shown on the Drawings or directed by the Engineer and the profile of the ground after clearing and grubbing and removal of topsoil.
 - i) Payment for preload material for abutment (surcharge embankment and removal) will be made through pay item 03500-10.
 - ii) The unit rate of the pay items for preload material (surcharge embankment and removal) shall include the costs of setting aside material for reuse, disposing surplus or unsuitable material on or off Site, in accordance with the Engineer's instruction. No separate pay item will be measured or paid for this work.
- k) The volume of removal of preload material (cross structures) will be measured and paid by the number of cubic meters of material excavated. The actual volume shall be calculated from the agreed cross sections using the profile of the top of the embankment surcharge after the settlement period as shown on the Drawings or directed by the Engineer and the profile of the ground after clearing and grubbing and removal of topsoil.
 - i) Payment for removal of preload material (cross structures) will be made through pay item 03500-11.
 - ii) The unit rate of the pay items for preload material (surcharge embankment and removal) shall include the costs of setting aside material for reuse, disposing surplus or unsuitable material on or off Site, in accordance with the Engineer's instruction. No separate pay item will be measured or paid for this work.
- l) The Softsoil Improvement Measure provisions, material requirements and construction requirements and test frequencies identified in this Specification Section shall be measured for payment in pay items 03500-02, 03500-03, 03500-04, 03500-06, 03500-07, 03500-09, 03500-10, 03500-11, 03500-12, 03500-13, 03500-14, 03500-15 and 03500-16.
- m) Any Softsoil Improvement Measure Works not specifically identified in this Specification Section but which are necessary for the performance of the Works shall be deemed to be included in pay items 03500-02, 03500-03, 03500-04, 03500-06, 03500-07, 03500-09, 03500-10, 03500-11, 03500-12, 03500-13, 03500-14, 03500-15 and 03500-16.

4.2 Basis of Payment

- a) The accepted quantities, measured as provided above, will be paid at the Contract price per unit of measurement for the pay items of the Bill of Quantities listed below. Payment will be full compensation for the works prescribed in this Section including all the soil improvement measures required in these Specifications, and for furnishing all labor, materials, tools, equipment and any incidentals to complete the works as shown on the Drawings and as required in accordance with these Specifications and/or as directed by the Engineer.
- b) Unit prices for removal of surcharge embankment, removal of preloading embankment at location of cross structures or abutment shall include for, inter alia:
 - i) Setting aside soil material for reuse on Site.
 - ii) Disposal of unsuitable material off Site.
 - iii) Disposal of surplus material off Site.

The works for “Setting Out”, “Embankment Instrumentation and Monitoring”, and “Stability and Settlement Monitoring Surveys” will not be paid separately, but will be deemed included and distributed in all the Contractor’s rates and unit prices for soft soil improvement measures.

<u>Pay Item</u>	<u>Description</u>	<u>Unit</u>
03500	Softsoil Improvement Measures	
03500-02	Sand Drains, diameter 0.4m	m
03500-03	Sand Compaction Pile, diameter 0.7m	m
03500-04	Coarse Sand Layer (Sand Blanket)	m3
03500-06	Geotextile Filter Fabric (non-woven)	m2
03500-07	Geotextile Filter Fabric (woven) 200kN/m	m2
03500-09	Preload material (Surcharge Embankment and Removal)	m3
03500-10	Preload material for Abutment (Surcharge Embankment and Removal)	m3
03500-11	Removal of Preload Material (Cross Structures)	m3
03500-12	Settlement Plates (include monitoring)	set
03500-13	Electric Piezometers	set
03500-14	Lateral displacement observing stake (Wood stake)	set
03500-15	Observation well	set

<u>Pay Item</u>	<u>Description</u>	<u>Unit</u>
03500-16	Inclinometers	set