

SPECIFICATION FOR VIBRATED STONE COLUMNS

1.0 GENERAL

1.1 Works in Accordance with Specifications

All materials and workmanship shall be in accordance with the appropriate British Standards current at the time of tender, including those listed in this Specification, except where the requirements of British Standards are in conflict with this Specification, the latter shall take precedence unless otherwise approved by the Engineer.

All work shall be carried out generally in accordance with the principles of relevant codes of practice or design manuals current at the time of tender, including those referred to in this Specification.

In this Specification the terms 'approved', 'approval' and 'required' mean 'approved by the Engineer', 'approval of the Engineer' and 'required by the Engineer' respectively.

The Contractor, where so directed by the Engineer, shall be required to work to other contractors' drawings whenever drawings for temporary works not included in the Contract are related to particular details of the Works.

The ground treatment described in this Specification shall be carried out by deep vibratory compaction incorporating stone columns formed with imported granular backfill complying with the requirements of BS EN 14731: 2005.

2.0 PERFORMANCE

The execution and performance of the ground treatment shall be the responsibility of the Contractor, who shall, nonetheless, satisfy the Engineer that all treated ground has attained the required degree of improvement.

Where appropriate, estimates of the total and differential settlement anticipated at the working load shall be given by the Contractor.

The Contractor shall supply detailed and dimensioned layouts of the treatment points in duplicate for the approval of the Engineer. Such approval shall not remove the responsibility of the Contractor for the accuracy of the drawings. Each treatment point shall have a unique reference number for record purposes. Neither the spacing nor location shall be varied without the prior agreement of the Engineer.

At the commencement of the Contract, the Contractor shall provide a detailed method statement. This shall include a programme giving full details of both type and quantity of all the plant he proposes to use, the order of carrying out the work, and where not already specified by the Engineer the detailed and dimensioned layout of the ground treatment, type and frequency of the proposed control testing, and where applicable, the anticipated ground heave after treatment.

The ground treatment shall be carried out in a safe manner. Account shall be taken of concurrent site activities and all plant movement necessary to properly carry out the Works.

3.0 MATERIALS

The sources of supply of materials shall be approved by the Engineer and shall not be changed

without prior approval of the Engineer in writing.

Rejected materials shall be removed promptly from the Site.

Stone used shall be clean, hard, inert material and shall be natural sand, gravel, crushed rock, crushed hardcore, crushed slag or well burnt non-plastic shale. The material shall be suitable for the ground conditions in which the stone columns are formed and have no adverse effects on other work on the site. The material selected to form the stone columns shall be able to withstand the impact forces of the vibrating poker and retain long-term integrity under the applied foundation loads. It shall not excessively crush or break down during compaction or under long-term static loads applied in service. The hardness can be defined by an Aggregate Impact Value (AIV – BS 812: Part 112: 1990), an Aggregate Crushing Value (ACV – BS 812: Part 110: 1990) or a Ten per cent Fines Value (TFC – BS 812: Part 111: 1990). Materials with an ACV or AIV greater than 30% are not suitable for stone column construction. Materials likely to degrade or significantly weaken when saturated in-situ is also not suitable for stone column construction.

The materials shall be graded appropriately for compaction to form a dense column fully interlocked with the surrounding ground and in compliance with other requirements such as drainage. The materials shall also be compatible with the plant used and flow freely within bottom-feed and through-feed delivery systems without arching which may block these systems. The gradings shall be as follows unless otherwise approved by the Engineer:

- a) Dry top-feed – A nominal single-size material within the range 40mm to 70mm or a graded material within these limits with a maximum fines content (material of silt and clay sized particles) of 5%.
- b) Dry bottom-feed – A nominal single-size material within the range 20mm to 50mm and the fines content should not be greater than 5%.
- c) Wet top-feed – A nominal single-size material within the range 20mm to 50mm, with not greater than 5% fines.

For graded materials, the material passing the BS 425 μ m sieve shall be non-plastic.

The material used by the Contractor for filling to make up ground levels to the working surface prior to treatment shall be hard inert granular material capable of passing a BS 106 mm sieve with not more than 10% passing the BS 75 μ m sieve.

4.0 GROUND TREATMENT

Treatment may be either the wet or dry process but if the dry process is used it shall be demonstrated on site that the hole made by the machine will remain open to enable the stone to be placed cleanly to the bottom of the hole to form a continuous column to the surface. Where a change in the method of treatment is required by the Contractor, the prior agreement of the Engineer shall be sought without delay.

The stone column shall be formed to the working surface without inclusion of clay or other unsuitable material preventing intergranular contact between stone particles.

When the dry top-feed process is being used the vibrator may be removed completely from the hole to allow access for the stone. Where the dry bottom-feed process is used, the depth vibrator shall not be removed from the ground during column construction. When the wet process is being used the vibrator shall be kept in the hole at all times in order to maintain stability of the sides and to ensure that the stone shall reach the required depth via the annular space around the vibrator.

The Contractor shall provide a supply of water. If the wet process is selected, the Contractor shall indicate the rate of water supply required and be responsible for checking that this is available. The Contractor shall be responsible for supplying any extra storage tanks and pumping as required.

The Contractor shall be responsible for disposing of effluent to a watercourse or sewer and for complying with the requirements of the relevant Authorities. The Contractor shall state clearly the number and size of any silt traps required. These shall be provided and maintained by the Contractor. On completion of the ground treatment the Contractor shall remove all such equipment and backfill any pits.

Working platforms shall be prepared and maintained in a manner suitable for the safe movement and working of the vibro plant. Material used to provide working platforms shall be granular, suitable for the ground conditions on which it is placed and shall not prevent poker penetration. Site working levels for the treatment shall be provided and maintained throughout the duration of the Works.

In ground conditions where pre-boring is deemed necessary, it shall be carried out by a method and to a sequence agreed by the Engineer. Pre-boring shall be carried out immediately before, or as near as practicable, to stone column construction to mitigate any safety issues associated with open excavations and prevent unnecessary deterioration of the underlying ground, for example due to water ingress.

4.1 Verticality

In the penetration stage the vibrator shall be kept as near vertical as possible and never deviate by more than 1 in 20 when forming the stone columns.

4.2 Depth and Spacing

The depth and spacing of the stone columns shall be as shown on the Drawings and neither the depth nor spacing shall be varied without the prior agreement of the Engineer. Any variations in depth of stone columns due to site conditions not anticipated in the design shall be reported immediately to the Engineer who shall advise on any action to be taken.

4.3 Tolerances

All stone columns shall be located to within 150mm of the plan positions shown on the ground treatment layout drawings.

4.4 Stone Quantities

Significant variations in the quantity of stone used in forming stone columns of the same length shall be reported immediately to the Engineer.

4.5 Buried Obstructions

Prior to commencement of ground treatment, services in the ground and overhead shall be identified and clearly marked on site or relocated by the Contractor.

The Contractor shall break out known near-surface obstructions and fill the resulting voids with suitable granular material prior to the commencement of ground treatment works by the Contractor.

Where an unforeseen obstruction is encountered below ground level, the Engineer shall be informed immediately. The Engineer will then decide with the Contractor whether the obstruction is to be removed or the stone column layout modified.

Where it is decided to remove the obstruction the Engineer will inform the Contractor to excavate the obstruction and backfill the void with approved granular material. The approved granular material shall be placed in a loose condition such that, while capable of safely supporting the vibro plant, it does not impede poker penetration and can be treated in a similar manner to the surrounding ground.

4.6 Ground Heave

In order to reduce ground heave, excessive treatment in the final stage of the column formation shall be avoided. If ground heave does occur then the spoil so formed shall be removed from the working area by the Contractor.

4.7 Overtreatment

In soft cohesive soils particular care shall be taken to minimize the reduction of local soil strength by remoulding. Vibration treatment beyond the optimum, with unnecessary additions of stone, shall be avoided.

4.8 Debris in Hole

Lumps of spoil shall not be permitted to fall into the bore. Hand spades shall be kept available for this purpose. If the hole is unstable, thus posing the risk of contaminating and weakening the stone column being formed, the treatment method shall be altered to the bottom-feed or wet method.

4.9 Surface Compaction

Where ground treatment is being applied to areas where the foundations are less than 600mm below the treatment working surface, measures shall be taken by the Contractor on completion of the treatment to ensure that this depth is adequately compacted using rollers or tampers to the satisfaction of the Engineer.

All surface layers shall be properly compacted using rollers or tampers upon completion of the treatment works.

5.0 SITE CONDITIONS

Factual information or reports on site investigations for the Works will be made available to the Contractor upon request.

Prior to commencement of the works, the Contractor may carry out additional site investigations at their own cost and time to verify the ground conditions of the Site and the Contractor is deemed to have familiarised himself with the existing site conditions. Any claims arising from unforeseen ground and site conditions will not be entertained.

The Contractor shall report immediately to the Engineer any circumstance which in the Contractor's opinion indicates that the ground conditions differ from those expected by him from his interpretation of the site investigation report.

6.0 WORKMANSHIP

The Contractor shall satisfy the Engineer regarding the suitability, efficiency and adequacy of the equipment to be employed. The Contractor shall state the type and number of rigs he intends to use.

On completion of each area of ground treatment the Contractor shall grade debris and surplus material arising from the ground treatment to leave a reasonable firm and level working surface.

On completion of the treatment to the satisfaction of the Engineer, the Contractor shall remove from the site all plant and unwanted material.

7.0 SETTING OUT

Setting out shall be carried out by the Contractor from grid lines provided and maintained by the Contractor. Immediately before treatment, each treatment position shall be marked by the Contractor with suitable identifiable pins or markers.

The Contractor shall provide and maintain bench marks throughout the duration of the Works.

8.0 PROGRAMME

The Contractor shall inform the Engineer at regular mutually agreed intervals of the forward programme of ground treatment.

The Contractor shall submit to the Engineer on the first day of each week, or at such longer periods as the Engineer may from time to time direct, a progress report showing the current rate of progress and progress during the previous period on all important items of each section of the Works.

9.0 RECORDS

The Contractor shall keep daily records of the treatment carried out and shall submit signed copies of these records to the Engineer within two working days (both hard & softcopy in format approved by the Engineer). The records shall show as a minimum the following information:

- a) date and time of work at each treatment point
- b) compaction point reference number
- c) location of treatment point
- d) weather conditions
- e) method of treatment, reference type of equipment and personnel
- f) presence of heave or settlement of ground surface (plus estimate if detected)
- g) depth of penetration at each compaction point
- h) quantity of stone used in each column
- i) vibrator power consumption
 - i. during penetration
 - ii. during compaction
- j) jetting pressure (where applicable)
- k) duration of
 - i. penetration
 - ii. compaction
- l) obstruction and delays
- m) any unforeseen conditions encountered
- n) with wet or bottom-feed processes, any occasions when the depth vibrator has had to be removed from the ground during column construction
- o) number and type of tests carried out

In addition the above, the following shall also be monitored:

- a) significant variations in consumption of granular material used in forming columns of the same length
- b) any changes in supply or specification of the materials

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

10.0 DAMAGE

If during the execution of the work damage is, or is likely to be, caused to mains, services or adjacent structures, the Contractor shall inform the Engineer of his proposals for avoidance or

repair of such damage.

The Contractor shall arrange the sequence and timing of the Works to ensure that damage does not occur to treated ground by any subsequent work.

The Contractor shall assess the possibility of adverse effects on existing adjacent foundation systems, buildings and services, earthworks, slopes, retaining structures and buried structures, arising from ground movements, pore pressures or vibrations induced by the ground treatment and inform the Engineer of his proposals for mitigating the adverse effects.

In cases where adverse effects on adjacent buildings and infrastructure are of concern, a dilapidation or pre-condition survey shall be carried out. Where required, vibration monitoring shall be carried out during the treatment process with prior agreement of threshold levels.

11.0 AS-BUILT

The as-built drawings and records shall include the following information:

- a) the as-built position and depth of each treatment point noting any deviation outside specified tolerances. The as-built drawing shall be certified by a licensed surveyor and endorsed by a Professional Engineer registered with the Board of Engineers, Malaysia engaged by the Contractor.
- b) particular directives associated with design and execution which are relevant to subsequent use of the treated ground
- c) the source, type and quality of granular material used for the stone columns

12.0 TESTING OF GROUND TREATMENT WORKS

12.1 Definitions:

In-situ tests shall be used for performance testing where changes in ground properties can be measured. One or more of the following in-situ tests may be carried out:

- a) cone penetration tests (CPT and CPTU) carried out to provide a continuous record of penetration resistance, friction ratio and, for CPTU, induced pore pressure
- b) dilatometer tests (DMT) carried out to determine deformation moduli
- c) dynamic probing (DP) carried out to provide a record of the penetration resistance
- d) pressuremeter tests (PMT) carried out to determine deformation moduli and/or limit pressures
- e) standard penetration tests (SPT) carried out to determine the penetration resistance

Large scale tests shall be carried out using plate load tests and zone tests defined as follows:

Proof load:	A proof load is a load applied to a selected area of working foundation to confirm that it is suitable for the load at the settlement specified.
Plate test:	A plate test is a loading test carried out using a plate on treated ground essentially used as a control of workmanship.
Zone test:	A zone test is a loading test carried out with a slab, intended to test bearing pressure over a wider and deeper zone than in the plate bearing test. A zone test may be a full-scale test of a structural member.

Safety precautions shall comply with all statutory safety requirements.

12.2 Kentledge

Where kentledge is used the Contractor shall construct the foundations for the kentledge and any cribworks, beams or other supporting structure in such a manner that there will not be differential settlement, bending or deflexion of an amount that constitutes a hazard to safety or impairs the efficiency of the operation. The kentledge shall be adequately bonded, tied or otherwise held together to prevent it falling apart, or becoming unstable because of deflexion of supports.

The weight of kentledge shall be greater than the maximum test load, and if the weight is estimated from the density and volume of the constituent materials, an adequate factor of safety against error shall be allowed.

12.3 Ground Anchors

Where ground anchors are used the Contractor shall ensure that the load is correctly transmitted to all the tie rods or bolts. The extension of rods by welding shall not be permitted unless it is known that the steel will not be reduced in strength by welding. The bond stresses of the rods in tension shall not exceed nominal permissible bond stresses for the type of steel and grade of concrete used and shall comply with the requirements of BS 8081: 1989.

12.4 Testing Equipment

In all cases the Contractor shall ensure that when the hydraulic jack and load-measuring device are mounted the whole system will be stable up to the maximum load to be applied. Means shall be provided to enable dial gauges to be read from a position clear of the kentledge stack or test frame in conditions where failure in any part of the system due to overloading, buckling, loss of hydraulic pressure and so on might constitute a hazard to personnel.

The hydraulic jack, pump, hoses, pipes, couplings and other apparatus to be operated under hydraulic pressure shall be capable of withstanding a test pressure of 1.5 times the maximum pressure without leaking.

The maximum test load or test pressure expressed as a reading on the gauge in use shall be displayed and all operators shall be made aware of this limit.

12.5 Preliminary Tests

The Contractor shall give the Engineer at least 48 hours' notice of the commencement of treatment of an area for preliminary test loading.

The ground treatment for the area for preliminary test loading shall be carried out in a manner similar to that proposed for the working area and using similar equipment and materials.

12.6 Preparation of Ground Surface

The Contractor shall excavate for the test to the level specified.

For plate bearing tests, the excavated surface shall be cleaned of loose material and blinded with a layer of sand not exceeding 150mm in average thickness.

For zone tests, the excavated surface shall be cleaned of loose material and blinded with 50mm concrete.

12.7 Concrete Test Cubes

The Engineer may call for test cubes to be made from the concrete used in the slab for any zone test. The cubes shall be made and tested in accordance with BS 1881.

The zone test shall not be started until the concrete in the slab has attained the 28 days strength as indicated by cube crushing tests.

12.8 Spread of Test Load

The steel plate or the reinforced concrete slab shall be of sufficient thickness to spread the concentrated load supplied to its upper surface evenly over the base.

12.9 Reaction Systems

The reaction for plate bearing tests may be provided by use of mobile plant on site such as the crawler crane. Where suitable plant is not available, kentledge or anchors shall be used.

The reaction for zone tests shall be provided using kentledge or ground anchors.

The distance from the edge of the area to be tested to the near part of the foundation supporting the kentledge shall be such as to avoid interaction between the two stressed areas.

The size, length and number of the anchors, or the area of the cribs and mats, shall be adequate to transmit the maximum test load to the ground in a safe manner without excessive movement or influence on the test area.

The method employed in the installation of any anchors, or erection of any cribs and mats or kentledge, shall be such as to prevent damage to any treated areas.

The loading arrangement used shall be designed to transfer safely to the test area the maximum load required in testing. Full details shall be submitted to the Engineer prior to any work relating to the testing process being carried out on the Site.

12.10 Equipment for Applying Load

The equipment used for applying load shall consist of one or more hydraulic rams or jacks. The total capacity of the jacks shall be arranged in conjunction with the reaction system to deliver an axial load to the area. The complete system shall be capable of transferring the maximum load required for the test.

12.11 Measurement of Load

The load shall be measured by a load-measuring device (e.g. load cell) and by a calibrated pressure gauge included in the hydraulic system. Readings of both the load-measuring device and the pressure gauge shall be recorded.

A spherical seating shall be used in conjunction with any devices that are sensitive to eccentric loading; care must be taken to avoid any risk of buckling. Load-measuring devices and jacks shall be short in axial length in order to achieve the best possible stability. Sufficient attendance shall be arranged by the Contractor to ensure that axial load is maintained.

The load-measuring device shall be calibrated before and after each series of tests, whenever adjustments are made to the device or at maximum intervals of six (6) months. The pressure gauge and hydraulic jack shall be calibrated together. Certificates of calibration shall be supplied to the Engineer.

12.12 Adjustability of Loading Equipment

The loading equipment shall be capable of adjustment throughout the test to obtain a smooth increase of load or to maintain each load constant at the required stage of a maintained loading test.

12.13 Measuring Movement During Tests

The movement of the plate/slab shall be measured by not less than four deflexion gauges

positioned symmetrically around the plate/slab. Each gauge shall enable readings to be made to within 0.1mm and shall be mounted on a reference frame which will not be affected by the movement of the ground due to weather, kentledge load, application of test loads, movement of site traffic or other such causes.

The reference frame should be protected from direct impact, and also from temperature effects where appropriate.

An optical levelling method by reference to an external datum shall be used to check movement of the plate/slab and supports for the kentledge. A precise level and staff shall be used, the level and scale of the staff being chosen to enable readings to be made within an accuracy of 0.5mm. A scale attached to the plate/slab may be used instead of a levelling staff. At least two datum points shall be established on permanent objects or other well founded structures, or deep datum points shall be installed. Each datum point shall be situated so that only one setting up of the level is needed.

No datum point shall be affected by the test loading or other operations on the Site.

Where another method of levelling is proposed this shall be approved in writing.

12.14 Protection of Testing Equipment

Suitable tarpaulins or other protection to shield the reference beams from direct sunlight or adverse weather shall be provided to minimize the effect of temperature variations on the readings obtained.

12.15 Supervision

The Contractor shall give the Engineer at least 24 hours' notice of the commencement of the test.

During the progress of a test, the testing equipment and all records of the test shall be available for inspection by the Engineer.

12.16 Test Procedure

Plate bearing test

The maximum load which shall be applied in a plate bearing test is 3 times the working load. The load shall be applied in at least six approximately equal increments.

Following each application of load the settlement shall be measured at intervals of one minute until no change is detected and then at intervals of 5 minutes. The load shall be held for 10 minutes or until two successive readings at 5 minute intervals are the same, whichever is the greater.

The maximum load shall be held for 15 minutes or until three successive readings at 5 minute intervals are the same, whichever is the greater. The settlement shall be measured on release of the load and again after 5 minutes.

Zone test

The test load shall be applied in increments not exceeding 25% working load in three stages

- a) to working load
- b) to 200% working load
- c) to 250% working load

Incremental loading shall not be applied until the rate of settlement under the preceding load is less than 0.5 mm/h, as determined by the average readings of the deflexion gauges taken at 5

minute intervals. The test load shall be removed in stages equivalent to the loading stages and the recovery measured.

12.17 Presentation of Results

Within 24 hours of the completion of the test, unless otherwise directed, a summary of the results in writing shall be submitted to the Engineer.

For a plate bearing test, the summary shall give the maximum load applied, the period for which it is held, the maximum settlement recorded, and the recovery on unloading.

For a zone test the summary shall give, for each stage of loading, the period for which the load was held, the load and the maximum settlement recorded.

Within seven (7) days of the completion of the test, the completed schedule of recorded data shall be submitted to the Engineer. This shall be as specified below for a plate bearing test or a zone test as appropriate.

12.18 Schedule of Recorded Data

Plate bearing tests

The Contractor shall provide information about the tested ground in accordance with the following schedule where applicable

- a) general
 - contract identification
 - date of test
- b) test area details
 - identification of area relative to site layout drawing
 - brief description of position in structure
 - ground level at test position
 - excavated test level
- c) treatment details
 - date and time of treatment
 - unexpected circumstances or difficulties
- d) stone columns
 - identification numbers of stone columns
 - diameter and depth of stone columns exposed
 - spacing of adjacent columns
 - depth
 - stone consumption
- e) test procedure
 - approximate weight of kentledge
 - date and times of load application
- f) test results
 - load and settlement with time reported in tabular form, and in graphical form, load and settlement being plotted against time, and load against settlement.

Zone tests

The Contractor shall provide information about the tested ground in accordance with the following schedule where applicable

- a) general
 - contract identification
 - date of tests
- b) test area details
 - identification of area relative to site layout drawing
 - size and position of area

- ground level at test position
- excavated test level
- c) treatment details
 - date and time of treatment
 - unexpected circumstances or difficulties
 - identification number of stone columns
 - depth of treatment
 - stone consumption
- d) test details
 - weight of kentledge
 - ground anchor details
 - plan of test arrangement showing position and distances to test area of kentledge supports, rafts or ground anchors and reference frame
 - jack capacity
 - method of load-measurement
 - dates and times
- e) test results
 - load and settlement with time reported in tabular form, and in graphical form, load and settlement being plotted against time, and load against settlement

12.19 Completion of a Test

The concrete slab used for a zone test shall be broken up and the resulting material disposed of off the Site. If it is in a working area care shall be taken not to disturb the soil beneath the slab.

Excavations to foundation level shall be carefully backfilled and compacted with suitable materials up to the general level of the Site.

On completion of any test, ground anchors (if used) shall be distressed, and all parts which would later cause an obstruction to the Works removed.

TABLE OF CONTENTS

	Description	Page
1.0	GENERAL	VSC1
1.1	Works in Accordance with Specifications	VSC1
2.0	PERFORMANCE	VSC1
3.0	MATERIALS	VSC1
4.0	GROUND TREATMENT	VSC2
4.1	Verticality.....	VSC3
4.2	Depth and Spacing	VSC3
4.3	Tolerances	VSC3
4.4	Stone Quantities	VSC3
4.5	Buried Obstructions	VSC3
4.6	Ground Heave	VSC4
4.7	Overtreatment	VSC4
4.8	Debris in Hole	VSC4
4.9	Surface Compaction	VSC4
5.0	SITE CONDITIONS.....	VSC4
6.0	WORKMANSHIP.....	VSC4
7.0	SETTING OUT	VSC5
8.0	PROGRAMME	VSC5
9.0	RECORDS	VSC5
10.0	DAMAGE.....	VSC5
11.0	AS-BUILT	VSC6
12.0	TESTING OF GROUND TREATMENT WORKS.....	VSC6
12.1	Definitions	VSC6
12.2	Kentledge	VSC6
12.3	Ground Anchors	VSC7
12.4	Testing Equipment	VSC7
12.5	Preliminary Tests	VSC7
12.6	Preparation of Ground Surface	VSC7
12.7	Concrete Test Cubes	VSC7
12.8	Spread of Test Load.....	VSC8
12.9	Reaction Systems	VSC8
12.10	Equipment for Applying Load.....	VSC8
12.11	Measurement of Load	VSC8
12.12	Adjustability of Loading Equipment.....	VSC8
12.13	Measuring Movement During Tests.....	VSC8
12.14	Protection of Testing Equipment.....	VSC9
12.15	Supervision	VSC9

12.16	Test Procedure.....	VSC9
12.17	Presentation of Results.....	VSC10
12.18	Schedule of Recorded Data.....	VSC10
12.19	Completion of a Test.....	VSC11