TRANSPORT FOR NSW (TfNSW)

QA SPECIFICATION R223

DRY DEEP SOIL MIXING

REVISION REGISTER

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Ed 1/Rev 0		First issue.	GM, CB	24.05.17
Ed 1/Rev 1	Global	References to “Roads and Maritime Services” or “RMS” changed to “Transport for NSW” or “TfNSW” respectively.	DCS	22.06.20

GUIDE NOTES

(Not Part of Contract Document)

GN1 General

The dry mixing method of deep soil mixing (DSM), with the binder delivered via compressed air, is the method covered in this Specification.

Dry deep soil mixing (DSM) involves penetration of a special mixing tool into the ground to the required depth of treatment, injecting the binder (as a dry powder) through the tip of the tool at the required quantity, and mixing the binder and soil by mechanical means to cause disaggregation of the soil and thorough mixing with the binder.

GN2 Definitions

Each defined area for DSM ground treatment is referred to as a "Lot".

Each Lot should generally be less than 200 m in length along the road alignment, where soft ground conditions do not vary much in the soil properties of shear strength, compressibility, clay mineralogy and organic content.

The TfNSW Project Manager must identify the number of Test Areas required within each Lot, based on factors such as similar depth and thickness of strata and similarity in soil properties, and show the Lots and the associated number of Test Areas in Annexure R223/A1. The minimum number of Test Areas per Lot is one Test Area.

GN3 Columns and Panels

The positions, spacings, diameters and depths of the columns are shown on the Drawings. Columns which are shown as overlapping with other columns to form a contiguous panel are generally located beneath embankment batters, while non-overlapping columns are generally located beneath embankment crests.

GN4 Laboratory Mixes and Mix Design

The Contractor must carry out preliminary laboratory testing to estimate the minimum binder content to achieve a 28 day unconfined compressive strength (UCS) of at least 2.5 times the specified design UCS of the DSM column. The adopted factor of 2.5 is to cater for ground condition variability, construction tolerances and other related issues.

Under this Specification, the design undrained shear strength of DSM column is assumed to be half the design UCS.

The Project Manager must specify in Annexure R223/A2 the type of binder to be used by the Contractor for the soil mixing, and the design parameters specified on the Drawings.

GN5 Trial Columns

The quantity of binder used in production of DSM columns generally is in the range of 120 to 200 kg/m^3 of the volume of insitu soil, depending on soil type, moisture content and organic content. The efficiency of the DSM equipment and ground treatment construction time may be factors in determining the quantity of binder required.

Within each Test Area, the Contractor must propose three trial mixes to determine the production mixing parameters. For each trial mix, the Contractor must construct three trial columns as a minimum for preliminary field trial construction.

GN6 Production Mixing Parameters

As a guide, the Blade Rotation Number (BRN) which defines the minimum mixing energy requirements for the production of DSM columns should be as follows:

(a) BRN – Insertion: Contractor to advise.

(b) BRN – Extraction and Mixing: typically ≥ 600 (to be confirmed by field trials).

The Contractor must determine the production mixing parameters from the results of Preliminary Testing and trial column construction in Clauses 3 and 5 considering the soil characteristics, binder content and the specialist equipment used.

GN7 Production Testing Requirements

When testing production columns, the Contractor must develop a shear strength calibration factor "N" for interpreting the shear strength obtained from column penetration tests. This calibration must be based on the UCS testing of field coring samples of test columns. If a calibration is not performed, a default "N" value of 13 is to be adopted.

Transport for NSW

QA SPECIFICATION R223

DRY DEEP SOIL MIXING

IC-QA-R223

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CLAUSE PAGE

FOREWORD

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REVISIONS TO PREVIOUS VERSION

This document has been revised from Specification TfNSW R223 Edition 1 Revision 0.

All revisions to the previous version (other than minor editorial and project specific changes) are indicated by a vertical line in the margin as shown here, except when it is a new edition and the text has been extensively rewritten.

PROJECT SPECIFIC CHANGES

Any project specific changes are indicated in the following manner:

(a) Text which is additional to the base document and which is included in the Specification is shown in bold italics e.g. ***Additional Text***.

(b) Text which has been deleted from the base document and which is not included in the Specification is shown struck out e.g. ~~Deleted Text~~.

TfNSW QA SPECIFICATION R223

DRY DEEP SOIL MIXING

1 GENERAL

1.1 SCOPE

This Specification sets out the requirements for ground improvement by deep soil mixing (DSM) using the dry mixing method.

1.2 STRUCTURE OF THE SPECIFICATION

This Specification includes a series of annexures that detail additional requirements.

1.2.1 Project Specific Requirements

Project specific details of work are shown in Annexure R223/A.

1.2.2 Measurement and Payment

The method of measurement and payment is detailed in Annexure R223/B.

1.2.3 Schedules of HOLD POINTS, WITNESS POINTS and Identified Records

The schedules in Annexure R223/C list the **HOLD POINTS** and **WITNESS POINTS** that must be observed. Refer to Specification TfNSW Q for definitions of **HOLD POINTS** and **WITNESS POINTS**.

The records listed in Annexure R223/C are **Identified Records** for the purposes of TfNSW Q Annexure Q/E.

1.2.4 Planning Documents

The PROJECT QUALITY PLAN must include each of the documents and requirements listed in Annexure R223/D and must be implemented.

1.2.5 Frequency of Testing

Your Inspection and Test Plan must nominate the proposed testing frequency to verify conformity of the item, which must not be less than the frequency specified in Annexure R223/L. Where a minimum frequency is not specified, nominate an appropriate frequency. Frequency of testing must conform to the requirements of TfNSW Q.

You may propose to the Principal a reduced minimum frequency of testing. The proposal must be supported by a statistical analysis verifying consistent process capability and product characteristics. The Principal may vary or restore the specified minimum frequency of testing, either provisionally or permanently, at any time.

1.2.6 Referenced Documents

Unless otherwise specified, the applicable issue of a referenced document, other than a TfNSW Specification, is the issue current at the date one week before the closing date for tenders, or where no issue is current at that date, the most recent issue.

Standards, specifications and test methods are referred to in abbreviated form (e.g. AS 1234). For convenience, the full titles are given in Annexure R223/M.

1.3 DEFINITIONS AND ACRONYMS

1.3.1 Definitions

The terms "you" and "your" mean "the Contractor" and "the Contractor's" respectively.

The following definitions apply to this Specification:

Binder Cement or other approved cementitious products used for DSM columns.

Blade rotation number Total number of mixing blade rotations per metre of shaft movement of the mixing equipment.

Column design depth Depth to the base level of the production column as shown on the Drawings. Where columns designated as "full depth columns" are shown on the Drawings as terminating at the top of the founding layer, an additional one metre of penetration into the founding material beyond the base level shown on the Drawings must be added to make up the full column design depth.

Lot A site defined area to be treated which is not greater than 200 m in length measured along the road alignment.

Test Area An area within each Lot nominated for Preliminary Testing and trial column construction.

Preliminary Testing A pre-production testing program comprising:

- site investigation of untreated soil, and
- preparation and testing of laboratory mixes.

Production columns Deep soil mixing columns shown on the Drawings.

Trial columns Columns constructed in Test Areas prior to commencement of production column construction to determine production mixing parameters.

1.3.2 Notation

$\mathbf{E_{sec50}}$ Secant modulus of elasticity of binder treated soil, at 50% unconfined compressive strength when tested in accordance with AS 1289.6.4.1.

1.3.3 Acronyms

BRN Blade rotation number

DSM Deep soil mixing

GGBFS Ground Granulated Blast Furnace Slag

PIRT Push In Resistance Test (using vane equipment)

PORT Pull Out Resistance Test (using vane equipment)

UCS Unconfined compressive strength

2 MATERIALS

2.1 GENERAL

All materials used in the Works must conform to the relevant standards, except where the requirements in the standards conflict with those in this Specification, in which case the requirements in this Specification take precedence.

2.2 BINDERS

Binders used must comply with Specification TfNSW 3211.

Unless otherwise approved or specified, use general purpose cement (Type GP) as the binder for DSM columns. You may propose the use of other binders, such as hydrated lime alone or Granulated Blast Furnace Slag (GGBFS) in conjunction with GP cement.

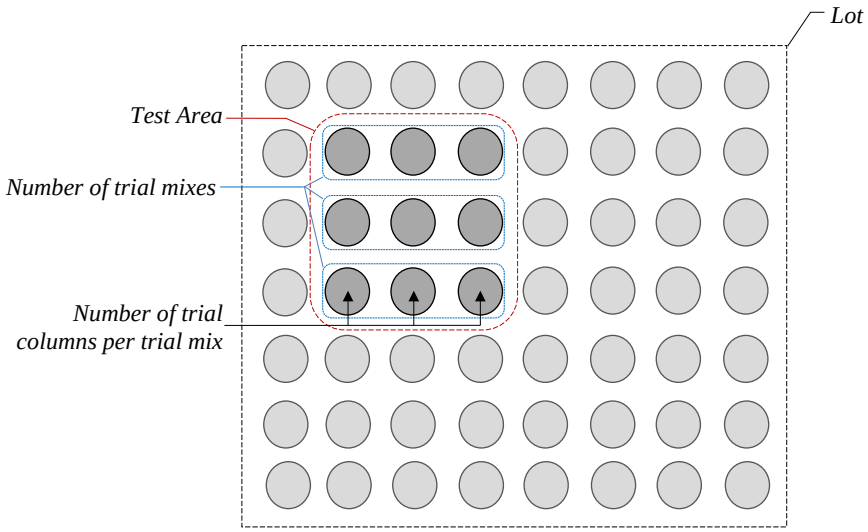
Fly ash must not be used as a binder under this Specification.

3 PRELIMINARY TESTING

3.1 GENERAL

Prior to any column construction, carry out Preliminary Testing to determine the mixing parameters, including binder content for deep soil mixing.

3.2 TEST AREAS WITHIN LOTS



Notes:

(1) *The figure above serves merely as an illustration of a Test Area, and its associated trial columns, within a Lot.*

(2) *The total number of columns shown in the figure above is for illustration purposes only, and not indicative of the total number of columns required. The actual total number of columns within a Lot will differ from project to project.*

(3) *At least 3 trial mixes each with a different binder content must be carried out for each Test Area, and at least 3 trial columns must be constructed for each trial mix, as shown in the figure above. Hence the minimum number of trial columns for each Test Area is 9.*

Figure R223.1 – Trial Columns, Test Area and Lot for Field Trials
(illustration only)

3.2.1 Lot Identification and Location

The Lot identification and its location details (indicating the total number of Lots), and the number of Test Areas within each Lot, is stated in Annexure R223/A1.

3.2.2 Test Areas

For each of the Test Area specified in Annexure R223/A1 to be required, in consultation with the Principal, delineate the boundary of the Test Area and mark out the columns to use for Preliminary Testing. The Test Areas selected must be adjacent to and similar in soil characteristics to the permanent works areas, so that the results of the Preliminary Testing are representative.

The Principal may request Test Areas additional to those specified in Annexure R223/A1 to cater for variable ground conditions within a Lot.

3.3 SITE INVESTIGATION TO DETERMINE SOIL PROPERTIES

3.3.1 Drilling and Sampling

Drill at least one borehole to the column design depth in each Test Area, using thin-walled tubes of minimum 75 mm diameter, and retrieve a continuous insitu soil sample from the borehole. Where there are varying column design depths within the Test Area, drill the borehole to the deepest column design depth. (Refer to Clause 1.3.1 for definition of “column design depth”.)

3.3.2 Soil Properties

Divide the tube sample obtained under Clause 3.3.1 into sections of two metre intervals, and take sufficient number of representative samples from each section to carry out at least one test for each of the soil properties shown in Table R223.1. The topmost (from the ground surface) two metre section may be ignored and samples do not need to be taken from this two metre section.

Table R223.1 – Soil Properties

Soil Property	Test Method
Moisture Content (MC)	T120
Plasticity Index (PI)	T108 and T109
Organic Content (OC)	T1022
Specific Gravity of soil particles (SG)	T127
Fine Particle Size Distribution (FPSD)	T107 and T190

3.3.3 Site Investigation Report

Submit a complete site investigation report showing the results of all the tests carried out under Clause 3.3.2 above.

3.4 LABORATORY MIXES AND TRIAL BINDER CONTENT

3.4.1 Representative Samples

Using the tube sample obtained under Clause 3.3.1, take representative soil samples from each two metre interval section. Again, as in Clause 3.3.2, the topmost (from the ground surface) two metre section may be ignored and samples do not need to be taken from this two metre section.

You may, with the Principal's approval, vary the interval limits for taking samples to ensure that representative soil samples are taken from each major soil layer, and to reduce the number of samples taken from the same soil layer.

3.4.2 Laboratory Mixes

For each representative soil sample taken, produce three laboratory mixes using GP cement as the binder, unless otherwise specified in Annexure R223/A2. The three laboratory mixes must each have a different binder content (in kg of binder per m^3 of insitu soil) which is determined by you, but the same binder content must be used consistently for all samples of the same laboratory mix.

3.4.3 Test Specimens

For each laboratory mix of each sample, prepare and cure two cylinders as test specimens. Preparation of the laboratory mixes, and preparation and curing of the cylinders, must be in accordance with the EuroSoilStab CT97-0351.

3.4.4 UCS and E_{sec50}

Test the specimens for unconfined compressive strength (UCS) at 28 days in accordance with AS 1289.6.4.1.

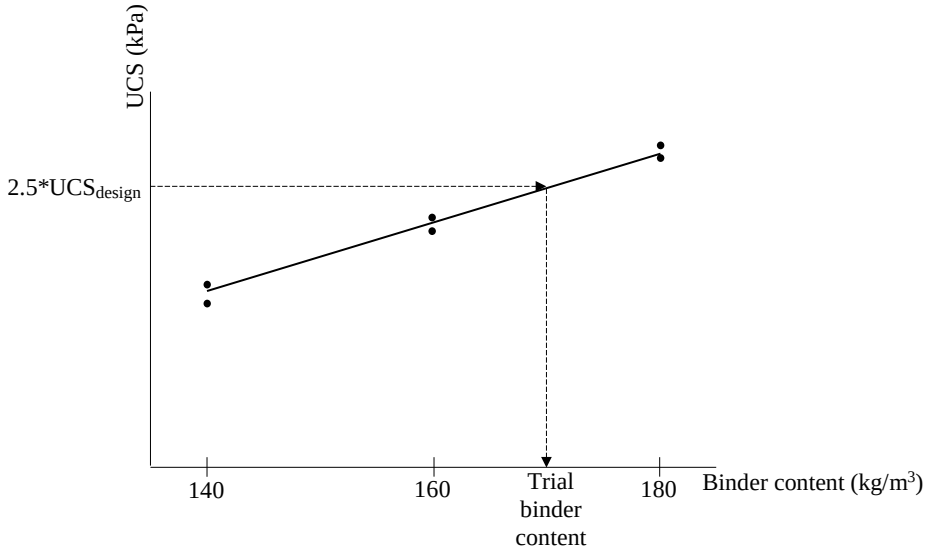
Determine the 50% UCS secant modulus (E_{sec50}) from the stress-stain curve for each test specimen.

3.4.5 Plotting UCS Results

Plot the UCS results against the binder content of the associated test specimens, as shown in Figure R223.2.

For each Test Area, determine the minimum binder content for the full column depth that corresponds to 2.5 times the design column UCS specified in Annexure R223/A2, to cater for ground condition variability, construction tolerances and other related issues. You may use interpolation but not extrapolation of the test results to determine this binder content.

The binder content thus determined will be termed the "trial binder content".



Notes:

(1) *The figure above serves merely as an illustration of the procedure to determine the "trial binder content" for a Test Area.*

(2) *The binder contents of 140, 160 and 180 kg/m³ shown in the figure above are for illustration purposes only. The actual binder contents will be determined by the Contractor and will differ from project to project.*

(3) *Only one set of test results, comprising 3 laboratory mixes from one sample, is shown in the figure. The actual plot will contain multiple sets of test results from different samples, with a pair of UCS test results corresponding to each of the three binder contents (140, 160 and 180 kg/m³ in this example).*

Figure R223.2 – Plot of UCS against Binder Content (illustration only)

3.4.6 Laboratory Mixes Test Report

Submit a report, containing the following information for each Test Area:

(i) plotted stress-strain curves, E_{sec50} values, UCS test values and other reporting requirements as specified in AS 1289.6.4.1;

(ii) plot(s) of UCS against binder content, carried out in accordance with Clause 3.4.5;

(iii) trial binder content, determined in accordance with Clause 3.4.5.

3.4.7 Test Results from Other Areas

You may propose to forgo the testing carried out under Clause 3.4, and use test results and associated trial binder content from other areas of similar soil characteristics for approval by the Principal.

4 CONSTRUCTION – GENERAL

4.1 PROGRAM, SAFETY AND WORKING PLATFORM

4.1.1 Program

Provide a program showing the Preliminary Testing (refer Clause 3), trial column construction (refer Clause 5) and production column construction (refer Clause 6), including their sequence and timing.

4.1.2 Safety

Prior to commencement of work on the DSM columns each day, carry out a safety inspection of the entire binder injection line and associated equipment to ensure safe working conditions. Examine all lines for wear, joints for correct coupling and coupling clamps for tightness.

This safety inspection is additional to all other WHS requirements that are applicable to the site and associated construction activities.

4.1.3 Working Platform

Construct working platforms as required to suit your DSM plant. Maintain the working platforms for the safe movement and working of your plant, including repairing any damage caused by your work, flooding or other causes.

Unless otherwise approved by the Principal, use granular material for construction of the working platforms.

4.2 METHOD STATEMENT

Prior to commencement of any column construction, submit a method statement as part of your PROJECT QUALITY PLAN incorporating, as a minimum, the following:

(a) plan(s) showing each Lot, the Test Area(s) and trial columns within each Lot, and proposed sequence of column construction;

(b) plant and equipment details, including monitoring systems;

(c) full description of mixing tool;

(d) work procedures, including penetration and retrieval, and mixing and execution sequence;

(e) penetration termination criteria for the full depth and floating columns;

(f) procedures for handling possible interruptions during deep mixing operations;

(g) installation accuracy and methods to verify compliance with the specified tolerances;

(h) measures to protect adjacent structures or previously installed columns against ground heave and settlement arising from the DSM column construction;

(i) procedures for identification and control of nonconformities;

(j) spoil management;

(k) details of construction records and their submission;

(l) safety and environmental risk assessment.

4.3 COLUMN POSITION AND DIMENSION

4.3.1 Set Out

Set out the columns to the positions and spacing(s) shown on the Drawings.

Set out columns which overlap to form a panel with a column overlap of 150 mm, measured along the centreline of the panel at the cut off level, unless shown otherwise on the Drawings.

4.3.2 Check and Control Position and Verticality

Check the position and verticality of the mixing shaft prior to commencement of each DSM column construction.

For DSM panels, control the position and verticality of the shaft during mixing such that the column overlap is not less than 80 mm at any level along the column depth.

4.3.3 Column Diameter and Depth

Construct the columns to the diameter and depth(s) shown on the Drawings.

Where columns designated as “full depth columns” are shown on the Drawings as terminating at the top of the founding layer, construct the columns with an additional one metre of penetration into the founding material beyond the base level shown on the Drawings.

4.4 CONTROL AND MONITORING

4.4.1 Air Pressure for Binder Injection

Keep the injection air pressure to the minimum required to ensure even delivery of binder over the full cross section of the column, and to control levels of air entrainment in the columns and surrounding soil, to avoid subsequent excessive creep settlements within the columns.

4.4.2 Automated Monitoring System

Provide an automated monitoring system that indicates continuously, or at depth intervals of 0.1 m as a minimum, the following construction parameters during trial and production column construction:

(a) rate of mixing shaft withdrawal (mm/rev or mm/min);

(b) mixing shaft rotation speed during withdrawal (rev/min);

(c) binder addition rate per metre of depth during withdrawal (kg/m³/m);

(d) binder injection air pressure (kPa);

(e) profile of torque generated varying with depth during penetration and withdrawal;

(f) profile of the column shape along the depth.

4.5 CONSTRUCTION RECORDS

For each trial and production column, take construction records containing the following details as a minimum:

Before commencement of each DSM

(a) date and time of construction;

(b) column reference number and diameter;

(c) working platform and ground levels (Australian Height Datum);

(d) operator and supervisor details;

(e) plant details;

(f) binder type and binder content (kg/m^3);

During penetration and withdrawal

(g) BRN;

(h) profile of generated torque;

(i) penetration termination criteria applied;

During withdrawal

(j) log of rate of mixing shaft withdrawal (mm/rev or mm/min);

(k) log of mixing shaft rotation speed (rev/min);

(l) log of binder addition rate per metre of depth ($kg/m^3/m$);

On completion of mixing

(m) column verticality, overlapping, positional and dimensional values achieved;

(n) toe level and top mixing level;

(o) profile of the column shape, demonstrating uniformity along its depth.

Submit to the Principal construction records taken for each column, no later than two working days after construction of the column, in the form of a signed paper copy, and an electronic copy.

5 TRIAL COLUMNS

5.1 FIELD TRIAL MIXING PARAMETERS

5.1.1 Field Trial Mixes

For each Test Area, use the trial binder content derived from the testing of the laboratory mixes under Clause 3.4 to produce a field trial mix for use in construction of a set of 3 trial columns in that Test Area.

Nominate two other binder contents, one for each field trial mix, for use in construction of two more sets of 3 trial columns (Refer also Figure R223.1). Use the three sets of trial mixes to determine an optimum binder content for use in the production columns.

5.1.2 Range of Mixing Parameters

Nominate a range of mixing parameters to cover the variations likely to be encountered during construction of the production columns.

5.1.3 Additional Trial Mixes

You may use additional field trial mixes with other binder contents at your own risk.

5.2 CONSTRUCTION OF TRIAL COLUMNS

5.2.1 Confirmation of Mix Design and Method

For each Test Area, construct a set of at least three trial columns for each of the three field trial mixes (i.e. minimum total of nine trial columns for each Test Area) in accordance with Clause 5.1.1, to determine and confirm:

(a) production mix design and mixing parameters that will achieve the column design parameters stated in Annexure R223/A2;

(b) installation parameters including penetration termination using the same equipment, blade rotation number, materials, technique and procedure for the construction of the production columns.

5.2.2 Hold Point and Witness Point

HOLD POINT	
Process Held:	Construction of the first trial column in each Test Area.
Submission Details:	Method statement (refer Clause 4.2), laboratory mixes test report (refer Clause 3.4.6), and details of nominated trial mixes for the Test Area, at least 10 working days prior.
Release of Hold Point:	The Principal will consider the submitted documents prior to authorising the release of the Hold Point.

WITNESS POINT	
Process Witnessed:	Construction of subsequent trial columns, after the first trial column in each Test Area.
Submission Details:	Notification of the time and location of the trial column construction, at least one working day prior to commencing.

5.3 TESTING OF TRIAL COLUMNS

5.3.1 Frequency of Testing

Carry out the tests and at the frequencies specified in Annexure R223/L on the constructed trial columns.

5.3.2 Testing Methods

Carry out the testing in accordance with the testing methods specified in Clause 7.

5.3.3 Trial Column Test Report

Following completion of testing for each Test Area, prepare and submit a trial column test report containing the following details as a minimum:

(a) Mixing parameters used in the construction of the trial columns, including penetration termination for each set of trial columns, and reasons for their selection.

(b) Monitoring records during mixing for each of the trial columns (refer Clause 4.4).

(c) Results of the trial columns testing, and analysis and discussion of the results.

(d) Recommended binder content for use in the production columns. This will be termed as "production binder content".

(e) Recommended mixing parameters and their variation ranges, for production columns.

(f) Certification that the recommended mixing parameters, equipment and process for construction of the production columns will be suitable to meet the specified design requirements.

5.4 ACCEPTANCE OF TRIAL COLUMNS

Trial columns satisfying the conformity requirements of Clause 8 may be accepted by the Principal as production columns.

6 PRODUCTION COLUMNS

6.1 CONSTRUCTION OF PRODUCTION COLUMNS

6.1.1 Hold and Witness Point

HOLD POINT

Process Held:	Construction of the first production column in each Lot.
Submission Details:	Trial column test report (refer Clause 5.3.3) and construction program (refer Clause 4.1.1), at least seven working days prior.
Release of Hold Point:	The Principal will consider the submitted documents and assess the recommended mixing parameters and their variation ranges prior to authorising the release of the Hold Point.

WITNESS POINT	
Process Witnessed:	Construction of subsequent production columns, after the first column in each Lot.
Submission Details:	Notification of the time and location of the column construction, at least one working day prior to commencing.

6.1.2 Variations to Production Mixing

Following the release of the Hold Point in Clause 6.1.1 for construction of the production columns, no mixing parameter is permitted to be varied outside the approved variation ranges (refer Clause 5.3.3).

Examples of such variations include the following:

(a) changes to binder content;

(b) increase in auger withdrawal speed;

(c) reduction in binder injection air pressure;

(d) reduction in rate of binder addition;

(e) changes to BRN.

Where required because of unfavourable ground conditions, you may propose to the Principal to vary a mixing parameter beyond the approved variation ranges.

The Principal may then re-impose the Hold Point of Clause 6.1.1 and require you to carry out additional trial columns and their testing to demonstrate that the varied parameters are capable of achieving the design requirements.

6.1.3 Variations in Diameter

Notify the Principal immediately of any variations in diameter, spacing or depth of the columns arising from site conditions which have not been anticipated in the design, and take corrective actions as required.

6.2 TESTING OF PRODUCTION COLUMNS

6.2.1 Frequency of Testing

Carry out the tests and at the frequencies specified in Annexure R223/L on the constructed production columns.

The Principal will nominate all the columns and samples to be tested under this Clause.

6.2.2 Testing Methods

Carry out the testing in accordance with the testing methods specified in Clause 7.

6.2.3 Submission of Test Results

Submit all test results within 48 hours of testing to the Principal for review.

7 TESTING METHODS

7.1 GENERAL

Carry out testing of the trial and production columns in accordance with Clauses 7.2 to 7.4.

You may propose for the Principal's approval alternative methods of sample recovery and insitu testing of columns. Alternative sample recovery methods must be capable of obtaining an undisturbed sample of sufficient diameter and length for the proposed testing. Alternative insitu testing must be capable of assessing the shear strength of columns based on established methods.

7.2 COMPRESSIVE STRENGTH – CORES

7.2.1 Coring Method

Carry out triple tube coring (minimum core diameter of 63 mm), or other approved insitu sampling method, to the full depth of the test column at between 7 and 14 days after the DSM column construction.

7.2.2 Test Core Samples

From each 2 m depth interval section of the full length of the recovered core, take 3 sets of samples, with each set comprising a pair of test cylinders, at locations within the core selected by the Principal.

The number of sets of samples may be reduced if approved by the Principal in instances where the length of intact core samples retrieved is limited.

7.2.3 Storage and Curing

Seal the samples and store them in an environment of constant 90% humidity at a temperature of $20 \pm 2°C$ prior to testing.

Water curing method at a temperature of $20 \pm 2°C$ may be used if approved by the Principal in instances where the humid curing environment is impractical.

7.2.4 Testing

For all of the samples taken, test one set at 28 days age in accordance with AS 1289.6.4.1. You may use one of the remaining two sets to test at an earlier age.

Store the remaining set(s) of samples and the remainder of the core under the same humid environment as that specified in Clause 7.2.3 until conformity with the 28 days strength is verified, or use them for further testing if required. Hand any remaining samples over to the Principal.

7.3 COLUMN PORT OR PIRT

7.3.1 Submission of Testing Method Details

Submit details of the PORT or PIRT testing method to the Principal, stating the type of equipment, testing procedure and proposed interpretation procedure to be adopted, for review and approval at least five working days prior to the testing.

7.3.2 Vane Equipment Details

Use the vane equipment shown in Figure R223.3 for PORT and PIRT column penetration tests.

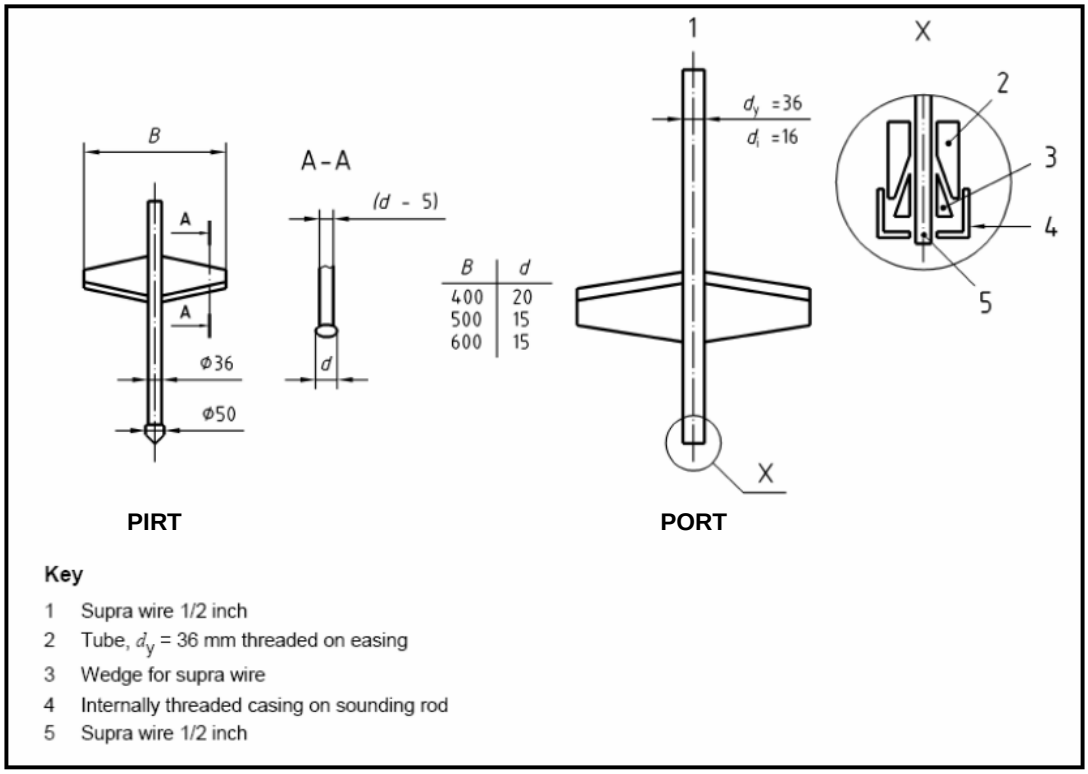


Figure R223.3 – Vane for PORT and PIRT Column Penetration Tests
(Source: SGF Report 4:95E)

7.3.3 Testing Procedure - PORT

For PORT, install the vane to below the base of the column immediately after mixing by pushing the vane through the column. Rotate the vane blade 90 degrees after it has been installed below the column in order to align it with the intact column material.

Pull the vane up 100 mm to 200 mm within 48 hours of installation to reduce the bond between the cable and the column.

At between 7 and 14 days after its installation, pull out the vane through the column at a constant penetration rate of 20 ± 4 mm per second and record the resistance continuously.

7.3.4 Testing Procedure - PIRT

For PIRT, at between 7 and 14 days after its installation, insert the vane into the column at its centre by pushing in the vane through the column at a constant penetration rate of 20 ± 4 mm per second and recording the resistance. If required, use pre-boring to maintain verticality during the push in.

7.3.5 Submission of Test Results

Analyse and report the results of the PORT/PIRT testing using the method described in SGF Report 4:95E, with the exception that the shear strength calibration factor “N” is to be determined using the UCS test results described in Clause 7.2 above, and approved by the Principal.

If a calibration is not performed, use a default "N" value of 13.

7.4 COLUMN HEAD EXAMINATION AND TESTING

Excavate to expose the test column to a depth of 1 m below the ground surface for visual inspection, and carry out hand vane testing at 0.1 m centres on two orthogonal lines across the centre of the column to assess uniformity of the column strength.

7.5 TEST HOLE REINSTATEMENT

Fill with cement grout all core and penetration test holes at completion of testing.

8 CONFORMITY REQUIREMENTS

8.1 POSITION AND VERTICALITY TOLERANCES

8.1.1 Plan Position

For individual columns that do not overlap with other columns, the maximum deviation of the column centre from its design plan position is 75 mm in any horizontal direction, measured at the column cut off level.

For columns which overlap with other columns to form a panel, the maximum positional deviation of overlapping columns must be such that a minimum overlap of 80 mm is achieved at the cut off level.

8.1.2 Verticality

The maximum deviation from the vertical at any level of DSM columns at any stage of the construction is 1:75 (H:V).

8.2 ACCEPTANCE CRITERIA

8.2.1 General

The compressive and shear strength used in these acceptance criteria for trial and production columns, are based on the 28 day strengths specified in Annexure R223/A2.

Where this strength is verified as achieved by testing at an earlier age, the Principal will waive the 28 day testing requirement.

If approved by the Principal, you may determine the 28 day strength by extrapolation from the 7 day or 14 day results using data from the laboratory and field trials.

For the columns to be conforming, the acceptance criteria stated in Clauses 8.2.2 to 8.2.4 must be met.

8.2.2 Compressive Strength - Cores

Not more than 10% of the test results fall below the specified strength, provided that these test results are equal to or greater than 75% of the specified strength.

8.2.3 Column PORT or PIRT

(a) **Topmost 3 m** (from the ground surface) of the test columns: all results exceed the specified strength;

(b) **Below topmost 3 m** of the test columns: not more than 5% of any test section measuring 1 m in depth, has strength below the specified strength, provided that the strength of the remaining test section is equal to or greater than 90% of the specified strength.

8.2.4 Column Head Exposure Test

No diagonal cracks or discontinuities visible. Not more than 10% of the hand vane test results fall below the specified strength.

8.3 TREATMENT OF NONCONFORMITY

For columns which do not meet the acceptance criteria, you may propose further testing of the columns, or demonstrate that the nonconformity will not compromise the design intent of the DSM columns, or carry out remedial measures approved by the Principal, at your own cost.

9 ACCEPTANCE

Following completion of construction and testing of the production columns, filling of all core and penetration holes and rectification of all nonconformities to the satisfaction of the Principal, submit all outstanding construction records and results of tests carried out on the production columns, together with a written certification that the constructed Works conform to the requirements of this Specification and the Drawings.

Completion will not be achieved until the above documents have been submitted and reviewed by the Principal, and all columns have been accepted by the Principal.

ANNEXURE R223/A – PROJECT SPECIFIC REQUIREMENTS

Refer to Clause 1.2.1.

A1 LOTS AND TEST AREAS

NOTES TO TENDER DOCUMENTER: (Delete this boxed text after customising Annexure R223/A1)

Complete the table below by filling in the required details. Insert additional rows as necessary to include all Lots.

Under the column "Description of Lot Location", insert details of the Lot location, e.g. "Shallow Creek Bridge Abutment B approach".

Refer to Clause 3.2.

Lot Identification	Description of Lot Location	Number of Test Areas

A2 BINDER TYPE AND DESIGN STRENGTH

NOTES TO TENDER DOCUMENTER: (Delete this boxed text after customising Annexure R223/A2)

Complete the table below by deleting whichever option is not applicable, and filling in the required details.

In Item A2.1 below, "cement" is shown as the default option, but if another binder is preferred, delete "cement" and insert in the table the name of the preferred binder.

Refer to Clause 3.4.

Item	Description	Requirement
A2.1	Binder type	Cement / ……
A2.2	Design column 28 day undrained shear strength [(1)] (kPa)	

Note:

[(1)] Undrained shear strength = ½ Unconfined compressive strength

ANNEXURE R223/B – MEASUREMENT AND PAYMENT

Refer to Clause 1.2.2.

Payment will be made for all costs associated with completing the work detailed in this Specification in accordance with the following Pay Items.

Where no specific pay items are provided for a particular item of work, the costs associated with that item of work are deemed to be included in the rates and prices generally for the Work Under the Contract.

Unless otherwise specified, a lump sum price for any of these items will not be accepted.

Pay Item R223P1 Preliminary Testing

Pay Item R223P1.1 Site Investigation to Determine Soil Properties

The unit of measurement is "each" Test Area.

The schedule rate must cover all costs associated with drilling a borehole to the column design depth, soil sampling, laboratory testing (but subject to the qualification described in the paragraph below), and reporting of the soil properties as specified under Clause 3.3.

The schedule rate must include the cost of laboratory testing where Primary Testing does not apply to the Contract; otherwise the cost of laboratory testing will be paid under Primary Testing for those tests which are listed in Specification G2.

For this Pay Item R223P1.1, itemise each Test Area within the identified Lots shown in Annexure R223/A1. Where there is more than one Test Area within a Lot, but all the Test Areas within the Lot require drilling the borehole to the same or similar column depths, the Test Areas within the Lot may be grouped together under one item.

Example:

If on the project there are two Lots, ABC-X and ABC-Y, and Lot ABC-X has two Test Areas of similar column design depth, while Lot ABC-Y has one Test Area, the Pay Item should be itemised as shown below:

Pay Item R223P1.1 – Site Investigation to Determine Soil Properties

(a)	***Lot ABC-X***	***2***	***each***
(b)	***Lot ABC-Y***	***1***	***each***

Pay Item R223P1.2 Testing of Laboratory Mixes

The unit of measurement is "each" Test Area.

The schedule rate must cover all costs associated with soil sampling and laboratory testing of soil layers to the design column depth using three different binder contents and provision of laboratory mixes test report for each Test Area in accordance with Clause 3.4.6.

For this Pay Item R223P1.2, itemise each Test Area within the identified Lots shown in Annexure R223/A1 as for Pay Item R223P1.1.

Pay Item R223P2 Construction of Columns

The unit of measurement is per lineal metre of trial and production column constructed.

The schedule rate must cover all costs associated with the construction of the trial and production columns, including the cost of materials, equipment, instruments, site monitoring, and any ancillary work required for the construction of the columns.

Pay Item R223P2.1 Construction of Trial Columns

Pay Item R223P2.2 Construction of Production Columns

Trial columns accepted as production columns must be paid under Pay Item R223P2.1 and not under Pay Item R223P2.2.

Pay Item R223P3 Coring of Columns and Testing of Core Samples

Pay Item R223P3.1 Coring of Columns

The unit of measurement is per lineal metre of column cored.

The schedule rate must cover all costs associated with coring of the columns to the required depth, including establishment and disestablishment of the coring equipment and storage and curing of the cores.

Pay Item R223P3.2 Testing of Core Samples

The unit of measurement is “each” set (pair) of core samples tested.

The schedule rate must cover all costs associated with preparation of the core samples, compressive testing of the cores and reporting.

Pay Item R223P4 Column Pull Out/Push In Resistance Test (PORT/PIRT)

The unit of measurement is “each” test carried out.

The schedule rate must include all costs associated with carrying out the tests, analysis of the test results, provision of test reports, and any ancillary work required, for testing of the trial and production columns.

Pay Item R223P4.1 Column Pull Out Resistance Test (PORT)

Pay Item R223P4.2 Column Push In Resistance Test (PIRT) – Provisional Quantity

Pay Item R223P5 Exposure and Inspection of Column Head

The unit of measurement is “each” column exposed by excavation and inspected.

The schedule rate must cover all costs associated with excavation to a minimum depth of 4 m as directed by the Principal and back filling with approved material, visual inspection of cracked columns and reporting, including establishment and disestablishment of excavation equipment.

ANNEXURE R223/C – SCHEDULES OF HOLD POINTS, WITNESS POINTS AND IDENTIFIED RECORDS

Refer to Clause 1.2.3.

C1 SCHEDULE OF HOLD AND WITNESS POINTS

Clause	Type	Description
5.2.2	Hold	Construction of the first trial column in each Test Area
5.2.2	Witness	Construction of subsequent trial columns
6.1.1	Hold	Construction of the first production column in each Lot
6.1.1	Witness	Construction of subsequent production columns

C2 SCHEDULE OF IDENTIFIED RECORDS

The records listed below are Identified Records for the purposes of TfNSW Q Annexure Q/E.

Clause	Description of Identified Record
3.3.3	Site investigation report
3.4.6	Laboratory mixes test report
4.5	Column construction records
5.3.3	Trial columns test report
6.2.3	Production columns test results
9	Certificate of conformity of constructed Works

ANNEXURE R223/D – PLANNING DOCUMENTS

Refer to Clause 1.2.4.

The following documents are a summary of documents that must be included in the PROJECT QUALITY PLAN. The requirements of this Specification and others included in the Contract must be reviewed to determine additional documentation requirements.

Clause	Description of Document
4.2	Method statement of DSM works

ANNEXURES R223/E TO R223/K – (NOT USED)

ANNEXURE R223/L – MINIMUM FREQUENCY OF TESTING

Carry out the tests and at the frequencies specified in Table R223/L.1 to verify conformity of both trial and production columns.

Table R223/L.1 – Test Types and Frequencies

Type of Tests	Trial Columns	Production Columns (1, 2)
Compressive strength - Cores	One column cored per trial mix in each Test Area, i.e. minimum of three columns per Test Area.	0.5% of the number of columns per Lot cored with a minimum of one column per Lot.
Column PORT	All columns other than those to be cored for UCS testing.	2% of the number of columns per Lot with a minimum of one column per Lot.
Column PIRT	Only if proposed by you and approved by the Principal as an alternative to PORT and at the same frequency specified.	Only if proposed by you and approved by the Principal as an alternative to PORT and at the same frequency specified.
Column head exposure tests	At least one column with mixing parameters to be adopted for production columns per Test Area.	Minimum of 3 columns per Lot.

Notes:

(1) Tests carried out on trial columns which have subsequently been accepted as production columns do not count towards the percentage of production columns to be tested.

(2) The number of columns per Lot quoted is the number of columns shown on the Drawings for the Lot, regardless of whether some of the production columns were originally trial columns.

ANNEXURE R223/M – REFERENCED DOCUMENTS

Refer to Clause 1.2.6.

TfNSW Specifications

TfNSW Q	Quality Management System
TfNSW 3211	Cements, Binders and Fillers

TfNSW Test Methods

TfNSW T107	Fine Particle Size Distribution of Road Construction Materials
TfNSW T108	Liquid Limit of Road Materials
TfNSW T109	Plastic Limit and Plasticity Index of Road Construction Materials
TfNSW T120	Moisture Content of Road Construction Materials (Standard Method)
TfNSW T127	Apparent Density of Fine Soil Particles
TfNSW T190	Fine Particle Size Distribution by Hydrometer
TfNSW T1022	Organic Content

Australian Standards

AS 1289.6.4.1	Methods of testing soils for engineering purposes - Soil strength and consolidation tests - Determination of compressive strength of a soil - Compressive strength of a specimen tested in undrained triaxial compression without measurement of pore water pressure

Other Technical Documents

CT97-0351	EuroSoilStab - Design Guide Soft Soil Stabilisation
SGF Report 4:95E	Swedish Geotechnical Society - Lime and Lime Cement Columns - Guide for project planning, construction and inspection