# APPENDIX C

Standardised Specification : Sprayed Concrete

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## STANDARDISED SPECIFICATION : SPRAYED CONCRETE

*This document has been prepared with reference to the COLTO Standard Specifications for Road and Bridge Works for State Road Authorities.*

## 1. SCOPE

This Specification pertains to; the supply, installation, construction, and testing of the following components of the required lateral support:

- Welded Mesh Reinforcement
- Sprayed Concrete / Gunite / Shotcrete
- Subsoil Drains
- Wick Drains

## 2. DEFINITIONS

2.1 **Welded Mesh Reinforcement** comprises an integrated steel wire mesh that is laid in adjoining panels across a slope face to restrict the occurrence of rock fall or soil debris from the slope.

2.2 **Sprayed Concrete / Gunite / Shotcrete** comprises a wet* mix of coarse sand and cement that is sprayed onto the surface of a slope and allowed to set. The sprayed concrete is reinforced with steel mesh.

* Gunite is a dry concrete mix that mixes with water at the nozzle. Shotcrete refers to wet, fully-mixed concrete sprayed onto a final surface. (The use of gunite or shotcrete shall be at the Contractor's discretion, unless specifically detailed.)

2.3 **Subsoil Drains** comprise a 100mm diameter perforated geo-pipe in a 19mm crushed stone bedding wrapped in geotextile; the purpose of which is to intercept, collect and convey

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groundwater away from the toe of the sprayed concrete wall.

2.4 **Wick Drains** comprise a high density polyethylene open structure grid that is cut to suit to the required width and wrapped in a light, non-woven geotextile to intercept subsurface water from behind the sprayed concrete wall and convey it to the toe of the wall where it is discharged into weepholes.

## 3. GENERAL REQUIREMENTS

### 3.1 Protective Measures

Protective measures are the precautions which the Contractor must take to avoid any damage to the existing structures and materials below and within the work area as a result of the movement of plant and other construction activities required to undertake the drapery activities or any other reason related to the Contractor's construction activities in this regard.

If any element of the lateral support system is damaged or becomes ineffective due to any cause, it shall be repaired or replaced. Such repair or replacement of damaged or ineffective lateral support elements shall be carried out by the Contractor without additional payment.

### 3.2 Access To Construction Area

Drive on access for the Contractor's plant, equipment, materials, and other resources will be available. However, the Contractor is to coordinate with Others to construct bench working platforms from which to carry out the Works. A top-down procedure is envisaged.

### 3.3 Inspections by Engineer

The installation of the welded mesh will only be undertaken once the stabilisation of the cut slope has been carried out by the installation of the required lateral support and written approval of the Engineer has been obtained. Once this has been completed the Contractor is in a position to proceed with the drapery work. The Contractor will give the Engineer at least 48 hours advance-notice of any inspection required.

The Contractor shall make available suitable equipment, together with a qualified operator, with which the specialist representative of the Engineer can be brought to within half a metre of any part of the surface of the slope.

## 4. MATERIALS AND EQUIPMENT

### 4.1 Welded Mesh Reinforcement (Drape Mesh)

Welded mesh reinforcement to be Mesh Ref. 245, comprising steel fabric to SABS 1024 utilising wire with the following characteristics.

- Wire diameter 6.3mm with tolerances as per SANS 675:1997.
- Tensile strength between 350-575 N/mm2 according to SANS 675:1997.
- Elongation not less than 10% (when carried out on a sample at least 25 cm long) in accordance with EN 10223-3.

The mesh shall be galvanized to SANS 935 and securely fixed at an optimum distance from the excavation/cut face for the application process such as to minimise sprayed concrete rebound and prevent voids. It shall be secured to the lateral support by means of 6mm diameter steel pins of suitable length set at a minimum of 1m centres so as to be drawn tight against the lateral support.

The minimum cover between the mesh and the exposed face of the sprayed concrete shall be 25mm, or greater cover if ordered by the engineer. The mesh shall be set at a normal distance of 50mm from the excavation/cut face. Joins shall be lapped by 2 full squares.

### 4.2 Gunite

The term 'gunite' will be used for sprayed concrete where the maximum aggregate size is less than 9.5mm, and the term 'shotcrete' where the maximum aggregate size is 9.5mm or greater.

Sprayed concrete may be applied by either a wet- or dry-mix process. The sprayed concrete (after completion) is not to be touched up, troweled, smoothed off, or worked in any way, but left undisturbed unless otherwise specified. The Engineer may direct that sprayed concrete be applied to the cut face as soon as possible after excavation. Areas to be treated shall be agreed with the Engineer prior to application.

Sprayed concrete shall be applied to the mesh reinforced excavation/cut face and to the final thickness or as specified on the drawings. Large radius irregularities will be permitted but local roughness and re-entrant angles are to be covered. Where specified by the Engineer sprayed concrete shall be applied in one or more layers to reach the specified total thickness.

#### 4.2.1 *Materials*

4.2.1.1 *Cement, Cement Extenders and Water*

Cement, cement extenders, and water shall comply with the requirements of the COLTO Standard Specifications, Section 6400.

Silica fume shall comply with the requirements of SABS 1491, Part 3.

4.2.1.2 *Aggregates*

Aggregates shall comply with the requirements of the COLTO Standard Specifications, Section 6400 except with regard to the grading requirements given in Table 1. The combined aggregates shall normally lie within the following grading limits by mass. Aggregates with a grading outside these limits will not be accepted unless the contractor has demonstrated in full-scale trials that a satisfactory end product can be produced with such aggregates.

Table 1. Aggregate Grading Limits

| Sieve Size (mm) ASTM | Percentage Passing | |
|---|---|---|
| | Gunite | Shotcrete |
| 13.20 | | 100 |
| 9.504 | | 90 - 100 |
| 4.75 | 100 | 75 - 100 |
| 2.36 | 80 - 100 | 55 - 90 |
| 1.18 | 50 - 85 | 40 - 70 |
| 0.60 | 25 - 60 | 20 - 70 |
| 0.30 | 10 - 30 | 10 - 25 |
| 0.15 | 2 - 10 | 4 - 12 |

4.2.1.3 *Accelerators*

Accelerators shall not be caustic or corrosive to reinforcements and it shall be of a type with a history of satisfactory long-term performance. Reference shall be obtained from suppliers and submitted to the Engineer for approval.

4.2.1.4 *Compressed Air*

Compressed air used in the process shall be clean, dry, and free of oil.

4.2.1.5 *Steel Fibres*

Steel fibres shall comply with ASTM 820 - Standard Specifications for Steel Fibre for Fibre Reinforced Concrete or such other Standard acceptable to the Engineer. A minimum fibre tensile strength of 1000 MPa is required.

Steel fibres shall be Type I deformed or equivalent diameter 0.5 mm and aspect ratio of 40 to 80 or such type acceptable to the Engineer. The length of fibre should not exceed 70% of the internal

diameter of the hose or pipes to prevent blockage.

### 4.2.2 *Design of Sprayed Concrete*

Sprayed concrete shall meet the requirements of Table 2. The mix design shall be carried out by the Contractor and details thereof submitted to the Engineer.

The mixers for sprayed concrete shall lie within the following proportions:

- Cementitious content (kg/m$^3$) 330 - 450
- Aggregate/cement ratio 3.00 - 5.00
- Water/cement ratio 0.35 - 0.45
- Silica fume (kg/m$^3$) where required 30 - 50
- Steel Fibre (kg/m$^3$) where required 30 - 40

Water/cement ratio is defined as the mass of the free water in the mix divided by the total mass of the cementitious mixture in the mix.

Where the use of an accelerating admixture is required, the amount used shall be within the limits recommended by the Manufacturer but shall not exceed 4% by mass of total cementitious context unless the Contractor can satisfy the Engineer that the five-year strength is not detrimentally affected. In the case of the cement containing fly ash, the advice of the Manufacturer of the additive (and the cement if necessary) shall be sought before the Engineer will approve the use of the accelerating admixture. Minimum admixture should be used to obtain the specified early strength appropriate to the conditions.

In addition, the Engineer reserves the right at any time during the process of the work to instruct the Contractor to vary the proportions of the constituents of the sprayed concrete mix or order further trial applications to ensure that adequate densities and high early strengths are maintained.

Table 2. Sprayed Concrete Performance Requirements

| **Sprayed Concrete Class** | | **A** | **B** | **C** | **D** |
|---|---|---|---|---|---|
| **Mix Description** | **Test Method** | **P** | **Steel Reinforcement** | **Steel Reinforcement + Accelerator** | **Pla + Accelerator** |
| Equivalent Cube Strength | | | | | |
| MPa @ 8hr | SABS | N/A | N/A | 5 | 5 |
| MPa @ 24hr | | N/A | N/A | 9 | 9 |
| MPa @ 28day | | 35 | 35 | 35 | 35 |
| Peak Flexural Strength | | | | | |
| MPa @ 28day | ASTM C1018 | 3.5 | 4.0 | 4.0 | 4.0 |
| Residual Flexural strength | | | | | |
| MPa @ 28day | ASTM C1018 | N/A | 3.2 | 3.2 | N/A |
| Toughness Index | | | | | |
| $1_{20}$ @ 28day | ASTM C6642 | N/A | 16 | 16 | N/A |
| $1_{30}$ @ 28day | | N/A | 22 | 22 | N/A |
| $1_{50}$ @ 28day | | N/A | 30 | 30 | N/A |
| Boiled Absorption | | | | | |
| % Vol. of Permeable Voids | ASTM C403 | 8 | 8 | 9 | 9 |
| % @ 7day | | 17 | 17 | 19 | 19 |
| Setting Time | | | | | |
| Initial set, min | BS EN 196-3 | N/A | N/A | 3 | 3 |
| Final set, min | | N/A | N/A | 9 | 9 |

Notes: 1. The above values are all "minimum" acceptable limits, except for boiled absorption and volume of permeable voids, which are "maximum" acceptable limits.

2. N/A indicates "non-applicable"

### 4.2.3 *Acceptance Testing*

Prior to commencement of spraying concrete in the works testing shall be carried out by the Contractor are as follows.

4.2.3.1 Test panels shall be constructed in the presence of the Engineer for each mix design. Cores shall be cut from the panels and three cores tested at each

specified strength requirement. The average of the three results tested at 24 hours and 28 days shall not be less than the 24hr and 28day specified strengths respectively. In addition, the values of each core tested shall be within 20% of the average value.

4.2.3.2 Sufficient testing to prove the acceptability of the sprayed concrete to meet the requirements with regard to:

- Boiled absorption.
- Volume of permeable voids.
- First crack and ultimate tensile strength.
- Toughness index.

### 4.2.4 *Equipment*

All equipment used for batching and mixing of the materials and the application of sprayed concrete shall be of approved design and in proper working order. The sprayed concrete gun and ancillary equipment shall be of adequate capacity for the volume to be applied. The equipment shall be capable of handling and applying 1 mm maximum size of aggregate. A standby gun and ancillary equipment shall be available at all times. Air for the equipment is to be provided at the equipment at not less than the operating pressure specified by the Manufacturer.

Dosing of additive by hand will not be permitted. Equipment for dosing of additives shall be adjustable for various quantities and provide a uniform rate of discharge evenly mixed with the other ingredients of the mix. The equipment shall be capable of delivering admixture to ensure the approved dosage ratio to an accuracy of ±5%.

Protective clothing and dust masks shall be provided for and used by all sprayed concrete Operators.

## 4.3 Subsoil Drains

Subsoil drains are supplied in lengths of 6m or rolls of 50m with couplings; Flopipe (or equal approved) is recommended and has the following characteristics.

- Outside diameter of 110mm
- Infiltration area > 5000mm2/m
- Ring stiffness > 450kPa

The subsoil drain shall be laid with the yellow marker on top ensuring correct positioning.

### 4.4 Wick Drains

Wick drains comprising a Flownet (or equal approved) shall be manufactured from an HDPE polymer with a tensile yield strength of 21MPa. The overall thickness of the HDPE grid when manufactured shall not be less than 4mm under 2KPa pressure with a rate of flow of not less than 150l/s/$m^2$ when sandwiched between two plates of glass applying a confining pressure of not less than 200kPa.

The wick drain shall comprise 2 layers of Flownet (or equal approved) wrapped in a non-woven polyester geotextile manufactured from continuous needlepunched filaments. The mass of the geotextile shall not be more than 200g/$m^2$.

## 5. MANUFACTURE

### 5.1 Manufacture of Sprayed Concrete

Materials shall be batched by mass and cement shall not be added more than one hour before the anticipated time of placing the sprayed concrete unless the use of a retarder has been approved by the Engineer. Mixed ingredients shall be placed before the initial set of the cement has taken place. Aged materials shall be discarded.

Feed systems for all materials are to be interconnected such that the correct proportions are maintained irrespective of feed rate and if one feed stops the whole plant stops.

Batching and mixing equipment shall be cleaned at least once per shift to prevent accumulations of aged material.

## 6. HOMING AND GROUTING

### 6.1 Welded Mesh

Ref. Mesh 245 (galvanized) is supplied in sheets or rolls which need to be cut on site to suit. The cut panels are fastened to each other and positioned prior to fixing.

### 6.2 Guniting

#### 6.2.1 *Preparation of Surfaces*

Before sprayed concrete is applied, checking and correction of the excavated cross-section profile shall be carried out. The surfaces to which sprayed concrete is to be applied are to be barred down of all loose material and the area cleaned down of all loose and foreign material with a

mixture of water and air applied at high pressure (where applicable). All surfaces to receive sprayed concrete shall be moist and free of all traces of dirt, oil, rebound or other deleterious material.

Where sprayed concrete is to be placed over a previous layer, the layer shall be first allowed to reach its initial set and then cleaned of all rebound or other loose material to the approval of the Engineer.

Sprayed concrete shall not be applied to any surface without the prior inspection and approval of the Engineer.

The cost of wastage as a result of rebound and slump shall form part of the Contractor's normal process control and shall be deemed to be included in his tendered rates and shall not be paid for separately.

### 6.2.2 Placing

Sprayed concrete shall be placed in accordance with good practice as detailed in AC 1- 506R-85 Guide to Shotcrete except that with silica fume sprayed concrete it is usually possible to build up relatively thick layers in a single pass.

Where necessary freshly sprayed concrete shall be protected from rain or water until the surface is of sufficient hardness to prevent damage.

There shall be no inclusion of rebound in the finished work, any hollow areas, good adherence to the excavated/cut face and a reasonably smooth surface finish. Rebound shall be kept clear of sprayed concrete being placed.

The minimum specified layer thickness shall be controlled by depth pins attached to the lateral support surface and reinforcement, or by other approved means.

Before a succeeding layer is placed the existing work shall be checked for hollow or non-adhering areas and these shall be cut out and replaced to the satisfaction of the Engineer.

Construction joints in the layer shall be formed at 45° to the face and precautions shall be taken to prevent weak and unsightly edges at construction joints. If necessary, timber strips may be temporarily fixed in place to give a neat, strong edge. Before placing the adjoining work the edge shall be cleaned and thoroughly wetted.

### 6.2.3 Curing

The use of a sprayed surface curing compound will not be permitted. The sprayed concrete shall be kept moist continuously for three days by spraying with a fine mist of water at intervals not exceeding four hours.

### 6.2.4 Operators for Sprayed Concreting

Only trained and tested Operators shall be used for sprayed concreting operations. The Contractor shall satisfy the Engineer that the personnel are capable of doing work of a high standard prior to any sprayed concrete work being undertaken in the Works. For this purpose each nozzleman and backup team shall carry out a series of trial applications in the presence of the Engineer to demonstrate their ability in applying sprayed concrete on vertical surfaces. Test panels as described above shall be made by each Operator. No Operator will be approved unless the 28 day crushing strength of all tests exceeds the design requirements.

The engineer may at any time withdraw his approval of personnel if the quality of sprayed concrete applied falls below the specified standard.

## 6.3 Wick Drain

The wick drains shall be supplied to site complete with 2 layers of Flownet 500HP (or equal approved) wrapped in a non-woven geotextile and shall not be more than 100mm in width. The wick drain shall be placed behind the mesh and secured to the excavated/cut face to prevent slippage prior to application of sprayed concrete.

Wick drains to be installed on the excavated/cut face as per the design drawings behind the drape mesh. Wick drains to extend the full height of the slope to intercept subsurface water from behind the gunite wall and convey it to the foot of the wall where it is discharged into weepholes.

# 7. TESTING

## 7.1 Sprayed Concrete

### 7.1.1 *Checking of Applied Thickness*

The thickness of applied sprayed concrete shall be checked by the Contractor by means of randomly positioned test holes. An acceptable procedure for these test holes shall be such that, on average, in any 100m² area of sprayed concrete area at least 10 test holes shall be drilled with a percussion drill where directed by the Engineer.

The Contractor may drill additional holes if he wishes at points intermediate to those located by the Engineer.

The basis of acceptance shall be that in any area of 100m² the arithmetic mean thickness of all the points checked shall be equal to or greater than the specified thickness. In addition at no point checked shall the thickness be less than 70% of the specified thickness. When the thickness is not acceptable, the Engineer may order an additional layer of sprayed concrete to be applied and rechecked for thickness without additional payment until the placed thickness is acceptable.

### 7.1.2 *Routine Testing*

On average, one test panel shall be made and tested by the Contractor on each shift when sprayed concrete is applied. Such test panels shall be prepared by the nozzleman when doing the work during normal sprayed concreting operations for the first 50m cubed of sprayed concrete applied in each heading. Test panels shall be prepared and tested for each 10 m cubed applied.

Test panels are to be made and sprayed into modules 750mm x 450mm x 200mm deep with sides sprayed onwards at 45° to prevent the entrapment of the rebound. Panels shall be placed against the side wall. Panels shall be clearly marked to identify the time and date of spraying and the area where they were sprayed. Subject to satisfactory test results the testing frequency may be reduced at the discretion of the Engineer.

### 7.1.3 *Testing of Sprayed Concrete*

For acceptance and routine testing, 100 mm diameter cores of a length between 110mm and 150mm after the ends are cut and trimmed shall be drilled from test panels by the Contractor. The remainder of the test panel shall be broken up to provide samples for density testing. The panels shall be field cured in the same manner as the work, after which the Contractor shall deliver the panels to the laboratory where the panels shall be cured in water as specified in SABS Method 865.

Three cores shall be cut and tested for compressive strength at 3 or 7 and 28 days as directed by and in the presence of the Engineer. The compressive strength shall be corrected to the equivalent cube strength by multiplying the estimated actual strength, determined as set out in SABS 865, by a factor of 1.20.

In places where the thickness of the sprayed concrete layers are such that it will be possible to cut out 100mm test cores, the Engineer may specify that such cores be cut out for testing.

Three samples each shall be tested at 7 days for volume of permeable voids and boiled absorption (density tests).

For the purpose of sampling and testing sprayed concrete the contractor shall supply all the panel moulds and core sampling equipment.

### 7.1.4 *Failure of Sprayed Concrete*

For the purpose of routine testing the quality of the sprayed concrete will be considered satisfactory if every test result is at least 80% of the specified result and if at least 80% of all results exceed the specified result.

Should test samples of sprayed concrete not achieve the specified minimum result, the Engineer will (if necessary) order that additional test be carried out by the Contractor to determine new mix proportions and/or application methods to avoid further such failures. If the Engineer considers

that the low test results of the applied sprayed concrete may reduce the safety of the Works and personnel or be detrimental to the effectiveness of the support, he may order that the following action is taken.

7.1.4.1 Remove the defective sprayed concrete in strips or panels in such a way that the safety of the Works and personnel is not endangered and replace with sprayed concrete that is acceptable (which may also require the replacement of mesh), or

7.1.4.2 Apply an additional thickness of sprayed concrete not exceeding the thickness originally required.

In either case no payment will be made for the defective sprayed concrete already applied, nor for the work involved in removing it from the areas where it has been applied, nor for any mesh that must be replaced, including additional laps, nor for any work involved in removing the resultant rubble and spoiling it at an approved spoil dump. Payment will only be made for that sprayed concrete placed as specified.

## 8. MEASUREMENT AND PAYMENT

The cost of delays and disruption shall not be included under items for installation of lateral support elements. Such costs shall be deemed to be included in the relevant item for excavation.

### 8.1 Welded Mesh Reinforcement

The unit of measurement shall be the square meter for the drape mesh and all other incidentals required to complete the work to the Engineer's details. The rate tendered shall be full compensation for all labour, plant, material and everything necessary to install and fix the drape mesh to the slope in the required location as specified.

### 8.2 Establishment (Sprayed Concrete)

The tendered lump sum shall include full compensation for establishment on the site and subsequent removal of all structural platforms, rafts and all special plant and equipment for the application of sprayed concrete and for carrying out operations, the cost of which does not vary with the actual amount of sprayed concrete applied.

This work will be paid for by way of a lump sum, 50% of which will become payable when all the equipment is on the site and the first sprayed concrete has been applied. The second installment of 25% of the lump sum will be payable after half the application of sprayed concrete and the final installation installment of 25% after completion of the sprayed concrete and the equipment has been removed from the site.

### 6.3 Sprayed Concrete

The unit of measure of sprayed concrete will be the net area measured on the theoretical cross-section profile given on the drawings at the specified thickness, and is to include for all wastage, and up to 50mm overbreak.

The rate tendered for application of sprayed concrete for the thicknesses specified shall include for all work required for the preparation of surfaces and application of sprayed concrete, all materials including rebound, cleaning and disposal of rebound, thickness control measures, drilling of holes for checking thickness, all design testing and routine testing.

All costs incurred due to sprayed concrete delaying or disrupting the advance of the excavation shall be priced for by the Contract under the sprayed concrete items.

### 6.4 Install and Fix Wick Drains

The unit of measurement shall be to cover the square meter wall face with 100mm wide wick drains complete with 2 layers of HDPE open structure grid, wrapped in a non-woven geotextile and all other incidentals required to complete the work to the Engineer's detail. The rate tendered shall be full compensation for all labour, plant, material and everything necessary to supply, cut, wrap, install and fix the Flownet wick drain to drape over the complete face of the slope to tie into the subsoil drain. The rate tendered shall include the outlet drainage weepholes.