MOKOLO AND CROCODILE WATER AUGMENTATION PROJECT PHASE 2 (MCWAP-2)

TENDER NO 054/2024/PMID/MCWAP2/RFB

PART C3.1
SPECIFICATION

SECTION 13

ROCK SUPPORT

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ROCK SUPPORT

13.1 SCOPE

This Section deals with the supply, installation and testing of rock support for use in excavations and structures – i.e. the anti-flotation anchors below the Low Lift Pump Station.

Rock support will consist of one or more of the following elements:

a) Tensioned fully grouted or friction rock bolts;

b) Fully grouted dowels;

c) Anti-floatation anchors for reinforced concrete structures;

d) Mesh reinforcement; and

e) Sprayed concrete.

The objective of installing dowels, rock bolts, welded wire mesh (weldmesh) and sprayed concrete is to assure the stability of the excavation as well as the safety of personnel and equipment working in the excavation.

The Contractor shall inspect the excavation as it progresses, and if conditions arise that require a change in the excavation and/or support system used, revised proposals shall be agreed with the Engineer.

The Contractor is responsible for the timely and proper installation of rock support and for checking and maintaining such support until Completion. As the required amount of rock support shall be entirely dependent on the actual ground conditions encountered during the course of the excavation, the Contractor shall at all times until the Works is nearing completion, keep an appropriate amount of contingency rock support of all types specified in storage on Site so that undue delays in excavation are avoided. The actual amount of contingency support to be stored on Site at any time is to be agreed with the Engineer.

Section 13 shall be read in conjunction with Section 20: Concrete Works (Structural).

13.2 DEFINITIONS, ABBREVIATIONS AND REFERENCES

13.2.1 Definitions

a) **"Rock bolt"** means a high yield deformed bar of specified diameter and length (in rock) which is end anchored, fully column bonded with cement grout, equipped with a faceplate, hemispherical washer and nut and tensioned to a specified load. **"Dowel"** means a high yield deformed bar of specified diameter and length (in rock) for which the protruding portion may be either straight or bent, and which is fully column bonded with cement grout. Dowels will not be tensioned. **"Anti-floatation anchor"** means a high yield deformed bar similar to a "dowel" which is grouted with specified cementitious grout and which is used for anchoring reinforced concrete structures to rock.

b) **"Sprayed concrete (or shotcrete)"** means concrete projected pneumatically onto a receiving surface to produce a dense, homogeneous mass. Sprayed concrete normally incorporates admixtures and may also include additions of fibres or a combination of these.

c) **"Overspray"** means sprayed concrete placed outside of the intended receiving surface.

d) **"Rebound"** means sprayed concrete material that ricochets off the receiving surface and falls to accumulate on the ground or other surface.

e) **"Sloughing, or sagging"** means subsidence of sprayed concrete, due generally to excessive water in the mix or placing too great a thickness of sprayed concrete in a single pass.

13.2.2 Abbreviations

ASTM	:	American Society for Testing and Materials
BS	:	British Standard
CEM	:	Calcium-Enriched Mixture
CSF	:	Condensed Silica Fume
DCP	:	Double Corrosion Protection
DSI	:	DYWIDAG Systems International
EFNARC	:	European Federation for Specialist Construction Chemicals and Concrete
EN	:	European Norm
FA	:	Fly Ash also known as Pulverised Fuel Ash (PFA)
GEWI®	:	Registered International Patent Holder of the GEWI Threadbar System
GGBS	:	Ground Granulated Blast-Furnace Slag
GGCS	:	Ground Granulated Core Slag
IRSM	:	International Railway Strategic Management (Corten IRSM steel)
JSCE	:	Japan Society of Civil Engineers
MQC	:	Manufacturing Quality Control
OPC	:	Ordinary Portland Cement
RHPC	:	Rapid-Hardening Portland Cement
RPM	:	Revolutions Per Minute
SANS	:	South African National Standard
SANAS	:	South African National Accreditation System
UFC	:	Ultra Fine Cement

13.2.3 References

When reference is made to a Code of Practice, Specification or Standard, the reference shall be taken to mean the latest edition or replacement at time of tender of the Code, Specification or Standard; including addenda, supplements, modifications and revisions thereto. Where a previous version is intentionally used, it will be indicated as such. Where reference is made to a Code, Specification or Standard that has subsequently been withdrawn and not replaced, the intended content will remain relevant unless confirmed otherwise in writing by the Engineer.

13.3 GENERAL

13.3.1 Responsibilities

(a) Rock Support of Temporary Works

The Contractor shall determine the support requirements for all Temporary Works. The Contractor shall submit a Method Statement, in accordance with the provisions of Clause 1.10.1.1 for approval by the Engineer. The Contractor shall design the rock support and submit such design to the Engineer for approval at least 7 days prior to commencement of the excavation. Any approval, consent, acceptance, agreement, review, etc., by the Engineer (under this Clause or otherwise) shall not relieve the Contractor from any obligation or responsibility under the Contract.

Provision is made in the Bill of Quantities for the pricing of selected typical rock support elements that may be required to safeguard rock faces, which form part of the Temporary Works. The Contractor shall assess the adequacy of this provision prior to ordering any material.

The final chosen support system shall be installed immediately following each excavation advance unless otherwise agreed by the Engineer.

The relaxation or intensification of support measures previously determined by the Contractor shall be done in consultation with the Engineer and will be dependent on the geotechnical conditions observed and monitored during and/or after excavation.

Notwithstanding any decision taken by the Contractor in regard to temporary support, the Engineer reserves the right to instruct the Contractor to install additional support at any location without relieving the Contractor from any obligation or responsibility under the Contract.

(b) Rock Support of Permanent Works

The Contractor shall install permanent support as detailed on the drawings and in accordance with determinations and specifications by the Engineer.

13.3.2 Quality Control

The Contractor shall satisfy the Engineer that the installation and testing of rock support shall only be undertaken by operators who are experienced in the various techniques offered.

The diameter, orientation and lengths of drill holes for rock bolts, dowels and anchors, the method of drilling, cleaning etc., shall be such as to ensure that the correct setting and anchorage of the bolts, dowels and anchors as required by the design can be achieved to the satisfaction of the Engineer.

The Contractor shall be responsible for checking the rock support periodically, at intervals stated in the Method Statement, and for maintaining it in a sound condition.

Maintaining rock support shall include inter alia the removal of any cracked or defective sprayed concrete and any loosened material caught by mesh reinforcement and the subsequent reinstatement of such support. The correct seating of faceplates and tightness of nuts shall be ensured.

13.3.3 Timing and Program

Rock support measures may be required at any location on the excavated profile and at any time after excavation has been completed.

The Contractor shall be responsible for ensuring that there are sufficient rock support materials of all types on Site in order to avoid undue delays in the support of excavations.

Whenever the excavation work is planned to be interrupted for more than 24 hours, initial support shall be installed, where necessary, on the excavated face before the interruption commences.

13.3.4 General Approach and Definitions

Where considered necessary, additional support measures shall be installed in order to upgrade support previously installed (if any) in accordance with instructions by the Engineer. The following definitions shall apply:

a) In basements excavated by drill and blast:

- Forward Area - within 3 m of the invert or excavation face;
- Rear Area - more than 3 m from the invert or excavation face or anywhere in a basement where excavation has been previously completed; and
- Upgrade Support - support installed after completion of the excavation where the existing support is considered inadequate by the Engineer, or where water flowing into the basement has caused damage, or where required as a final lining, and the like.

b) In surface and trench excavations:

- Forward Area - support installed during excavation; and
- Upgrade Support - support installed after completion of the excavation where existing support is considered inadequate by the Engineer.

13.4 ROCK BOLTS AND DOWELS

13.4.1 General

Rock bolts and dowels other than those specified herein shall not be used in the Works.

Where directed by the Engineer or shown on the Drawings, galvanised rock bolts and rock bolt accessories or dowels shall be used. Galvanizing shall be in accordance with Section 37 – Painting and Corrosion Protection, to a mean coating thickness of 85 microns.

The Contractor shall be responsible for checking the rock support periodically at intervals to be agreed with the Engineer and maintaining it in a sound condition. The correct seating of face plates and tightness of nuts shall be ensured.

The Contractor shall provide Method Statements for installation of all temporary and permanent rock support elements to the Engineer at least 14 days prior to the start of rock support work.

Method Statements shall provide the following:

a) Details of the dowels and rock bolts to be used. Samples of materials proposed shall be supplied to the Engineer if so requested;

b) Details of any proprietary rock support systems proposed, with supporting test data;

c) Details of the method of corrosion protection;

d) Details of drilling methods and equipment;

e) Details of all equipment and accessories to be used for dowel and rock bolts installation;

f) Details of the proposed grouting procedures and admixtures, and if so requested, samples of the proposed grouting admixtures; and

g) Details of equipment and methods to be used for pull testing of dowels and rock bolts, with calibration certificates attached.

13.4.2 Materials

Temporary tensioned rock bolts and dowels shall consist of either:

a) Deformed steel bars (Y-bars) with a minimum yield stress of not less than 450 MPa complying with SANS 920 and with a minimum threaded length of 150 mm at one end with a coarse cut thread which shall not reduce the overall specified bar diameter by more than 3 mm, and cut at an oblique angle at the other end to facilitate installation when using resin or cement grout cartridges; or

b) Deformed steel bars (GEWI bars) with a minimum yield stress of not less than 540 MPa.

Permanent tensioned rock bolts and dowels shall consist of:

a) Deformed steel bars (GEWI bars) with a minimum yield stress of not less than 540 MPa and are to be of the DSI DCP type with double corrosion protection,

with the various diameters and lengths as shown on the drawings and detailed in the Schedule of Quantities.

Face plates shall be of the 150 mm diameter, 8 mm thick domed load (10 tonne) indicating type.

The face plates shall be fitted with a hemispherical washer to permit seating of the face plate at inclinations up to 30° from normal to the bolt.

Grout for rock bolts and dowels shall consist of either:

a) Resin grout which shall be a commercially produced epoxy product in capsule form with both fast and slow setting times as applicable especially formulated for use with rock bolts or dowels, and transported, stored and utilised in accordance with the manufacturer's recommendations; or

b) Cement grout which shall be a commercially prepared product in capsule form especially produced for use with rock bolts or dowels. The product shall not contain any material which could corrode the rock bolts or dowels; alternatively,

c) Where a pumped cement grout is acceptable to or is specified by the Engineer for the installation of dowels, the materials shall comply with the requirements of Section 18 - Drilling and Grouting. Pumped cement grout may only be used in downward inclined holes.

Where site conditions are appropriate, mechanically anchored rock bolts may be used but only with the approval of the Engineer. All such mechanically anchored bolts shall comply with the latest requirement of the Chamber of Mines for rock bolts. All mechanically anchored rock bolts which are installed but are not thereafter fully grouted, shall be checked and re-tensioned at regular intervals as determined by the Engineer.

13.4.3 Manufacture of Rock Bolts

Rock bolts shall be manufactured from high yield deformed bar to the lengths as specified or detailed on the Drawings and with a characteristic strength of at least twice that of the specified working load. The bar length specified shall be the required length of bar to be bonded to the rock and due extra allowance in the cutting length shall be made for any other length including the threaded portion protruding from the rock and for the mechanical anchorage as required for installation. A minimum threaded length of 150 mm shall be allowed beyond the nut on installation to allow tensioning of the rock bolt. Face plates shall be 150 mm diameter (or alternatively, 150 mm x 150 mm square), domed, deformable plates of the load indicating type. The face plates shall deform at minimum 80% of the specified working load of the bolt as shown on the Drawings, and its performance verified by means of Site trials as directed by the Engineer prior to the commencement of any excavations. Installation and testing of rock bolts during such trials shall be carried out using the same equipment, including hydraulic tensioning device, as will be used in the works.

The face plates shall be fitted with a hemispherical washer to permit seating of the face plate at inclinations up to 30° from normal to the bolt.

Where specified on the Drawings hot dip galvanizing of rock bolts and rock bolt accessories will be required.

13.4.4 Manufacture of Dowels

Dowels shall be manufactured from high yield, deformed bar in various lengths and diameters as specified or detailed on the Drawings.

Dowels shall be either straight bars or shall have the protruding end bent to facilitate the specified anchor between the rock and the surrounding concrete or sprayed concrete when so detailed on the Drawings.

Dowels for installation with resin or cement capsules shall be threaded at one end sufficiently for attachment of the installation equipment. The other end shall be chamfered to facilitate installation. Where specified on the Drawings hot dip galvanizing of dowels and dowel accessories will be required.

13.4.5 Testing of Rock Bolts and Dowels

Prior to the installation of rock bolts or dowels in the Works, the Contractor shall carry out a series of tests as agreed with the Engineer to prove the capacity of the system and the Contractor's capability to correctly install dowels and rock bolts and tension the rock bolts.

The tests shall demonstrate:

- The anchorage assembly required to provide the end anchorage with an applied load equal to the bar's characteristic strength and taking into account the over-length variation of holes. The anchorage assembly may consist of resin or grout cartridges or a mechanical anchorage;

- The number of cartridges to fill the annulus around the rock bolt over the length of the hole between the anchorage and collar of the hole;
- The strength of the cement or resin grout to fully anchor the bars up to the characteristic strength of the rock bolts;
- The capacity of the equipment to install the longest required fully grouted rock bolts;
- The equipment required for tensioning the bolts to the specified loads; and
- The capability of each crew to correctly install and tension the rock bolts.

The Contractor shall undertake the tests with the equipment to be used on the Works.

The Contractor shall provide a suitably calibrated hydraulic direct tensioning jack and/or load cell of capacities in excess of 1,5 times the maximum characteristic strength of the rock bolts to be used in the Works. Loads applied and bolt elongations shall be recorded during the tests.

13.4.6 Installation of Rock Bolts

The method of installation and tensioning of bolts shall be to the approval of the Engineer. Manufacturer's instructions for the use of proprietary components shall be followed wherever these exist. Rock bolts shall be installed as soon as possible after excavation as shown on the drawings.

Unless otherwise proven acceptable by Site trials, the rock bolts shall be installed in percussion drilled holes of diameter from 10 mm to 15 mm greater than the maximum diameter of the rock bolt. Holes in excess of this diameter shall be abandoned and re-drilled. The holes shall not be more than 100 mm longer than the grouted length of the rock bolt unless otherwise proven acceptable by Site trials. Holes shall be drilled straight and to an accuracy of ± 5 degrees. Holes shall be cleaned by flushing with compressed air or clean water to remove debris immediately prior to installing the rock bolt. Where holes are cleaned by flush water, the amount of water employed shall be kept to an absolute minimum. Sufficient cementitious grout or cartridges of cement / resin grout shall be used to ensure the annulus around the rock bolt is completely filled over the full length of the hole.

Where utilised, end cartridges for the anchorage zone shall be of fast setting resin whilst the column shall be filled with slow setting resin or cement cartridges. Tensioning shall be carefully controlled to ensure that it takes place after setting of the end cartridges but prior to commencement of setting of the column grout.

Alternatively, the column of the rock bolt shall be filled to the collar of the hole using pumped cement grout as shown on the Drawings, after tensioning of the rock bolt as specified.

Installation of the rock bolt is to ensure that the steel bar is installed central in the hole.

Quick setting cement grout for bedding of rock bolt face plates shall be as approved by the Engineer.

The rock bolts shall be centrally located in the drilled holes and held in position by means of non-corrosive spacers which shall be firmly secured in position. Wooden spacers shall not be used.

The rock bolts shall be tensioned to 10 tonnes.

Tensioning of rock bolts shall preferably be carried out by means of a device imparting a direct pull to the bolt. The device shall be fitted with a gauge to indicate the tension in the bolt and shall be calibrated at regular intervals and when directed by the Engineer. The use of a torque wrench or similar tool shall be subject to the approval of the Engineer.

Those parts of the bolts that are to be grouted or surrounded with mortar or epoxy resin shall be cleaned of grease, oil, loose rust or other matter that may impair the bond.

13.4.7 Installation of Dowels

The method of installation of dowels shall be to the approval of the Engineer. Manufacturers' instructions for the use of proprietary components shall be followed wherever these exist.

Percussion drilled holes of diameter from 10 mm to 15 mm greater than the maximum diameter of the dowel shall be drilled and cleaned to the approval of the Engineer. Holes shall be drilled straight and to an accuracy of ± 5 degrees and shall not be more than 100 mm longer than the grouted length of the dowel unless otherwise proven acceptable by Site trials. Where holes are cleaned by flush water, the amount of water employed shall be kept to an absolute minimum.

The dowels shall be centrally located in the drilled holes and held in position by means of non-corrosive spacers which shall be firmly secured in position. Wooden spacers shall not be used.

The gauged amount of pumped cement grout or capsules of resin or cement grout shall then be inserted and the bar driven firmly into the hole (by spinning in the case of capsules). If pumped cement grout is used, the grout shall be inserted using a tremie pipe pushed down to the bottom of the hole and withdrawn slowly as the grout is placed. After installation the bar shall be vibrated for a short period to ensure the complete distribution of the grout around the full length of the bar. Additional grout shall be added to make up any shortfall. Where specified, grouting of the hole shall be carried out in stages to allow the flow of grout into cavities, each stage being topped up by the successive stage.

Those parts of the dowels due to be grouted or surrounded with grout shall be cleaned of grease, oil, loose rust or other matter that may impair the bond.

13.4.8 Maintenance of Rock Bolts and Dowels

If a bolt or dowel is damaged by blasting operations or becomes ineffective due to any cause, it shall be repaired or additional bolts or dowels shall be installed. The Contractor shall carry out such repair or replacement of damaged or ineffective bolts or dowels without any additional payment.

13.4.9 Routine Quality Control Testing

The Contractor shall carry out in-situ tests on dowels and rock bolts installed in the Works as agreed with the Engineer. Testing is to be generally in accordance with the procedures given in the ISRM Suggested Methods for Rock bolt Testing.

The Contractor shall check the effectiveness of both the dowel and rock bolt installation procedures by testing a minimum of 1 in 200 units installed to a test load of 70% of their specified characteristic strengths.

Dowels shall be tested after the grout has achieved its design strength. Rock bolts to be tested shall be selected (pointed out) by the Engineer after the rock bolt has been tensioned but prior to the free column of the bolt being filled with pumped cement grout. Tests on rock bolts selected for such routine quality control testing shall be carried out prior to full column cement grouting of the free length of the rock bolt.

Any dowel or rock bolts that fails at a tension of less than or equal to 70% of its specified characteristic strength shall be replaced. Also, in such event, for the last 200 dowel and/or rock bolts units installed, the end anchorage zone of such rock support will be considered unbonded from the rock and additional rock support shall be installed over the affected surface area of the excavation with the diameter, length and spacing of such additional support as directed by the Engineer. The Contractor shall install such additional support before advancing the excavation any further, and without any additional payment for installation of such additional support.

The Contractor shall furthermore investigate the cause of such failure and make such proposal for amendment of the installation procedure as may be necessary. Tests shall continue thereafter at a rate of 1 in 50 units installed until the Engineer is satisfied that the cause of the failure has been overcome. Should 1 in 50 dowel or rock bolt units thereafter tested still fail at tensions of less than 70% of its specified characteristic strength, then all further work in that Portion of the Works shall be suspended and the Contractor shall install trial rock bolts and conduct pull-out tests on trial rock bolts installed outside that area of works as directed by the Engineer, until the Contractor's method of dowel or rock bolt installation proves satisfactory to the Engineer.

The Contractor, in the presence of the Engineer, shall carry out regular calibration of hydraulic tensioning devices.

13.5 ANTI-FLOATATION ANCHORS FOR REINFORCED CONCRETE STRUCTURES

13.5.1 General

In addition to the requirements for rock bolts and dowels specified in Clause 13.4, the below shall apply specifically to Anti-floatation anchors for reinforced concrete structures.

13.5.2 Drilling of Holes for Anti-floatation Anchors

On completion of the drilling, each hole shall be thoroughly flushed with water to ensure good grout to rock bond.

The drill hole shall commence at the location shown on the Drawings or as directed by the Engineer within a tolerance of $\pm$ 150 mm.

The initial alignment of the drill hole shall be shown on the Drawings or as directed by the Engineer within an angular tolerance of $\pm$ 2°.

The deviation of the drilled hole at any point shall not vary from the initial alignment by more than 3% of the length of the hole to that point, as measured by the Engineer. Downward inclined holes shall be drilled 100 mm longer than the anchors to provide a sump for debris that cannot be washed out.

13.5.3 Water Testing of Holes for Anti-floatation Anchors

Prior to installation of any anchor, the hole shall be tested for water tightness by checking the total water loss along the full length of the hole. Where the water loss exceeds 5 litres/minute at a pressure of 100 kPa in excess of the local water table (which shall be measured) over a period of 10 minutes, the hole shall be cement grouted, re-drilled and retested until the water loss is less than this criterion.

13.5.4 Cement Grout for Anti-floatation Anchors

Material used for grouting shall comply with the following requirements:

- Cement shall comply with SANS 50197-1 and be of the strength class 32.5 or higher;
- Sand shall comply with the requirements of SANS 1083 for sand for concrete, except that the grading shall be such that 100% passes through a 1.18 mm;
- Admixtures shall not contain chlorides, nitrates, sulphides or sulphites and when aluminium powder is used, the total expansion of grout shall not exceed 10%; and
- Water for mixing grout shall comply with the requirements of EN 1008.

At least 28 days before the commencement of grouting on site, the Contractor shall carry out tests to determine whether the grout complies with the requirements for fluidity, bleeding and strength. After establishing a mix design that complies with the requirements, the mix design shall not be altered unless trial mixes of any altered mix are made, tested and approved by the Engineer.

A suitable plasticizer shall be used in the grout. The grout shall be tested by placing a 100 mm high sample of grout in a covered cylinder of approximately 100 mm, fitted with a thermometer, to ensure that the temperature is kept at 20ºC ± 2ºC. The bleeding shall not exceed 2% after 3 h, or 4% max, when bleeding is complete, and the bleed water shall be re-absorbed fully after 24 h.

To determine the compressive strength of the grout a sample shall be taken in accordance with SANS 5861-2 and tested in accordance with SANS 5863. Cubes (of sides 100 mm) cured at temperature of 22ºC to 25ºC and at a relative humidity of at least 90% for the first 24 h, and kept in water at 22ºC to 25ºC, shall have a compressive strength that exceeds 20 MPa at 7 days.

The viscosity of grout for horizontal holes shall be 500 to 2 500 cP and for vertical holes 400 to 1500 cP, when measured using a standard flow cone in accordance with ASTM 939. The viscosity of the grout, 20 minutes after mixing, shall not exceed 2 500 cP and 1 500 cP for horizontal and vertical holes respectively.

When grout is mixed, first water shall be added to the mixer and then the cement. Only after the water and cement have been thoroughly mixed shall any admixture or sand be added. Mixing shall be continued until a uniform consistency is obtained but, in any event, for at least 2 min. The water cement ratio of the mix shall be as low as possible within the mass fraction range 0.35 to 0.5 and the mix shall have the required fluidity. Mixing shall not be done by hand.

13.5.5 Installation of Anti-floatation Anchors

The gauged amount of grout shall be introduced using a tremie pipe pushed down to the bottom of the hole and withdrawn slowly as the grout is placed. The anchor shall then be driven firmly into the hole and vibrated for a short period after insertion to ensure the complete distribution of the grout around the embedded length of the anchor. Excessive bleeding of the grout shall be avoided. Additional grout shall be added to make up any shortfall.

Immediately before being placed in the hole the anchor shall be thoroughly cleaned of mill scale, rust, mortar, oil, paint, dust, grease, soap or any other coating or foreign matter, to the satisfaction of the Engineer.

The anchors shall be centrally located in the drilled holes and held in position by means of non-corrosive spacers and which shall be firmly secured in position. Wooden spacers shall not be used.

Anchors shall be installed at least 5 days prior to the fixing of reinforcement, concreting or other work in the vicinity. Care shall be taken to not in any way disturb the anchors during this period.

13.6 WELDED MESH REINFORCEMENT

13.6.1 General

Welded mesh reinforcement shall comply with the relevant requirements of Section 20 - Concrete Works (Structural). Weldmesh reinforcement shall be transported, handled and stored in a manner approved by the Engineer.

The mesh shall be securely fixed as described below, generally in hollows at the optimum distance from the rock face for the application process such as to minimise sprayed concrete rebound and prevent voids. The minimum cover between the mesh and the exposed face of the sprayed concrete shall be 25 mm, or a greater cover if instructed by the Engineer, or shown on the Drawings. The mesh shall be set at a nominal distance of 20 mm from the rock face. Joints shall be lapped by 2 full squares.

Where welded mesh is used without initial sprayed concrete support, all loose material behind the welded mesh shall be completely removed before concrete is placed against the rock face. The welded mesh may be cut open to remove loose rock prior to lining. Continuity of the welded mesh shall be restored if required for safety but otherwise the welded mesh shall be trimmed neatly so that there are no loose portions which might interfere with the concreting operation.

13.6.2 Fixing Arrangements for Drill and Blast Drives

Mesh reinforcement shall be retained to the rock by one of the following methods:

a) Where mesh reinforcement consists of squares greater than 100 mm x 100 mm (i.e. mass 1.93 kg/m^2 for use in Shotcrete), mesh retaining spiders shall be fixed beneath the faceplate of the rock bolts such that the mesh reinforcement may be later secured with sufficient wire ties to the spider. Spiders shall consist of eight (8) No. 6 mm diameter mild steel legs each 800 mm long. In addition, mesh fixing pins to the details shown on the Drawings shall be provided at intermediate points as required, but not exceeding 1 m centres both ways.

b) Where mesh reinforcement consists of squares 100 mm x 100 mm or smaller (i.e. mass 1.56 kg/m^2 for use without Shotcrete), the mesh may be fixed beneath the bolt faceplate and with intermediate fixing pins at a maximum spacing of 600 mm.

The mesh shall be fastened in such a way that if shotcrete is to be applied subsequently, the mesh will not sag or vibrate excessively and impair the effectiveness of the shotcrete.

Where mesh is required to be placed after an Initial layer of shotcrete has been applied to the excavated surface, the mesh shall be fixed to the excavated surface by means of pins, bolts, wire ties or loops or other approved fixings fastened to rock bolts already in place. The mesh shall sit snugly against the initial shotcrete layer.

13.6.3 Defects and Repairs

Where fixing of the weldmesh reinforcement is not to the satisfaction of the Engineer, the Contractor shall carry out the necessary remedial work at no additional cost, as directed by the Engineer.

Weldmesh reinforcement damaged during transport or installation shall be cut out and replaced, with reference to the required lapping of weldmesh fabric as described above, to the satisfaction of the Engineer.

13.7 DOUBLE TWISTED WIRE MESH

Double twisted wire mesh rolls shall be used for the protection of slopes and cliffs where there may be danger of falling rocks.

All wire shall be hexagonal-woven Mesh type 80, zinc coated by hot-dip galvanising, as specified for 0.2 m – 0.3 m deep gabions in Section 21 – Gabions and Reno Mattress Structures.

13.8 SPRAYED CONCRETE

13.8.1 General

Sprayed concrete shall be applied to the rock surface where directed by the Engineer and as soon as possible after excavation. Areas to be treated shall be agreed with the Engineer before the application.

Sprayed concrete shall be applied to both clear and mesh reinforced faces and to the final thickness, all as specified on the Drawings. Large radius irregularities will be permitted, but local roughness and re-entrant angles are to be covered and smoothed out by the application of additional sprayed concrete.

Sprayed concrete shall be applied by the wet mix process.

Where specified by the Engineer sprayed concrete shall be applied in one or more layers to reach the specified total thickness.

The sprayed concrete after completion is not to be touched up, trowelled, smoothed off or worked in any way, but left undisturbed unless otherwise specified.

13.8.2 Submittals and Records

The Contractor shall submit the following not less than 14 days prior to first application of sprayed concrete:

- Mix designs of all proposed sprayed concrete mixes, including test results demonstrating conformance with design requirements and compatibility of all mix components;
- Certificates of compliance with the relevant standards for the materials specified, with the source of such materials indicated;
- Qualifications, experience and work functions of personnel assigned to sprayed concreting; and
- Details of all equipment to be used for batching, mixing, conveying, applying and curing.

The Contractor shall retain the following on Site for the duration of the Works:

- Methods statements;
- Sprayed concrete application details, such as type of sprayed concrete used, strength and ductility requirements, sequences and methods of application, and any other relevant application details, as well as reference to the section of work to which the records relate; and
- A record in a form to be agreed with the Engineer, of all the tests on sprayed concrete, which shall be kept at the Site identifying the tests with the section of work to which the results relate. Copies of results of all records of inspections, testing and verification shall be submitted to the Engineer on an on-going basis.

13.8.3 Materials

13.8.3.1 Cement, Cement Extenders and Water

Cement, cement extenders, and water shall comply with the requirements of Section 20 – Concrete Works (Structures).

13.8.3.2 Aggregates

Aggregates shall comply with the requirements of Section 20 - Concrete Works (Structural), except as regards grading requirements which shall be as given in Table 13/1.

The nominal particle size shall be 10 mm unless otherwise agreed with the Engineer and the grading shall lie within the envelope given in Table 13/1 unless otherwise approved.

TABLE 13/1
AGGREGATE GRADING LIMITS

Sieve Size (mm) (ASTM)	Percentage Passing by Mass	
	Maximum	Minimum
9.50	100	100
4.75	100	70
2.36	100	45
1.18	75	30
0.60	50	18
0.30	30	10
0.15	15	5

Aggregates with gradings 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.

13.8.3.3 Admixtures

The percentage of chlorides in admixtures shall not exceed 0,1% by weight. Apart from this, admixtures shall not contain any substances corrosive to steel and shall not induce other detrimental effects such as cracking or spalling.

Accelerators shall not be caustic or corrosive to reinforcement, and shall be of a type with a history of satisfactory long term performance. References shall be obtained from suppliers and submitted to the Engineer for approval.

Only the minimum quantity of accelerator necessary shall be permitted in normal concrete spraying operations, with the quantity to be used to be determined in Site trials. The amount of accelerator to be used shall be within limits recommended by the manufacturer but shall not exceed 3% by mass of the total cementitious content unless the Contractor can satisfy the Engineer that the 5 year strength of the sprayed concrete will not be detrimentally affected. Accelerators showing excessive variability with dosage will not be permitted.

Accelerators delivered to Site shall be tested at least once every two months for their reaction with the cement used with particular reference to the setting behaviour, early strength and decrease of strength after 28 days. Storage times and working temperature ranges shall be in accordance with the manufacturer's recommendations and the manufacturer's safety instructions shall be observed.

Plasticisers and retarders complying with Section 20 (and, where relevant, appropriate international standards e.g. ASTM C1141M-15) may be used to reduce the quantity of the mixing water and to improve the pumpability of the concrete. Plasticisers and retarders shall be checked regularly for setting time, water reduction and the development of strength as compared with the base concrete. Compatibility of plasticisers and retarders with cements, latent hydraulic binders and accelerators shall be verified during Site trials.

Hydration control admixtures may be used to control hydration of the mix as appropriate to expedite construction, subject to agreement with the Engineer. The effects and optimum dosages of hydration control admixtures shall be determined during the Site trials. Compatibility of hydration control admixtures with cements, latent hydraulic binders and accelerators shall be verified during Site trials. Such admixtures shall be used in accordance with the manufacturer's instructions.

13.8.3.4 Compressed Air

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

13.8.3.5 Fibre reinforcement

a) Steel fibres shall comply with ASTM 820 – Standard Specification for Steel fibre for Fibre Reinforced Concrete or such other Standard acceptable to the Engineer. A minimum fibre tensile strength of 1 000 MPa is required.

   Steel fibres shall be Type 1 deformed of equivalent diameter 0.5 mm and aspect ratio of 40 to 80 or such other type acceptable to the Engineer. The length of fibre should not exceed 70% of the internal diameter of the hoses or pipes to prevent blockage.

   Fibres shall be stored in dry sealed containers until ready for use and shall be free from corrosion, oil, grease, chlorides and deleterious materials which may reduce the efficiency of mixing or spraying processes or which may reduce the bond between the fibres and the sprayed concrete.

b) Where specified, synthetic fibre reinforcement shall be used provided that it complies with the specified performance requirements for fibre reinforced sprayed concrete.

   Fibres shall be stored in dry sealed containers until ready for use and shall be free from corrosion, oil, grease, chlorides and deleterious materials which may reduce the efficiency of mixing or spraying processes or which may reduce the bond between the fibres and the sprayed concrete.

c) Fibre suppliers must be able to satisfy the performance criteria of the Works Information by means of an appropriate and established energy absorption panel test, to be carried out during the Site trials. Approval shall be obtained from the Engineer should an energy absorption panel test other than that as described in ASTM 1550-19: Standard Test Method for Flexural Toughness of Fibre Reinforced Concrete (Using Centrally Loaded Round Panel) or as alternative, the European Specification for Sprayed Concrete, EFNARC (1996 and Final Version June 1999) be used.

13.8.3.6 Pigment

Where specified on the Drawings or directed by the Engineer, pigment shall be added to the sprayed concrete. An inorganic pigment suitable for use in concrete/shotcrete shall be used. Suitable products are available from Bayer SA, Cemcrete, Chryso and others. The pigment shall be dosed at 5% by mass of cement. The colour of the pigment shall be as agreed with the Engineer or shown on the Drawings.

13.8.4 Design of Sprayed Concrete

Sprayed concrete mixes shall be capable of placement without excessive rebound or segregation, and of meeting the specified strength requirements with the lowest practicable water/cement ratio.

Sprayed concrete shall meet the requirements specified in Table 13/2. The mix design shall be carried out by the Contractor and details submitted to the Engineer for approval.

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

a)	Cementitious content	380	-	480 kg/m^3
b)	Aggregate/cement ratio	3.00	-	5.00
c)	Water/cement ratio	0.35	-	0.45
d)	Silica fume where required	30	-	50 kg/m^3
e)	Steel Fibre where required	30	-	80 kg/m^3 (i.e. 0,5 to 2,0 % by volume)
f)	Synthetic Fibre where required	4,5	-	18 kg/m^3

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

Where Fly Ash is utilised, the advice of the manufacturer of the additive (and of 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 progress 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 13/2
SPRAYED CONCRETE PERFORMANCE REQUIREMENTS

Sprayed Concrete Class		**A**	**B**	**C**	**D**
Description	**Test Method**	**Plain**	**Plain + Accelerator**	**Fibre Reinforced**	**Fibre Reinforced + Accelerator**
Compressive Strength: - at 8 hours (MPa) - at 24 hours (MPa) - at 28 days (MPa)	 SANS 5865 SANS 5865 SANS 5865	 n/a n/a 35	 5 8 40	 n/a n/a 40	 5 8 40

Sprayed Concrete Class		A	B	C	D
Description	**Test Method**	**Plain**	**Plain + Accelerator**	**Fibre Reinforced**	**Fibre Reinforced + Accelerator**
First Crack and Ultimate Flexural Strength: - at 28 days (MPa)	SANS 5864	3,5	4	4	4
Residual Flexural Strength: - at 28 days (MPa)	SANS 5864	n/a	n/a	3,2	3,2
At 28 days:					
- I_{20} Toughness Index	SANS 5864	n/a	n/a	16	16
- I_{30} Toughness Index	SANS 5864	n/a	n/a	22	22
- I_{50} Toughness Index	SANS 5864	n/a	n/a	30	30
Boiled Absorption: - at 7 days (%)	ASTM C642-13	8	9	8	9
Volume of Permeable Voids: - at 7 days (%)	ASTM C642-13	17	19	17	19
Setting Time:					
- Initial Set (minutes)	ASTM C403/ C403M-99	n/a	3	n/a	3
- Final Set (minutes)	ASTM C403/ C403M-99	n/a	9	n/a	9
Toughness Classification (also see Note (iii) below)	EFNARC 1999	n/a	n/a	Class b	Class b

Notes: i) The above values are all 'minimum' acceptable limits except for boiled absorption and volume of permeable voids, which are 'maximum' acceptable limits;

ii) n/a indicates 'not applicable'; and

iii) Or equivalent toughness class in terms of the ASTM 1550-19 classification.

13.8.5 Acceptance Testing

The Contractor shall propose to and agree with the Engineer, trial mixes for the Works as well as a subsequent programme of acceptance testing.

Trial mixes shall be prepared employing the Plant and labour to be used on the Works and sprayed in test panels to the required thickness. Constituent materials shall be fully representative of those to be used in the Works.

As minimum requirement, test panels of at least 1000 mm x 1000 mm in size and 200 mm thick and with sides splayed outwards at 45° to prevent the entrapment of rebound, shall be sprayed in the presence of the Engineer for each mix design. The test panel moulds used shall be constructed of steel or other rigid, non-water absorbing materials.

The sprayed concrete in the panels shall adhere well to the back form, be properly compacted and exhibit no sagging.

Test panels shall not be moved for 18 hours after spraying and shall be stored without disturbance at a temperature of +20°C (± 5°) and covered by polythene sheet until the time of coring.

Cores for 8 hours, 24 hours and 28 day compressive strength tests shall be obtained from each panel with cores for 24 hours and 28 day strength tests to be stored in water, in accordance with SANS 5865 (1994). Each cored cylinder shall be marked with an appropriate reference mark and the date and time of spraying.

No two cores to be tested at any given age shall come from the same panel. Cores to be tested at different ages (i.e. 8 hours, 24 hours and/or 28 days) may come from the same panel. For each age of testing, at least one spare specimen shall be provided. In accordance with SANS 5865 (1994), the testing requirements shall be:

- Compressive strength in spray direction after 8 hours, 24 hours and 28 days on 3 cores each. The prepared test cores shall be 100 mm diameter and 100 mm long; and
- Compressive strength perpendicular to spray direction after 8 hours, 24 hours and 28 days on 3 cores each. The prepared test cores to be taken from the different panels, shall be 100 mm diameter and 100 mm long.

The sprayed concrete density of all test cores shall be determined prior to testing, in accordance with SANS 6251 (1994).

Sufficient panels shall be sprayed to also allow testing to prove the acceptability of the sprayed concrete to meet the requirements with regard to (refer Table 13/2):

- First crack and ultimate flexural strengths (minimum of 3 beams to be tested for every trial mix design, cut from separate test panels) (SANS 5864);
- Toughness indices (SANS 5864);
- Boiled absorption (ASTM C642-13);
- Volume of permeable voids (ASTM C642-13);
- Setting time (ASTM C403/C403M-99); and
- Energy absorption of fibre reinforced sprayed concrete panels (ASTM 1550-19 or EFNARC (1996 and Final Version June 1999)).

The Contractor shall carry out such other tests and trials during the period of Site trials as may be necessary, or as agreed with the Engineer, to confirm that proposed mixes and methods meet the minimum performance requirements.

Based on the above requirements, Table 13/3 summarises the minimum number of core specimens required per spraying position per trial mix for testing as part of this programme.

TABLE 13/3
NUMBER OF SPECIMENS REQUIRED/SPRAYING POSITION/TRIAL MIX

Description	Test Method	Min. No. of Specimens to be Tested (Min. No. of Spare Specimens to be Available)		
		8 hours#	24 hours#	28 days
Compressive strength of cores in direction of spraying	SANS 5865	3 (1)	3 (1)	3 (1)
Compressive strength of core perpendicular to direction of spraying	SANS 5865	3 (1)	3 (1)	3 (1)
Other/additional testing	tba	As required by Contractor / tba		

Notes: i) tba indicates 'to be advised by the Engineer'

ii) # denotes 'where applicable', refer Sprayed Concrete Classes, Table 13/2

Similarly, Table 13/4 summarises the minimum number of other specimens required per trial mix for testing as part of this programme.

TABLE 13/4
NUMBER OF OTHER SPECIMENS REQUIRED/TRIAL MIX

Description	Test Method	Minimum Number of Specimens to be Tested
Flexural strengths and toughness indices from testing fibre reinforced sprayed concrete beams	SANS 5864	3 (tested at age 28 days) (+ 1 spare)
Boiled absorption, volume of permeable voids	ASTM C642-13	5 (tested at age 7 days)
Setting times	ASTM C403/C403M-99	5
Energy absorption of fibre reinforced sprayed concrete panels	EFNARC (1999) (or ASTM 1550-19)	3 (tested at 28 days) (+ 1 spare)
Other/additional testing	tba	As required by Contractor/tba

Notes: i) tba indicates 'to be advised by the Engineer'

The compressive strength of cylindrical cores cored from test panels, cored either in or at right angles to the direction of spraying, shall be acceptable if the average result for 3 cores tested at 8 hours, 24 hours and 28 days is not less than the respective 8 hours, 24 hours and 28 day specified strengths as listed in Table 13/2, and with no individual core having less than 70% of the specified strength.

The Site trials shall be repeated if the source or quality of any of the materials or the mix proportions is to be changed during the course of the Works.

Should any mix fail to produce satisfactory results in terms of the above acceptance testing, the Contractor shall repeat the spraying of panels and test either the same mix, Plant and labour or make such adjustments as he considers necessary to achieve the required performance.

The Contractor shall provide all material, labour and equipment required for preparation of test panels and the extraction of cores therefrom. The Contractor shall provide an on Site facility for sample preparation and compressive strength testing of cores at 8 hours. However, the Contractor may propose alternative methods for assessing the strength of sprayed concrete at 8 hours (e.g. the Hilti method (1992) and/or a pull-out test as described in JSCE-G561-1999). Acceptance by the Engineer will be subject to satisfactory evidence of an acceptable correlation between such tests and the tests prescribed in the Works Information. The Contractor shall carry out all other testing at an appropriately accredited testing laboratory, as agreed with the Engineer.

13.8.6 Equipment

All the equipment used for batching and mixing of 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 volumes to be applied. At least one Plant shall have a minimum output of 5 m^3/hr. The equipment shall be capable of handling and applying 13 mm maximum size of aggregate. A stand-by gun and ancillary equipment shall be available at all times. Air for the equipment is to be provided to the equipment at not less than the operating pressure specified by the manufacturer.

Dosing of additives by hand will not be permitted. Equipment for dosing 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%.

The working area shall be well illuminated to a minimum lighting intensity of 50 lux. Cap lamps attached to safety helmets will not be accepted as sufficient. Dust pollution shall be minimised by means of pre-damping of materials, additional ventilation, water sprays, and maintaining equipment in good order. Protective clothing and dust masks shall be provided for and used by all sprayed concrete operators. The provisions of Section 2 – Occupational Health and Safety, shall also be enforced.

If at any time the Engineer considers that the environmental conditions of the area where sprayed concrete is being applied are likely to cause a health hazard or affect the quality of the finished work because of excessive dust or lack of adequate ventilation or lighting, he may order the Contractor to suspend operations on sprayed concrete work until steps are taken to improve the conditions in the affected area. No additional payment will be made either for the additional measures called for or for any delays resulting from such suspension of Works.

13.8.7 Batching

Materials shall be batched by mass of dry materials and cement shall not be added more than 1 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 material shall be discarded.

The batching accuracy shall be within ± 3% for all constituents. Admixtures may be measured by volume, to an accuracy of ± 5%.

Batching and mixing shall be carried out by equipment capable of properly mixing materials in sufficient quantity to maintain the continuous application of sprayed concrete.

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.

The addition of fibres, if required, shall be at a stage in the mixing suitable for the sprayed concreting equipment. The procedure for the addition of fibres shall be determined during Site trials. Fibres shall be added and mixed in a manner to avoid clumping and bending of the fibres. Any fibre clumps in the mix shall be diverted and removed by means of a screen placed over the sprayed concrete hopper. Fibres shall be uniformly distributed throughout the mortar mix without isolated concentrations. Fibres shall not be added to the mix at a rate faster than that at which they can be blended with the other ingredients without forming balls or clumps.

13.8.8 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 large 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 the inflow of groundwater renders the surface too wet for the normal application of sprayed concrete, the surface shall be treated as set out in Section 8 – Dealing with water.

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, that 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.

13.8.9 Placing

Sprayed concrete shall be placed in accordance with good practice as detailed in AC1-506R-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.

No sprayed concrete shall be placed in air temperatures less than 1°C. Where necessary freshly sprayed concrete shall be protected from rain or water until the surface is of sufficient hardness to prevent damage.

The base concrete mix for the wet mix process shall be applied within 1,5 hours from first mixing the component materials. This time may be extended by the use of retarders, plasticisers or hydration control admixtures, as approved by the Supervisor. Aged concrete shall be discarded.

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

The minimum specified layer thickness shall be controlled by depth pins attached to the rock surface and reinforcement, or 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 existing edge shall be cleaned and thoroughly wetted.

Dust pollution shall be minimised by choice of appropriate equipment and by means of additional ventilation, water sprays, and by maintaining equipment in good order. Appropriate hard hats, protective clothing and dust masks shall be provided for and used by all sprayed concrete operators. Appropriate first aid facilities and eyebaths specifically, shall be readily available in the immediate vicinity of sprayed concrete application.

13.8.10 Curing

Sprayed concrete shall be cured by a method to be approved by the Engineer and in compliance with Section 20.

The use of a sprayed surface curing compound will not be permitted. The sprayed concrete shall be kept moist continuously for 3 days by spraying with a fine mist of water at intervals not exceeding 4 hours. Should it not be practical to keep the sprayed concrete moist for 3 days due to the disruptive effect that this may have on other operations, the Contractor shall give consideration to using an internal curing additive, provided that bonding between different layers of sprayed concrete are not adversely affected by such addition.

Proprietary curing compounds or methods may be used only with the approval of the Supervisor.

Membrane curing shall not be used where a further layer of sprayed concrete is to be applied.

Curing shall ensure that the sprayed concrete exhibits proper strength gain and a minimum of cracking.

13.8.11 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 nozzle man and back-up team shall carry out a series of trial applications in the presence of the Engineer to demonstrate their ability in applying sprayed concrete. Test panels as described in Clause 13.8.15 shall be made by each operator. No operator will be approved unless the 28 day crushing strengths of all tests done by an operator exceed 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.

13.8.12 Drainage Holes

Where groundwater inflows could interfere with the application of sprayed concrete or cause a reduction in the quality of sprayed concrete, the Contractor shall take action to control such groundwater inflows. Such action shall include the channelling of water by means of pipes and chases.

Where required drainage holes shall be provided in accordance with the provisions of Section 18 – Drilling and Grouting. Where sprayed concrete is applied after completion of the drainage holes the drainage holes shall be extended through the sprayed concrete with suitable formers or similar approved method. Plastic pipes or tubes used for this purpose may be left in holes drilled into the rock and embedded in sprayed concrete.

13.8.13 Pressure Relief Holes

Generally one (1) day after spraying concrete, pressure relief holes of 38 mm diameter shall be drilled through the sprayed concrete and 450 mm minimum into the rock as shown on the Drawings or as directed by the Engineer. In general a spacing of 1 hole per 4 m^2 shall be provided in areas where a build up of water pressure could be expected.

13.8.14 Checking of Applied Thickness

The thickness of applied sprayed concrete shall be checked by the Contractor by means of an agreed grid of test holes. An acceptable procedure for these test holes shall be such that on average in any 100 m^2 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 100 m^2 the arithmetic mean thickness of all the points checked shall be equal to or greater than the specified thickness. In addition, at no point shall the thickness be less than 70% of the specified thickness for layers less than 100 mm specified thickness or 50% for layers of 100 mm specified thickness or more. Where 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.

13.8.15 Testing

On average, one test panel shall be made and tested by the Contractor on each shift when sprayed concrete is applied in each shaft and each surface location. Such test panels shall be prepared by the nozzle man doing the work during normal sprayed concreting operations. For the first 50 m^3 of sprayed concrete applied in each heading, test panels shall be prepared and tested for each 10 m^3 applied.

The test panels are to be made by spraying into moulds 750 mm x 450 mm x 200 mm deep with sides splayed outwards at 45° to prevent the entrapment of rebound. Panels shall be placed against the sidewall. 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.

13.8.16 Testing of Sprayed Concrete

For acceptance and routine testing, 100 mm diameter cores of a length between 110 mm and 150 mm 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 BS 1881.

Three cores shall be cut and tested for compressive strength at 3 days, 7 days and 28 days as directed by and in the presence of the Engineer. The compressive strengths shall be corrected to the equivalent cube strength as set out in BS 1881.

In places where the thickness of the sprayed concrete layers is such that it will be possible to cut out 100 mm test cores, the Engineer may specify that such cores be cut out for testing. An average of not more than 2 x 100 mm cores shall be required for every 100 m².

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. The concrete testing machine supplied by the Contractor for testing concrete cubes shall also be suitable for testing sprayed concrete samples.

13.8.17 Failure of Sprayed Concrete

For the purposes 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 tests 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 persons or be detrimental to the effectiveness of the support, he may order that the following action be taken:

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

b) Apply 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 from the underground Site and spoiling it in an approved spoil dump. Payment will only be made, once, for that sprayed concrete placed as specified.

13.8.18 Defects and Repairs

Before a subsequent layer of sprayed concrete is placed, the preceding layer shall be checked for defects in the presence of the Engineer.

Areas of work shall be properly compacted and bonded and free from segregation, honeycombing, laminations, dry or ‘sandy’ patches, voids, sagged or slumped material, rebound, excessive cracking, single voids with dimensions in excess of 15 mm in any direction, and overspray.

Delamination either within sprayed concrete or at the rock/sprayed concrete interface shall constitute cause for sprayed concrete rejection. The extent of delamination shall be evaluated by sounding with a blunt metal object and, where necessary, verified by coring.

Where defects occur the Contractor shall agree with the Engineer proposals for the removal of the defective material and replacement material without defect. Where a defect is required to be rectified, the area to be replaced shall in any event be not less than 300 mm x 300 mm.

13.9 MEASUREMENT AND PAYMENT

The rates tendered under this Section shall not include for the general obligations, Contractor’s Equipment and work deemed to be covered by the items provided in Section 1 - General.

13.9.1 General Principles of Measurement and Payment

Rock support measures may be required at any location on the excavated profile and at any time after excavation has been completed and the various rates tendered for the work shall be deemed to include for all direct and consequential costs.

The repair or replacement of damaged or ineffective bolts or dowels, which was damaged by blasting or becomes ineffective due to any cause, shall be carried out by the Contractor without additional payment.

13.9.1.1 Support for Drill and Blast Excavations

Distinction shall be made between support installed in the forward area, rear area and the upgrade of support. The various areas of support are as defined in Clause 13.3.

Separate payment items are provided for each support element in the forward and rear areas and for the upgrade of support.

13.9.1.2 Support for Surface and Trench Excavations

Distinction shall be made between support installed in the forward area and the upgrade of support. The various areas are as defined in Clause 13.3.

13.001 Rock bolts **Unit: number (No)**

Measurement of rock bolts will be by number of effective bolts installed and approved at any orientation required by the Supervisor. Distinction shall be made between rock bolts of different lengths and different diameter.

The rate tendered shall include full compensation for the supply of all materials including the bolt, faceplate assemblies, galvanising if required, resin and cement capsules, drilling of holes, installation and tensioning of rock bolts and the replacement of any damaged or defective rock bolts. All trials to establish correct grouting and anchorage procedures, and all tests on the effectiveness of the bolt installations, shall be included in the tendered rate.

13.002 Dowels **Unit: number (No)**

Measurement of dowels will be by number of effective dowels installed and approved at any orientation required by the Engineer. Distinction shall be made between dowels with straight ends or dowels with hooked ends for tying into concrete or sprayed concrete and dowels with bends for anchoring reinforced concrete structures. Distinction shall also be made between dowels and drill holes of different lengths and if galvanising is required.

The rate tendered shall include full compensation for the supply of all materials including the dowel, galvanising if required, grout, setting up equipment, drilling and cleaning out of holes, installation of dowels and the replacement of any damaged or ineffective dowels.

13.003 Mesh **Unit: square metre (m^2)**

Measurement for welded mesh reinforcement and double twisted wire mesh will be the net area, with no allowance for laps, of mesh fixed to the excavated surface based on an area measured on the theoretical excavation cross-section profile given on the Drawings.

The rate tendered shall include full compensation for the supply and installation including all holding down pins, spacers and spiders.

13.004 Sprayed concrete **Unit: square metre (m^2)**

Measurement of sprayed concrete will be the net area measured on the theoretical cross-section profile given on the Drawings at the specified thickness.

The rates tendered for application of sprayed concrete for various thickness specified shall include for all work required for the preparation of surfaces and application of sprayed concrete, all materials, any additional ventilation and lighting requirements, cleaning and disposal of rebound, thickness control measures, drilling of holes for checking thickness, all design and routine testing. Where ordered by the Engineer that the full specified layer be built up in separate layers, payment shall be made at the rates tendered for the separate individual layers.

13.005 Extra-over Item 13.004 for the addition of pigment **Unit: square metre (m^2)**

Measurement of pigment in sprayed concrete will be the net area measured on the theoretical cross-section profile given on the Drawings.

The rates tendered for application of pigment to sprayed concrete shall include for all work required for the addition of pigment to sprayed concrete.

13.006 Anti-floatation anchors for reinforced concrete structures **Unit: number (No)**

Measurement shall be by the number of Anti-floatation anchors of each type installed as specified, with distinction being made between different lengths and diameter of anchor embedded in rock and different inclinations.

The anchors used on this project: 40 mm diameter GEWI Pile, B500B and S555/700 up to 30 m in length (vertical).

The rate tendered shall include for setting up equipment for drilling, for the accurate drilling of holes, for the supply and installation of anchors complete, for grouting and for shear bolts where specified and for hot-dip galvanising where required. The cost of water testing, grouting and re-drilling where necessary shall also be included in the rate tendered.

13.007 Extra over Item 13.006 for additional length **Unit: metre (m)**

Measurement will be by the additional anchor length required through the foundation fill concrete.

The rate tendered shall include full compensation for all additional operations required to provide and install the additional anchor length.

13.008 Pressure relief holes **Unit: number (No)**

Measurement will be the number of pressure relief holes drilled as specified.

The rate tendered shall include full compensation for all operations required to drill a 38 mm diameter hole through sprayed concrete and 450 mm into rock.

13.009 Extra-over sprayed concrete for steel or synthetic fibre reinforcement **Unit: square metre (m^2)**

Measurement shall be the area of sprayed concrete measured which is reinforced with fibres at the specified thickness of sprayed concrete. Distinction shall be made between steel and synthetic fibres.

The rates tendered shall include for all labour, materials and other work required for the inclusion of steel fibres in sprayed concrete.

13.010 Barring down rock surfaces **Unit: square metre (m^2)**

Measurement shall be the area barred down.

The rate tendered shall include for all labour, equipment and materials and other work required to bar down the shaft wall and to remove the excavated material to stockpile.