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

TENDER NO 054/2024/PMID/MCWAP2/RFB

PART C3.1
SPECIFICATION

SECTION 18

DRILLING AND GROUTING

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SECTION 18

DRILLING AND GROUTING

18.1 SCOPE

This Section covers the planning and execution of drilling and grouting of foundations for structures requiring consolidation grouting and or the management of groundwater flow. The scope includes all aspects (labour, materials, equipment etc.), processes and procedures required for the execution of the tasks.

The jet grouting foundation treatment forms an integral part of this Section. It includes the following grouting processes:

a) Drilling of holes for grouting;

b) Pressure jet-grouting to control water seepage;

c) Pressure jet-grouting for ground improvement below the weir;

d) Pressure grouting of rock / concrete interfaces;

e) Pressure grouting of rock fissures and cavities;

f) Testing;

g) Stemming of grout holes; and

h) Cleaning up after grout operations.

This Section shall be read in conjunction with Section 1: General and Section 20: Structural Concrete.

18.2 DEFINITIONS, ABBREVIATIONS AND REFERENCES

18.2.1 Definitions

The following terms whenever used in this Section shall have the following meanings:

a) **"Cavity grouting"** means grouting to fill any voids at rock / concrete interfaces around structures.

b) **"Consolidation grouting"** means the injection of grout into fissured rock below the structure foundations to the depths specified on the Drawings.

c) **"Depth"** means the distance from the start of the hole regardless of direction.

d) **"Drain hole"** means the drilling of a hole in the rock to a specified depth and inclination for the purposes of draining water from the rock and preventing the build-up of water pressure in the rock.

e) **"Fissure grouting"** means using patterns of grouted holes in order to seal off water passages intercepting the excavation face or the structure foundations.

f) **"Grouting in descending stages"** means the procedure of drilling a hole to a limited depth, setting a packer and grouting the hole, permitting the grout injected around the hole to set sufficiently to prevent its entering the hole when the hole is cleaned, cleaning out the hole, drilling the hole to a deeper stage, setting a packer at the bottom of the previously grouted

stage or elsewhere as directed by the Engineer, grouting the new stage, and thus continuing in as many cycles of drilling and grouting as are required.

g) **"Grouting in ascending stages"** means the procedure of drilling a hole to full depth in one operation and grouting from the end of the hole towards the surface in successive stages by setting the packers at predetermined depths.

h) **"High pressure hammer action jet grouting"** means the combined application of high pressure hammer action drilling and jet grouting. The use of specialised jet grouting hammer heads are required for construction in difficult deep cobble and boulder matrix founding conditions.

i) **"Jet Grouting"** means an in-situ injection technique employed with specialized equipment that includes grout pump(s), grout mixer, drill rig, drill rods and injection monitor with 1, 2 or 3 horizontal radial nozzles delivering high velocity fluids to erode, mix, and stabilize in-situ soils and cobbles and boulders as a soil / aggregate cement matrix in the shape of a column.

j) **"Monitor" (adjusted for single, double, and triple systems)** means a single, double, or triple fluid drill pipe attached to the end of a drilling string and designed to deliver one to three elements of the Jet Grouting process, typically air, water, and grout. The monitor has one or more injection points (nozzles).

k) **"Parameters" m**eans the pressure of the fluid(s) within the jet grouting string; flow rate of the fluid(s); grout composition; rotational speed of the jet grouting string; and rate of withdrawal or insertion of the jet grouting string.

l) **"Soil / aggregate-cement structure"** means a single zone or block of jet grout elements (columns) that are partially or fully interlocked as indicated on the Drawings. Soil / aggregate cement structures shall be comprised of soil, cobbles and boulders, and cement elements (columns) of sufficient pattern and spacing as to stabilize the soil mass within the limits shown on the Contract Drawings to meet the performance requirements specified in this Section.

m) **"Stage"** means a partial or complete length of hole in which grouting is performed.

n) **"String"** means jointed rods with simple, double or triple inner conduit that conveys the jet grouting fluid(s) to the monitor.

18.2.2 Abbreviations

ASTM	:	American Society for Testing and Materials
BoQ	:	Bill of Quantities
BS	:	British Standard
CQC	:	Construction Quality Control
CSF	:	Condensed Silica Fume
FA	:	Fly Ash also known as Pulversised Fuel Ash (PFA)
GGBS	:	Ground Granulated Blast-Furnace Slag
GGCS	:	Ground Granulated Core Slag
L	:	Lugeon
MPa	:	Megapascal
MQC	:	Manufacturing Quality Control
PVC	:	Polyvinyl Chloride
OPC	:	Ordinary Portland Cement
RHPC	:	Rapid-Hardening Portland Cement
RPM	:	Revolutions Per Minute

SANS : South African National Standard
UFC : Ultra Fine Cement
UCS : Unconfined Compressive Strength

18.2.3 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.

18.3 GENERAL

The general requirements for drilling and grouting are shown on the Drawings. However, the final extent of the drilling and grouting will be determined by the conditions which are encountered during the progress of the work. The number, location, spacing, direction, inclination and depth of the drill holes, the order of drilling such holes, the pressure and mixtures to be used for grouting, the depths at which the grout will be injected, the sequence of grouting holes and the pressures for water testing shall all be as per the Contractors method statement as approved by the Engineer. Decisions on these matters will depend upon the nature of the rock encountered in the excavations.

The Contractor shall provide all labour, materials and equipment to accomplish the following items of work:

a) Mobilisation and demobilisation;

b) Drilling;

c) Foundation-grouting;

d) Jet grouting inclusive of the combined use of hammer heads where required;

e) Quality Assurance / Quality Control and verification; and

f) Spoil containment, collection and disposal.

The Contractor shall employ an approved specialist Subcontractor to carry out drilling and grouting work unless he can satisfy the Engineer that he is experienced in this type of work and possesses the necessary staff and equipment for the proper execution of the work. The Contractor shall arrange at all times that the drilling and grouting operations are performed under the direct supervision of foremen thoroughly experienced in this type of work and who will be responsible for ensuring that good practice according to the current state of the art is observed.

The required procedures as stated in the approved method statement shall be strictly followed and records shall be accurately kept. Failure of any operator to comply with this requirement shall be sufficient grounds to exclude him from carrying out further work.

Fourteen (14) days before starting any drilling or grouting work the Contractor shall submit to the Engineer for his approval full details of the equipment, methods and procedures to be employed by the Contractor for drilling and grouting operations and associated work.

The Contractor shall, as far as practical, programme the work such that drilling of holes and grouting take place at different times or on different shifts to facilitate oral communication during grouting

operations. Where this is not possible the Contractor shall install a sound absorbent partition between the drilling and grouting operations.

The Contractor shall provide for the adequate disposal of all wash water and waste grout resulting from all grouting operations. He shall not allow such water and grout to contaminate any fill, backfill or other works, and such water or grout shall not be allowed to flow into any water course until it has passed through settlement ponds or tanks approved by the Engineer.

The Contractor shall take all precautions necessary to prevent overheating of the grout in order to reduce the possibility of premature initial set.

18.4 OBJECTIVES

Two functional objectives are set for the integrated jet grouting systems application:

- To achieve a uniform founding condition by installing jet grouted columns adjacent to each other; and
- To achieve a water leakage barrier upstream of the weir, abstraction works and Low Lift Pump Station by installing overlapping jet grouted columns.

This will be achieved with Jet-Grouted columns in multiple rows as indicated on the Drawings. The Jet Grouting shall exhibit the following characteristics (Performance objectives):

a) Residual permeability of less than 1 Lugeon, i.e. a permeability (k) < 10^{-7} m/s;

b) The column matrix shall have a minimum Unconfined Compressive Strength (UCS) of 5 MPa;

c) The column grout quality shall exhibit a compressive strength of at least 20MPa at 7-days; and

d) Vertical and horizontal tolerances not exceeding 2% of the length of the column.

Two conventional grouting objectives are to provide for cavity and consolidation grouting operations that may be required at the pipe jacking operations or to reduce the seepage rate at the curtain upstream of the diversion weir.

18.5 GROUT

18.5.1 Materials

Grout for injection under pressure shall consist of a mixture of Ordinary Portland Cement (OPC), Rapid-Hardening Portland Cement (RHPC), Ultra Fine Cement (UFC), Fly Ash (PFA), Ground Granulated Blast-Furnace Slag (GGBS), Condensed Silica Fume (CSF), water and, where required by the Engineer, sand, or other additives, including bentonite, in proportions as approved by the Engineer and as applicable for different applications.

Materials for grouting shall comply with the requirements of Section 20 - Concrete Works (Structural) and in addition, the following Clauses 18.5.1.1 to 18.5.1.5:

18.5.1.1 Cement (CEM), Fly Ash (FA) and Condensed Silica Fume (CSF)

Cement shall be type CEM I Class 42.5 N (OPC) or CEM I Class 52.5 N (RHC) or Class 42.5 R (RHC) to SANS 50197-1 and passing a 0.090 mm sieve, and not more than 10% shall be retained

on a 0.045 mm sieve. The Blaine fineness shall be greater than 440 m^2/kg. Ultra fine cement shall have a Blaine fineness greater than 700 m^2/kg.

Fly Ash (Pulverised Fuel Ash) and Condensed Silica Fume shall also conform to the requirements of SANS 50197-1.

18.5.1.2 Sand

Sand shall comply with the requirements of Section 20 – Concrete Works (Structural); except that all sand shall pass a 2.36 mm sieve and not more than 10% shall pass a 0.075 mm sieve.

18.5.1.3 Water

In addition to the requirements of Section 20 – Concrete Works (Structural), water for grouting shall not contain organic matter in suspension or solution and shall contain no particles larger than 80 microns. The temperature of the water immediately prior to the preparation of grout shall be in the range of 5˚ to 35˚C.

18.5.1.4 Bentonite

Bentonite used in bentonite / cement grout shall have a Plasticity Index greater than 400. It shall be supplied from an approved source. Test certificates of the properties of the bentonite supplied shall be made available to the Engineer on request. When mixed with water the bentonite shall not contain any particle larger than 75 microns and shall not contain any substance detrimental to the setting and hardening of the bentonite / cement.

The Contractor’s arrangement for delivery and storage of bentonite shall comply with the requirements of Section 20 - Concrete Works (Structural) referring to the delivery and storage of cement.

The Contractor shall store on Site sufficient bentonite to satisfy grouting requirements for at least ten days.

The bentonite / water slurry base shall be prepared in advance using cement-free water in a high turbulence (colloidal) mixer and shall be kept agitated in a large container for at least 24 hours. Mixers used for grout shall not be permitted to mix the bentonite / water slurry.

18.5.1.5 Admixtures

Admixtures used shall comply with ASTM C-494, ASTM C260 or BS EN 934. Admixtures, such as plasticisers, accelerators and retarders, may be used only with the approval of the Engineer. In support of the request for the use of an additive the Contractor shall submit the results of relevant laboratory tests demonstrating the effectiveness and advantages of the product. Products whose chemical composition is not made known to the Engineer will not be approved for use in grout.

18.5.2 Testing

The Contractor shall provide approved Marsh flow cones, thermometers, mud balance and measuring cylinders (60 mm diameter) to enable the Engineer to check the consistency of the grout at any time. The applicable limits shall be jointly established by laboratory and field tests prior to work commencing.

18.5.2.1 Relative Density (Mud Balance)

Determination of the relative density of freshly mixed grout shall be with a mud-balance. Readings of relative density taken directly from the calibrated beam shall be converted to a water cement ratio by means of an agreed curve or table.

18.5.2.2 Viscosity (Flow Cone)

The fluidity of grout shall be measured with a flow cone, immersion apparatus or viscometer. The instrument shall be accurately calibrated in a laboratory so that the specified viscosity of the grout can be controlled satisfactorily.

The procedure for conducting the flow-cone test for measuring the fluidity of grout shall be as follows:

a) The type of flow cone shall be subject to the approval of the Engineer;

b) Immediately after the grout has been mixed, the pre-wetted flow cone, which is held firmly with its top rim in a level position, shall be filled with grout to the level indicated by the pre-set pointer, whilst the bottom orifice is held closed with a finger;

c) As soon as the required volume of grout, (± 1 750 mℓ), is reached, the finger shall be released to allow the grout to flow out freely through the bottom orifice. A stop watch shall be used to determine the flow time for emptying the cone, to the nearest second; and

d) The readings obtained during grouting shall be compared with the times determined in the laboratory for grouts of the specified viscosities.

18.5.2.3 Bleeding

The bleeding of grout shall be measured in a metal or glass container with an internal diameter of approximately 100 mm and a height of approximately 120 mm. The grout and water levels in the container shall be controlled with a metal bridge into which two adjustable studs A and B are secured.

The procedure for determining the bleeding of grout shall be as follows:

a) Studs A and B in the metal bridge shall be adjusted and locked so that the distance from the lower tips of the studs to the bottom of the container will be approximately 100 mm and 107 mm respectively. The volumes V_A and V_B for the container at the respective levels of the stud settings shall then be determined to the nearest millilitre;

b) The container shall be filled with freshly mixed grout to a level where the grout will just touch the tip of stud A which points downwards. The bridge shall then be removed and the container tightly sealed to prevent evaporation. The container shall then be stored at 20°C and kept free from vibrations for the entire duration of the test;

c) Three hours after the grout has been mixed, the container shall be opened and the free (bleed) water poured off. The bridge shall be placed over the container with the tip of stud B pointing downwards and water poured onto the grout with a measuring apparatus until the water level touches the tip of stud B. The volume of water added shall be determined to the nearest millilitre and designated as ΔV; and

d) The percentage of bleeding shall be calculated from the formula:

$$100 - \{(V_B - \Delta V)/ V_A\} \times 100$$

18.5.2.4 Test Cubes

For grout in production at each grout mixing station for use in the Works, samples of grout shall be taken by the Contractor at the point of mixing or of deposition as instructed by the Engineer and in the presence of an assistant of the Engineer, all in accordance with the sampling procedures described in SANS 5862.

Samples shall be taken on the basis of one for each 50 m^3 of grout pumped but in any case not less than one sample per day per mixing station.

The Contractor shall cast from each sample, cure and test six test cubes as set out in SANS 5863. Three (3) cubes shall be tested at 7 days and three (3) cubes at 28 days.

The average strength of the 3 cubes crushed shall be referred to as one test result.

Grout shall be deemed to comply with the strength specified if the average strength of any 4 consecutive test results exceeds the agreed characteristic strength by 2 MPa and the strength of any test result is not less than the specified characteristic strength minus 3 MPa.

The quantity of grout represented by any group of four consecutive test results shall include the batches from which the first and last samples were taken together with all intervening batches. When a test result fails to comply only the particular batch from which the sample was taken shall be deemed to fail to comply.

The Contractor's methods of sampling, making of cubes and testing shall not be considered as a valid reason for rejecting the results of such tests on grout placed in the Works. Should test results fail the remedial measures referred to in Section 20 - Concrete Works (Structural) shall apply.

18.5.2.5 Jet Grout Cores

Cores shall be taken from at least 10% of the jet grouted columns to test compressive strength as well as consistency. The drilling, core recovery and preparation and compressive testing shall comply with SANS Method 865. The positions of the core sampling shall be agreed with the Engineer.

18.5.3 Mix

The grout mix is specified as the ratio of water to cementitious material by mass. In principle a single grout mix shall be used for the grout curtain irrespective of depth of hole and location. However, the Engineer may require a thicker mix for use in zones of high take and a thinner mix for special cases. In case of major absorptions a cement mortar mix approved by the Engineer shall be used. The Contractor may, however, propose an admixture to render the grout thixotropic instead of using sand.

The appropriate grout mix shall be determined on the basis of grout tests prior to the commencement of the trial panels.

In carrying out the laboratory tests the mixing equipment to be used on the grouting works shall be used. Bentonite slurry shall be prepared in accordance with Clause 18.5.1.4 above.

Any grout which does not contain a retarder and has not been used within one hour of the time of mixing shall be discarded and disposed of in a manner approved by the Engineer.

Initially, grout tests shall be carried out on mixes with water/cement (W:C) ratios of 0.8:1, 0.7:1 and 0.6:1, aiming to provide stable mixes with less than 5% settlement at 2 hours and Marsh cone values of about 35 seconds. Admixtures may be used to reduce Marsh Cone values.

Compressive strengths at 7 days shall be greater than 20 MPa on 100 x 100 x 100 mm cubes cured under water. One set of cubes shall be tested per day until consistency of results allows testing intervals to be increased.

All grout shall be mixed in a high speed colloidal mixer for at least 1½ minutes from the time the last constituent is added to the mixer.

During grouting operations the following routine tests in accordance with Clause 18.5.2 shall be performed at the collar of the hole as directed by the Engineer:

- Density - Mud balance test.
- Viscosity - Marsh Cone.
- Bleeding - 60 mm diameter measuring cylinder.

The Contractor shall make arrangements for a location close to the hole being grouted where the bleeding test will not be disturbed.

18.6 EQUIPMENT

18.6.1 General

The Contractor shall provide sufficient drilling and grouting equipment and all necessary ancillary equipment, scaffolding and other accessories to complete the various types of drilling and grouting required. Such equipment shall be of types and capacities acceptable to the Engineer and shall be maintained in first class operating condition at all times.

Where equipment is air driven the Contractor shall provide sufficient compressors such that all equipment in use can operate together at the necessary pressure.

Equipment shall be suitable for operation on surface as well as in underground locations. The use of internal combustion engines for grouting in shafts will not be permitted.

For Jet Grouting applications all equipment used for drilling boreholes; lowering, raising and rotating jet monitors; mixing grout; supplying pressurized grout and air-water to jet monitors; and jet monitors shall have proven performance records for use in Jet Grouting work. Jet grouting equipment shall have the capacity to construct columns of between 600 mm and 1000 mm diameter up to 40 m depths in boulder matrix founding conditions. The combination of a down-the-hole hammer with an integrated jet monitor enables drilling and jet grouting in difficult formations. In this regard the Wassara high pressure hammer action jet grouting equipment or similar approved shall be used.

18.6.2 Drilling Equipment

18.6.2.1 Percussion Drills

Percussion drills shall be capable of drilling holes at not less than 38 mm diameter up to 50 m in length. Such drills shall be provided with a water supply at a minimum pressure of 8 bar at the drill, when all equipment on the same supply is operating together.

Rotary-percussion drilling equipment will be required that is capable of advancing a steel casing through overburden simultaneously while drilling through soil and rock, and allowing the drill string to be withdrawn through the casing.

The circulating / flushing medium shall be high-pressure water. Air flushing will only be permitted in exceptional circumstances, subject to the Engineer's approval.

Drilling with side-discharge bits will not be permitted for conventional percussion drilling.

For Jet Grouting applications, drilling equipment of a type and capacity suitable for drilling required hole diameters and depths, and lowering, raising, and rotating jet grout monitors to the depths and at the rates required to perform the work as shown on the Contract Drawings and as specified herein. The drill rig shall be equipped with automated controls to regulate and maintain consistent rod retraction rate, rod RPM and have pressure gauges for all fluids injected. The combination of a down-the-hole hammer with an integrated jet monitor enables drilling and jet grouting in difficult formations. In this regard the Wassara high pressure hammer action jet grouting equipment or similar approved shall be used.

18.6.2.2 Diamond Drills

A limited number of holes will require rotary diamond drilling with coring in rock or jet grouted concrete. The core diameter should not be less than BX size, and the diameter of the drilled hole and the steel casing through the overburden should be compatible with the pneumatic packers specified. In the case of the jet grouting cores the minimum diameter of 65mm is determined by SANS Method 865.

18.6.3 Water Testing Equipment

The water testing equipment should comprise a water tank, a progressing helical cavity pump (i.e. Mono type), a pressure hose, two pressure gauges capable of operating independently (one calibrated in kilopascals with a maximum capacity of 1000 kPa in 20 kPa divisions, the other calibrated in bars with a minimum capacity of 20 bars in 1bar divisions), a water meter calibrated in litres with 0.1 litre divisions, a bypass valve for pressure control, a pneumatic packer, and a nitrogen bottle and hose. This would usually be the same equipment that is used for the actual grouting operation.

18.6.4 Grouting Equipment

18.6.4.1 General

Grouting equipment shall be capable of effectively batching (with an accuracy of better than 2% for batching by volume or mass), and producing a colloidal mix as specified, and of delivering and pumping grout into the grout holes through grout connections in a continuous uninterrupted flow at any constant pressure up to the limiting pressure specified. Where required, equipment shall be protected against direct sunlight.

The arrangement of the grouting equipment shall be such as to provide a continuous circulation of grout of uniform consistency throughout the grouting system and to permit accurate pressure control at the collar of the hole being grouted at all rates of grout acceptance. Pressure gauges and valves shall be supplied at the pump, at each hole being grouted, and elsewhere as required to ensure the necessary control of grouting operations. In the case of all grouting activities automatic pressure / time and flow / time and total volume chart recorders shall be connected at the collar of

each hole being grouted unless otherwise agreed by the Engineer. A new chart shall be used for each hole injected. All grouting circuits shall be so designed as to provide a return line from the site of injection to the holding tank such that a continuous flow of grout is maintained in the delivery line between the grout pump and the collar of the hole being injected.

Grouting equipment shall be to the minimum requirements given in Clauses 18.6.4.2 to 18.6.4.14 and shall include all associated valves, water flow meters, pressure hoses, pipes, sleeves, packers, fittings and small tools necessary to complete the grouting as specified.

Constituent materials of the grout shall not segregate during transportation.

For Jet Grouting applications the Contractor shall use grout mixers and holding tanks, water tanks, air compressors, and pumps of sufficient capacity to ensure adequate supply of grout, air, and water at required pressure to the Jet Grouting monitors during a full work shift to produce grout elements of the quality and dimensions necessary.

In general grout mixers shall be high shear type and shall be equipped with load cells to accurately weigh and proportion each component of the grout mix for low flow applications. Under no circumstances shall paddle type mixers be utilised.

The combination of a down-the-hole hammer with an integrated jet monitor enables drilling and jet grouting in difficult formations. In this regard the Wassara high pressure hammer action jet grouting equipment or similar approved shall be used.

18.6.4.2 Pumps

Grouting pumps shall be double acting reciprocating, with pressure damping cylinder, positive displacement screw-feed or other type of pump acceptable to the Engineer.

The rate of pumping shall be readily and accurately adjustable from zero flow to the maximum capacity. Equipment shall be such that grout consistency can be adjusted without causing an interruption that could result in setting of grout before pumping is resumed.

Pumps shall be equipped with quick acting lubricating plug valves and accurate pressure gauges, reading in bars. Pumps shall be fitted with automatic pressure relief valves unless otherwise agreed by the Engineer.

Grout pumps shall be capable of pumping grout at a water/cement ratio of up to 1:3 as well as grout containing other materials such as bentonite, sand or other chemicals.

Jet-Grouting pumps shall be capable, with the nozzles proposed, of providing the required velocity and a delivery rate required for the execution of the work.

18.6.4.3 Mixers

Grout mixers shall be of the high speed colloidal type, with a minimum of 1200 rpm, designed primarily for mixing grout materials, including grout to which sand or additives have been added if required, and of sufficient capacity to ensure that the pumps are supplied with a continuous flow of thoroughly mixed grout.

18.6.4.4 Jet Grout Mixing and Injection Equipment

The Contractor shall use grout mixers and holding tanks, water tanks, air compressors, and pumps of sufficient capacity to ensure adequate supply of grout, air, and water at required pressure to the Jet Grouting monitors during a full work shift to produce grout elements of the quality and dimensions necessary.

18.6.4.5 Injection Manifold (Header)

The header should be equipped with two full-flow ball valves. One valve is located on the return circulation side of the header and diverts grout flow into the hole, while the other is located on the hole side of the header and is used to control the pressure when the return valve is fully open.

A union and a shut-off valve should be placed between the gauge and the hole to allow the grout lines to be removed when refusal pressure is reached, while maintaining pressure on the hole.

The individual components of the jet grouting equipment provided shall be capable of supporting the integrated system required to produce the jet grouted columns to the agreed parameters.

18.6.4.6 Tanks

Tanks for holding grout between mixing and grout injections shall be of the double drum type equipped with mechanical agitators capable of maintaining the solids of the grout in suspension. The feed into the tanks shall be equipped with adequately sized screens to remove any hardened grout or foreign material larger than 1 mm from grout entering the tanks from the mixers and from the grout return lines. The capacity of the holding tanks shall be not less than that of the grout mixer and the tanks shall be fitted with a graduated dip-stick or gauge glass which is capable of recording the volume of grout contained in the tank to within 2 litres.

The individual components of the jet grouting equipment provided shall be capable of supporting the integrated system required to produce the jet grouted columns to the agreed parameters.

18.6.4.7 Water Meters

Meters for the measurement of water to be used in grout mixes shall be large faced with adjustable volume markers graduated to read to an accuracy of one tenth of a litre at all rates of flow.

18.6.4.8 Flow Meters

Integrating flow meters capable of measuring volumes of grout injected during grouting operations to an accuracy of ± 2% shall be coupled to each grout pump unless otherwise agreed by the Engineer.

18.6.4.9 Pressure Gauges

Pressure gauges shall be capable of reading to an accuracy of 0.10 bars and shall be equipped with devices which will protect the mechanism of the gauge from being damaged by grout. The gauges shall have a range of approximately twice the expected maximum pressure for the particular hole and shall have an accuracy of ± 3%.

Gauges shall be provided at the grout pump and at the point of injection.

The Contractor shall have an accurately calibrated high-precision pressure gauge for checking the accuracy of all pressure gauges used in the grouting system.

A certified pressure gauge for calibration of working gauges and a 100% replacement stock of working gauges shall be on hand at all times. Working gauges shall not be used for longer than two shifts, hereafter they shall be cleaned and calibrated. All working gauges shall be marked with a number for identification.

The individual components of the jet grouting equipment provided shall be capable of supporting the integrated system required to produce the jet grouted columns to the agreed parameters.

18.6.4.10 Chart Recorders

Pressure/time chart recorders shall have a one hour time period and a pressure range of approximately twice the maximum specified pressure.

Chart recorders shall be connected at the collar of each hole such that the pressure in the hole is continuously recorded throughout the injection period.

18.6.4.11 Packers

Packers shall consist of pneumatic or hydraulic expandable tubes which can be set singly in a grout hole at any depth required. Packers shall be so designed that they can be expanded to seal the holes at the specified depths and that when expanded they shall be capable of withstanding without leakage, water pressures equal to the maximum grout pressures to which they will be subjected.

The Contractor shall also have double packers of the pneumatic or hydraulic type at least 1 m in length available for use when instructed by the Engineer.

18.6.4.12 Sleeve Pipes

In areas where grouting is to be carried out through concrete, PVC sleeves will be required through which drilling can be undertaken and into which packers can be installed or to which grout connections can be made.

18.6.4.13 Grout Stops

Grout stops shall be provided in locations where grout may escape to surface during grouting and where grouting is to be undertaken in compartments. The grout stop shall consist of geo fabric as approved by the Engineer.

18.6.4.14 Grouting Delivery Lines

All grout pipes, hoses and fittings shall be capable of withstanding a pressure of 5 bars and shall be protected from damage or breakage by vehicles, equipment, blasting operations, freezing and the like. A return line shall be provided for flushing hoses, to control the rate of pumping and for emergency pressure relief. These return lines shall be connected to the pump side of the recorder gauges at the collar of the grout hole and shall discharge into the holding tanks or to waste containers only. The Contractor will not be permitted to discharge grout without such collectors.

The length of grouting hose from the grout pumps to the hole to be grouted shall not exceed 300 m.

18.6.4.15 Standby Equipment

During curtain grouting, the Contractor shall have available at all times 100% standby equipment of all types to ensure that grouting operations can be continued without significant interruptions caused by breakdowns of equipment.

Circuits shall be provided such that standby pumps can be brought into operation within 10 minutes.

18.6.5 Communication during Grouting Operations

Where the various individual elements of the equipment are located in such positions that communication by normal voice between the hole being injected and the equipment is not satisfactory the Contractor shall install an effective means of clear oral communication such as a telephone or radio system to the satisfaction of the Engineer. If acceptable communication systems are not available the Engineer will stop the work until such system of communication is affected.

18.7 DRILLING PROCEDURES

18.7.1 General

The position, direction, inclination, spacing, depth, order and timing of drilling holes for drain holes or grouting, shall be as shown on the Drawings or as directed by the Engineer. The holes shall be drilled straight in the required direction and inclination, and the length of holes shall be established by reference to the collar level and profiles recorded by the Contractor or Engineer. Descending stage drilling and grouting will be executed in rock, the maximum stage length being 5 metres.

Unless otherwise required, holes shall be started within 250 mm of the specified position or plan or section and shall be drilled in the direction specified within a tolerance of 2% of the length of the hole. No hole shall be deepened or drilled within 5 m of freshly grouted holes until the Engineer is satisfied that the grout in the rock adjacent to the hole has set sufficiently to prevent it being washed into the hole.

Where water return drops below 50%, drilling shall be stopped and the hole grouted to within 0.5 metre of the point where water loss occurred. The same applies when artesian conditions are encountered or surface leakage occurs. Caving zones should be grouted after each drill run when they are encountered. Under all of these conditions the normal descending stage grout injection procedures and thickening sequence specified should be followed, and on no account should the hole be stemmed with a thick grout immediately on these conditions being encountered.

Holes shall be drilled wet and a constant flow of return water, sufficient to ensure that all drill grindings and sludge are completely washed out, shall be maintained at all times. Except where approved by the Engineer, the Contractor will not be permitted to use rod lubricants or other additives to the drilling water as an aid to drilling or stabilising the holes.

Where packers are to be used in any hole for grouting or water testing, the Contractor shall take every precaution to maintain a smooth wall in the hole in order that packers can be set at any location required by the Engineer.

The Contractor is to ensure that holes are protected against contamination by waste grout, soil, etc.

18.7.2 Holes through Concrete

Where holes are required through concrete, the Contractor will be permitted either to drill the holes or where indicated on the Drawings or as instructed by the Engineer shall embed PVC sleeves in the concrete through which the rock behind can be drilled.

No drilling shall be carried out in concrete less than 7 days old.

In the case of reinforced linings, the formwork shall be marked by means of plugs or in some other way approved by the Engineer to indicate positions where drilling may be carried out without obstruction by reinforcement.

Should steel reinforcement be encountered during the drilling of any hole in concrete, where required by the Engineer, drilling shall be discontinued immediately and a new hole shall be drilled alongside. Such discontinued holes shall be stemmed as specified in Clause 18.12. Where it is acceptable to drill holes through reinforcement, rates for drilling through concrete shall include the possibility of drilling through reinforcement.

18.7.3 Percussion and Rotary Core Drilling

Percussion drilling shall be used for cavity grout holes and reinforcement anchors, dowels and rock bolts as and where directed by the Engineer.

Percussion holes shall be flushed clean in terms of Clause 18.7.5.

All holes shall be drilled within the specified tolerances.

A limited number of holes will require rotary diamond drilling with coring in rock. The core diameter should not be less than BX size, and the diameter of the drilled hole and the steel casing through the overburden should be compatible with the pneumatic packers specified.

18.7.4 Drainage Holes

Unless otherwise directed, drain holes shall be drilled by percussion drilling and flushed clean. The holes shall be drilled to the diameter and in the direction, inclination and location as indicated in the Drawings or directed by the Engineer.

Drainage holes shall not be drilled until all grouting required within the vicinity has been completed to the satisfaction of the Engineer.

18.7.5 Washing, Protection and Identification

When drilling of a grout or drain hole has been completed to its final depth, the hole shall be washed with high pressure water to remove all drill cuttings, sediments, sludge and other loose or foreign materials until the return water is clear, and all downward holes shall be left filled with water to the surface, or to such level as the water will stand.

Each grout hole shall be protected from becoming clogged or obstructed until it is grouted and, where a grout pipe or standpipe is permanently embedded in rock or concrete, the Contractor shall provide a suitable cap to keep the hole sealed. Whether or not a grout pipe or standpipe is used, any hole which becomes obstructed before being grouted shall be cleared or re-drilled to the satisfaction of the Engineer without any additional payment.

Each grout hole shall be numbered as required by the Engineer to permit identification of each hole at all times until grouting and checking has been completed in the area.

18.7.6 Loss of Holes

If jamming of a hole or other cause makes continuation of the drilling impossible the Contractor shall immediately inform the Engineer and request instructions for siting of a substitute hole or otherwise. If the Engineer considers the desired purpose of the hole has been achieved no substitute hole will be necessary.

Should any hole become clogged before its intended purpose has been fulfilled and cannot be cleared to the satisfaction of the Engineer, it shall be replaced at the Contractor's expense.

Abandoned holes shall be washed out and grouted.

18.7.7 Pattern and Sequence for Grout Curtain

The primary hole spacing will be as shown on the Drawings, the holes serving initially as exploratory holes to confirm the need for more extensive grouting.

After completion of water acceptance tests and grouting of the primary holes, secondary holes will be drilled midway between primary holes, then tested and grouted if the test results exceed 1 Lugeon. This split-spacing sequence will be continued to tertiary holes, quaternary holes etc. until the required reduction in permeability (<1 L) is achieved. Within any section of the curtain being grouted, no secondary hole will be drilled until the primary holes on either side have been grouted and the initial set of the injected grout has taken place. The same restrictions apply to higher order holes.

18.8 WATER PRESSURE TESTING

In all holes each grouting stage is to be preceded by a water acceptance test, primarily to determine whether or not grouting of that stage is necessary.

The Lugeon value for each test is determined as follows:

$$\text{Lugeon value} = \text{water take in litres/metre/minute} \times \frac{10 \text{ bars}}{\text{Test pressure in bars}}$$

18.8.1 Five-minute Test

A single five-minute test for each grouting stage (or packer setting) will be sufficient in most cases.

At any packer setting water is run into the hole to verify that a tight seal has been achieved at the required pressure for that stage. A start reading is then taken at the water meter and at each minute thereafter for a total of five minutes, while the required pressure is maintained. The test period should be shortened if open hole conditions are found. The test result is reported as a Lugeon value.

During ascending stage grouting, succeeding higher stages can be tested immediately after the back-pressure has dissipated following completion of grouting of the preceding stage.

If it is not possible to seat the packer at the desired depth when grouting in ascending stages, the location may be adjusted upwards in 0.5 metre increments to a maximum of 2 metres above the planned depth, after which a longer soft rubber packer should be used. Where the water is bypassing the packer in highly fractured rock, in which case it will be necessary to raise the packer to a point above the fractures. If this condition persists during ascending stage grouting, it will be necessary to execute the drilling, testing and grouting operations in descending stages.

18.8.2 Fifteen-minute Test

In order to determine whether void-filling, washout or foundation uplift is occurring, it will be necessary to conduct a fifteen-minute test. After the final reading of a five-minute test, the pressure is reduced to zero and the test repeated for a second and third time. The test result is reported as three Lugeon values.

18.8.3 Comprehensive Lugeon Test

The comprehensive Lugeon test will only be carried out on the instruction of, and witnessed by an assistant of the Engineer.

The test entails recording the water take over a period of ten minutes at low pressure, then at medium pressure for the same period, then at high pressure for the same period before repeating at medium pressure and finally at low pressure. Start and finish readings are taken on the water meter at each pressure stage and the constant pressure for the stage is recorded. Pressures are not reduced to zero between increments. The test result is reported as a single Lugeon value after interpretation of the five individual Lugeon values.

18.8.4 Acceptance Criteria

Any stage drilled that has a water test result above 1 Lugeon shall be grouted. This applies to all holes, i.e. primary, secondary, etc.

18.9 GROUTING METHODS

Descending stage grouting will be employed, unless otherwise instructed by the Engineer, in which case ascending stage grouting will most probably be employed.

18.9.1 Grouting Procedures

18.9.1.1 General

Grouting will generally be undertaken with a stable mix to be determined in the laboratory (see Clause 18.5).

Careful control of pressures will be required during grouting as excessive local pressures could crack or buckle the concrete or hydro-fracture the rock. Pressure chart recorders shall be used during all such injections. Pressures shall be limited to those shown on the Drawings or agreed with the Engineer for individual sections of the Permanent Works and different grouting procedures. At no time shall grout from any one pump be injected into more than one hole at a time.

Equipment for mixing, holding and pumping the grout shall be kept as close as possible to the area being grouted and all pipelines and hoses between such equipment and the area being grouted shall be protected wherever necessary to reduce temperature build-up in the lines and the grout.

Grouting of any drill hole within 20 m of a concrete structure or which extends through concrete shall not start until the foundation concrete in the structure is a least 14 days old.

In the event of drilling water ceasing to return (total or partial water loss), drilling shall be interrupted, the packer placed one metre above the leak and the hole grouted irrespective of depth reached, and drilling resumed.

During grouting the Contractor shall take every precaution to prevent the grouting equipment and lines from becoming blocked. He shall accordingly continuously circulate the grout and periodically flush the system with water.

After grouting each scheduled hole, the remaining neighbouring hole shall be cleared of grout by washing or re-drilling as soon as the grout in the rock adjacent to the hole has set sufficiently to prevent it being washed into the neighbouring hole. Any re-drilling required to clear the grout in a hole completed prior to re-grouting shall be performed by the Contractor to the satisfaction of the Engineer without any additional payment, except where grout has been allowed to set in a stage by direction of the Engineer.

If a hole absorbs an abnormal amount of grout without reaching the maximum specified pressure the Contractor shall inform the Engineer immediately and the rate of injection shall then be reduced or injection shall be carried out intermittently or such other procedure as may be agreed with the Engineer shall be adopted.

While grouting is proceeding the Contractor shall watch for leakage of grout or other untoward happenings. Grout leaks shall be caulked but if this cannot be achieved and the leaks are excessive, grouting shall be stopped and resumed later when the grout already injected into the leaking fissures has hardened. The Engineer may order the establishment of level reference points, upheaval gauges, etc., to be observed as a check against uplift. Any appreciable movement shall be taken as an indication that the grout pressures being used are excessive and they shall be immediately reduced.

The Contractor’s grouting programme shall be such that there is no risk of permanent drains such as pipe drains, or pressure relief drains being blocked by grout. All grouting works shall be completed in any area before permanent drains or drain holes are constructed.

If the pipework or any other part of a drainage system becomes blocked by grout, injection shall be stopped and the whole system shall immediately be flushed out with clean water and all grout removed before injection is recommenced.

The temperature of the grout during mixing and grouting shall not exceed 30ºC or be lower than 10ºC.

In general no holes shall be left open whilst other holes in the vicinity are being grouted. The number of holes to be drilled at any time shall therefore be limited to the number which can be grouted simultaneously with the equipment provided. When drilling is interrupted or completed, holes shall be fitted with removable plugs or caps to prevent the ingress of foreign matter. When instructed by the Engineer a steel pipe shall be securely grouted or caulked into the hole and shall be protected by a screw cap.

Upon completion of the grouting all concrete, steel or foundation surfaces over which grout has flowed shall be cleaned and restored to their original condition.

All grouting operations shall be performed in the presence of the Engineer.

18.9.1.2 Surface Leaks and Inter-hole Connections

If, during the grouting of any hole, grout is found to flow from nearby grout holes the holes shall be left open until the grout emerging is of the same consistency as the grout being injected whereupon the holes shall be closed and injection continued to completion, provided the pressure in the interconnected holes does not exceed the maximum pressure specified for those holes.

If, during the grouting of any hole, grout is found to flow from cracks and fissures in the rock surface, such flows or leaks shall be plugged or caulked by the Contractor as directed by the Engineer. The Contractor shall have available on Site at all times sufficient wooden wedges, sacking, lead wool and other materials which can be used to seal surface leaks.

18.9.2 Curtain Grouting

18.9.2.1 Descending Stage Grouting

Descending stage grouting is used where the rock is weak or highly fractured and needs to be consolidated at higher levels before grouting the lower levels at high pressures. This entails drilling the grout hole to a specified limited depth, placing a packer at the top of the hole and grouting prior to drilling the hole to a greater depth and repeating the process. The grout is usually washed out of the hole after initial set to minimise re-drilling. Unless otherwise instructed by the Engineer, the packer for succeeding stages will be set at the top of the preceding stage, and not at the top of the hole.

Descending stage grouting in fractured rock is conducted in a series of steps in which the entire split-spacing sequence is completed to closure for the stage being grouted before any hole is deepened. Deepening to each lower stage is stepped back by a distance equal to the primary hole spacing, i.e. the area covered by the final (deepest) stage is smaller than the area of the first (highest) stage.

Should preliminary results indicate that conditions are less severe than anticipated, the Engineer may order that only the first stage be executed by descending stage, after which the hole may be drilled to the full depth and the remaining stages be done by the ascending method. In strong rock or in rock being grouted below deep overburden, the Engineer may instruct that the ascending method be used, with the packer for the final (highest) stage being set within the bottom of the temporary casing.

18.9.2.2 Ascending Stage Grouting

The hole is drilled continuously to the full planned depth prior to water testing and grouting. Water testing and then grouting commences with the packer placed at the top of the lowest grouting stage. When this stage has been water tested, grouted to refusal and the backpressure has dissipated, the packer is raised to the top of the next stage up and the process repeated.

In order to prevent clogging of fine fissures by thickened grout remaining in the packer pipe following completion of the preceding stage, the packer pipe and the upper part of the grout hole should be flushed with water each time the packer is released preparatory to being raised to the next setting position.

18.9.2.3 Mixing

The correct quantity of water should be metered into the mixer and, if bentonite is being used, the required quantity of bentonite should be sifted slowly into the water while the mixer is operated at full speed. Mixing should continue for **at least 5 minutes*** to achieve optimum dispersion and hydration, before adding the cement in a similar manner. The pump should then be kept at full speed for **not more than one minute**** before discharging through a screen into the agitator.

**Adding cement to the bentonite slurry will "kill" the hydration of the bentonite, so it is very important to allow sufficient mixing of the bentonite and water before the cement is added.*

***The mixing time of cement should not exceed 1 minute, nor should the colloidal mixer be used as an agitator, because sufficient heat is generated in the colloidal mixing process to cause premature hydration of the cement. This may prevent the grout from setting properly after injection.*

18.9.2.4 Grout Injection

The following stable bentonite-cement mixes are to be used. Bentonite must be hydrated in the high-speed colloidal mixer for 5 minutes before the OPC is added:

2:1 Mix: 120 litres water + 3 kg bentonite + 50 kg OPC.

1:1 Mix: 70 litres water + 3 kg bentonite + 50 kg OPC.

1:2 Mix: 45 litres water + 3 kg bentonite + 50 kg OPC.

After carrying out the water test, the water should be chased out of the circulating hoses with grout and injection of the thinnest grout mix commenced (water: cement ratio = 2:1 by weight). The volume of grout injection and the mix injected should be recorded at regular intervals. Unless refusal pressure is reached first, 10 No. 50 kg pockets OPC should be injected at 2:1 before thickening to 1:1, regardless of how rapidly the hole accepts grout.

Unless otherwise instructed, the quantity of each mix injected into any stage before thickening to the next mix should be:

2:1 Mix: 2 x 50 kg OPC per metre of stage length, or refusal pressure.

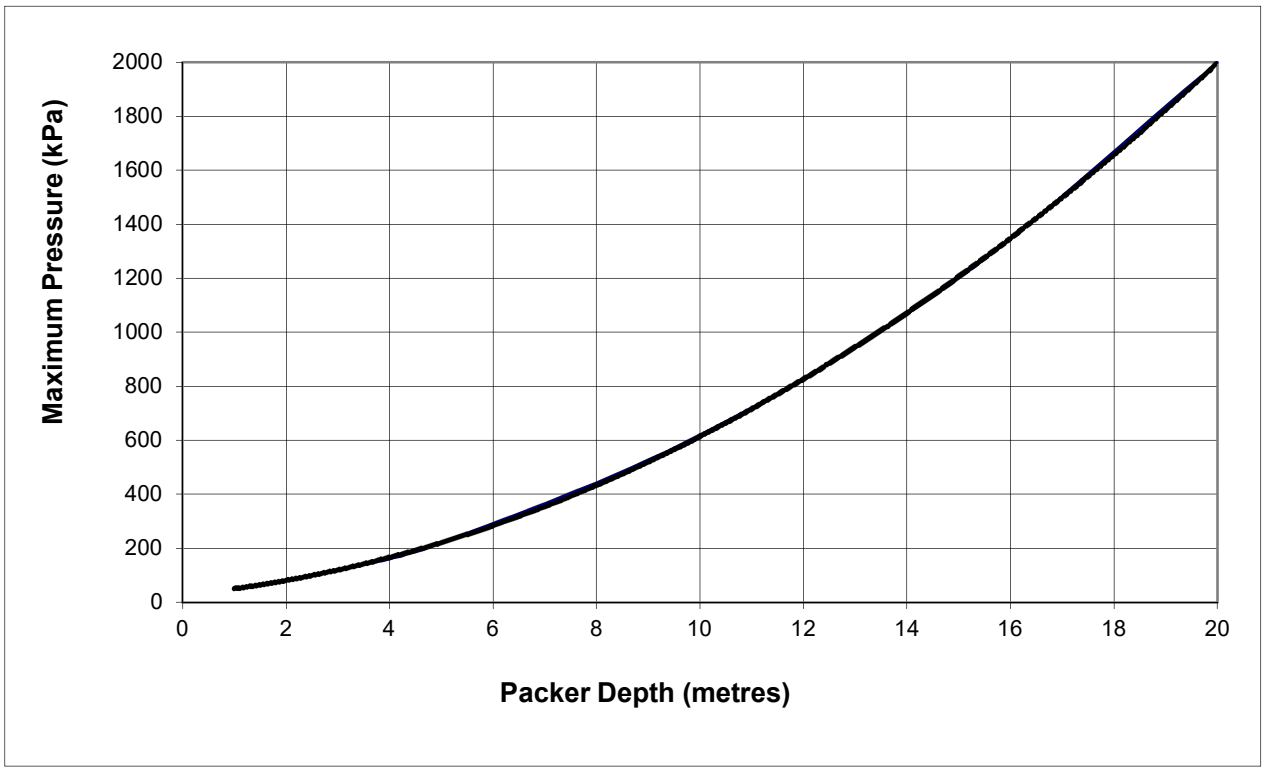
1:1 Mix: 10 x 50 kg OPC per metre of stage length, or refusal pressure.

2:1 Mix: 20 x 50 kg OPC per metre of stage length, or refusal pressure.

If, after this, refusal pressure for the stage has not been met, the hole should be flushed with about 200 litres water, and injection resumed after the grout has set. No payment will be made for grout injected in excess of 160 pockets OPC per stage unless authorised by the Engineer.

18.9.2.5 Injection Pressures

The required pressures for different packer depths may be varied depending on rock condition, overburden thickness and type, etc. The following injection pressures should not be exceeded unless otherwise instructed by the Engineer.



18.9.3 Cavity Grouting

Cavity grouting will be required between the jacked concrete pipe sleeve and the in-situ material. The extent of the cavity grouting operation depends largely on the type of material and the excavation methods applied.

Potential voids shall be continuously detected and recorded at the face of the jacking operation. The Contractor shall prepare a grouting plan based on these records for the approval of the Engineer. The Contractor shall determine the number and spacing of air release holes to be drilled from inside the concrete sleeve pipe and the bleed-pipes and bleed valves to be inserted.

Cavity grouting shall be carried out in the sequence and using mix proportions and pressures agreed by the Engineer. Generally, injection of grout shall be commenced at the lowest point to allow air and water to be displaced. When interconnections occur the holes shall be kept open until emerging grout is of the same consistency as the grout being injected, after which the holes shall be closed. A 1 cement: 2 sand mixture at a water/cement ratio of 0.60 or other mix as approved by the Engineer shall be injected. Injection shall continue until the hole refuses to accept grout at the specified maximum pressure. The grout take shall be measured and compared with the total void volume recorded.

If the Engineer considers that cavity grouting is not complete at the hole spacing adopted, he may instruct additional holes to be drilled and grouted.

Unless the holes are subsequently required for other grouting they shall be completely filled in accordance with Clause 18.12.

18.9.4 Consolidation Grouting

The extent of consolidation grouting required for pipe jacking operations will only be determined by the Engineer as the excavation proceeds.

Generally consolidation grouting shall not proceed in a section until the grout injected in the cavity or proof grouting stage has been allowed to harden and shrink for a period of three days or such lesser period as may be agreed by the Engineer depending on the magnitude of the grout takes recorded during the cavity or proof grouting operation.

In order to carry out individual hole consolidation grouting the percussion holes used for cavity grouting, or the preformed grout holes in the segmental lining shall generally be re-drilled and extended into the surrounding rock to the depths indicated on the Drawings. Where no cavity grouting has been specified to precede consolidation grouting, percussion holes not less than 38 mm diameter shall be drilled.

Grouting operations for any stage of grouting in a hole shall be preceded by an abbreviated water pressure test, except as otherwise directed by the Engineer. Immediately following the injection of water, grout shall be injected at pressures and rates as agreed with the Engineer.

Should the pressures not build up with the grout consistency first specified, the grout shall be gradually thickened up by adding cement and injection shall continue at a constant rate until the specified maximum pressures are achieved. If during this thickening process the pressures are built up rapidly, the grout consistency shall be thinned immediately and if necessary clear water shall be injected so as to avoid premature plugging.

The consistency of the grout mix shall be varied at any time as directed by the Engineer to suit the response of the stage being injected.

Under no circumstances shall the pressure or rate of pumping be increased suddenly or the pressure in the hole being grouted exceed the maximum grouting pressure specified. In the event that rock is disturbed due to negligence on the part of the Contractor, remedial measures to repair the damage as directed by the Engineer shall be carried out by the Contractor without additional payment.

The grouting of each stage shall be continued in accordance with the agreed procedures until the hole refuses to accept grout at the consistency and pressure required by the Engineer or until the Engineer directs that the injection should be terminated.

After each stage of grouting is completed in any hole the back pressure shall be maintained by closing the inlet valve at the collar until the grout has set sufficiently, where after the hole shall be flushed, tested and re-grouted if necessary.

18.9.5 Jet grouting

18.9.5.1 Trial Sections

Prior to commencement of production jet grouting, a preliminary field trial section shall be constructed to verify the appropriate jet grouting system (Single, double or triple tube system) and the design grouting parameters. The trial section location shall be within the treatment area and the proposed location shall be agreed with the Engineer. It shall consist of a sufficient number of jet grouted columns arranged in a circle formation to facilitate excavation on the inside for visual

assessment of the geometric, permeability and mechanical characteristics. The construction of the trial sections shall continue until the suitable parameters have been confirmed.

The acceptance testing shall also be calibrated during this trial operation. The testing shall be done prior to the confirmation excavation on the inside of the circular formation.

18.9.5.2 Acceptance Criteria

(a) Core Recovery

Refer to Clause 18.5.2.5. Minimum core recovery shall be 85%.

Since coring jet grouted soil may give misleading results about overall integrity, core recovery of 85% are not the sole criteria for acceptance.

Should the recovery be less than 85% this can also be supported by a borehole camera inspection, record of penetration rate and observations during the core drilling process. These should be considered and factored into the overall engineering judgment used for acceptance of geometric integrity.

(b) 28 Day Compressive Strength

The average 28 day unconfined compressive strength of the core samples taken from the matrix of any jet grouted column shall not be lower than 5 Mpa. Not less than 3 samples shall be tested per test hole. No cored samples consisting only of rock shall be tested for compressive strength unless specifically instructed by the Engineer.

(c) Permeability

The average permeability of each core hole shall be determined by conducting a comprehensive Lugeon Test. The average Lugeon value shall not be greater than 1 (i.e. 1 Lugeon = 10^{-7} m/s).

(d) Seismic Methods

The integrity of the jet grouted columns shall be determined utilizing a Pile Integrity Test such as the “Tap Hammer Test” where a small metal or hard rubber hammer is used to produce a light tap on top of the pile. The shock waves travel down the length of pile and is reflected back from the toe of the pile (or any intermediate weakness or anomaly) and recorded through a suitable transducer / accelerometer, which is also held on the top of the pile close to the point of impact.

18.10 CHECK HOLES

In order to check the effectiveness of grouting the Contractor may be required to drill additional percussion or cored holes at any location, angle and depth within the range of the adjacent grout holes not less than 14 days after completing grouting in an area to enable water tests and possible supplementary grouting to be carried out. The number of holes required will be approximately 10% of the holes detailed on the Drawings and shall be spread over the grouted area as directed by the Engineer.

Except as otherwise required by the Engineer, check holes shall be grouted to the same requirements as the original holes.

18.11 RECORDS

The Contractor shall provide to the Engineer each day, an accurate record, in duplicate hard copy and electronically (spreadsheet format) on an approved form of all drilling and grouting operations carried out the previous day.

The information provided shall include:

a) The location and reference number of the holes drilled and holes grouted;

b) The depth of concrete drilled and total depth of hole drilled with measurements of any voids encountered;

c) Details of grout injections giving pressures, grout consistencies, volumes of grout injected, quantities of other material injected, and injecting times throughout the period of injection;

d) Charts from the recording pressure gauges and flow metres;

e) Results of mix control tests, times of sampling and location where samples were taken; and

f) Remarks on grouting incidents, delays, surface leaks, interconnections, refusals and any other factors which might influence the effectiveness of the grouting.

On completion of the grouting of a hole, within 24 hours, the Contractor shall provide the Engineer with a fresh and complete log, produced on a spreadsheet, printed in duplicate of the grouting work in that hole.

18.12 STEMMING OF HOLES

Upon completion of the grouting and checking of any area, the holes shall be washed using a flushing pipe to remove all loose materials and laitance from grout which has not hardened. The Contractor shall then backfill all grout holes with a thick grout mix or dry pack mortar as directed by the Engineer.

Filling of upward inclined holes shall be by pressure injection unless a thixotropic grout is used. Filling of downward inclined holes shall be through tremie pipes pushed down to the bottom of the holes and withdrawn slowly as filling proceeds after first blowing all water out of the holes.

The end of each hole shall be filled to a depth equal to the lining thickness with dry pack mortar which is well rammed in and finished flush with the face of the concrete, or in the case of embedded sleeves, up to the end of the sleeve. If a box-out had been provided in the first stage concrete, if shall be filled with secondary concrete in accordance with Section 20 - Concrete Works (Structural).

If any hole shows signs of weeping water after being stemmed the hole shall be drilled out, re-grouted and re-stemmed without any additional payment.

18.13 REPAIR AND CLEAN-UP

Concrete surfaces and foundation surfaces over which grout has flowed shall be cleaned and restored to their original condition.

Upon completion of the grouting, the Contractor shall remove all removable grout nipples from grout pipes embedded in concrete.

18.14 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.

The rates tendered for drilling and grouting will be deemed to include the cost of supplying fuel and production related wearing parts (bucket teeth, cutters etc.) to the various sites of works, to all the equipment needed, the necessary skilled staff, supplying to Site and storing before use all the material needed, all drill bits, labour, the costs of drilling and grouting and the costs of the following:

a) Drilling of holes for grouting;
b) Grouting;
c) Re-drilling through grout;
d) Temporary casings and loss of casings;
e) Loss of rock bits and core barrels;
f) Protection against overheating;
g) Provision of piping;
h) Flushing of grout holes;
i) Environmental friendly disposal of wash water;
j) Standing time;
k) Preparing programmes;
l) Keeping records and preparing logs;
m) Supplying and delivering core boxes;
n) Providing packers, water meters and pressure gauges;
o) Supplying water for grouting;
p) Dealing with grout leaks and inter-connections;
q) Providing and operating communication equipment;
r) Handling drilling and grouting equipment;
s) Drilling of angled holes; and
t) Drilling and grouting records.

Measurement and payment for all work involved for drilling and grouting shall be made against the following items:

18.14.1 Conventional Drilling and Grouting Systems Application

18.001 Setting up of drilling equipment for grout and drainage holes

a) Rotary Percussion Drilling **Unit: Number (No.)**

b) Rotary Diamond Core Drilling **Unit: Number (No.)**

Setting up drilling equipment for drilling grout or drainage holes will be measured by the number of set ups at positions indicated on the Drawings or instructed by the Engineer irrespective of the number of stages drilled.

Separate items are provided for cavity grout holes and drainage holes.

The rates tendered shall include full compensation for setting up drilling equipment at each drill hole, any excavation necessary for setting up platforms, all Temporary Works and for moving all equipment and Temporary Works to each drill hole in a set up and subsequent removal. The rate shall also include for provision of all services to the rig, for taking all precautions against pollution and clearing up on completion at each set up position.

18.002 Drilling of grout and drainage holes **Unit: Metre (m)**

a) Rotary percussion drilling in soil **Unit: Metre (m)**

b) Rotary percussion drilling in Jet Grouted Columns **Unit: Metre (m)**

c) Rotary percussion drilling in Bedrock **Unit: Metre (m)**

d) Rotary diamond core drilling in soil **Unit: Metre (m)**

e) Rotary diamond core drilling in Jet Grouted Columns **Unit: Metre (m)**

f) Rotary diamond core drilling in Bedrock

Measurement will be the length of hole drilled as detailed on the Drawings or as instructed by the Engineer if different from the Drawings.

The rates tendered for drilling shall include the cost of moving and setting up drilling equipment at a hole (additional to the initial setting up at each hole), drilling, wear and tear on all equipment, capping and plugging the hole, disposal of drill cuttings and flushing water, and cleaning waste grout from rock foundation or concrete surfaces.

The rates tendered for drilling cored holes shall include the cost of core boxes and for transporting them to the storage area at the Site.

18.003 Re-drilling of grouted holes

a) Re-drilling with rotary percussion **Unit: Metre (m)**

b) Re-drilling with rotary diamond core **Unit: Metre (m)**

Measurement will be the length of hole re-drilled where grout has been allowed to set on instruction of the Engineer. Grouted holes re-drilled on account of the Contractor's failure to flush out grout before it has set, will not be measured.

The rate shall include full compensation for all work required to re-drill grouted holes, irrespective of the depth of grouted hole.

18.004 Temporary drill hole casings

a) Rotary percussion holes **Unit: Metre (m)**

b) Rotary diamond core holes **Unit: Metre (m)**

Solid steel casings for drill holes will be measured as the length of casing installed through the overburden onto bedrock.

The rate tendered shall include the cost of installing and removing casings, leaving temporary casings in place until completion of grouting of the hole, and the cost of supplying, storing and handling casings.

18.005 Extra over for permanent casings

a) Rotary percussion holes **Unit: Metre (m)**

b) Rotary diamond core holes **Unit: Metre (m)**

Casings left permanently in drill holes on the instruction of the Engineer will be measured for additional payment, over and above the payment for installing the casing. Measurement will be by length of casing installed.

The rate tendered shall include full compensation for leaving the casing in the hole.

18.006 Consolidation grouting (not used)

a) Descending stage grouting **Unit: Number Stages (No.)**

b) Ascending stage grouting **Unit: Number Stages (No.)**

Grouting will be measured for payment as the number of stages that are completely and successfully grouted irrespective of the length of the stage and the number of stages in any particular hole. A stage that has to be re-grouted for any reason will not be measured again.

The rate for grouting shall apply to all drill holes irrespective of diameter, length, orientation or location. The rate shall include for providing and moving all equipment into position, flushing the hole, installing and removing packers, mixing and injecting grout, and all other operations required for successfully completing grouting of the stage. The rate shall also include for providing grouting records as required by the Engineer, for laboratory tests carried out on the grout, for drilling through hardened grout and for cleaning and disposing of waste grout.

Injection of grout will not be paid for separately by volume, but grout materials will be paid for separately.

18.007 Cavity grouting **Unit: Cubic Metre (m^3)**

Measurement will be the total volume of combined materials used for cavity grouting, irrespective of the method used. Materials will not be measured separately.

The rate tendered shall include full compensation for all work required to effect the cavity grouting including stemming of holes and for cleaning up on completion. The rate shall also include for all materials required to fill any voids left by incomplete filling.

18.008 Grouting equipment (Excluding P&G's)

a) Drilling operations **Unit: lump sum (Sum)**

b) Grouting operations **Unit: lump sum (Sum)**

The rate tendered shall include the cost of supplying fuel and production related wearing parts.

18.009 Grouting materials

a) CEM I Class 52.5N or 42.5R (RHPC) or UFC **Unit: Tonne (t)**

b) Cement extenders GGCS, GGBS and CSF **Unit: Tonne (t)**

c) Bentonite **Unit: Tonne (t)**

d) Sand **Unit: Tonne (t)**

Cementitious materials, CSF, Bentonite and sand used will be measured separately on the basis of the quantity actually injected in grouting operations. Measurement will be the mass injected as calculated from the mix proportions and volumes injected. The mass of water will not be measured. If sand-cement grout is used the dry mass of sand used in the grouting operation will be measured separately. The rate tendered shall include full compensation for the supply of the materials and the work required for mixing and delivery of grout material.

No payment will be made in the case of any grout which was lost on account of the Contractor's failure to comply with the requirements of the Specification or which was rejected by the Engineer as being unsuitable for use in grouting operations or for losses from mixes, pumps and lines.

18.010 Grouting additives — Unit: Provisional Sum (PS)

Where ordered by the Engineer additives used in grouting operation shall be measured separately. Payment shall be made against a Provisional Sum.

18.011 Water pressure tests

a) Five-minute test (Clause 18.8.1) **Unit: Number (No.)**

b) Fifteen-minute test (Clause 18.8.2) **Unit: Number (No.)**

c) Comprehensive Lugeon test (Clause 18.8.3) **Unit: Number (No.)**

Water pressure tests will be measured on the basis of the number of successful pressure tests performed. Tests attempted but not completed due to leakage past the packer or to equipment failure will not be paid for.

The rates tendered shall apply to all grout holes irrespective of size, location and depth, and shall include the cost of moving equipment into position, testing the stage and supplying records of the testing.

18.012 Check Holes

Drilling and grouting of check holes as directed by the Engineer will be measured under the relevant Items 18.002 to 18.009 for the type of grouting being checked.

18.013 Loss of hole

No payment will be made for a "lost" hole, either for drilling, grouting or in any other respect unless the Engineer considers the desired purpose of the hole has been achieved in which case applicable work falling under the measurement Clauses above will be paid for.

18.014 Sleeve pipes (not used)

a) Steel sleeve pipe (diameter specified) Unit: Metre (m)

b) PVC sleeve pipe (diameter specified) Unit: Metre (m)

Measurement will be by the length of sleeve pipe installed in concrete as detailed on the Drawings or as ordered by the Engineer. The rate tendered shall include full compensation for the supply and installation of sleeve pipe, together with any fittings required, and securing during casting of concrete.

18.015 Grout stops (not used) Unit: Metre (m)

Measurement will be by the length of grout stop installed as detailed on the Drawings or as ordered by the Engineer. The rate tendered shall include full compensation for the supply and installation of the grout stop, and securing during casting of concrete.

18.016 Records

No separate payment will be made for providing the records required in terms of Clause 18.11 and the rates for the items of work concerned shall include full compensation for this work.

18.14.2 Integrated Jet Grouting Systems Application

Measurement and payment for all work involved for jet grouting shall be made against the following items: 18.017 to 18.032.

18.017 Setting up of drilling equipment for jet-grouting

a) Rotary Probe Drilling (Conventional Jet Grouting) Unit: Number (No.)

b) High Pressure Hammer Action (Jet Grouting) Unit: Number (No.)

Setting up drilling equipment for drilling grout holes will be measured by the number of set ups at positions indicated on the Drawings or instructed by the Engineer irrespective of the number of stages drilled.

The rates tendered shall include full compensation for setting up drilling equipment at each drill hole, any excavation necessary for setting up platforms, all Temporary Works and for moving all equipment and Temporary Works to each drill hole in a set up and subsequent removal. The rate shall also include for provision of all services to the rig, for taking all precautions against pollution and clearing up on completion at each set up position.

18.018 Drilling of grout holes

a) Rotary Probe drilling in Alluvium Unit: Metre (m)

b) High Pressure Hammer Action drilling in Alluvium Unit: Metre (m)

c) High Pressure Hammer Action drilling in Cobbles and Boulders and Weathered rock Unit: Metre (m)

d) High Pressure Hammer Action drilling in Bedrock Unit: Metre (m)

Measurement will be the length of hole drilled as detailed on the Drawings or as instructed by the Engineer if different from the Drawings.

The rates tendered for drilling shall include the cost of moving and setting up drilling equipment at a hole (additional to the initial setting up at each hole), drilling, wear and tear on all equipment, capping and plugging the hole, disposal of drill cuttings and flushing water, and cleaning waste grout from rock foundation or concrete surfaces.

The rates tendered for drilling cored holes shall include the cost of core boxes and for transporting them to the storage area at the Site.

The cost for drilling for high pressure hammer action jet grouting is included in item 18.022 c).

18.019 Re-drilling of grouted holes

a) Re-drilling by rotary percussion **Unit: Metre (m)**

b) Re-drilling by rotary diamond core **Unit: Metre (m)**

Measurement will be the length of hole re-drilled where grout has been allowed to set on instruction of the Engineer. Grouted holes re-drilled on account of the Contractor's failure to flush out grout before it has set, will not be measured.

The rate shall include full compensation for all work required to re-drill grouted holes, irrespective of the depth of grouted hole.

18.020 Temporary drill hole casings (not used)

a) Rotary percussion holes **Unit: Metre (m)**

b) Rotary diamond core holes **Unit: Metre (m)**

Solid steel casings for drill holes will be measured as the length of casing installed through the overburden onto bedrock.

The rate tendered shall include the cost of installing and removing casings, leaving temporary casings in place until completion of grouting of the hole, and the cost of supplying, storing and handling casings.

18.021 Extra over for permanent casings (not used)

a) Rotary percussion holes **Unit: Metre (m)**

b) Rotary diamond core holes **Unit: Metre (m)**

Casings left permanently in drill holes on the instruction of the Engineer will be measured for additional payment, over and above the payment for installing the casing. Measurement will be by length of casing installed.

The rate tendered shall include full compensation for leaving the casing in the hole.

18.022 Jet grouting

a)	**Rotary Probe jet-grouting in Alluvium**	**Unit: Metre (m)**
b)	**High Pressure Hammer Action Jet Grouting in Alluvium, Cobbles and Boulders, and Weathered Rock**	**Unit: Metre (m)**
c)	**High Pressure Hammer Action Jet Grouting in Bedrock**	**Unit: Metre (m)**

Measurement will be the length of hole grouted as detailed on the Drawings or as instructed by the Engineer if different from the Drawings.

The rate for grouting shall apply to all drill holes irrespective of diameter, length, orientation or location. The rate shall include for providing and moving all grouting equipment into position, flushing the hole, installing and removing packers, mixing and injecting grout, and all other operations required for successfully completing grouting of the stage. The rate shall also include for providing grouting records as required by the Engineer, for laboratory tests carried out on the grout, for drilling through hardened grout and for cleaning and disposing of waste grout.

Injection of grout will not be paid for separately, but grout materials will be paid for separately.

18.023 Cavity grouting (not used) **Unit: Cubic Metre (m^3)**

Measurement will be the total volume of combined materials used for cavity grouting, irrespective of the method used. Materials will not be measured separately.

The rate tendered shall include full compensation for all work required to effect the cavity grouting including stemming of holes and for cleaning up on completion. The rate shall also include for all materials required to fill any voids left by incomplete filling.

18.024 Grouting equipment (excluding P&G's)

a)	**Drilling operations – Rotary Probe**	**Unit: lump sum (Sum)**
b)	**Drilling operations – High Pressure Hammer Action**	**Unit: lump sum (Sum)**
c)	**Grouting operations – Rotary Probe**	**Unit: lump sum (Sum)**
d)	**Grouting operations – High Pressure Hammer Action**	**Unit: lump sum (Sum)**

The rate tendered shall include the cost of supplying fuel and production related wearing parts.

18.025 Grouting materials

a)	**CEM I Class 52.5N or 42.5R (RHPC) or UFC**	**Unit: Tonne (t)**
b)	**Cement extenders GGCS, GGBS or CSF**	**Unit: Tonne (t)**
c)	**Bentonite**	**Unit: Tonne (t)**

Cementitious materials, CSF, Bentonite and sand used will be measured separately on the basis of the quantity actually injected in grouting operations. Measurement will be the mass injected as calculated from the mix proportions and volumes injected. The mass of water will not be measured. If sand-cement grout is used the dry mass of sand used in the grouting operation will be measured

separately. The rate tendered shall include full compensation for the supply of the materials and the work required for mixing and delivery of grout material.

No payment will be made in the case of any grout which was lost on account of the Contractor's failure to comply with the requirements of the Specification or which was rejected by the Engineer as being unsuitable for use in grouting operations or for losses from mixes, pumps and lines.

18.026 Grouting additives **Unit: Provisional Sum (PS)**

Where ordered by the Engineer additives used in grouting operation shall be measured separately. Payment shall be made against a Provisional Sum.

18.027 Water pressure tests (not used – paid under Item 18.011)

a) Five-minute test (Clause 18.8.1) **Unit: Number (No.)**

b) Fifteen-minute test (Clause 18.8.2) **Unit: Number (No.)**

c) Comprehensive Lugeon test (Clause 18.8.3) **Unit: Number (No.)**

Water pressure tests will be measured on the basis of the number of successful pressure tests performed. Tests attempted but not completed due to leakage past the packer or to equipment failure will not be paid for.

The rates tendered shall apply to all grout holes irrespective of size, location and depth, and shall include the cost of moving equipment into position, testing the stage and supplying records of the testing.

18.028 Check Holes (not used – paid under Item 18.012)

Drilling and grouting of check holes as directed by the Engineer will be measured under the relevant Items 18.018 to 18.025 for the jet grouting being checked.

18.029 Loss of hole (not used)

No payment will be made for a "lost" hole, either for drilling, grouting or in any other respect unless the Engineer considers the desired purpose of the hole has been achieved in which case applicable work falling under the measurement Clauses above will be paid for.

18.030 Sleeve pipes (not used)

a) Steel sleeve pipe (diameter specified) **Unit: Metre (m)**

b) PVC sleeve pipe (diameter specified) **Unit: Metre (m)**

Measurement will be by the length of sleeve pipe installed in concrete as detailed on the Drawings or as ordered by the Engineer. The rate tendered shall include full compensation for the supply and installation of sleeve pipe, together with any fittings required, and securing during casting of concrete.

18.031 Grout stops (not used) Unit: Metre (m)

Measurement will be by the length of grout stop installed as detailed on the Drawings or as ordered by the Engineer. The rate tendered shall include full compensation for the supply and installation of the grout stop, and securing during casting of concrete.

18.032 Records

No separate payment will be made for providing the records required in terms of Clause 18.11 and the rates for the items of work concerned shall include full compensation for this work.