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DRAFT
TECHNICAL SPECIFICATIONS
FOR
UNDERGROUND WORK

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FÖRORD

Som ett led i BeFos engagemang för att stärka det svenska bergbyggandet utomlands genomfördes för några år sedan projektet Undermarksbyggande i svagt berg, bestående av fyra delar, som sammanfattade kunskapsläget inom förundersökningsteknik, bergbrytning, förstärknings- och tätningsarbeten.

Vid sidan av detta tekniskt inriktade arbete beslöt man också att se över kontrakts- och upphandlingsformer för utlandsprojekt. Som första uppgift valdes att ta fram en referenshandling för tekniska specifikationer, vilken nu färdigställts. Handlingen har tagits fram av en av BeFo utsedd arbetsgrupp bestående av Anders Heiner, VBB, Arne Fjällhed, SKANSKA och Claes-Göran Jonefjäll, ABV. Synpunkter på utformningen av handlingen har inhämtats från specialister inom de tre företagen.

Avsikten är att materialet skall prövas en tid i samband med olika utlandsprojekt innan man eventuellt går vidare med en utveckling eller komplettering av projektet. Då det inte är fråga om ett forskningsprojekt i vanlig mening har rapporten givits ut i något annan form än ordinarie BeFo-rapporter.

Stockholm i december 1989

Tomas Franzén

Introduktion

Föreliggande draft till tekniska specifikationer för internationellt bergbyggande har baserats dels på specifikationer framtagna av svenska konsulter dels på ett antal handlingar från utländska konsulter. Olikheter mellan olika länders konsultpraxis har studerats och en sammanvägning gjorts för att ta fram en handling som passar den "svenska modellen" av bergbyggande. Denna handling är i första hand avsedd att användas för internationella projekt där underjordiska bergarbeten utgör en väsentlig del av erforderliga byggnadsarbeten.

Specifikationerna omfattar underjordiska bergsprängningsarbeten, som avses utföras med modern teknik för borrhning, sprängning och borttransport av bergmassorna, samt tillhörande bergförstärkningsarbeten. De skall utgöra en integrerande del av för projektets utförande erforderliga kontraktshandlingar och måste för att rätt förstås läsas tillsammans med dessa övriga handlingar speciellt nedan nämnda allmänna kontraktsvillkor.

Entreprenör för utförande av arbetena förutsättes upphandlas genom internationellt anbuds-förfarande. Utförandekontraktets allmänna villkor utgöres av "Conditions of Contract for Works of Civil Engineering Construction", Fourth Edition 1987 utfärdade av Federation Internationale des Ingénieurs Conseils (FIDIC). Dessa villkor definierar bl a i specifikationerna använda benämningar såsom "Contractor", "Engineer" och "Bill of Quantities". Vidare föreskrives att utfört arbete skall betalas enligt i Bill of Quantities angivna å-priser eller lumpsums och att å-priserna därvid skall appliceras på faktiskt utförda kvantiteter.

Specifikationerna kan givetvis också användas i samband med andra upphandlingsformer och kontraktsvillkor såsom direktförhandlade totalåtaganden utan medverkan av den särskilda funktionen "the Engineer", löpande-räkningskontrakt etc. men måste då modifieras och kompletteras för det enskilda fallet.

Varje projekt är givetvis specifikt och en anpassning av de tekniska specifikationerna till de aktuella förhållandena är nödvändig. Den här presenterade handlingen kan ses som en stomme till en bergspecifikation och kan i viss mån fungera som checklista.

PREFACE

The Specifications cover underground rock excavation works, which are intended to be carried out using modern techniques for drilling, blasting and muck removal, as well as appurtenant rock strengthening works.

The Specifications constitute an integrated part of the contract documentation required for the execution of the particular project. In order to be correctly interpreted, the Specifications need to be read in conjunction with other parts of the contract documentation, especially the conditions.

Most commonly the contractor is engaged following the international competitive tendering procedure. In such case the conditions should be those issued by Federation Internationale des Ingénieurs Conseils (FIDIC) which are entitled "Conditions of Contract for Works of Civil Engineering Construction".

The FIDIC conditions define expressions commonly used in the Specifications, such as Tender, Contract, Permanent Works, Temporary Works, etc. Also, they set out detailed stipulations with respect to sub-contracting, general obligations of the parties, delays, defects, alterations, certifications, payment, etc.

However, the Specifications can also be used if the Contractor is engaged following other procedures than competitive tendering, such as for negotiated turn-key, cost-plus or cost-incentive projects. In such case, they need to be modified for such purpose.

Obviously, every project comprising underground rock excavation works is unique and an adaptation of the Specifications to actual conditions is necessary. The document which is here presented can be seen as the frame-work or a check-list for the drafting of the Specifications required in the particular case.

DRAFT

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SPECIFICATIONS FOR UNDERGROUND WORK

1. SCOPE

1.1 WORK LOCATION AND APPLICABLE DRAWINGS

The underground works to be carried out under this Contract will comprise the construction of the following parts:

- Portals
- Tunnels
- Caverns
- Shafts

The general layout of the Project is shown on Drwg_____.

Tunnel excavation is shown on Drwgs_____.

Cavern excavation is shown on Drwgs_____.

Shaft excavation is shown on Drwgs_____.

1.2 REQUIRED WORK OPERATIONS

1.2.1 Rock excavation

The Contractor shall, where shown on the Drawings or as otherwise directed by the Engineer, perform all rock excavation required for the Works in accordance with these Specifications. He shall transport and use in the Works, or dispose of in spoil dumps, the excavated material as directed by the Engineer.

1.2.2 Rock stabilization

1.2.2.1 Primary stabilization

The Contractor shall, as directed by the Engineer, perform all primary stabilization, see Section 4.9, required for the Works in accordance with these Specifications. With primary stabilization shall be understood such measures which are required in order to strengthen and support the rock until final stabilization can take place. Primary stabilization shall be carried out as soon as possible after blasting and after mapping of the blasted area. Primary stabilization may consist of:

- untensioned or tensioned rock bolts
- unreinforced or reinforced shotcrete
- steel sets
- concrete support(-ing)
- consolidation grouting and pregrouting

1.2.2.2 Final stabilization

The Contractor shall, where shown on the Drawings or as otherwise directed by the Engineer, perform all final stabilization required for the Works in accordance with these Specifications. As final stabilization shall be understood such measures which are required in order to safeguard the proper function of the Works for intended purpose. Final stabilization shall be carried out in accordance with an approved programme and may consist of:

- supplemented primary stabilization
- concrete linings
- cavity, contact or curtain grouting

1.2.2.3 Temporary stabilization

The Contractor may, as conditioned by his working method, carry out temporary stabilization. As temporary stabilization shall be understood such measures which, in the opinion of the Engineer cannot be accepted as forming part of the primary or final stabilization measures. Temporary stabilization is at the Contractor's expense.

2. GENERAL OBLIGATIONS

2.1 CONTRACTOR'S RESPONSIBILITY

The Contractor is responsible for the maintenance of safe working conditions in his undertaking, i.e. for the prevention of injury and damage to personnel, equipment, the Works and adjacent structures and installations.

2.2 CONTRACTOR'S EARLY DOCUMENTATION OF MATERIALS AND PROCEDURES

2.2.1 Rock excavation

Before underground rock excavation is commenced, the Contractor shall provide the Engineer with detailed proposals for carrying out the work, including a programme of operations, methods, plant to be used and drilling, charging and firing patterns. Similarly, the Contractor shall also submit plans for blasting adjacent to completed structures, outlining the measures taken for avoiding damage from vibration or flyrock. The excavation shall not be commenced without the approval of the Engineer and the Contractor shall not vary approved procedures without the prior agreement of the Engineer.

2.2.2 Rock stabilization

As soon as practicable after the acceptance of his tender, and in any case prior to commencing work, the Contractor shall submit to the Engineer information on his proposed rock stabilization methods.

Where conditions encountered are considered by the Engineer to require the installation of strengthening and support works, the Contractor shall install such works with minimum possible delay. When conditions encountered are considered by the Contractor to require the installation of strengthening and support works, he shall immediately inform the Engineer and the Engineer shall give his decision on the requirement of such works with due urgency.

2.2.3 Concreting

Similarly as for rock excavation, the Contractor shall submit to the Engineer full details of the plant he proposes to use, the methods of work he proposes to adapt and the programme he proposes to follow in placing concrete underground.

2.3 SAFETY PRECAUTIONS

2.3.1 General

At an early stage of the work, the Contractor shall undertake the organization, equipping and training of rescue teams. These teams shall be trained in underground rescue work and general first aid work. They shall be kept to full strength and in an efficient state of training.

No workmen shall be employed underground until they have shown themselves conversant with all basic safety precautions. All safety regulations shall be strictly enforced by the Contractor. The Contractor shall provide adequate protective clothing and equipment.

The Contractor shall observe all precautions to avoid accidents or injury to works or workmen and to minimize the extent and severity of any accident or injury which may occur. Such precautions shall have due regard to the skill and training of the labour force employed underground and shall comply with the local mining and other applicable regulations.

2.3.2 Use, storage and handling of explosives

The Contractor shall observe all rules and regulations regarding the import, transport, storage and use of explosives issued by any public authority having jurisdiction in respect of the same.

If an electric ignition system is used, warning systems for thunder storms shall be installed at the blasting site and protective measures taken against accidental ignition of charges by lightning.

Due precautions shall be taken to prevent unintentional ignition from electric installations.

2.3.3 Fire hazard

When welding equipment and other high temperature equipment is used underground, safety precautions shall be taken to prevent the initiation and spread of fire.

2.3.4 Flammable gases

The Contractor shall provide hand held gas detectors and shall make regular surveys to check for the presence of methane or other flammable gases. On detection of a flammable gas concentration at any point in excess of 1.5 per cent of the volume of ventilated air, the ventilation shall be increased in order to reduce the concentration below this value and all non-essential personnel shall be withdrawn from the underground works until this has been achieved.

In underground works where the concentration of flammable gases is expected to be above two per cent or is found to be above two per cent the Contractor shall take all necessary precautions to prevent explosions, including the use of flameproof equipment and of explosives and detonators which are made specifically for use in these conditions.

2.4 UNDERGROUND FACILITIES

2.4.1 General

The Contractor shall submit descriptions of the installations he proposes to use for supply of water, compressed air, lighting etc, and for disposal of water, etc, as well as a description of his intended ventilation system for the approval of the Engineer well in advance of starting underground works.

2.4.2 Telephone communications

Telephone communications shall normally be provided between the working faces, portals and other working areas. Telephone locations shall be prominently displayed.

2.4.3 Electric cables

All lighting and power cables installed in underground works shall be adequately insulated, with joints made in an approved manner. All installation and maintenance works shall be done by qualified personnel to a high standard. Cables shall be securely fixed above floor level with the exception of cables needed for occasional works.

Separate circuits shall be provided for power and lighting supplies and they shall be kept well separated from signalling and telephone cables.

Circuits used for firing explosives shall be kept separate from all other circuits by placing them at the opposite wall.

All electric installations shall be adequately earthed in accordance with normal practice and local requirements and be approved by the Engineer. Installations shall furthermore be protected by earth leakage trip circuit breakers, all in accordance with modern practice and safety standards.

2.4.4 Ventilation

The Contractor shall provide and maintain a ventilation system serving each working face in underground excavations.

After installation, the ventilation ducts shall be checked at regular intervals and any damage that might decrease their efficiency shall immediately be repaired. Spare ducts and spare ventilators shall be available on Site for this purpose. Diesel engines working underground shall be regularly checked and be kept well adjusted so that all harmful substances in the exhaust be kept to the minimum. Petrol engines shall not be permitted underground except where absolutely necessary.

At intervals approved by the Engineer, the Contractor shall perform measurements of gas pollution in the tunnels in order to early detect the presence of carbon monoxide, nitrogen dioxide, methane and other harmful or explosive gases.

The Contractor shall ensure that pollution percentages are kept within acceptable limits according to internationally recognized standards. The results of measurements shall be recorded and submitted once a week to the Engineer.

Satisfactory ventilation shall be maintained as long as any work is being carried out underground and no part of any ventilation system shall be dismantled and removed without the prior approval of the Engineer.

2.4.5 Lighting

All underground works shall be illuminated during working hours with electric lights of adequate size and number to allow work,

inspection, mapping and surveying to be carried out in a proper and safe manner.

The illumination on a horizontal plane at floor level shall be not less than 10 lux. At working faces and at other places where work is in progress or inspections are necessary, illumination shall be not less than 50 lux.

Hand inspection lamps and electric battery torches shall be available at working faces at all times.

2.4.6

Dewatering

The Contractor shall use highest endeavour to keep all parts of underground work areas free of water by providing ditches, pipes, drains, sumps, etc. He shall remove all water entering such areas and dispose of it.

The Contractor shall submit to the Engineer details of his proposals for dealing with water from any source prior to commencing the work.

In the event that gravity flow cannot be satisfactorily achieved, the Contractor shall remove the water by pumping and he shall provide, install, operate and maintain all necessary pumps, piping and other equipment required. The Contractor shall also provide, install and maintain sufficient standby pumps for removal of water from the excavations during period of breakdown or maintenance of the main pumping facilities.

Where water bearing seams, fissures or broken ground are yielding undesirably large quantities of water, the Engineer may instruct or agree that such seams, fissures or broken ground shall be grouted.

The Contractor shall provide, install and maintain devices for measuring the quantities of water removed from the underground excavations by pumping and by gravity. The Contractor shall provide up-to-date calibration charts for all measuring devices and shall at regular intervals submit to the Engineer a complete record of the quantities of water discharged and the times during which pumping has occurred.

2.5 RECORD KEEPING

2.5.1 Work performed

The Contractor shall keep a complete record of the underground excavations including bore hole diameters, length and pattern of drilling, details of charging and firing and length of advance of each round.

Other records shall include the dimensions and positions of rock strengthening and support works, including dimensions and positions of shotcrete, steel sets, etc.

Records of compressive strengths of cores extracted from shotcrete shall be kept.

All records shall be maintained fully up to date and shall be made available immediately for the Engineer's inspection on request. The original copy of the record shall be kept at the Contractor's office.

The Contractor shall furnish the Engineer with a copy of the record each week covering the progress of rock excavation and stabilization works for the previous week at each of the underground working faces.

2.5.2 Geological mapping

The Contractor shall, on daily basis, provide the Engineer with documentation in the form of maps, and when needed photographs, showing the pertinent geological features as observed at excavations opened up after each blasting operation.

3. ROCK EXCAVATION

3.1 GENERAL

The excavation shall be performed by such methods, and in such a manner, as will leave stable, regular surfaces with a minimum of overbreak.

Unless otherwise directed or approved by the Engineer, the methods given in "The Modern Technique of Rock Blasting", 3rd edition, by U. Langefors and B. Kilström and Rock Blasting by R. Gustafsson shall be used as guidelines.

3.2 CONTOUR BLASTING

3.2.1 General

Where undisturbed excavation surfaces are required, the Engineer will direct contour blasting by means of smooth blasting or pre-splitting.

Where contour blasting is prescribed, the collaring and alignment of the drillholes shall be made with special care to ensure a good result. The deviation in collaring of the holes in relation to the bottom of holes in the previous round shall be kept at an absolute minimum and the error in alignment shall not exceed the space required for the collaring of the following round or 5 per cent of the depth of the holes as the case may be.

3.2.2 Smooth blasting

Smooth blasting implies that the contour holes are closely spaced and lightly charged. The ratio between the spacing of contour holes and the burden shall be adapted to the rock conditions.

The ignition pattern shall be made in such a way that the contour holes have free breakage at the detonation and all contour holes shall, as far as practically possible, be fired with the same detonator number of lowest possible interval number. Charging of the stopping holes close to the contour holes must be made with care in order not to harm the result of the smooth blasting.

The spacing and charging of holes shall be approved by the Engineer. Smooth blasting shall be used where shown on the Drawings or as otherwise directed by the Engineer.

3.2.3 Presplitting

Presplitting implies that closely spaced contour holes are drilled, charged and fired in a separate operation thereby freeing a rock mass which will subsequently be blasted.

The spacing and charging of holes shall be approved by the Engineer. Presplitting shall be used where shown on the Drawings or otherwise as directed by the Engineer.

3.3 OVERBREAK

3.3.1 General

In unlined hydraulic tunnels, isolated rock points not exceeding 0.02 m^2 in area and spaced at a minimum clear distance of 2 m may project not more than 100 mm inside the theoretical section.

In underground excavations where a concrete lining is to be cast against rock, isolated points not exceeding 0.02 m^2 in area and spaced at a minimum clear distance of 0.5 m may project not more than 50 mm inside the theoretical section.

In permanent unlined access tunnels no projection of rock points inside the theoretical section will be accepted.

All excavation outside the theoretical section will be classed as overbreak. A distinction will be made for payment purposes between "ordered overbreak" (due to geological conditions which could not reasonably have been foreseen) or "approved overbreak" and normal overbreak which is an inevitable consequence of excavation methods.

Overbreak up to 300 mm beyond the theoretical section will normally be left as excavated.

Where overbreak occurs more than 300 mm beyond the theoretical section of unlined excavated surfaces, the Engineer will inspect the area and instruct if shotcrete, concrete or other filling will be required.

In areas where there is to be a concrete lining or concrete structure adjoining the rock, the overbreak filling shall be of the same quality as that required for the adjacent work. Elsewhere class D concrete shall be used.

3.3.2 Ordered overbreak

As ordered overbreak shall be considered such overbreak which is specifically ordered by the Engineer in order to prevent future rock slides or falls in weak zones.

3.3.3 Approved overbreak

As approved overbreak shall be considered such overbreak which, in the opinion of the Engineer, is the unavoidable result of weak rock and is not due to excavation methods chosen by the Contractor in order to facilitate progress or caused by the carelessness of the Contractor.

3.4 EXCAVATION FOR CONTRACTOR'S CONVENIENCE

The Contractor may construct temporary access tunnels, traffic by-passes, etc for his own use and convenience. Such work shall conform in every respect with these Specifications. For this purpose, the Contractor shall submit detailed proposals to the Engineer for his approval. The proposals shall include the Contractor's method of backfilling and reinstatement. Excavation for Contractor's convenience shall be at the Contractor's expense.

3.5 PROBING AHEAD OF TUNNEL FACE

Where deemed so required by the Engineer, holes shall be drilled from the tunnel face in order to probe ground conditions ahead of advancing tunnels. The drilling shall be made to such a depth that, after blasting of a new tunnel round, the distance between the tunnel face and the bottom of the probe hole shall be at least 10 m. The location and direction of probe holes shall be varied to take account of actual geological conditions.

The Contractor shall keep logs of all probe holes drilled. The following data, together with such additional data as the Engineer may direct, shall be given on the logs:

- (o) the date and hours of the drilling
- (i) the location, orientation and drilled length of each probe hole
- (ii) a plot of the rate of drill penetration versus drilled length
- (iii) the location, nature and quantity of any water inflows
- (iv) the location and extent of any changes in strata as determined by the penetration rate.

Three copies of each probe hole log shall be submitted to the Engineer within 24 hours of the completion of the probe hole.

3.6 CLEANING AND SCALING

Scaling, involving the removal of loose rock from excavated walls and roofs, shall be performed immediately after blasting and at intervals thereafter as necessary to prevent accidents. A complete final scaling of such excavation surfaces which are not to be covered up shall be carried out prior to acceptance of the underground works.

The final cleaning of the invert of all excavations shall be carried out as carefully as possible using mechanized equipment. Where deemed so required by the Engineer, the Contractor shall further clean inverts using hand-tools, jackhammers and air- or waterjets. Such further cleaning will be considered as daywork.

3.7 DENTAL EXCAVATION

Dental excavation shall include such removal of soil, rock fragments, decomposed rock, or other material from seams, faults, cavities, or from spaces between boulders beyond the lines of excavation shown on the Drawings or directed by the Engineer, which requires the use of hand tools. The use of a high-velocity air-water jet in connection with dental excavation may be required to remove stiff or hard materials.

The Engineer will determine the extent to which such material shall be removed, including the depth, direction, and dimensions of the dental excavation. The methods of dental excavation shall be such as to avoid fracturing of the rock adjacent to the material being removed.

Dental excavation will be considered as daywork.

3.8 DISPOSAL OF EXCAVATED MATERIAL

Excavated material which is not acceptable for use in the Works shall be disposed of in spoil dumps within areas shown on the Drawings or elsewhere as directed by the

Engineer. Excavated material which can be used at a later stage in the Works shall be temporarily stockpiled as directed by the Engineer.

While building up the spoil dump, it shall be graded to reasonably even surfaces with safe slopes approved by the Engineer. When a spoil dump has been filled up to its final elevation, the top surface shall be graded to a slight inclination in order to facilitate proper runoff of rain water and the top edge of any slope shall be smoothly rounded off.

3.9 FIELD CONTROL AND MONITORING EQUIPMENT

3.9.1 Setting out of line and level

Prior to starting excavation works, the Contractor shall submit to the Engineer for approval his proposals for setting out the works and for correcting any deviations. The Contractor shall keep daily records during construction of the line, level and profile of excavation works. Copies of these records shall be made available immediately to the Engineer.

3.9.2 Chainage markers

Chainage markers shall be provided in tunnels at 100 m and in shafts at 20 m intervals. The markers shall be painted in white durable paint.

3.9.3 Monitoring equipment

The Contractor shall provide equipment for measurement of deformations as specified in the Bill of Quantities. The types of equipment to be used may comprise: levelling instruments, wire extensometer (Distometer or similar) and single and/or multiple position borehole extensometers. The equipment shall be installed where directed by the Engineer. During the execution of excavation works, the need to procure other types of equipment, such as instrumentation for monitoring of strains, loads, stresses, ground water pressures, etc, may arise. The Contractor shall provide such equipment as directed by the Engineer.

Measurements shall be performed by the Contractor as directed by the Engineer. Results from each measurement shall be submitted to the Engineer expeditiously.

Provision and installation of the monitoring equipment and the taking of measurements will be considered as daywork.

4. ROCK STABILIZATION

4.1 GENERAL

The following sections describe the various work operations and methods anticipated to be used for primary and final stabilization of rock in potentially unstable areas.

4.2 DRILLING

4.2.1 General

The materials, equipment, methods and procedures used by the Contractor for drilling operations shall be approved by the Engineer.

4.2.2 Percussion drilling

Percussion drilling shall normally be used for drilling of holes for rock bolts and anchors, as well as for grouting, drainage and for investigation purposes. Water flushing shall be employed.

4.2.3 Rotary drilling

Rotary drilling shall be carried out with or without coring.

For rotary drilling with coring, core diameters shall be at least 42 mm with normal double core barrels and 37.8 mm with double core barrels with split inner tube. The equipment shall be capable of drilling holes in any direction to a depth of at least 100 m.

The radial deviation of boreholes shall not exceed 5 % of the borehole depth.

Where approved by the Engineer, drillholes shall be provided with casings through rock of poor quality.

Filling of part of the hole with grout and subsequent redrilling shall be carried out in zones of poor rock as directed by the Engineer.

During drilling with coring, the rotation speed, feeding pressure and amount of flushing water shall be adapted to the rock type, so as to obtain cores of the best possible quality.

Cores shall be placed in core boxes of type approved by the Engineer. The depth of each run shall be noted in the box and core losses marked by pieces of wood of corresponding length. The core boxes shall be transported and stored under roof in a fenced area.

Records of core drillings shall be submitted to the Engineer within 24 hours and shall comprise:-

- core recovery per run, as well as all core losses, Rock Quality Designation (RQD) and fracture spacing
- depth at each run
- length of casing, lengths grouted and re-drilled.

The format of the records shall be approved by the Engineer.

4.2.4 Washing of drillholes

All drillholes shall be washed after completion of drilling and prior to water pressure tests during drilling. Water pressure tests will be directed by the Engineer.

Washing of holes shall be carried out by flushing, alternately with compressed air and water under pressure, through pipes or stiff hoses reaching the bottom of the holes. Normally, flushing shall commence at the bottom and proceed towards the mouth of the drillhole.

Finished drillholes shall be properly plugged.

4.2.5 Pressure testing of drillholes

Water pressure tests shall be performed during drilling or after completed drilling as directed by the Engineer. The minimum inner diameter of the water conduit shall be 18 mm. Testing shall be made by means of single- or double-type packers. Double-type packers shall be spaced maximum 3 m apart. Suitable packers for testing of holes of all occurring diameters shall be available at all times. Packers which are used in weak rock shall have a length of at least 500 mm.

During testing, the water pressure shall be kept constant over three consecutive two-minute periods and the water leakage shall be measured during each of those periods. Pressure levels shall be as directed by the Engineer.

4.3 GROUTING

4.3.1 General

The materials, equipment, methods and procedures used by the Contractor for grouting operations shall be approved by the Engineer.

The pressure and mixtures to be used for grouting and the depths at which the grout shall be injected will be directed by the Engineer.

The Contractor shall provide for the adequate disposal of all wash water and waste grout resulting from grouting operations. He shall not allow such water and grout to contaminate

any part of the Works or flow into any water course, until it has passed through settling ponds or tanks approved by the Engineer.

4.3.2 Definition of terms

The following terms shall have the meanings herein assigned to them:

"Stage" means a partial length of hole in which grouting is performed.

"Split-spacing" means the system of locating an additional grout hole approximately midway between two grout holes which have been previously drilled and grouted.

"Consolidation grouting" means grouting carried out before excavation of portions of weak, fissured rock and/or grouting after cavity/contact grouting to stabilize weak rock.

"Pregrouting" means grouting carried out before excavation of portions of rock which are expected to leak substantial quantity of water.

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

"Contact grouting" means grouting to fill any voids at concrete/concrete or steel/concrete interfaces.

"Curtain grouting" means injection of grout to produce a screen of tight rock.

4.3.3 Grouting equipment

Grouting equipment shall be capable of effectively batching, mixing and maintaining grout mixtures in suspension and of delivering and pumping grout into the grout holes and joints in a continuous uninterrupted flow at any constant pressure up to the limiting pressure specified.

Grouting shall be either direct grouting or circuit grouting. In the latter case, the arrangement of the grouting circuit shall be such as to provide a return line from the site of injection to the holding tank, so that a continuous flow of grout of uniform consistency is maintained in the delivery line between the grout pump and the collar

of the hole being injected. Pressure gauges and valves shall be provided at the pump, at each hole being grouted and elsewhere as required to ensure the necessary control of grouting operations.

Grouting equipment shall be to the following minimum requirements and shall include all valves, water flow meters, pressure hoses, pipes, sleeves, packers, fittings and small tools necessary to complete the grouting:

- double acting flush pumps capable of operating at a discharge pressure of at least 2.5 MPa (25 kg/cm²)
- high speed mixers, capable of preparing a colloidal form grout
- mechanically agitated sumps with arrangements for screening and removal of particles not passing a 1.2 mm U.S. Standard Sieve, and with a capacity corresponding to not less than three batches of grout, each of minimum 50 l
- necessary valves, scales, pressure gauges and meters, packers, pipes, hoses, fittings, spares, etc
- adequate supply of air and water at a pressure of 0.6 MPa (6 kg/cm²) for washing of holes and crevices, pressure testing and grouting.

The grouting materials and equipment shall be adequately protected against rain, sunshine and other effects of weather. Grout supply conduits shall have an inner diameter of about 25 mm.

4.3.4 General requirements

Grouting may be required, either of complete drillholes in one operation, or of stages of drillholes down to two metres in length. When grouting of a hole is completed, the packer shall remain in place during a period of time approved by the Engineer.

The suitable time for drilling of a new round after grouting will be determined by the Engineer on the basis of experience gained on the setting time of the grout mix used.

Grouting will be carried out in one hole at the time or as multihole grouting i.e. several holes grouted from one pump unit.

A cement based grout mix shall normally be used with suitable additions of sand, bentonite, and/or accelerator. At high inflows of water a chemical grout (polyurethane or similar) shall be used as directed by the Engineer.

Grouting shall not be required to refusal and may be stopped when the waterflow is controlled.

4.3.5 Materials

Cement grout shall be composed of the following ingredients which may be used in varying combinations as directed by the Engineer:

- Portland cement, Type I, meeting the requirements of ASTM C-150 or other Standard approved by the Engineer.
- clean water, conforming to the requirements set out in Section CONCRETE WORKS.
- well graded sand passing a 0.30 mm sieve; the percentage by dry weight passing the 0.074 mm sieve should be less than 5%
- additives in accordance with the manufacturers' recommendations
- bentonite with a liquid limit not less than 400 %.

Tests to establish the composition of the grout shall be carried out by the Contractor and shall be approved by the Engineer before the grouting operations start. Different grout mixes shall be prepared in full scale using the actual grout mixer, and samples shall be taken for checking of segregation, hardening, etc. Similarly, samples shall also be taken from time to time during grouting operations, as directed by the Engineer.

4.3.6 Procedure

Grouting shall normally be preceded by a few minutes of pumping water into the holes. Where pressure tests give small water losses, grouting shall commence with a thin mix.

In holes with large water losses, a thicker mix shall be used. The water content of the mix shall be adjusted so that the grouting pump is operating at normal and practically constant speed, irrespective of the permeability of the grouted rock. The water-cement ratio shall be decreased, if necessary, to reach the required pressure. If, however, the pressure tends to rise excessively, the water-cement ratio shall be increased and periodic injection of water under pressure shall be carried out to counteract premature stoppage as directed by the Engineer. Under no conditions shall the grouting pressure or the rate of pumping be allowed to increase suddenly.

Grouting in a given hole shall normally continue until either no grout is taken at 75 percent of the maximum pressure permitted by the Engineer or less than 20 litres of grout is taken per 10 minute period at the maximum pressure. The water-cement ratio by weight shall normally not exceed 3. Holes which do not take grout shall be filled with mortar.

If so required for the execution of continued grouting, open fissures through which grout percolates to the surface shall be caulked using mortar, thick grout or other approved packing. Grout waste and loose material shall be removed from surfaces which are to receive concrete.

4.3.7 Consolidation grouting and pregrouting

4.3.7.1 Consolidation grouting

Consolidation grouting may be required in order to stabilize zones of excessively weak, fissured rock which cannot be satisfactorily secured by means of rock bolts and shotcrete.

4.3.7.2 Pregrouting

Pregrouting may be required to control the inflow of water at the workface. Probing ahead of tunnel face, see Section 3.5, and measured inflow of water will indicate the necessity of such type of grouting. The drilling of grout holes shall cover as many blasting rounds as practicable.

4.3.8 Contact and cavity grouting

4.3.8.1 General

Grouting shall normally be carried out by means of separate pipes used for introduction of grout and for release of air. The pipes shall be installed before concreting.

Careful control of pressures will be required during grouting. Much of the work will be at pressures of around 0.05 MPa, as excessive local pressures could adversely affect the concrete or steel linings. The Contractor may, however, be called upon to grout at up to 0.5 MPa pressure.

No grouting shall be carried out within 20 m of any incomplete section of concrete works nor within 20 m of any concrete less than 7 days old.

4.3.8.2 Installation of pipes in concrete

Prior to concreting linings, the Contractor shall install pipes or other type of form work for later drilling of grout holes as shown on Drawings or directed by the Engineer.

If pipes have not been provided, the reinforcing bars shall be located by means of suitable instrument before the drilling is commenced. No drilling shall be carried out in concrete less than 7 days old.

4.3.8.3 Contact grouting

The location of voids behind steel linings shall be established by sounding tests.

Grout sockets shall generally be arranged so that it will be possible for the grout to flow from one socket to the next behind the lining. Sockets shall be grouted at as low pressure as possible; adjacent holes being capped after the emerging grout has displaced any water behind the lining and the pressure has been brought up to the value directed by the Engineer.

Grouting shall start with a water test to gauge the size of cavity and lubricate the concrete/steel interface. Grouting shall proceed with a thin mix which shall be thickened once interconnections between sockets have been established.

During the continued grouting, the Contractor shall control the grouting pressures with particular care and continuously monitor the escape of air and grout through holes taken up for such purpose, so that grouting can be stopped at short notice. The Contractor shall protect steel linings from damage during grouting and shall continuously hose and brush down the steel face to prevent spilt grout from drying and adhering.

Where so directed by the Engineer, the grouting shall be performed with epoxy resin.

Where sounding tests indicate that there are still voids behind the lining despite grout refusal at an adjacent socket, the Contractor will be directed to drill holes in the lining and install further grout sockets for continued grouting.

4.3.8.4 Cavity grouting

The rock/concrete interface of concrete linings, whether steel lined or not, shall be grouted when so directed by the Engineer. If cavity grouting is performed behind any lining before it has been completed, such grouting shall not be carried out within 20 m of an incomplete section. Drillholes for grouting shall extend 300 mm into rock.

In the case of steel linings, cavity grouting will normally be carried out after contact grouting. Packers shall be used to prevent the grout pressure to enter behind the steel lining.

If a pipe has been provided through the concrete to facilitate cavity grouting, the pipe shall be plugged during the contact grouting. The plug shall be removed and the pipe flushed out as soon as the grout has taken up its initial set.

4.3.9 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 grouting behind concrete linings, the Contractor shall remove all grout nipples from embedded grout pipes.

Pipes shall be cut off flush with the concrete surface. Holes in concrete for such connections shall be filled.

On completion of grouting behind steel linings, the Contractor shall remove all grout nipples and seal the holes by threaded light conical plugs greased with epoxy resin. The plugs shall then be ground flush with the surrounding steel lining. Furthermore, the steel surface shall be cleaned to a condition suitable to receive paint when dry.

4.3.10 Records

Records, the format of which shall be approved by the Engineer, shall be submitted daily and shall give all relevant data such as:-

- Location and depth of holes
- Water losses measured during drilling and Lugeon values determined during water pressure tests
- Grout composition used, pressure and grout takes for each stage
- Possible rock movement recorded.

4.4 ROCK BOLTS AND ANCHORS

4.4.1 General

The materials, equipment, methods and procedures used by the Contractor for installing rock bolts and anchors shall be approved by the Engineer. With rock anchors shall be understood rock bolts required for fixation of concrete structures to rock.

The Contractor shall provide on Site a number of rock bolts and anchors to be directed by the Engineer from time to time.

4.4.2 Procedure

Drillholes shall have diameters recommended by the supplier or as proposed by the Contractor and approved by the Engineer.

Bolts and anchors shall be thoroughly cleaned and be free from loose rust, scale, dirt, grease or any other coating before they are inserted into the drillholes.

If not otherwise directed by the Engineer, the bolts and anchors shall be surrounded along the entire length of the hole by grout consisting of cement and water, with or without the addition of sand. The grouting shall be carried out in a manner preventing formations of voids or air pockets.

4.4.3 Untensioned rock bolts and anchors

Bolts and anchors shall be deformed bars of types approved by the Engineer and shall as a minimum meet the requirements for Grade 40, ASTM-A615.

Bolts and anchors shall be grouted in by means of the Perfo method or other methods approved by the Engineer. The methods shall comply with the manufacturer's recommendations.

If not otherwise directed by the Engineer, rock bolts shall protrude a sufficient length outside the rock surface to allow load testing according to Section 4.4.5. The protruding ends of rock bolts shall be threaded and provided with anchor plates where directed by the Engineer. Where the rock surface will be provided with reinforced shotcrete, the anchor plates shall be located outside the reinforcement. Protruding ends shall be covered with shotcrete or concreted in, as the case may be.

The protruding ends of anchors shall have been bent at right angles and as a minimum extend one anchorage length from the rock surface.

4.4.4 Prestressed rock bolts and cables

Prestressed rock bolts and cables shall be of types approved by the Engineer and shall be installed in accordance with the manufacturer's recommendations.

The bolts shall be prestressed as directed by the Engineer. The prestressing force shall be achieved by using jacks imposing a direct pull. The protruding end of the bolts and cables shall be provided with rolled or cut threads for fixing of anchor plates by nut and washer.

Protruding ends shall be covered with shotcrete or concreted in, as the case may be.

4.4.5 Testing of rock bolts

The appropriateness of the procedures for grouting and fixation of rock bolts shall be ascertained in preconstruction tests carried out by the Contractor as directed by the Engineer. For this purpose the Contractor shall provide all necessary equipment.

Running tests shall be performed routinely on % of all untensioned rock bolts. Such bolts shall be tested to 1.5 x working load. In case bolts fail before this load is achieved the Contractor shall test additional bolts as directed by the Engineer. If the failure depends on poor workmanship, the bolt shall be replaced by the Contractor at his own expense. If satisfactory results are consistently obtained, the number of tests may be decreased.

All prestressed rock bolts shall be tested between 7 and 10 days after installation. If tension has not been maintained, such bolts shall be retensioned to the working load. Bolts which have lost more than 30% of their load shall be considered defective and shall be replaced. Further testing and retensioning may be directed by the Engineer for all or any bolt.

4.5 SHOTCRETE

4.5.1 General

The materials, equipment, methods and procedures used by the Contractor for installing shotcrete shall be approved by the Engineer.

In general, the ACI Manual of Concrete Practice "Recommended Practice for Shotcreting", Committee 506, shall be followed. These practices may be modified, as directed or approved by the Engineer, to suit actual conditions.

The Contractor is free to use either dry mix or wet mix shotcrete.

4.5.2 Materials

Cement shall be low alkali Portland Cement meeting the requirement of ASTM-C150, Type II, Type III or other standard approved by the Engineer.

For aggregates, relevant parts of Section CONCRETE WORKS shall apply.

When early setting is required an accelerating admixture shall be used to develop quick setting and high early strength. The suitability and the required amounts of the admixture shall be established in preconstruction tests. Admixtures shall not contain water-soluble chlorides or substances corrosive to steel. Furthermore, admixtures shall not entail other detrimental effects, such as cracking and spalling of applied shotcrete. The proportion of admixture shall normally be restricted so that the strength requirements specified in Section 4.5.5 are satisfied. However, a higher proportion may be accepted where rapid treatment of weak rock is needed.

Water shall conform to the requirements set out in Section CONCRETE WORKS.

Steel reinforcement shall consist of hot rolled, deformed bars or welded steel wire fabric of mild steel, Grade 40, meeting the requirements of ASTM-A615 or ASTM-A185.

The use of steel fibres as reinforcement is allowed. A length/thickness ratio for the fibres of 60 is preferable, but fibres with other ratios may be used if approved by the Engineer.

4.5.3 Batching and mixing

4.5.3.1 Dry mix

The quantities of cement and aggregates shall be gauged by weight and be mixed dry in a mixing drum during at least 2 minutes or by continuous mixing methods approved by the Engineer.

Proportioning by volume may be allowed in the case of mobile mixers, provided that regular checking of mix proportions is carried out and have been approved by the Engineer.

The dry mix shall be batched in special batching plants or mobile mixers, solely used for this purpose, and placed within an appropriate distance from the various places where shotcrete shall be applied. The aggregate and the cement shall be well protected against

water and sunshine. The transport of the dry mix from the respective batching plant to the place of application shall be carried out with specially equipped vehicles and the dry mix shall throughout the transport be protected against water and sunshine.

4.5.3.2 Wet mix

Batching of wet mixed shotcrete shall be done at the concrete station and transported, ready to use, to the place of work by trans-mixers. The concrete shall be well protected against water and sunshine before application.

Proportioning by volume may be allowed in the case of mobile mixers, provided that regular checking of mix proportions is carried out and have been approved by the Engineer.

The proportions of cement, aggregates and admixture shall be determined in preconstruction tests. The proportions of cement and dry aggregates shall be between 1:3 and 1:5 by weight.

The steel fibre content in the shotcrete shall be determined in preconstruction tests.

4.5.4 Equipment and application

The Contractor shall provide an adequate number of mobile units with a remote-controlled swivel nozzle mounted on an extendable boom of such length that the operator can work under the shotcrete cover applied during the previous round. In addition to the mobile units, the Contractor shall provide an adequate number of manually held and operated nozzles.

The water shall be added in the nozzle when installing dry mix shotcrete and be supplied through a regulating valve, easily and accurately controllable by the "nozzleman".

Air shall be supplied at constant and sufficient pressure and volume. The air shall not be contaminated by oil.

Before the commencement of spraying, loose rock fragments shall have been removed. The rock surface or the surface of previously applied shotcrete shall be cleaned in order to ensure required bond. Groundwater per-

colating from the rock shall be drained by means of pipes, hoses or other appropriate methods approved by the Engineer.

In case welded steel wire fabric is to be used, it shall be fixed with 150 mm long steel nails, driven into previously drilled holes provided with plastic plugs, or with other appropriate method approved by the Engineer.

Spraying shall be carried out with the nozzle at right angles to the rock surface and at a distance of about one metre.

Should the mix be too dry or too wet or of uneven quality, the spraying shall be stopped.

The shotcrete shall be applied in layers, the thickness of which shall be determined so that rebound is minimized. Before the application of the next layer, the shotcrete of the previous layer shall have attained initial set. Rebound shall be removed and dumped.

No special measures are required for curing of shotcrete in underground locations.

4.5.5 Testing of shotcrete

Shotcreting shall only be carried out by experienced nozzlemen or by personnel under their immediate supervision. When required by the Engineer, each crew shall demonstrate its proficiency by producing test panels before beginning production work.

Well in advance of placing any shotcrete, the Contractor shall prepare and test not less than three test panels for each mix design. Sets of test panels shall comprise one shot downwards onto a horizontal surface, one shot onto a vertical surface and one shot upwards onto a horizontal surface. The panels shall be obtained by attaching 500 x 500 x 100 mm deep timber boxes securely to appropriately aligned surfaces and applying shotcrete to the areas contained in the boxes using the same mixing and placing equipment as for the production work.

When the final set has taken place, the test panels shall be transported to the laboratory where the Contractor shall determine the

crushing strength by testing cylindrical cores cut from the panels. The following minimum compressive strength requirements shall normally be met:

12 MPa (122 kp/cm²) at 3 days
30 MPa (306 kp/cm²) at 28 days.

These strength requirements refer to test cylinders with length and diameter both of 100 mm.

During placing of shotcrete, routine test panels shall be prepared beside the application zones for the purpose of quality control. One panel shall be provided and from this three samples shall be tested as described above for each 50 m³ of the first applied 1000 m³ of shotcrete. The frequency of testing may be decreased by the Engineer depending on test results.

The quality of the shotcrete will be considered satisfactory if every test result shows at least 80 per cent of the specified strength and if at least 80 per cent of all results exceed the specified strength.

4.6 STEEL SETS

4.6.1 General

The materials, methods and procedures used by the Contractor for installing steel sets shall be approved by the Engineer.

The Contractor shall provide on site a number of steel sets as directed by the Engineer from time to time.

4.6.2 Procedure

Steel sets shall be stored properly protected and be ready for immediate installation at all times during the excavation work.

The steel sets shall normally be installed immediately after a first layer of shotcrete has been applied. In certain places, it may be necessary to install intermediate steel sets (jump sets) at later stages, between those initially installed.

The steel sets shall not be removed, but shall be concreted in upon completion of the excavation work, thereby forming part of the final stabilization measures. The sets may intrude into the concrete section by no more than dimension of the rib plus 50 mm. Invert struts shall be installed where invert heave and/or appreciable side pressure is expected. The sets shall be made of profiles meeting the requirements of ASTM-A36 or equivalent standard.

The provision and installation of steel sets will be considered as daywork.

4.7 ROCK STRENGTHENING FOR CONTRACTOR'S CONVENIENCE

The Contractor may at his own expense install supports at excavations made for his convenience, see Section 3.4. Such supports shall be approved by the Engineer. Rock strengthening for Contractor's convenience shall be at the Contractor's expense.

4.8 STRUCTURAL CONCRETE

4.8.1 General

Concrete structures, including formwork and reinforcement, shall meet the requirements set out in Section CONCRETE WORKS.

Concrete structures may consist of arches, buttresses, linings, etc.

4.8.2 Preparation of surfaces

The ground against which concrete is to be placed shall be cleaned from loose material and dirt. Water shall be removed and water entering the area to be concreted shall be diverted. Anchors shall have been approved by the Engineer.

No concreting shall take place before surfaces which are to receive concrete have been approved by the Engineer.

4.8.3 Placing concrete in linings

Concrete shall be placed so that the space between the formwork and the surrounding ground is filled as completely as possible, including any voids in the crown of the arch.

Not sooner than 28 days after placing the concrete, the interface between the concrete and the surrounding rock in the crown shall be cavity grouted as directed by the Engineer, see Section 4.3.8.4.

4.8.4 Testing of concrete

Testing of concrete samples shall be performed as set out in Section CONCRETE WORKS.

4.8.5 Blasting adjacent to structures

Blasting in the vicinity of completed or partially completed concrete structures shall be subject to the approval of the Engineer. Normally, blasting shall not take place in the vicinity of newly concreted structures until 7 days after concreting.

4.9 PRIMARY STABILIZATION

4.9.1 Classification of rock quality

The rock classes are defined as follows:

Rock class	Description
I	Massive or blocky rock mass of competent hard rock, partly foliated.
II	Jointed, fractured or thinly foliated rock mass of competent hard rock, foliation perpendicular to the tunnel.
III	Jointed, fractured or thinly foliated rock mass of competent hard rock, foliation parallel to the tunnel.
IV	Fractured or thinly foliated rock of low or medium strength.
V	Crushed and scattered rock mass with clay and gouge material or weathered rock.
VI	Squeezing or swelling ground.

4.9.2 Tentative support system

Based on the results of site investigations, the following tentative support system has been established for tunnels:

Rock class	Roof	Walls
I	Rockbolts $l = 3 \text{ m}$ ($1/12 \text{ m}^2$) Shotcrete $t = 30 \text{ mm}$ (50 % of area)	-
II	Rockbolts $l = 3 \text{ m}$ ($1/6 \text{ m}^2$) Shotcrete $t = 30-60 \text{ mm}$	Spotbolting -
III	Rockbolts $l = 3 \text{ m}$ ($1/4 \text{ m}^2$) Shotcrete $t = 60 \text{ mm}$	Spotbolting -
IV	Rockbolts $l = 4 \text{ m}$ ($1/4 \text{ m}^2$) Shotcrete $t = 100 \text{ mm}$ (wire mesh or fibre)	Rockbolts $l = 4 \text{ m}$ ($1/10 \text{ m}^2$) Shotcrete $t = 50 \text{ mm}$
V	Rockbolts $l = 6 \text{ m}$ ($1/2 \text{ m}^2$) Shotcrete $t = 150 \text{ mm}$ (wire mesh or fibre)	Rockbolts $l = 6 \text{ m}$ ($1/2 \text{ m}^2$) Shotcrete $t = 150 \text{ mm}$, (wire mesh or fibre)

For rock class VI special treatment may be needed. Pre-grouting, consolidation grouting, forepoling, breast-boarding or installation of steel sets, with and without invert struts, may thus be required. Such measures will be considered as daywork.

The support system, as indicated above, will be modified to suit actual ground conditions encountered and experience gained by measuring of convergence, see Section 3.9.3.

5 MEASUREMENT AND PAYMENT

5.1 EXCAVATION

5.1.1 Excavation

Measurement shall be based on theoretical sections shown on Drawings or dimensions otherwise directed by the Engineer.

Payment shall be made according to the rates given in the Bill of Quantities for the different rock classes. The rates shall cover the cost of drilling, blasting, loading, haulage and dumping of excavated materials, as well as the scaling of excavated surfaces. The rates shall also include the cost for drainage of working faces up to the quantity specified in Section 5.1.3, as well as ventilation, lighting and all other facilities and safety precautions necessary for the execution of underground excavation in accordance with these Specifications.

5.1.2 Overbreak

No payment shall be made for overbreak, except for "ordered overbreak" and "approved overbreak". For "ordered overbreak" and "approved overbreak" special measurements of the quantities shall be made. For such quantities situated in a zone beyond a limit of 300 mm outside the theoretical section, the Contractor shall be entitled to payment according to the same rate as for excavation within the theoretical section. Claims for payment of overbreak shall be forwarded immediately, so that the cause for the overbreak can be established.

5.1.3 Dewatering

Excavation rates, see Section 5.1.1, shall cover the cost for drainage of working faces if the inflow from surrounding rock is less than 1,200 l/min and face. Pumping in excess of this quantity will be paid according to the rates given in the Bill of Quantities.

5.1.4 Probing ahead of tunnel face

Payment shall be made according to the rate given in the Bill of Quantities.

5.2 DRILLING

5.2.1 Percussion drilling other than for blasting

Measurement shall be based on lengths drilled in rock or concrete.

Payment shall be made according to the rates given in the Bill of Quantities.

5.2.2 Rotary drilling

Measurement shall be based on lengths drilled in rock or concrete.

Payment shall be made according to the rates given in the Bill of Quantities, which shall include compensation for normal waiting-time during the drilling, as well as the provision of core boxes.

5.3 GROUTING

Measurement shall be based on the number of grouted stages and the number of tonnes (kg) of cement, chemicals and other additives consumed.

Payment shall be made according to the rates given in the Bill of Quantities which shall include leakage testing, grouting, caulking of rock fissures and cleaning of rock upon completion. Payment for grouting of rock bolts and anchors is covered by Section 5.4.

5.4 ROCK BOLTS AND ANCHORS

5.4.1 Untensioned rock bolts and anchors

Measurement shall be based on numbers and lengths drilled in concrete and rock.

Payment shall be made according to the rates given in the Bill of Quantities. The rates shall cover drilling and cleaning of the holes, as well as the supply, placing and grouting of the bolts and anchors.

No extra payment shall be made for such extra length of bolts that may be required for fixing the test jack, nor for removal of such extra length on completion of tests.

However, where it is specified that an anchor shall extend to a certain length into a subsequently poured concrete structure, this additional length shall be measured and paid in accordance with Section 5.6.3.

5.4.2 Prestressed rock bolts and cables

Measurement shall be based on numbers and lengths drilled in concrete and/or rock.

Payment shall be made according to the rates given in the Bill of Quantities. The rates shall cover drilling, cleaning and leakage testing of the holes, as well as the supply, placing, tensioning and grouting of the bolts and cables.

5.5 SHOTCRETE

Measurement shall be based on the quantity sprayed.

Payment shall be made according to the rate given in the Bill of Quantities.

The steel reinforcement shall be measured and paid in accordance with Section 5.6.3

5.6 STRUCTURAL CONCRETE

5.6.1 Concrete

Measurement shall be based on theoretical inner contours shown on Drawings and on the configuration of the actual rock surfaces. No deduction will be made for space occupied by steel reinforcement or embedded pipes with less than 150 mm diameter.

Payment shall be made according to the unit rates given in the Bill of Quantities. In the case of concrete placed in overbreak zones, full payment will be made for all concrete within a 300 mm zone outside the theoretical section. Beyond this limit, payment will only be made where "ordered overbreak" or "approved overbreak" occurs, see Section 5.1.2.

5.6.2 Formwork

Measurement shall be based on the actual area of forms in contact with concrete, including forms in construction joints and in recesses.

Payment shall be made according to the unit rates given in the Bill of Quantities, which shall cover the supply, transport, erection and removal of the formwork, including scaffoldings.

5.6.3 Steel reinforcement

Measurement shall be based on the theoretical weight of the bars shown in the Bending Schedules, as adjusted for the configuration of the actual rock surfaces. Extra bars added for erection purposes shall not be measured.

Payment shall be made according to the rates given in the Bill of Quantities, which shall cover the supply, transport, cutting, bending and placing of the steel reinforcement.