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ROAD DIRECTORATE
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Public Company
"REPUBLIC OF SRPSKA ROADS "
Banja Luka

GUIDELINES FOR ROAD DESIGN, CONSTRUCTION, MAINTENANCE AND SUPERVISION

VOLUME II: CONSTRUCTION

SECTION 3: SPECIAL TECHNICAL CONDITIONS FOR TUNNELS

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CONTENTS

2.3.1 SITE INSTALLATION

2.3.1.1 GENERAL

Site installations. Site clearance (including removal) shall be carried out in accordance with the provisions of the SPECIAL TECHNICAL CONDITIONS.

The CONTRACTOR shall organize the installation site in a way that his temporary buildings, plants, equipment etc. will not hinder the final works on the motorway and other objects.

The CONTRACTOR shall remove all his temporary facilities which were installed for execution of the work and biotechnical replant all the areas which shall be put into primary condition.

2.3.1.2 LIST OF WORKS

a) The drawings for the site installation which are a part of the project can be used by the CONTRACTOR as information. The CONTRACTOR can organize the installation site on his own technology. The CONTRACTOR is obliged to provide site, which will be used during construction, for his own technology at his expenses. The CONTRACTOR is also obliged to organize access roads and transport of material to the construction site.

b) The CONTRACTOR shall get all the necessary permissions that are related to the construction, such as the agreement from the electrical distributors for site power supply, permission for connection to the existing water supply system, sanitary permission necessary for dewatering of technological (contaminated) water from the tunnel excavation and all other necessary permissions which are related to the execution works. The CONTRACTOR shall include all the costs for temporary facilities into the relevant Unit Prices.

c) Provisions are made in this Section for the case construction works are interrupted due to „ force majeure „ or as directed by the ENGINEER. The CONTRACTOR is responsible for security at the site during interruptions.

2.3.1.3 MEASUREMENT AND PAYMENT

The works specified in this Section will be measured as follows:

- *Works for site installation will not be measured separately. All the costs shall be included into Unit Prices for the whole execution works on Tunnel construction and for the whole period of construction.*
- *The axis setting out, protection and control measurements during the execution works should be carried out in linear meters. The Unit Price shall include all labour, necessary equipment and materials during the whole execution works.*
- *The removal of bushes, trees, branches and tree stumps of old and newly felled trees is measured on the actually performed work according to the provisions of the SPECIAL TECHNICAL CONDITIONS. The Unit Price for the certain items shall include the whole work process according to the provisions of the SPECIAL TECHNICAL CONDITIONS.*
- *The extent of other removals has to be assessed by the actually performed work and quantity and in the corresponding unit measures also according to the SPECIAL TECHNICAL CONDITIONS.*

2.3.2 EARTHWORKS ON PORTALS

Figures attached:

Figure 2.1 Scheme for measurements and payments – cut and cover section

2.3.2.1 GENERAL

a) This section contains the requirements which shall apply to site clearance, demolition, general open excavation and backfill.

b) Earth works and foundation works shall be executed according to the SPECIAL TECHNICHAL CONDITIONS, unless otherwise specified in this section.

c) The requirements related to underground excavation are covered in Section 2.3.4.

2.3.2.2 BULK EXCAVATION

2.3.2.2.1. GENERAL

In general excavation, including top soil stripping, bulk excavation, excavation of foundation and building pits, shall be carried out in accordance to the provisions of the SPECIAL TECHNICAL CONDITIONS, unless otherwise specified in this section.

2.3.2.2.2. MATERIALS

All types of soil and rock for construction work will be classified according to the specific provisions in the above mentioned SPECIAL TECHNICAL CONDITIONS.

2.3.2.2.3. EXECUTION

Excavation work shall be carried out in such a way as to ensure proper quality and conformance to the specifications and provisions of the SPECIAL TECHNICAL CONDITIONS.

2.3.2.2.4. MEASUREMENTS

2.3.2.2.4.1 TOP SOIL STRIPPING

Top soil stripping shall be measured in cubic meters for actual quantities in-situ.

2.3.2.2.4.2 BULK EXCAVATION

Bulk excavation as executed in the cut and cover sections and portal cuts will be measured in cubic meters for the different types of soil and rock according to SPECIAL TECHNICAL CONDITIONS.

2.3.2.2.4.3 EXCAVATION OF FOUNDATION

Excavation of foundation will be measured in cubic meters for each class of material, according to the provisions of the SPECIAL TECHNICHAL CONDITIONS.

2.3.2.2.4.4 EXCAVATION OF BUILDINGS PITS

Excavation of building pits will be measured for the different types of soil and rock and different depths in cubic meters (m^3) according to the provisions of the SPECIAL TECHNICAL CONDITIONS (see also FIG. 2.1).

2.3.2.2.5. PAYMENT

a) Payment for excavation will be made for at the Unit Prices per cubic meter (m^3) for each class of material. These Unit Prices include transport to a temporary or permanent disposal site or to an embankment site of the roadway project at distance 300 m from temporary portals.

b) The Unit Prices for excavation shall include all labour, equipment and materials necessary for excavation, loading, transport inside of distance 300 m of temporary portals and unloading.

c) The Unit Prices for excavation of portal cuts shall also include the preparation and construction of an adequate working surface of the pre-cuts and catching drain at the top and the toe of

the slopes. The pre-excavation plateau shall be covered with gravel layer of adequate quality in thickness of 100 cm. The material used shall be approved by the ENGINEER.

2.3.2.3 BACKFILLING

2.3.2.3.1. GENERAL

Backfills shall be carried out in accordance with the provisions of the SPECIAL TECHNICAL CONDITIONS.

2.3.2.3.2. MATERIALS

The materials to be used for backfills shall be in accordance to the provisions of the SPECIAL TECHNICAL CONDITIONS.

2.3.2.3.3. EXECUTION

a) Backfill works shall be executed referring to the related chapters in the above mentioned SPECIAL TECHNICAL CONDITIONS.

b) Backfilling of cut&cover tunnels shall be carried out systematically layer by layer symmetrically. The difference in height between backfilling on both sides of the tunnel lining shall not exceed 1 m.

2.3.2.3.4. MEASUREMENTS

Backfilling will be measured for the different types of soil and rock and different depths in cubic meters (according to FIG. 2.1).

2.3.2.3.5. PAYMENT

Payment for backfilling will be made for at a Unit Price per cubic meter separated for the different types of materials. The Unit Price includes loading of adequate material, transport to the site, unloading and compaction.

2.3.2.4 TRANSPORT OF EXCAVATED MATERIAL

2.3.2.4.1. GENERAL

a) Excavation material adequate for construction of embankments shall be transported to embankment sites as stated in designers specification of quantities.

b) Material not suitable for construction of embankments shall be transported to a disposal as stated in designers specification of quantities.

2.3.2.4.2. MEASUREMENT

a) Transport of excavated material from the site to an embankment site or deposit has to be included in unit price for excavation.

b) Hindrances due to coordination problems with other construction sites (e.g. traffic) shall be included in excavation costs and will not allow the CONTRACTOR to claim for additional payment.

2.3.2.4.3. PAYMENT

Transport of excavation material from temporary disposal in portal area (300m) to embankments or disposal sites measured from the respective temporary tunnel portals have to be included in unit price for excavation and will not be paid separately. Loading, unloading and dewatering of material at temporary disposal sites shall be included in the unit price for excavation.

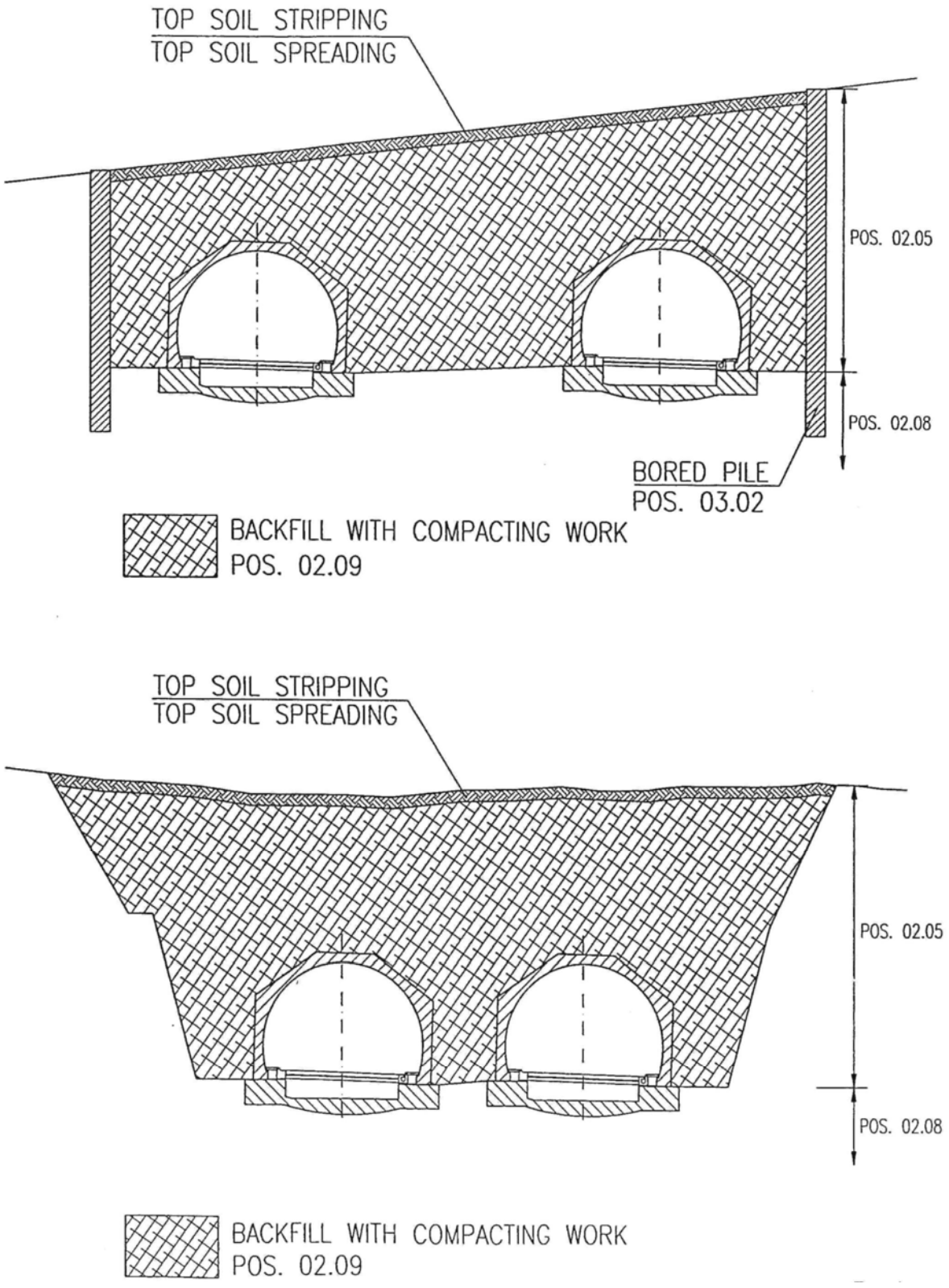


Figure 2.1 Scheme for measurements and payments – cut and cover section

2.3.3 RETAINING STRUCTURES AND SLOPE SUPPORT

2.3.3.1 GENERAL REQUIREMENTS

This section covers the requirements for retaining structures and slope support necessary to establish the permanent stability of cut slopes for portal structures and cut & cover tunnels.

2.3.3.1.1. CONSTRUCTION METHOD

a) In general, retaining structures will consist of anchored bored pile walls, anchored concrete beams, shotcrete structures and rock bolts.

b) Bored pile excavation shall be executed by cased drillings. For concreting of piles " CONTRACTOR-method " shall be applied (see Chapter 2.3.3.2.3 - Execution).

2.3.3.1.2. SUBMISSIONS

a) Prior to the commencement of any works covered by this specification, the CONTRACTOR shall submit to the ENGINEER for approval a method statement. The method statement shall include a comprehensive program for material testing and quality control covering all elements of the designed retaining structures.

b) Manufacturer's certificates of compliance shall be submitted certifying that the materials used meet specification requirements.

c) The method of installation of each type of support element including description, specification and pertinent manufacturer's literature for drilling, anchoring etc. shall be submitted to the ENGINEER.

d) The ENGINEER shall be provided with all submissions in sufficient time ahead of the construction works, or at such dates as mutually agreed upon.

2.3.3.1.3. CONSTRUCTION TOLERANCES

Construction tolerances shall comply with the provisions stipulated in OENORM B 4440 - Large bored piles.

According to above standard permissible execution tolerances are:

a) maximum deviation between actual centre point and designed centre of bored pile at the top of the piles shall not exceed e = 0,05 d, where "d" is diameter of bored pile

b) maximum deviation of the actual inclination from the design must not exceed 1 %

2.3.3.1.4. RECORDS

a) Detailed records containing all particulars of every bored pile actually installed and its performance in the course of the works shall be prepared and maintained by the CONTRACTOR and made available to the ENGINEER. These records shall include quality control and location of bored pile constructed, deviations from the designed support system, results of testing according to the valid standards of SPECIAL TECHNICAL CONDITIONS.

b) All the records will be submitted to the ENGINEER for approval.

2.3.3.1.5. EQUIPMENT AND MATERIAL SUPPLY

a) Any mechanical plant and equipment for installation of retaining structure and slope support shall be suitable for the works specified with respect to performance and current safety regulations and shall also be of sufficient capacity to fulfil production requirements in terms of the construction programme.

b) Proper maintenance of equipment and adequate provision of spare parts shall be made to ensure the immediate availability of equipment required for support installation.

2.3.3.2 BORED PILES

2.3.3.2.1. GENERAL

All works shall be carried out in accordance with „SPECIAL TECHNICAL CONDITIONS: Piles and drop shafts".

2.3.3.2.2. MATERIALS

a) Specifications for cement concrete and reinforcement according to Chapter 2.3.9 -Concrete Works and Reinforcement.

b) Due to the great depth of some bored piles, retarding additives may be added for concreting work with the approval of the ENGINEER.

2.3.3.2.3. EXECUTION

a) All the work in connection with pile foundation shall be carried out by the CONTRACTOR in accordance with the relevant provisions of the " SPECIAL TECHNICAL CONDITIONS "

b) After completion of excavation work the well bottom shall be cleared and the reinforcement cage shall be adjusted properly.

c) The concreting work must be executed according to the requirements of the "CONTRACTOR method". Concreting pipes reaching to the bottom of the well will be pulled slowly and constantly during concreting. The end of the pipe shall remain in the concrete during pouring. Concrete works for each pile must be executed without interruption.

2.3.3.2.4. TESTING

According to Chapter of the SPECIAL TECHNICAL CONDITIONS.

2.3.3.3 ANCHOR BEAMS

2.3.3.3.1. GENERAL

For specification of concrete works and steel reinforcement see Section 2.3.9 - CONCRETE WORKS AND REINFORCEMENT.

2.3.3.4 SHOTCRETE

For specification of shotcrete see Section 2.3.7 - TUNNEL SUPPORT.

2.3.3.5 ROCK BOLTS

For specification of rock bolts see Section 2.3.7 - TUNNEL SUPPORT.

2.3.3.6 CABLE ANCHORS

2.3.3.6.1. GENERAL

a) This part of Section 3 applies to the supply and installation of prestressed cable anchors required and used as additional support for the bored pile wall in the open cut sections.

b) All works shall be carried out in accordance with the following standards:

- *SIA 191 (1996)*
- *BAS*

2.3.3.6.2. MATERIALS

2.3.3.6.2.1 GENERAL

Anchors shall not contain materials that are mutually incompatible with each other and the surrounding environment.

2.3.3.6.2.2 PRESTRESSING STRANDS

a) The prestressing steel shall consist of prestressing steel strands according to OENORM B 4258. The distance between the individual strands shall be sufficiently large to provide for faultless

embedding in cement or mortar or in the permanently plastic corrosion protection material. The strands shall be made of high, tensile steel.

b) The mechanical properties and technical characteristics shall comply with the code OENORM B 4258, as follows:

- o *Steel strands with seven wires, low relaxation* *ST 1570/1770*
- o *Nominal steel area* *100 mm²*

2.3.3.6.2.3 GROUT

a) SPECIAL TECHNICAL CONDITIONS Grouting and Injecting Work

b) Grout shall consist of Portland Cement, water and admixtures, if required. The cement shall not contain (by weight) more than 0.02% chlorides or 0.10 % sulfides. The admixtures shall not harm strands or grout properties. The water/cement ratio shall be kept as low as possible. In no case it shall exceed 0.45. The grout mix shall not be subject to bleeding in excess of 0.5 percent by volume 3 hours after mixing or 1 % maximum when measured at 20° C in a covered glass or metal cylinder of 100 mm diameter and with a grout depth of approximately 100 mm.

c) At prestressing the compressive strength of the grout shall be at least 20 N/mm².

2.3.3.6.2.4 PROTECTIVE TUBES

a) The free length of the strands shall be encased in a smooth HDPE-tube. The HDPE shall be homogeneous and free of voids. No regenerated material is allowed. Thickness of the tube-wall shall be at least 3 mm.

b) The bond length of the strands shall be encased in a corrugated tube with a minimum wall thickness of 1 mm.

2.3.3.6.2.5 ANCHOR HEAD

The strength of the anchor head shall be at least the same as of the strands.

2.3.3.6.3. SYSTEM REQUIREMENTS

2.3.3.6.3.1 CORROSION PROTECTION

a) The corrosion protection of anchoring system has to be made according to SIA 191 (1996).

b) This includes all parts such as anchor head, packer, free anchor length and bond length of the strands and the distant end of the anchor.

c) The bond length is principally corrosion protected by cement suspension and one corrugated HDPE tube. Grouting of the cement suspension is performed before or after anchor installation, depending on application.

d) The bond length shall be determined by suitability tests.

2.3.3.6.3.2 SYSTEM COMPONENTS

a) The system shall be designed to provide an ultimate load holding capacity of not less than s x Pw (Pw.....working load). The safety factor according to SIA 191 (1996) is specified as follows:

- o *against failure of tendon*
- o *against yield tendon*
- o *against limited creep load*
- o *against failure of grout body*

b) The anchor shall be designed to allow monitoring of the load (e. g. with hydraulic load cells or equivalent)

c) The stressing anchorage shall be designed to enable release of load in the case that the working load is considerably exceeded due to ground movements

2.3.3.6.4. ANCHOR INSTALLATION

2.3.3.6.4.1 DRILLING

a) Anchor length are to be such, that boreholes can be drilled with normal face drilling rigs. Borehole diameters for anchors shall be 130 mm, depending on the rock quality respectively and is given in drawings.

b) In ground likely to collapse, the sides of the boreholes shall be supported by suitable casing tubes.

c) Before insertion of the anchor the drill hole shall be washed clean.

d) A drilling record, containing all relevant information such as drilling method, borehole depth, flushing medium, flushing return, drilling speed, kind of rock drilled etc. shall be taken by the CONTRACTOR'S geologist for each hole drilled. The records shall be made immediately available to the ENGINEER.

2.3.3.6.4.2 WATER PRESSURE TESTS

a) Water pressure tests shall be carried out in defined boreholes only in rock that is not sensible on water. The first three boreholes in each typical geological section shall be tested to 4 bar. After the experience of these tests it shall be decided by the ENGINEER if the water pressure tests shall be continued or can be omitted for the subsequent anchors at each location. Every 15th borehole shall be tested routinely.

b) If loss of water exceeds 5 liter per minute over a period of 5 minutes in the bond section of the anchor at a water pressure of 3 to 4 bars in the test section, the borehole shall be pregrouted, redrilled and tested again.

c) A full record of water pressure tests shall be taken by the CONTRACTOR and submitted to the ENGINEER.

2.3.3.6.4.3 INSERTION OF ANCHOR

a) The anchor shall be inserted as soon as practicable after but at most within 12 hours of completion of the drilling.

b) During installation the anchor shall be handled with care. The anchor shall be installed with an injection pipe and an ventilation pipe.

c) The anchor shall be positioned in the center of the borehole by use of spacers and the bearing plate shall be at a right angle to the borehole axis. To achieve the latter it may be necessary to cut out pockets in the rock.

2.3.3.6.4.4 GROUTING

a) The grouting procedure shall ensure that there are no air or water pockets left in the grouted zone.

b) Grouting shall proceed at a slow, steady rate and continue until grout of the same composition and consistency as mixed can be seen emerging from the outlet of the vent pipe for at least one minute.

c) A record giving full details of the grouting operation for each anchor shall be submitted by the CONTRACTOR to the ENGINEER.

d) Grouting of the free anchor length shall be done after prestressing of the anchor.

2.3.3.6.5. ANCHOR TESTING PROCEDURES

Anchor testing procedures should follow standards as SIA 191 (1996) as well as SPECIAL TECHNICAL CONDITIONS.

2.3.3.6.5.1 SUITABILITY TESTS

Suitability tests are carried out on anchors constructed under similar conditions as for the working anchors. These tests indicate the results, which shall be obtained subsequently from the working anchors by the routine acceptance tests. Considerable and significant changes of the conditions for the working anchors e.g. geological conditions, require the execution of suitability tests.

2.3.3.6.5.2 ACCEPTANCE TEST

a) In the course of the acceptance test each anchor will be stressed to the relevant test load. In cohesive soils the creep-values shall be determined as well.

b) Test programme:

A cyclic loading and unloading procedure shall be carried out with the load being increased from a initial load in successive cycles by load steps until a specified maximum load. At each load increment the displacement of the strands at the anchor head relative to a fixed point in the environment shall be observed at constant load according to the schedule set up.

2.3.3.7 MEASUREMENT

2.3.3.7.1. BORED PILES

a) Bored piles excavation as well as chisel drilling will be measured by linear meter for the actual depth drilled.

b) Bored piles concrete for retaining structure will be measured by cubic meter.

c) Pile reinforcement will be measured by weight for actual quantities (t) installed as shown on drawings.

2.3.3.7.2. ANCHOR BEAM

a) Concrete will be measured in cubic meter according Section 2.3.9.6. Form work for construction of the concrete beams will not be measured in the Unit price for concrete.

b) Reinforcement for concrete beams will be measured by weight for actual quantities (t) installed as shown on the drawings.

2.3.3.7.3. SHOTCRETE

Shotcrete lining applied for retaining structure, will be measured by square meter for the theoretical thickness designed.

2.3.3.7.4. CABLE ANCHORS

Cable anchors will be measured by pieces for the various length, types and working loads designed. Installment and supply material, such as anchor plates, packings, nuts and joints shall be included in the Unit Price.

2.3.3.8 PAYMENT

2.3.3.8.1. BORE PILES

a) The Unit Prices for the different pay items of the bored piles shall include all labour, equipment and materials required for complete execution of the works, including quality control and testing.

b) The installation and clearing of a working platform for the bore pile jumbo shall be included in the Unit Price for linear meter of bored pile.

2.3.3.8.2. ANCHOR BEAMS

a) The Unit Prices for the different pay items shall include all labour, equipment and materials required for execution of the works.

b) According to Section 2.3.9 - Shuttering and scaffolding required for the construction of the anchor beams shall be included in Unit Price for concrete.

2.3.3.8.3. SHOTCRETE

The Unit Price for shotcrete shall include all labour, equipment and materials required for execution of the works, including quality control and testing, as well as concrete after-treatment.

2.3.3.8.4. ROCK BOLTS

The Unit Price for rock bolts shall include all labour, equipment and materials required for execution of the works, including quality control and testing.

2.3.3.8.5. ANCHORS

a) The Unit Prices for the different pay items shall include all labour, equipment and materials required for execution of the works, including coupling, grouting of free anchor length, prestressing, quality control and testing. Drilling and grouting of bond length will be paid separately.

b) The Unit Price for anchors of different length than specified will be calculated by linear interpolation or extrapolation .

c) Drilling for anchors will be paid for at the Unit Price per linear meter considering the respective total length of the bore hole.

d) The unit price should also cover the installment of anchors over head in inclined direction.

2.3.4 UNDERGROUND EXCAVATION

Attached Figures:

FIG. 4.1 Definition of Tolerances for Deformation and Construction

FIG. 4.2 Excessive Overbreak due to Unfavorable Geologic Conditions

FIG. 4.3 Lines for Measurement and Payment

FIG. 4.4 Lines for Measurement and Payment for Regular Cross-Sections without Invert Arch

FIG. 4.5 Lines for Measurement and Payment for Regular Cross-Sections with Invert Arch

FIG. 4.6 Lines for Measurement and Payment for Regular Cross-Sections with Niches

FIG. 4.7 Lines for Measurement and Payment for Regular Cross-Sections with Cross Passages for Pedestrian

2.3.4.1 GENERAL

2.3.4.1.1. DESCRIPTION

This section applies to the execution of all underground excavation works in any type of rock. Excavation may be carried out by drill and blast using pre-split or smooth blasting techniques or by mechanical equipment (e.g. road header or tunnel excavator). The CONTRACTOR is responsible to choose the method of excavation and the necessary equipment.

The CONTRACTOR shall adhere to all procedures as detailed on the drawings, described in the specification and in the submissions required in accordance with chapter 2.3.4.1.2 of this specification or other procedure as agreed with the DESIGNER and approved by the ENGINEER.

The CONTRACTOR shall carry out excavation and support work so as to accomplish the requirements of the particular support class agreed and to minimize the deterioration and loosening of the rock mass surrounding the excavation, to restrict overbreak and to prevent damage to the initial lining previously installed.

Excavation sequences and subdivision of excavation headings shall be in accordance with tender drawings, specifications and detailed design drawings prepared by the CONTRACTOR.

2.3.4.1.2. SUBMISSIONS

a) Prior to commencement of any underground excavation, the CONTRACTOR shall submit to the ENGINEER for approval detailed drawings and/or descriptions of proposed excavation methods and sequences, including necessary site drainage, safety measures and the results of test programmes carried out in accordance with local law.

b) The sequence of excavation of the various underground works of the tunnels shall be presented to the ENGINEER in a general schedule for all tunneling works by CONTRACTOR.

c) Based on the rock classification system as specified in Section 2.3.6 the CONTRACTOR shall submit to the ENGINEER for approval a detailed schedule of the working cycle for excavation and support in each rock type class and for each type of excavation profile.

d) The method of excavation in each type of soil or rock, including the description, specification and pertinent manufacturer's literature for drilling, mucking and transporting, equipment shall be submitted to the ENGINEER.

e) All blasting work shall be carried out in accordance with the local regulations for precautions and safety measures for manipulation with explosives.

f) Particulars of the proposed blast design shall be submitted to the ENGINEER for each cross section or subdivided cross section, containing the following information:

- *Drilling pattern, hole diameters, spacing, depth and inclination.*
- *Type, strength, amount in terms of weight and cartridges of explosives to be used in each hole, on each delay and the total for each blasting round.*
- *Distribution of the charge in the holes, and priming of each hole.*

- o *Type, sequence and number of delays, delay pattern; wiring diagram for blast; size and type of hook-up lines and lead lines; type and capacity of firing sources; type of condenser discharge blasting machine.*
- o *Stemming of holes and matting or covering of blast area.*
- o *Written evidence of the qualifications of the persons who will be directly responsible for supervising the charging and firing of the round.*

g) The material excavated in the tunnel and found suitable for forming motorway embankments shall be used on the permanent motorway works unless otherwise instructed by the ENGINEER. Prior to dumping or stockpiling of any material the CONTRACTOR shall submit layouts of stockpile and spoil areas for approval to the ENGINEER. The layouts shall show all pertinent data of working methods, stability, provisions for security and both temporary and permanent drainage arrangements and the final landscaping.

h) The ENGINEER shall be provided with all submissions in sufficient time ahead of construction works, or at dates mutually agreed upon.

2.3.4.2 EXECUTION

2.3.4.2.1. EQUIPMENT

a) Any mechanical equipment for underground excavation works and transportation shall be suitable for the works specified with respect to performance and current safety regulations, as well as for compliance with the requirements of the construction time programme, to the approval of the ENGINEER.

b) Underground mechanical plant and equipment shall be powered by electricity, compressed air or diesel engine. Diesel engines must be fitted with filters for the treatment of exhaust fumes. Petrol or paraffin appliances shall not be used underground.

c) Rock-drilling with water flushing shall not be allowed in rock formations sensitive to water , unless required by the ground conditions as approved by the ENGINEER.

2.3.4.2.2. LIGHTING AND POWER DURING CONSTRUCTION

a) The CONTRACTOR shall be responsible for providing and maintaining in good working order the whole of the installation of the load side of the points of supply and in relation thereto shall take all precautions necessary to ensure the safety of every person on the site. The ENGINEER may require the disconnections or alterations of parts which he considers dangerous.

b) The CONTRACTOR shall install at the site of each heading his own standby diesel or fuel driven generator capable of operation the whole of the lighting system and the pumps required at any time for discharging seepage water.

c) A minimum light of 100 Watts per 10 m length of the tunnels or such higher level that may be required shall be installed and maintained by the CONTRACTOR.

2.3.4.2.3. VENTILATION DURING CONSTRUCTION

a) Ventilation during construction is the responsibility of the CONTRACTOR. The ventilation system shall be designed and operated in accordance with the local regulations (Off. list SRS - No. 26/88 - Regulation of safety measures at works on tunnels, drifts and underground roadways).

b) The ventilation system shall be designed to suit the length of the tunnel, excavation method used and number of labourers working inside the tunnel. Toxic gases, smoke and dust particles indicated by measurements at the working sites shall not exceed permissible concentrations (MPC).

c) For tunnels with the occurrence of explosive gases (e.g. methane gas) the ventilation system shall be designed and operated to achieve an adequate dilution of hazardous gases (CO_2, CO, NO, NO_2). Measurements of gas concentrations shall be carried out by portable and fixed installed measuring devices.

d) In general the ventilation system shall be designed to blow-in fresh air to the excavation headings. The distance between the end of the ventilation duct or hose pipe and the

excavation face shall not exceed 30 m. The thrust of the ventilation fans shall be sufficient to dilute the concentration of explosive gases below 0.5 % and simultaneously ensure a velocity of the air stream of minimum 0.5 m/sec.

e) Only well instructed personnel shall be allowed to work in tunnels with possible gas occurrences. Smoking inside the tunnels is prohibited. It shall be made effective through visible signs at the tunnel entrances.

2.3.4.2.4. DEFINITION OF EXCAVATION PROFILE

a) The excavation profile as indicated on the drawings (regular tunnel cross sections) refers to the theoretical excavation profile defined as T-line (see FIG.4.1).

b) Depending on the quality of the rock, an appropriate enlargement of the theoretical excavation profile shall be made in order to provide enough space for radial deformations and construction tolerances.

c) The excavation line defined as D-Line (see FIG.4.1) to compensate for radial deformation "a" for the various rock mass types considers allowances for deformation (deformation tolerance t_D). The values given on related drawings or in the tender documents for expected deformations "a" may be adjusted to suit actual deformations as experience is gained during excavation. Adjustments shall be made by the DESIGNER and shall be approved by the ENGINEER.

d) The D-line represents the minimum profile to be excavated. In general, rock shall not protrude inside this line at the moment of excavation except locally where a tolerance of two thirds of the nominal shotcrete thickness will be allowed for protruding edges and corners of sound rock.

e) The CONTRACTOR shall make all reasonable effort to maintain the profile as defined by the D-Line by exercising careful control of drilling and by varying the various elements of smooth blasting or pre-splitting.

f) In order to maintain the excavation profile as defined by the D-Line the CONTRACTORmust allow for a construction tolerance (tc) for excavation and support installation. The construction tolerance (tc) shall also include survey inaccuracies. Refer also to FIG.4.1.

2.3.4.2.5. OVERBREAK

a) Overbreak is the space created when the ground breaks beyond the profiles including deformation and construction tolerances. Occurring overbreak may be caused by improper workmanship and careless working technique (avoidable overbreak) and/or by reasons which cannot be influenced by the CONTRACTOR (unavoidable overbreak).

b) Unavoidable overbreak is caused by two sources:

- *natural overbreak which cannot be avoided by careful work and proper workmanship.*
- *Overbreak caused by prevailing unfavorable geological conditions.*

The average order of magnitude of the so-called "unavoidable overbreak" is estimated for all rock mass types and indicated on the drawings or in the tender documents, and is defined as value "b" (see FIG. 4.1).

c) Excessive overbreak (see FIG.4.2.) may be caused by extremely un-favorable and/or non predictable geological conditions. Unavoidable overbreak means again that the CONTRACTOR exercised most care and best possible workmanship and he could not prevent the overbreak due to prevailing unfavorable geological conditions.

d) In the event of excessive overbreak, support shall be installed immediately as required to stabilize the ground. The DESIGNER and/or the ENGINEER shall be informed. Remedial works shall be discussed and agreed between the CONTRACTOR and the DESIGNER or the ENGINEER. The detail design for the repair works shall be done by the CONTRACTOR and shall be approved by the ENGINEER. Remedial works shall be executed before further advance of the face unless approved or directed otherwise by the ENGINEER.

e) Where it is decided that overbreak has been caused by physical conditions beyond the control of the CONTRACTOR and has not arisen because of incorrect methods of work or carelessness, the cavity or void formed by the overbreak shall be measured in-situ. The materials required to complete the designed repair shall be quantified and approved by the ENGINEER and certified for payment.

2.3.4.2.6. EXCAVATION REQUIREMENTS

a) Drilling and blasting shall be done in such a manner as to ensure that the rock will break along the desired lines.

b) The diameter and the spacing of the blast holes shall be adapted to the actual rock conditions on site. The CONTRACTOR shall develop and continuously improve the blasting techniques as the works progress to obtain the best possible excavation surface after blasting.

c) Rock excavation shall be performed by using modern blasting methods. Controlled blasting methods such as "smooth blasting" or pre-splitting shall be used to limit the overbreak and to prevent shattering of the rock surfaces.

d) The excavation of niches, except parking bay niches, in tunnel side walls and cross passages shall be carried out after installation of the initial support in the main tunnel. Shotcrete and steel ribs in the tunnel side wall shall be carefully cut along the profile of the niches or cross passages and excavation shall be carried out in such a manner that the remaining tunnel support will not suffer any damage.

e) The excavation of parking bay niches shall be carried out by widening the regular cross section of the main tunnel during tunnel driving with an inclination of 40°. Excavation shall be carried out in accordance with the provisions mentioned in this section. The final profile will be achieved by reshaping the widening section at the beginning of the parking bay niche.

f) Excavation in Rock Mass Types with high water sensibility (swelling rock) has to be carried out with special care to avoid any damages due to swelling rock. In these areas construction work and proper workmanship shall be provided to avoid contacts between rock mass and water.

2.3.4.2.7. SAFETY PRECAUTIONS

a) Careful and proper scaling after each blast is imperative. The support elements are considered to be sufficient for the overall stability of the tunnels, however, the CONTRACTOR shall perform the installation of local rock bolts as required to prevent loosening of rock blocks in the immediate heading area. Periodical inspection of the tunnel sidewalls and roof areas shall be performed by the CONTRACTOR to detect possible cracks or signs of instability of the tunnel support. Assessment of cracks shall be made in association with the results of the geotechnical measurements in co-operation with the DESIGNER.

b) Blasting will be permitted only after proper precautions have been taken for protection of all persons, work, and property.

c) Drilling, blasting, excavating and shotcreting operations shall be conducted by methods and with equipment which shall positively control dust, fumes, vapours, gases, fibres, fogs and mists.

2.3.4.2.8. CONTINUOUS WORKING

a) To ensure the safety and the security of the works, tunnel excavation shall be continuous by day and night except as otherwise approved by the ENGINEER. If the state of the work permits, intermissions will be allowed at weekends and general holiday periods, provided that the works are secured in a safe condition.

b) The intermission shall not be allowed to start until all the support elements in the support class at the particular locations have been completed.

c) In addition the face of any heading shall be sealed with shotcrete (minimum thickness 3 to 5 cm) except in stable rock conditions (specified as Rock Mass Types A1 and A2).

2.3.4.2.9. DRAINAGE DURING CONSTRUCTION

2.3.4.2.9.1 SCOPE

a) The CONTRACTOR shall supply, install, operate and maintain sufficient pumps and pipework to control and remove water from any part of the underground works. Standing water will not be allowed.

b) The capacity of pumps installed at each working face shall always be at least one and a half times the normal volume of the inflow of water plus the volume of flushing water used by the drilling equipment.

c) The CONTRACTORshall store or immediately have available standby pumps in good working conditions of the same capacity as installed in the tunnels.

d) The CONTRACTOR shall provide settling tanks or other decontamination facilities as required by the ENGINEER before the water is discharged to waste.

e) The CONTRACTOR shall remove all accumulated slurry, silt or other debris from the underground works as required by the ENGINEER.

f) The CONTRACTOR shall manufacture, maintain and operate required facilities and plants to treat and clean all contaminated water discharged at the tunnel portals during construction. Such facilities and plants shall include 2 sedimentation basins, oil trap, neutralization plant and necessary control stations. The neutralization plant shall be designed and operated to maintain the pH-value of the treated water between 6.5 and 8.5 prior to dischargement.

2.3.4.2.9.2 MATERIALS AND EXECUTION

a) Longitudinal Drainage: The tunnel shall be drained during construction by trenches in the bottom of the respective heading. The trenches shall be sealed with shotcrete. In areas of large water inflows, installation of partly perforated or slotted hard-PVC pipes with a diameter of 150 mm to 250 mm depending on the amount of water to be diverted may be necessary.

b) The CONTRACTOR shall pay utmost attention to collection and drainage of seepage water and water needed for construction in rock mass sensitive to water.

c) In case of descending headings sumps shall be provided at regular intervals from where the water shall be pumped out of the tunnel in steel or PVC pipes.

d) Radial Drains: For concentrated water inflows, relief holes shall be made into the ground and or shotcrete. Perforated steel pipes or hard-PVC pipes, diameter 1,5 to 2 inch, shall be installed into the holes. The space between the pipe and mouth of the borehole shall be sealed with quick-setting mortar. Quick setting mortar is a material which provides setting and hardening within a couple of minutes used for temporary fixation or sealing. No specific properties are required. The mouth of the pipe shall be connected to a hose for diversion to the temporary longitudinal drainage, to sumps or longitudinal trenches in the bottom of the respective headings.

e) Ring drains: In wet areas on the rock surface, water shall be collected by half shells (preferably corrugated, soft-PVC pipes) which are fixed to the rock by quick setting mortar or shotcrete and diverted to sumps or longitudinal trenches in the bottom of the respective headings.

f) Later occurring wet areas in the shotcrete lining shall be drilled open and treated as above.

g) In tunnels, constructed in permeable soil or highly fractured rock, ring drains with a diameter of 4 cm minimum shall be installed systematically to avoid the build-up of water pressure behind the shotcrete lining, as approved by the ENGINEER.

h) The CONTRACTORshall ensure that the sumps installed are kept clean and the drainage system maintained so that all water during the construction period is adequately controlled.

2.3.4.2.10. EXPLORATORY BOREHOLES

Exploratory boreholes shall be carried out in accordance with the provisions of Section 11.

2.3.4.2.11. SITE TRAFFIC ON FINAL EXCAVATION LEVELS

a) Final excavation levels (formation level) for pavement construction shall be protected against any wear or deterioration of rock properties following site traffic by backfilling with rock material excavated in the tunnel or similar to a minimum thickness of 0.5 meters.

b) CONTRACTOR has to prevent Ponding of water and traffic through ponding water shall not be allowed.

c) Any deteriorated material shall be removed and replaced prior to pavement works as directed by the ENGINEER.

d) The backfill material used for protection of transport route shall not be removed until final works on road structure begin.

2.3.4.2.12. SITE TRAFFIC ON INVERT SUPPORT

No site traffic shall be allowed to run on unprotected invert structures, temporary or final, concrete or shotcrete.

Structures as such shall be protected against destruction by backfilling with suitable excavation material from the tunnel or similar with a minimum thickness of 0.5 metres. Backfilling material shall not contain boulders larger than 150 mm diameter.

2.3.4.3 MEASUREMENT FOR EXCAVATION

The work specified in this Section will be measured as follows:

a) Excavation of the tunnels and parking bay niches in all rock mass types will be measured by cubic meter (in-situ) along "Line 2" (equal to D-Line) as shown on FIG. 4.3, FIG. 4.4 and FIG. 4.5. The length of each round will be calculated along the centre line of the tunnels. Measurement will be done for subdivisions of excavation cross sections as shown on the drawings. In case a temporary invert is required for top heading the measurements for bench excavation will be reduced accordingly.

b) Excavation of cross passages in all rock mass types will be measured by cubic meter along "Line 2" (equal to D-Line) as shown on FIG. 4.3 and FIG. 4.7.

c) Excavation of niches will be measured for payment by cubic meter along "Line 2" according to FIG. 4.6.

d) Enlargement of the excavation profile for allowance of construction tolerances (tc) and unavoidable overbreak ("b") inside the O-Line will not be measured for payment (see Figure 4.2).

e) Excessive overbreak beyond (outside) the O-Line due to unfavorable geological conditions will be measured in-situ by actual quantities, provided the volume of the overbreak exceeds 2 cubic meter. Over breaks less than 2 m^3 will not be measured for payment.

f) Additional excavation due to the widening of the cross section under the pipe roof will not be measured and paid by separate item.

g) Additional excavation required for temporary footings will be measured by linear meters of footings.

h) Additional works and materials necessary due to careless work in Rock Mass Types with high water sensibility (swelling rock) will not be measured for payment.

i) For descending headings temporary water control for quantities up to 5l/sec, including adequate drainage, diversion and disposal of water during excavation works is the responsibility of the CONTRACTOR and will not be measured for payment. Temporary water control for quantities exceeding 5 l/sec will be measured separately by required pumping hours. Water used for drilling, flushing, grouting or other works will not be measured for payment.

j) For ascending headings temporary control of all seepage water, including adequate drainage, diversion and disposal of water during excavation works is the responsibility of the CONTRACTOR and will not be measured for payment.

k) Hindrance of excavation works in ascending and descending headings due to seepage water exceeding 10 l/sec. will be measured for payment. Measurements shall not include water used for drilling, flushing, grouting or other works. Only water inflow within a distance of 20 m from each excavation face will be measured for payment.

l) Ventilation during construction is the responsibility of the CONTRACTORand will not be measured for payment.

m) Initial rock support including shotcrete, wire mesh, steel ribs, rock bolt, sealing of the face and forepiling will be measured separately (see Section 2.3.7 of this Specification).

n) Transport of excavation material from the tunnel portal or temporary disposal site near a tunnel portal to a permanent disposal area or to an embankment site have to be included in unit price for excavation.

o) Hindrances due to co-ordination problems with other construction sites (e.g. traffic) shall be included in Unit price for excavation and will not allow the CONTRACTORto claim for additional payment.

p) Interruptions of excavation work up to 6 hours due to heavy water inflow, large overbreaks or other unintended occurrences will not be measured for payment.

q) Interruptions of excavation work up to 2 hours due to high concentrations of explosive gases (e.g. methane gas) will not be measured for payment.

2.3.4.4 PAYMENT

a) The Unit Price for excavation shall include all labour, equipment and materials required for excavation within the specified limits, removal of temporary rock support (e.g. temporary shotcrete invert, face bolts), necessary changes of excavation equipment, removal and disposal of all excavated material from the excavation face to the tunnel portal or to a temporary disposal site within a distance of 300 m from the respective tunnel portal or to permanent disposal area, temporary water control in ascending headings, hindrances of excavation work due to seepage water up to 10 l/sec, hindrances due to geotechnical measurements and geological mapping, hindrances due to installation of support elements, ventilation and lighting during construction, the development and adapting of blasting patterns and all potential additional measures, hindrances and problems mentioned in the previous chapter 2.3.4.3.

   - *Underground excavation for the various rock mass types will be paid for at the Unit Price per cubic meter*
   - *Hindrances of excavation work due to seepage water exceeding 10 l/sec will be paid for at the Unit Price per cubic meter excavated material during the excessive water inflow.*
   - *Temporary control of seepage water exceeding 5 l/sec in descending headings will be paid for at the Unit Price per pumping hour. The Unit Prices for temporary control of seepage water shall include all labour, equipment and materials (e.g. pipes, sumps) required for execution of the work.*
   - *Interruptions of excavation work exceeding 6 hours due to heavy water inflow, large overbreaks or other unintended occurrences will be paid for at the Unit Price per hour of interruption. Payment will only be made if the miners, support personnel and equipment employed at the respective heading cannot be transferred to another heading.*
   - *Interruptions of excavation work exceeding 2 hours due to unpermitted high gas concentrations will be paid for at the Unit Price per hour of interruption. Payment will only be made if the miners, support personnel and equipment employed at the respective heading cannot be transferred to another heading.*

b) The Unit Price for excavation shall include all labour, equipment and materials necessary for monitoring and dilution of gas concentrations during tunnel drivage.

c) The Unit Price for excavation offered shall be independent from the method actually used for underground excavation (drill and blast method or by mechanical means).

d) The Unit Price for excavation has to include loading, transport and unloading of the material. Loading and unloading of material at temporary disposal sites under maintenance of the dewatering system shall also be included in the Unit Price for excavation.

e) The Unit Price for excavation shall also apply for the local widening of the cross section at the temporary mining portals required to increase lining thickness of the C&C section.

f) All labour, equipment and materials required for cleaning and treatment of all contaminated tunnel water prior to dischargement shall be include in the Unit price for excavation and will not be extra paid.

g) Final excavation levels (formation level) for pavement construction shall be included in the Unite price for excavation and will not be extra paid.

h) Unite price for excavation shall include obstructions due to the synchronically execution of geological – geotechnical documentation

i) Unite price for excavation shall include all kind of backfilling work (e.g. protection of invert support of minimum 0,5 m)

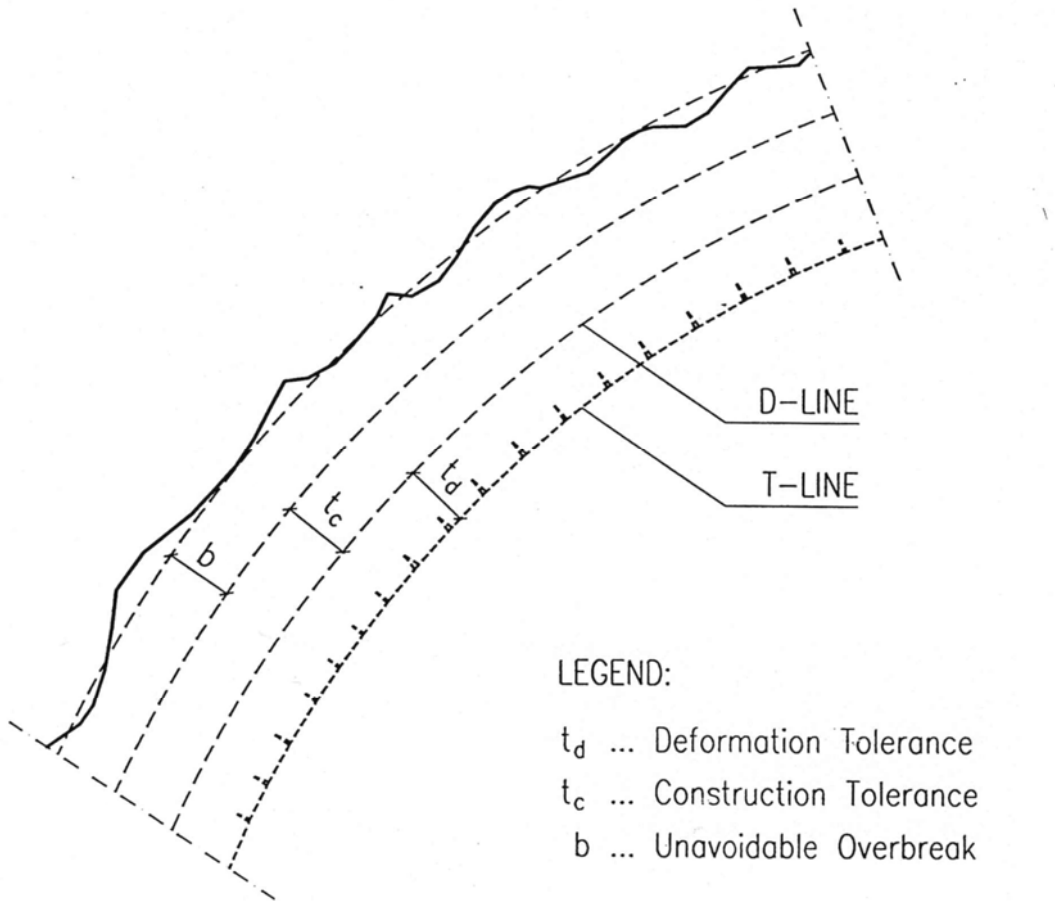


FIG. 4.1 Definition of Tolerances for Deformation and Construction

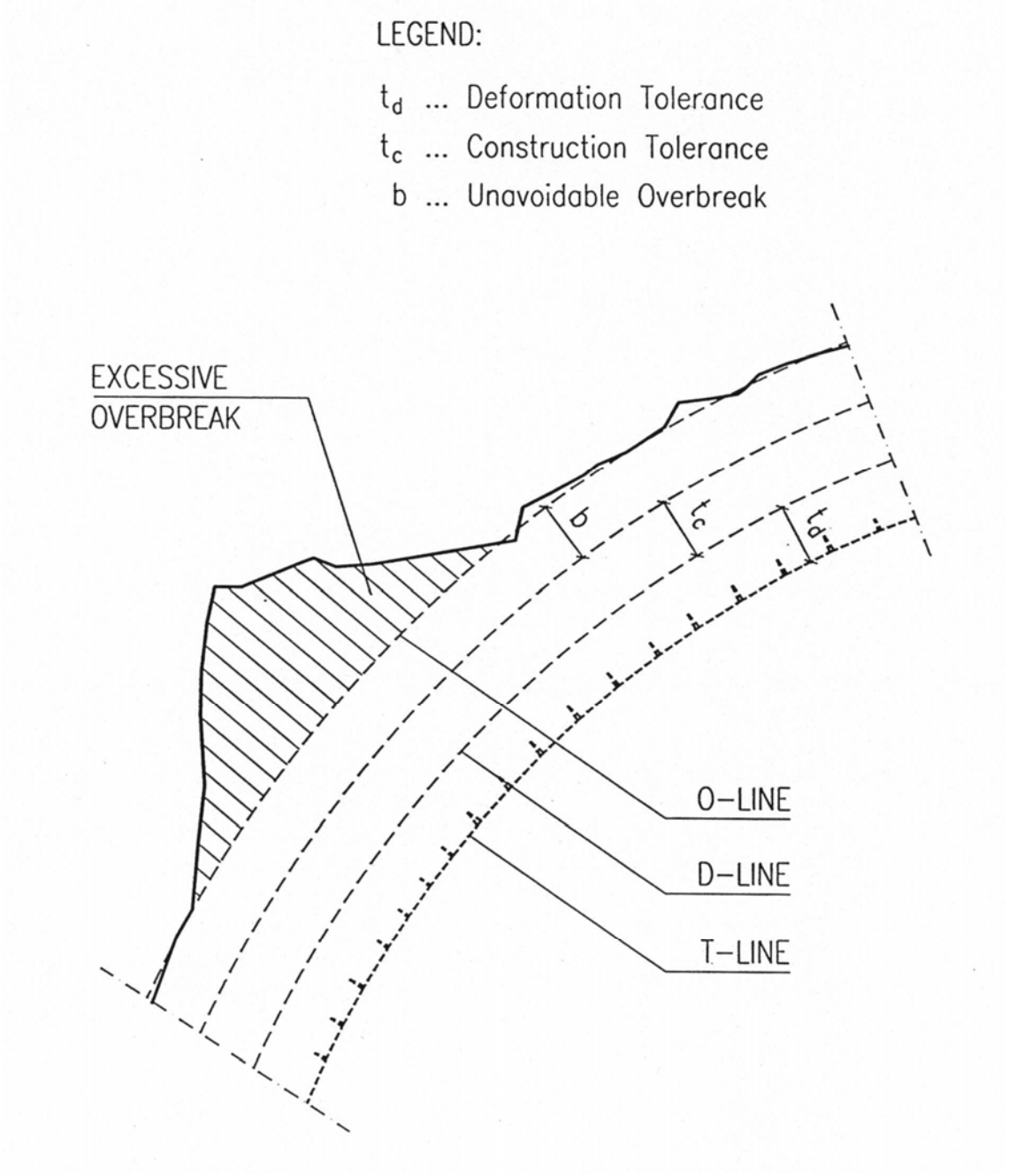


FIG. 4.2 Excessive Overbreak due to Unfavorable Geologic Conditions

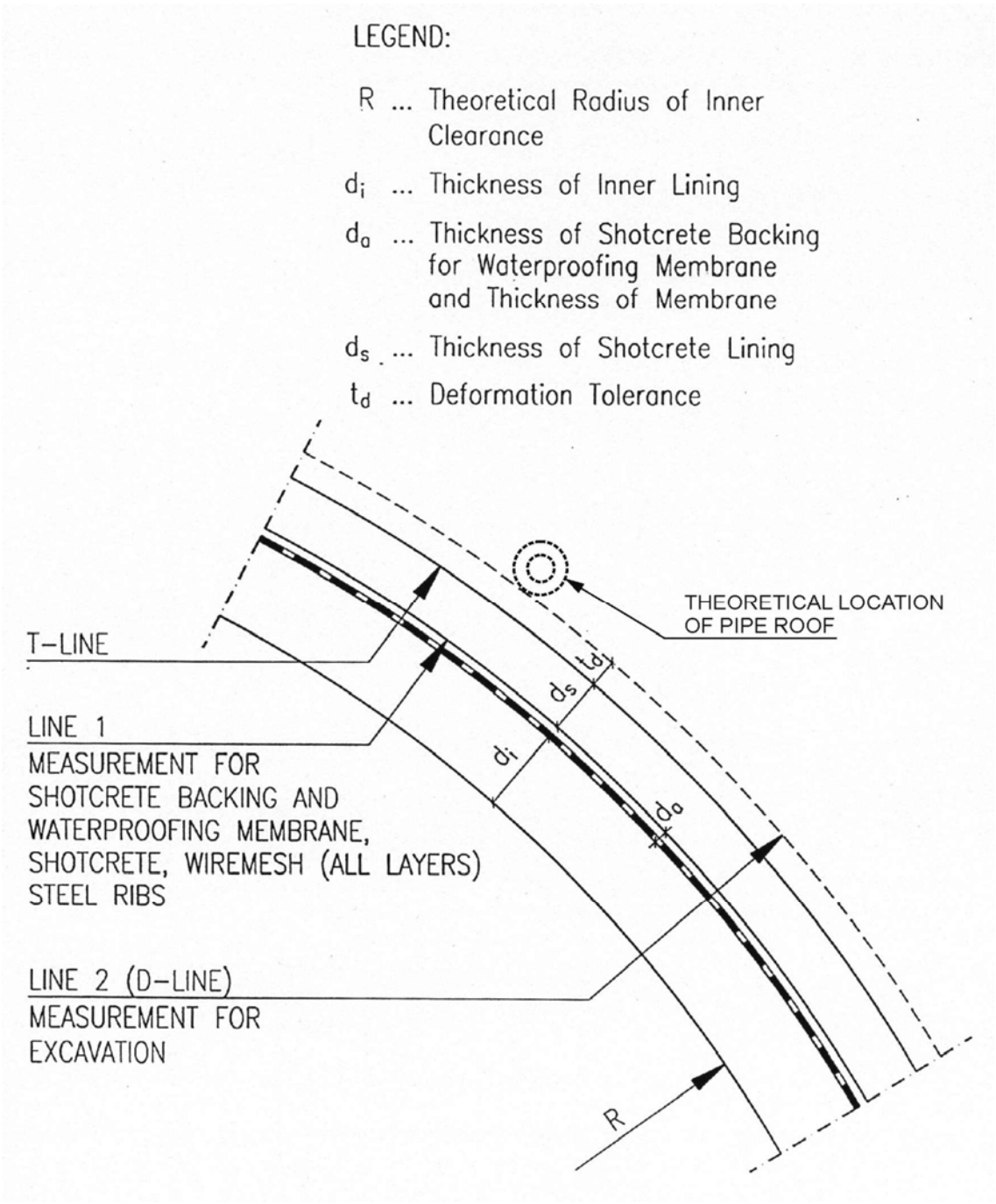


FIG. 4.3 Lines for Measurement and Payment

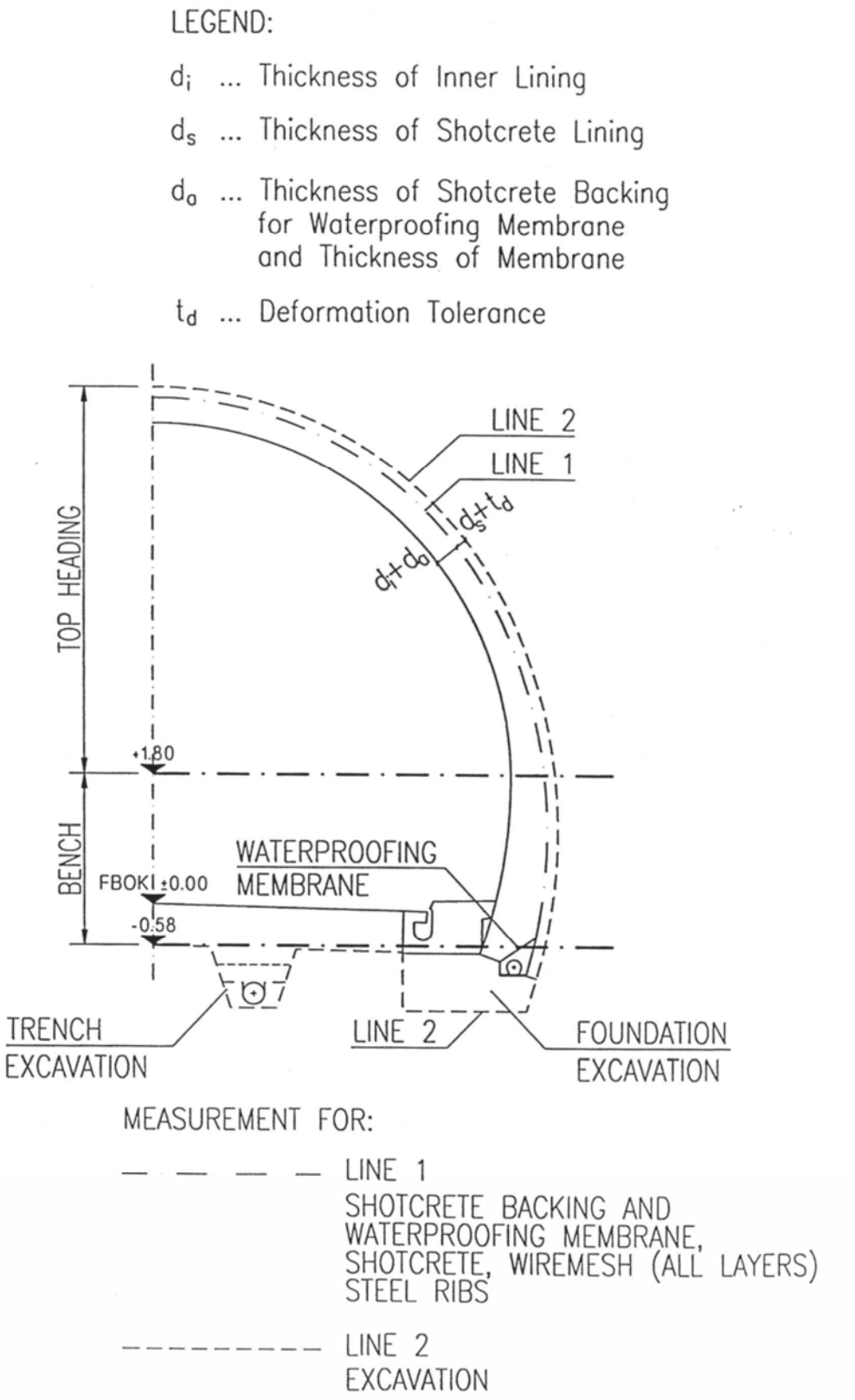


FIG. 4.4 Lines for Measurement and Payment for Regular Cross-Sections without Invert Arch

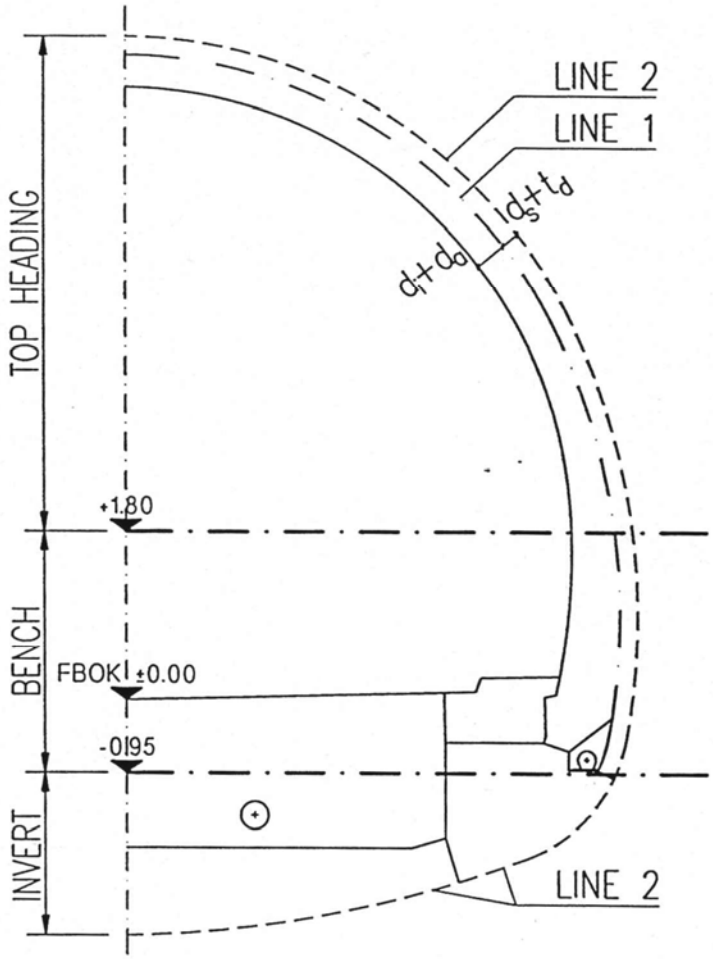
LEGEND:

d_i ... Thickness of Inner Lining

d_s ... Thickness of Shotcrete Lining

d_a ... Thickness of Shotcrete Backing for Waterproofing Membrane and Thickness of Membrane

t_d ... Deformation Tolerance



MEASUREMENT FOR:

— — — — LINE 1
SHOTCRETE BACKING AND WATERPROOFING MEMBRANE, SHOTCRETE, WIREMESH (ALL LAYERS) STEEL RIBS

– – – – – – – – – LINE 2
EXCAVATION

FIG. 4.5 Lines for Measurement and Payment for Regular Cross-Sections with Invert Arch

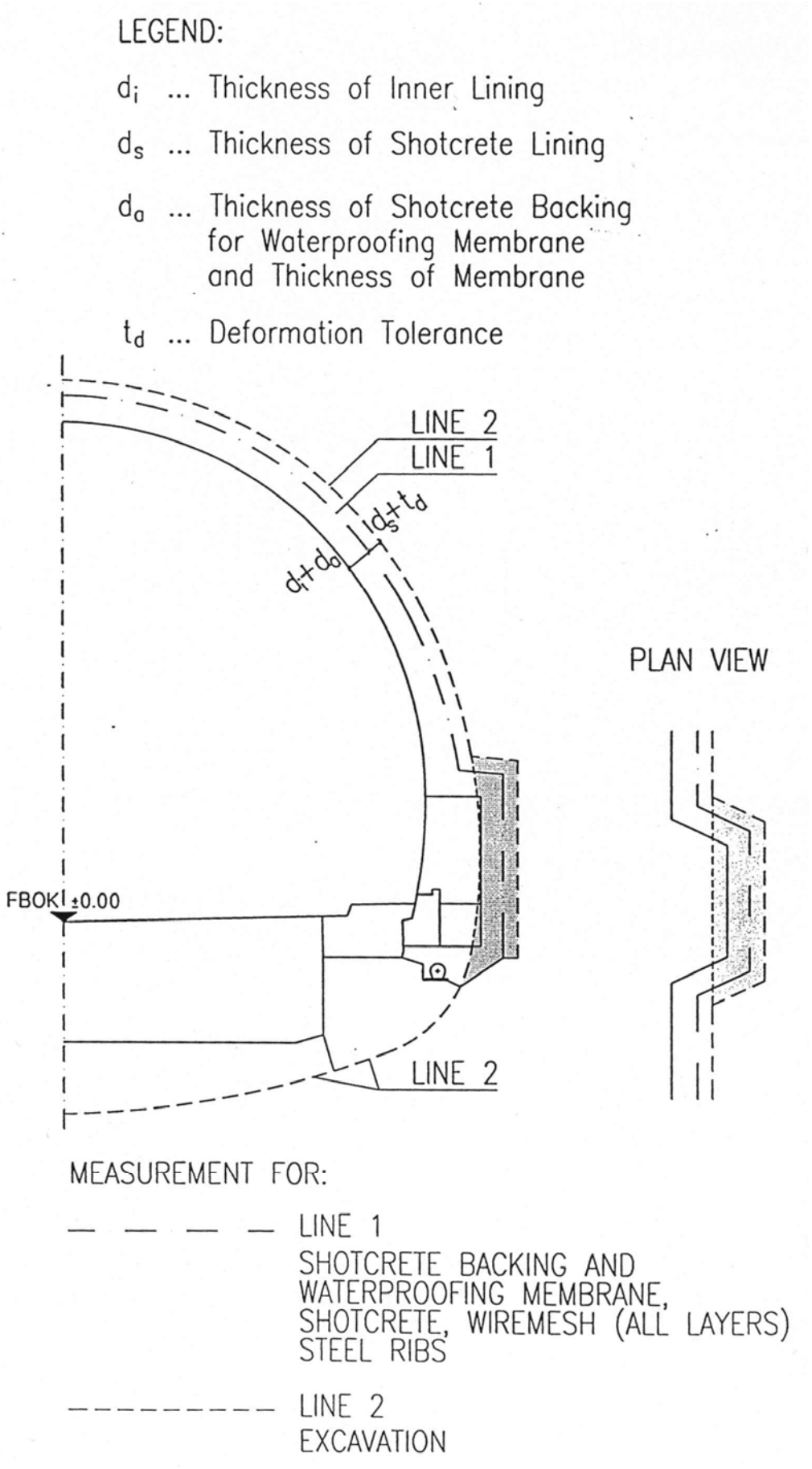


FIG. 4.6 Lines for Measurement and Payment for Regular Cross-Sections with Niches

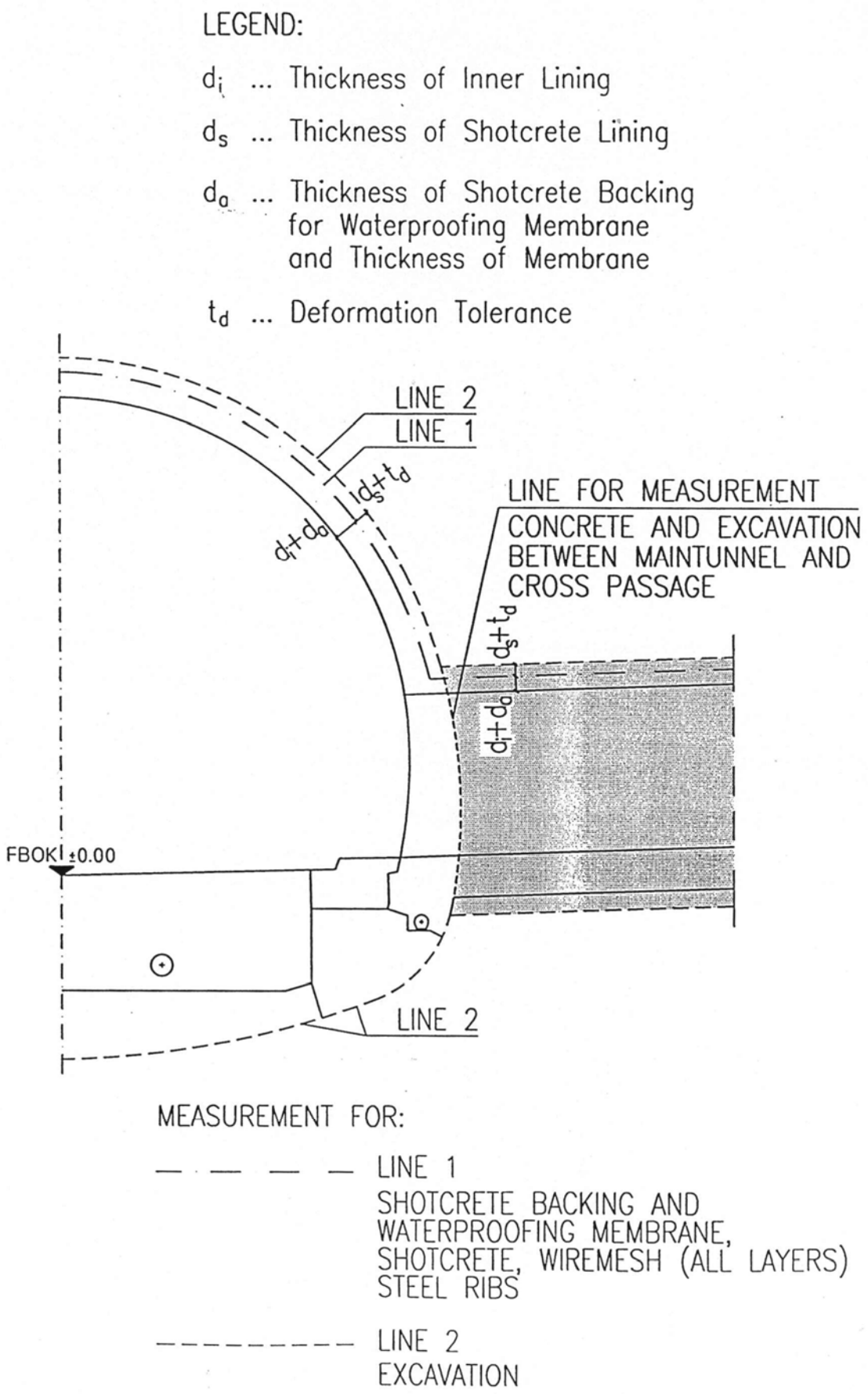


FIG. 4.7 Lines for Measurement and Payment for Regular Cross-Sections with Cross Passages for Pedestrian

2.3.5 PROFILE CONTROL AND TOLERANCES

2.3.5.1 PROFILE CONTROL

2.3.5.1.1. SCOPE

The CONTRACTOR is required to perform a careful and systematic checking of the final clearance of the primary tunnel lining in order to accommodate the designed nominal thickness of the inner concrete lining.

2.3.5.1.2. METHOD OF PROFILE CONTROL FOR FINAL CONCRETE LINING

a) Provision is made for the final concrete lining to be cast using a rail mounted steel shutter running on the footing beams.

b) The CONTRACTOR is solely responsible for the accuracy in setting out and the construction of the footing beams with their cast in fixings which will align the rail track at each side of the tunnel and on which the tunnel shutter will be mounted.

c) It is the CONTRACTOR'S responsibility to ensure that the minimum clearance for the final lining as shown on the drawings is provided. In order to establish deviations from the theoretical profile the CONTRACTOR shall provide a gantry furnished with a template set to show the minimum profile required for the nominal thickness of the final concrete lining. The gantry shall be designed to move along the rail tracks to be used for the movement of the tunnel shutter and is to provide access for the marking out of the areas of the initial lining which protrude into the minimum clearance zone. The gantry may also be designed as a working platform for the re-shaping of the initial lining should this prove to be necessary and for the surface preparation work outlined in this specification.

d) The CONTRACTOR shall submit full details of the design of the gantry with its template for the approval of the ENGINEER. On approval the ENGINEER will issue instructions with regard to the systematic checking of the geometry of the template during profiling operations.

e) The CONTRACTOR may prefer to use advanced surveying techniques and data processing to establish the final clearance profile subject to the approval of the ENGINEER.

2.3.5.1.3. EXECUTION

a) The checking of the final clearance shall not proceed before the geotechnical measurements show that the rate of radial displacement at any position of the tunnel periphery is less than 4 mm per month. Precision defined for absolute measurement.

b) After completion of support works, after surface preparation as described in this specification and after deformation as per (a) of this clause, the final clearance for the inner lining shall be conform with the minimum thickness of the inner lining as indicated on the drawings.

c) Profile control shall be carried out either continuously by using a gantry furnished with a template or at least every 2,0 m by using advanced surveying techniques.

d) Any deviations from the theoretical clearance for the inner lining shall be made good, either by providing extra shotcrete or a thicker inner concrete in the case of excess clearance, or by reshaping any parts of the tunnel support protruding into the clearance profile. CONTRACTOR is responsible for these works without any extra payments.

e) The CONTRACTOR shall submit a proposal for the remedial works to the ENGINEER.

f) No reshaping of the tunnel support shall be carried out without the approval of the ENGINEER.

g) Geotechnical measurements before, during and after the respective measures shall be carried out in compliance with the relevant design specification. The measurement points such as convergency bolts and / or extensometers shall be retained or substitutions shall be installed well in advance of the heading in order to establish "transfer - zero - readings" and it is not paid separately.

h) Geotechnical measurement stations shall not be removed and abandoned without the approval of the ENGINEER.

2.3.5.1.4. RECORDS

a) Records shall be kept for each stage of remedial measures.

b) The final clearance profile shall be recorded at intervals in longitudinal direction and points along the periphery of the tunnel. The recording can be executed by means of clearance profile measuring carriage equipped with sensors (contact method). In such a case, the protocol on the clearance profile shape shall be prepared for at least every 5 m in the tunnel longitudinal direction. Alternatively, the clearance profile can also be recorded by introducing a non-contact method (manually or automatically – e.g. by means of a »profiler«). The protocol on the clearance profile shall be made for at least every 2 m in the tunnel longitudinal direction. The clearance profile control shall be performed in compliance with the recommendations provided by the DESIGNER, with the proposal by the CONTRACTOR, and upon preliminary approval issued by the ENGINEER.

c) The final checking of the clearance profile after completion of reprofiling and surface preparation shall be done in presence of the ENGINEER.

2.3.5.2 CONSTRUCTION TOLERANCES

2.3.5.2.1. TOLERANCES FOR THE INITIAL LINING

a) No reduction of the theoretical thickness of the inner concrete lining is permitted unless approved by the ENGINEER. To achieve this requirement, no support elements such as shotcrete, anchor heads, steel ribs etc. may protrude into the theoretical inner concrete lining, as shown on the drawings.

b) In the area of the invert and the foundation beams no rock parts or rock peaks may protrude into the theoretical excavation line.

2.3.5.2.2. TOLERANCE FOR EXCAVATION LEVEL OF INVERT

a) For tunnel sections without a concreted invert arch the CONTRACTOR shall excavate the bottom level of the invert with an accuracy of +0 to -100 mm related to the theoretical excavation line of the invert.

b) If the bottom excavation level, after cleaning from mud, loose materials etc. is more than 100 mm below the designed theoretical excavation line, the CONTRACTOR shall backfill such areas up to the designed, theoretical level by means of sub-base material or as directed and approved by the ENGINEER.

c) For tunnel sections with a concrete invert arch or shotcrete invert no reduction of the designed, theoretical thickness of the concrete structure is permitted. Over-excavation must be compensated with structural concrete or shotcrete for the invert arch as specified. The inside face of a concrete invert arch may deviate not more than +/- 50 mm in elevation from the theoretical cross section.

2.3.5.2.3. TOLERANCES FOR THE INNER CONCRETE LINING

2.3.5.2.3.1 SURVEY TOLERANCES

The tunnel axis of the completed tunnel cross section may deviate from the calculated tunnel axis (alignment) not more than ± 30 mm in plan. The tolerance in elevation is limited to ± 10 mm.

2.3.5.2.3.2 FORMWORK TOLERANCES

Formwork tolerances including manufacturing tolerances of the shutter, inaccuracies in shutter erection and deformation of the formwork during concreting shall not exceed 60 mm in radial direction.

2.3.5.2.3.3 EFFECT OF CURVES:

Since tunnel formworks are straight, a curved tunnel is actually of polygonal shape. There will therefore be a deviation from the theoretical shape with a maximum at the centre of a concreting block. This tolerance depends on block length L, width of clearance envelope B and radius R of tunnel alignment. The necessary "curve tolerance C" can be calculated according to the following formula:

$$C = R + \frac{B}{2} - \sqrt{\left[\left(R + \frac{B}{2}\right)^2 - \left(\frac{L}{2}\right)^2\right]} \qquad \text{[in mm]}$$

2.3.5.2.3.4 TOTAL TOLERANCE FOR INNER LINING

a) The total tolerance for a concrete inner lining can be calculated by adding the "survey tolerance", "formwork tolerance" and "tolerance for curves".

b) The deviation of the inner face of the concrete lining according to the theoretical cross section may in general not exceed 100 mm (in radial direction) to the inner side. At the elevation of the walkways the deviation of the inner face is limited to 50 mm to the inner side in order to maintain the minimum dimensions of the cable ducts.

c) In any case and for all specified deviations permitted, the specified theoretical thickness for the inner concrete lining as well as the specified clearance profile for the roadway and the walkways shall be maintained.

2.3.5.2.3.5 OTHER TOLERANCES

a) Niches, recesses and similar structures are to be constructed with a tolerance of $\pm$ 50 mm related to the designed location. Deviations of their size are limited to $\pm$ 10 mm.

b) Pre-cast elements and cable ducts shall be placed with a tolerance of $\pm$ 10 mm, related to the theoretical position.

2.3.6 ROCK CLASSIFICATION

2.3.6.1 GENERAL

a) This section covers the description and classification of Rock Mass Types relevant to underground excavation with respect to the geotechnical properties of rock encountered and its behaviour under the influence of tunnel con-struction. In general, the classification of Rock Mass Types is in accordance with the new Austrian Standard ÖNORM B2203 (issue 1994-10).

b) The defined Rock Mass Types reflect not only the behaviour of the surrounding ground after excavation, but they are also related to expected deformations, requirements for subdivision of excavation cross sections, possible length of rounds, driving sequence, ground water, and requirements for installation of rock support.

c) Standard support types and the range of possible round lengths for each Rock Mass Type specified are shown on the tender drawings. Difficult, inhomogenious ground conditions frequently require adjustments of the tunnel support during drivage works as experience is gained. The rock support shown on the drawings for a particular Rock Mass Type is regarded as "typical" for that class. Number of rock bolts may be slightly changed and the direction of the bolts shall be adjusted to prevailing discontinuity pattern. Shotcrete thickness and layers of mesh may be increased or decreased. The spacing of ribs or lattice girders shall be adjusted to the selected round length. Any change to the standard support system to suit varying ground conditions must be approved by the ENGINEER.

2.3.6.2 APPLICATION AND PROCEDURES

a) Rock Mass Types are determined on the grounds of the appearance of the rock at the excavation face of the tunnel before the commencement of the respective drivage sequence.

b) The results of geotechnical measurements under similar rock conditions shall be taken into account for prediction of deformations and for classification of Rock Mass Types.

c) Depending on the size of the overall excavation and the ground conditions, subdivisions for the excavation may become necessary and may influence the classification and its evaluation.

d) In case of a regular drivage subdivided into top heading - bench - invert excavation, the rock conditions of the top heading drivage shall govern the classification. In case of a drivage sequence with side galleries, each drivage shall be regarded as a separate one and classified accordingly.

e) For excavation and support of niches and parking bays the classification of the tunnel tube excavated in advance shall be applied.

f) The behaviour of the rock at the face of a tunnel excavation is time dependent, i.e. rock mass strength and quality will decrease within the free span if no support is installed within a reasonable time. Accordingly, the maximum length of a round which can be excavated and supported in time, is depending on the rock quality and therefore shall be taken into account for evaluation of the Rock Mass Type. Primary stress conditions, quality and structure of rock formations, discontinuities, existing tectonic structures, groundwater conditions as well as influence of water and air on newly exposed rock surfaces shall be taken into consideration too.

g) The rock classification at the face for each round shall be determined jointly by one authorized representative each from the ENGINEER and the CONTRACTOR.

   The inspection team shall determine the Rock Mass Type, possible round length and modifications of the related standard support, if necessary.

h) If no agreement can be reached by the inspection team the decision shall be transferred to the GEOTECHNICAL COUNCIL consisting of the authorized representative of the DESIGNER and one or more independent EXPERTS. The independent EXPERT(S) will be appointed by the CLIENT prior to commencement of the excavation work. Until an agreement is reached excavation work shall be continued according to the decisions of the ENGINEER.

i) The classification shall be done in writing on jointly agreed form-sheets.

j) The Classification Record is a collection of all classification sheets, which shall be kept accessible for consultation whenever drivage works are under progress.

k) Before commencement of any cycle of operations the CONTRACTOR'S SHIFT SUPERVISOR shall consult the rock classification records and ensure that work is carried out in accordance with the last entry.

l) Notwithstanding the duties of the inspection team the CONTRACTOR is solely responsible for the safety of the works under construction.

2.3.6.3 GENERAL CLASSIFICATION SYSTEM

The following Table shows the Rock Mass Types used for classifaction of underground excavation. In general, the description of Rock Mass Types is in accordance with Chapter 1.4.2 of the Austrian Standard ÖNORM B 2203, issue October 1994.

ROCK MASS TYPE	SHORT DESCRIPTION
A1	stable rock conditions
A2	slightly overbreaking
B1	friable
B2	heavily friable
B3	loose ground with low cohesion
C1	rock burst phenomena
C2	pressure exerting rock conditions
C3	heavily pressure exerting rock conditions
C4	soft, squeezing or flowing ground
C5	swelling rock conditions

Additionally four support categories were specified for designing standard support measures. These types are:

ROCK MASS TYPE	SHORT DESCRIPTION
PC	portal class
LOC	low overburden class
CA	concrete arch
SWG	side wall galleries

2.3.6.4 ROCK MASS TYPES

In the following chapters only the behavior of Rock Mass Types and general rules for excavation and timing is described. The CONTRACTOR should follow rules stated in technical report where rock mass types applicable to this project are described in detail. Standard support systems for each Rock Mass Type are shown on the relevant drawings.

2.3.6.4.1. ROCK MASS TYPE A1

2.3.6.4.1.1 BEHAVIOR OF ROCK MASS

Addressed as "stable" rock mass the rock mass behaves elastically and provides favorable geotechnical construction conditions. Deformations are small and decrease rapidly. There is no tendency of overbreaking after scaling of the rock portions disturbed by blasting. The rock mass is permanently stable without support.

2.3.6.4.1.2 EXCAVATION

Theoretically, the excavation could be done "full face". In reality, a subdivision in top heading and bench will generally be maintained in case of large excavation profiles. Drill and blast will be required for excavation.

Both, smooth blasting requirements and practical construction aspects limit the length of each round.

2.3.6.4.1.3 SUPPORT INSTALLATION AND TIMING

No installation of systematical support is required. Only local support elements might be necessary.

2.3.6.4.2. ROCK MASS TYPE A2

2.3.6.4.2.1 BEHAVIOR OF ROCK MASS

Addressed as "slightly overbreaking" rock mass. The rock mass behaves elastically. Deformations are small and decrease rapidly.

A slight tendency of shallow overbreaks exists in the tunnel roof and in the upper portions of the sidewalls caused by unfavourable discontinuities and the dead weight of small blocks.

2.3.6.4.2.2 EXCAVATION

Theoretically, the excavation could be done "full face". In reality, a subdivision in top heading and bench will generally be maintained in case of large excavation profiles. Drill and blast will be required for excavation.

Requirements for smooth blasting, limitation of overbreaks and practical construction aspects limit the length of round to a range between 2.5 and 3.5 meters in top heading and to 4.0 meters in benching.

2.3.6.4.2.3 SUPPORT INSTALLATION AND TIMING

Support is required in the tunnel roof and in the upper sidewalls. Rock bolts shall be installed not later than one round behind the face, except in areas which tend to overbreak, which should be supported immediately. The rock bolting direction shall be chosen in accordance with the orientation of the discontinuities.

2.3.6.4.3. ROCK MASS TYPE B1

2.3.6.4.3.1 BEHAVIOR OF ROCK MASS

Addressed as "friable" rock mass. The surrounding rock mass behaves elastically. Deformations are small and decrease rapidly.

Low rock mass strength and limited stand-up times related to the prevailing discontinuity pattern yield overbreaks and loosening of the rock strata in tunnel roof and upper sidewalls if no support is installed in time.

2.3.6.4.3.2 EXCAVATION

The cross section of excavation shall be subdivided into top heading and bench. Length of rounds are presented in technical report and enclosed drawings. For the excavation, drilling and blasting method or using a powerful road-header is suitable.

2.3.6.4.3.3 SUPPORT INSTALLATION AND TIMING

A systematic support pattern is required. In most cases rock bolts can be limited to top heading only.

The support shall be installed not later than one round behind the face. Endangered areas shall be supported immediately. Forepoling may be required locally to assure adequate stability conditions for construction.

2.3.6.4.4. ROCK MASS TYPE B2

2.3.6.4.4.1 BEHAVIOR OF ROCK MASS

Addressed as "heavily friable" rock mass. This type of rock mass is characterized by large areas of non- elastic zones extending far into the surrounding rock mass. Immediate installation of the tunnel support, will ensure deformations can be kept small and cease rapidly. In case of a delayed installation or an insufficient quantity of support elements, the low strength of the rock mass yields deep loosening and loading of the initial support.

Stand-up time and unsupported span are short. The potential of deep and sudden failures from roof, sidewalls and face is high.

2.3.6.4.4.2 EXCAVATION

The subdivision into top heading and bench is imperative. Length of rounds are presented in technical report and enclosed drawings.

Excavation is done either by smooth blasting; rock masses with lower strength may be excavated by road header. Invert excavation and installation of an invert concrete arch may be necessary.

2.3.6.4.4.3 SUPPORT INSTALLATION AND TIMING

Tunnel roof and sidewalls require a systematic support which shall be installed after each round and before any further advance. Systematic forepoling may be required for extended areas. The installation of a cast - in - place invert arch may be required in accordance with the geotechnical requirements and shall be placed not later than 200 metres behind the top heading face.

2.3.6.4.5. ROCK MASS TYPE B3

2.3.6.4.5.1 BEHAVIOR OF ROCK MASS

Described as rock mass with "low cohesion". No stand up time without support by forepoling or forepiling installed in advance and shotcrete sealing of faces simultaneously with excavation. Depending on the size of the tunnel cross section the low cohesion may require a number of subdivisions of the excavation profile as well as face support by a "support body". It might be necessary to improve the ground conditions prior to excavation, e.g. by grouting.

2.3.6.4.5.2 EXCAVATION

A subdivision of the excavation cross section as shown on the relevant drawings will be required in order to avoid face stability problems. Additionally, support bodies for the top heading faces will be necessary. Installation of a temporary shotcrete invert may be required.

Length of rounds is presented in technical report and enclosed drawings. Excavation shall be done by tunnel excavator or manually.

2.3.6.4.5.3 SUPPORT INSTALLATION AND TIMING

All tunnel support with the exception of the inner layer of wire mesh is required before any further advance at the face of top heading and bench. Forepoling or lagging must be required over the majority of the roof section. Shotcrete sealing simultaneously with the excavation of subdivided section will be required. Temporary ring closures of the subdivided cross sections of the top heading drivages may become necessary. The ring closure of the temporary invert arch may be required as short as 5 to 10 metres behind the top heading face. In accordance with the geotechnical requirements the ring closure at the final invert is required to be not later than 40 metres behind bench excavation. Due to the close distance to bench excavation it is necessary to install a shotcrete invert first.

2.3.6.4.6. ROCK MASS TYPE C1

2.3.6.4.6.1 BEHAVIOR OF ROCK MASS

At the states of high stress, in a massive, solid, and brittle rock the elastic energy is accumulated by squeezing. By sudden release of that energy, a shock failure phenomenon occurs where stone particles are ejected from the rock mass.

The rock mass particles are mainly sharp-edged; such a phenomenon is characteristic for small depths only. .

2.3.6.4.6.2 EXCAVATION

If necessary, suitable measures to reduce the hazard of rock mass shocks shall be introduced

2.3.6.4.7. ROCK MASS TYPE C2

2.3.6.4.7.1 BEHAVIOUR OF ROCK MASS

Described as "pressure exerting" rock mass. Rock Mass Type C2 is characterized in cohesive rock by plastic zones extending far into the surrounding rock mass and in brittle rock by failure mechanisms such as spalling, buckling, shearing and rupture of the rock structure. Squeezing behaviour may occur. The rock mass shows a moderate, but distinct time depending squeezing behaviour, deformations level off slowly.

2.3.6.4.7.2 EXCAVATION

The subdivision into top heading and bench is imperative. Invert excavation is required. Length of rounds is presented in technical report and enclosed drawings. Excavation may be done by smooth blasting or by roadheader, or tunnel excavator. Shotcrete sealing may be required immediately after scaling.

2.3.6.4.7.3 SUPPORT INSTALLATION AND TIMING

All tunnel support is applied systematically and before any further advance at the face. Forepoling may be required over the whole roof section.

In accordance with the geotechnical requirements the invert arch is required to be installed not later than 150 metres behind the top heading face.

2.3.6.4.8. ROCK MASS TYPE C3

2.3.6.4.8.1 BEHAVIOUR OF ROCK MASS

Described as "heavily pressure exerting" rock mass.

Rock Mass Type C3 is characterized by the development of deep failure zones and a rapid and significant movement of the rock mass into the cavity and deformations which decrease very slowly. Support elements may frequently be overstressed.

2.3.6.4.8.2 EXCAVATION

A subdivision into top heading, bench and invert is imperative. A support body for the top heading face will be required in most of the cases. Length of rounds is presented in technical report and enclosed drawings. Excavation may be done by smooth blasting, by roadheader or by tunnel excavator. Shotcrete sealing is required immediately after scaling.

A dense support pattern at all exposed surfaces will be required. The magnitude of deformations may require special features such as deformation slots in the shotcrete and/or the application of highly deformable support elements like lining stress controller. The support elements installed shall maintain the triaxial stress state of the rock mass.

In case that shortening of the length of round, the increase of the length of the forepoling, and a large support body at the top heading face is not sufficient, a further subdivision of the face may be required. Possible solutions may be a half side drivage or four quarter of top heading or side galleries. Also a subdivision of the bench is possible. In case of excessive vertical movements of the complete excavation section, further measures such as widening of the lining foot, bolting and grouting of the abutment zone of the shotcrete shell and an increasing amount of face bolting may become necessary.

In case of invert excavation without shotcrete invert longitudinal subdivision with longitudinal subdivision the max. round length of 12.0 metres to be carried out. In case of invert excavation without shotcrete invert and without longitudinal subdivision the max length of round has to be reduced to 6.0 metres.

2.3.6.4.8.3 SUPPORT INSTALLATION AND TIMING

All tunnel support is applied systematically and before any further advance at the face of top heading and bench. Forepoling will be required over the whole roof section. Tunnel face support with wire mesh reinforced shotcrete and face bolting with load plates may be required. If there are

heavy squeezing rock conditions deformation gaps and deformation pipes (LSC) have to be placed in the shotcrete lining.

Subdivided cross sections may become necessary. The ring closure of the final invert arch may be required as short as 30 meters behind the top heading face.

2.3.6.4.9. ROCK MASS TYPE C4

2.3.6.4.9.1 BEHAVIOUR OF ROCK MASS

The rock mass is characterized by low cohesion and shear strength. A soft-plastic consistency of the rock leads to flowing phenomena even at very small and short-term excavated and non-supported surfaces.

2.3.6.4.9.2 EXCAVATION

2.3.6.4.9.3 SUPPORT INSTALLATION AND TIMING

2.3.6.4.10. ROCK MASS TYPE C5

2.3.6.4.10.1 BEHAVIOUR OF ROCK MASS

This rock mass type is described as „swelling„. Rock Mass Type C5 is described as rock mass with clay minerals, which have swelling characteristics. This means that, depending on the level of destressing, by adding water a volume increase of the rock mass is induced and therefore swelling pressure is excerted.

2.3.6.4.10.2 EXCAVATION

The cross section has to be divided in top heading, bench and invert excavation. Length of rounds is presented in technical report and enclosed drawings. The cross section can be excavated by smooth blasting, road header or tunnel excavator.

Rock support installation is required around the whole excavation surface, including the invert, in order to take the forces of the swelling rock mass and to limit the development of cracks. Rock support consists of rock bolts, steel arches, wire mesh and shotcrete at all exposed surfaces.

In order to take swelling forces, immediate ring closure is imperative in the top heading (temporary invert top heading) as well as in the invert. Rock support of the top heading face, a supporting core as well as rock support measures ahead of the face (for example forepiling) may be required. Maximum distance between top heading face and top heading invert is limited to 6.0 m, with a maximum opening width of the temporary invert of 2.0 m. The ring closure has to be achieved maximum 10 m behind the bench excavation face, with a maximum opening width of the invert of 5.0 m.

2.3.6.4.10.3 SUPPORT INSTALLATION AND TIMING

All tunnel support is applied systematically and before any further advance at the face of the top heading and bench. Forepoling may be required in the roof.

Subdividing cross sections may be necessary. Installation of a temporary ring closure in the top heading is required.

2.3.6.4.11. PORTAL CLASS

2.3.6.4.11.1 BEHAVIOUR OF ROCK MASS

The behavior of the rock mass at the tunnel portals in weathered or sheared rock conditions can be addressed as "friable to heavy friable". Due to shallow overburden expected deformations are small and decrease rapidly. Immediate installation of the tunnel support will ensure deformations can be kept small and cease rapidly.

In case of a delayed installation or an insufficient quantity of support elements, tunnel deformations may trigger movements and instabilities of cut slopes at the portal.

2.3.6.4.11.2 EXCAVATION

The subdivision into top heading and bench is imperative. Length of rounds are presented in technical report and enclosed drawings. Generally excavation is done by smooth blasting or mechanical equipment (back-hoe; roadheader). Invert excavation and installation of an invert schotcrete arch will be necessary.

2.3.6.4.11.3 SUPPORT INSTALLATION AND TIMING

Tunnel roof and sidewalls require a systematic support which shall be installed at the face and before any further advance. Forepiling will be required. Installation of invert arch shall be done as close as possible and as soon as possible behind bench excavation, but in no case later than 30 metres behind the top heading face. Stability of the tunnel and slopes shall be monitored continuously by geotechnical measurements.

2.3.6.4.12. LOW OVERBURDEN CLASS (LOC)

2.3.6.4.12.1 BEHAVIOUR OF ROCK MASS

A special Rock Mass Type (Support Type) was defined for tunnel sections with shallow rock cover and/or running under houses. The Low Overburden Class was designed with a stiff support to minimise settlements and deformations. By stiff support and quick ring closure it will be avoided that shear planes above the tunnel developed to the surface and entire overburden layer has to be carry by the primary lining.

2.3.6.4.12.2 EXCAVATION

The cross section shall be subdivided into top heading, bench and invert arch excavation. A subdivision of the top heading cross section and a supporting body may be required in order to avoid face stability problems. Sealing of the excavation face with shotcrete will be necessary.

The installation of a temporary shotcrete invert is imperative in order to achieve an earlier ring closure.

Length of rounds is presented in technical report and enclosed drawings. Generally excavation shall be executed smoothly by mechanical equipment (e.g. back-hoe; breaker; roadheader).If necessary, the rock mass has to be loosened locally by smooth blasting.

2.3.6.4.12.3 SUPPORT INSTALLATION AND TIMING

To achieve stability of the excavation face and to minimize settlements 15 meter long roof pipes will be installed in the tunnel crown as shown on the relevant drawings. Excavation of top heading must be stopped at least 4 meter before the end of the pipe roof in order to ensure 4 meter overlap with the next umbrella.

Systematic support with steel ribs wire mesh, forepoling (at the side wall) and shotcrete is required for roof and sidewalls. Rock bolts are intended for sidewalls and face-bolting.

The final invert arch (shotcrete invert) shall be installed not later than 40 m behind the top heading face.

2.3.6.4.13. EXCAVATION UNDER CONCRETE ARCH (CA)

2.3.6.4.13.1 GENERAL

In sections with extreme low rock cover (less than 10 m) a concrete arch above the tunnel will be cast in an open cut prior to tunnel excavation.

2.3.6.4.13.2 EXCAVATION

Stability of the tunnel roof is already achieved by the reinforced concrete arch which has to be constructed in an open cut prior to tunnel driving. A subdivision into to heading, bench and invert is imperative. Length of rounds is presented in technical report and enclosed drawings. The invert arch is required to be installed not later than 100 m behind the top heading face. Excavation may be done by roadheader or tunnel excavator.

2.3.6.4.13.3 SUPPORT INSTALLATION AND TIMING

Tunnel sidewalls require a systematic support by shotcrete wiremesh and anchors which shall be installed every round before any further advance.

2.3.6.4.14. SIDE WALL GALLERIES (SWG)

2.3.6.4.14.1 BEHAVIOUR OF ROCK MASS

In case of soft soil conditions (e.g. within or close to major fault zones), shallow cover and buildings on top of the tunnel it might be necessary to change the construction sequence and excavate side wall galleries in advance of the main top heading. The construction of side wall galleries will minimize surface settlements and will help to avoid damages (cracks) on existing buildings.

2.3.6.4.14.2 EXCAVATION

The cross section shall be subdivided into 2 side wall galleries, main top heading, bench excavation (between the side wall galleries) and invert arch excavation. The excavation of the side wall galleries will be subdivided into top heading bench and invert.

For the sidewall galleries length of rounds shall not exceed 1.0 meter in the top heading, 2.0 meters in the bench and 2.0 meters in the invert. For the main invert between the sidewall galleries the round length is limited to 4.0 meters.

Generally excavation shall be executed smoothly by mechanical equipment (e.g. back-hoe).

2.3.6.4.14.3 SUPPORT INSTALLATION AND TIMING

In longitudinal direction the distance between the excavation face of the 2 sidewall galleries shall not be less than 20 meters. The entire outer lining shall be closed to a ring not later than 40 meters behind excavation of the main top heading.

Systematic support with steel ribs, wiremesh and shotcrete is required for roof and sidewalls. Rockbolts are foreseen for sidewalls only. The rockbolts have to be installed within the sidewall galleries and must be coupled.

2.3.7 TUNNEL SUPPORT

Attached Figures:

FIG. 7.1 Grain size distribution of aggregates

Attached Tables:

TAB. 7.1 Suitability Tests for Shotcrete

TAB. 7.2 Quality Control for Shotcrete

2.3.7.1 GENERAL REQUIREMENTS

This section covers the requirements for initial tunnel support which shall be considered to comprise those elements of the tunnel lining which are necessary to establish the permanent stability of the excavated tunnels.

2.3.7.1.1. CONSTRUCTION METHOD

The CONTRACTOR shall understand and recognize the technical and design concepts of the NATM for the mined tunnels and shall appreciate the function and merits of each component of the tunnel support.

2.3.7.1.2. SUBMISSIONS

a) Prior to the commencement of any works covered by this Specification, the CONTRACTOR shall submit to the ENGINEER for approval a comprehensive programme for material testing and quality control covering all elements of the tunnel support.

b) Manufacturer's certificates of compliance shall be submitted certifying that the materials used meet specification requirements.

c) The method of installation of each type of support element including description, specification and pertinent manufacturer's literature for drilling, rock bolting, anchoring etc. shall be submitted to the ENGINEER.

d) The ENGINEER shall be provided with all submissions in sufficient time ahead of the construction works, or at such dates as mutually agreed upon.

2.3.7.1.3. IMPLEMENTATION OF TUNNEL SUPPORT WORKS

a) The type and amount of tunnel support to be installed immediately after excavation is directly related to the rock classification as established. The standard initial support associated with the established rock classification system is shown on the drawings. However, as a consequence of variations from the anticipated rock conditions the standard support systems as shown on the drawings for each Rock Mass Type may require modifications and adjustment during construction as agreed between the authorized representatives from the ENGINEER and CONTRACTOR or as directed by the GEOTECHNICAL COUNCIL (in accordance with Section 6.2).

b) The CONTRACTOR shall ensure that support elements will be installed or applied in such a manner and sequence as to prevent disintegration and loosening of the rock mass in front and around of the excavated tunnel.

2.3.7.1.4. CONSTRUCTION TOLERANCES

See Section 5 of this Specification.

2.3.7.1.5. RECORDS

a) Comprehensive records containing all particulars of the tunnel support actually installed and its performance in the course of the works shall be prepared and maintained by the CONTRACTOR and made available to the ENGINEER on a daily basis. These records shall include type, quantity and location of support elements installed, the clearance profile after installation of support, deviations from the standard support systems, observations of

excessive deformations, shotcrete cracking, etc. Observations of excessive deformations, shotcrete cracking shall be notified immediately to the ENGINEER.

b) The CONTRACTOR shall keep a record of the chainage of each face position and shall keep this record updated as the face progresses. This record shall be available for consultation at any time at a convenient location close to the relevant face. The formats of all records listed above shall be agreed with the ENGINEER in advance.

c) All the above records will be submitted daily to the ENGINEER for approval. Format of records shall be agreed with ENGINEER in advance.

2.3.7.1.6. EQUIPMENT AND MATERIAL SUPPLY

a) Any mechanical plant and equipment for installation of underground support shall be suitable for the works specified with respect to performance and current safety regulations and shall also be of sufficient capacity to fulfill production requirements in terms of the construction programme.

b) Proper maintenance of equipment and adequate provision of spare parts shall be made to ensure the immediate availability of equipment required for support installation whenever underground excavation works are under progress.

c) Unimpeded supply of materials to all working faces required for support construction shall be ensured at all times. It shall be recognized that for excavation in poor rock this pre-requisite is strongly related to safety matters of tunnel construction.

d) The CONTRACTOR shall provide each tunnel heading with the necessary materials and equipment to deal quickly and effectively with emergency situations, such as unexpected unstable rock conditions, heavy water inflows etc., which cannot be handled with the regular procedures of tunnel support installation.

e) The CONTRACTOR shall maintain on site or have immediately available at least two-week supply of any of the support elements required according to the Rock Mass Classifications indicated on the drawings and according to the work programme.

2.3.7.2 SHOTCRETE

2.3.7.2.1. GENERAL

a) All shotcrete works shall be carried out in accordance with actual issue of Austrian "Sprayed concrete guideline"; published by the Austrian Concrete Society, unless otherwise specified in this Section.

b) For acceleration of setting and development of early strength (see also requirements for "young" shotcrete) either "no-alkali" accelerating admixtures or a special "cement-binder" (without accelerating admixtures) shall be used. Alkali-accelerators are not allowed to be used.

c) For a "no-alkali" accelerator the quantity of alkali (Na_2O-equivalent) shall not exceed 1 % by volume. The decrease in compressive strength of shotcrete with "alkali-free" accelerator compared with the base shotcrete (without accelerating admixtures) at an age of 7 and 28 days shall not exceed 10 %, independent from the actual strength.

d) Only wet mix shotcrete is allowed. But at any case a dry mix plant has to be kept on site in case of eventual failure of the wet mix plant but prior to approval of the ENGINEER.

2.3.7.2.2. MATERIALS

2.3.7.2.2.1 CEMENT

a) The cement used for shotcrete shall be in accordance with the BAS standard.

b) The cement used together with an "alkali-free" accelerator shall be Portland Cement PC 450 and shall meet the following requirements for compressive strength in accordance with the Austrian Standard ÖNORM B3327-1:

age at test: 1 day	min. compressive strength: 9 N/mm^2 (5% fractile)

age at test: 28 days	min. compressive strength: 40 N/mm^2 (5% fractile)

c) Special "cement-binder" shall meet the following requirements:

Specific surface:	4500 cm2 /g ±300 cm2 /g
Na_2O equivalent:	< 10%

2.3.7.2.2.2 AGGREGATES

a) The aggregates shall be clean, strong, durable, suitably graded and shall not contain detrimental amounts of dust, mud, clay or organic impurities.

b) The coarse aggregates shall not contain a large quantity of long stone pieces.

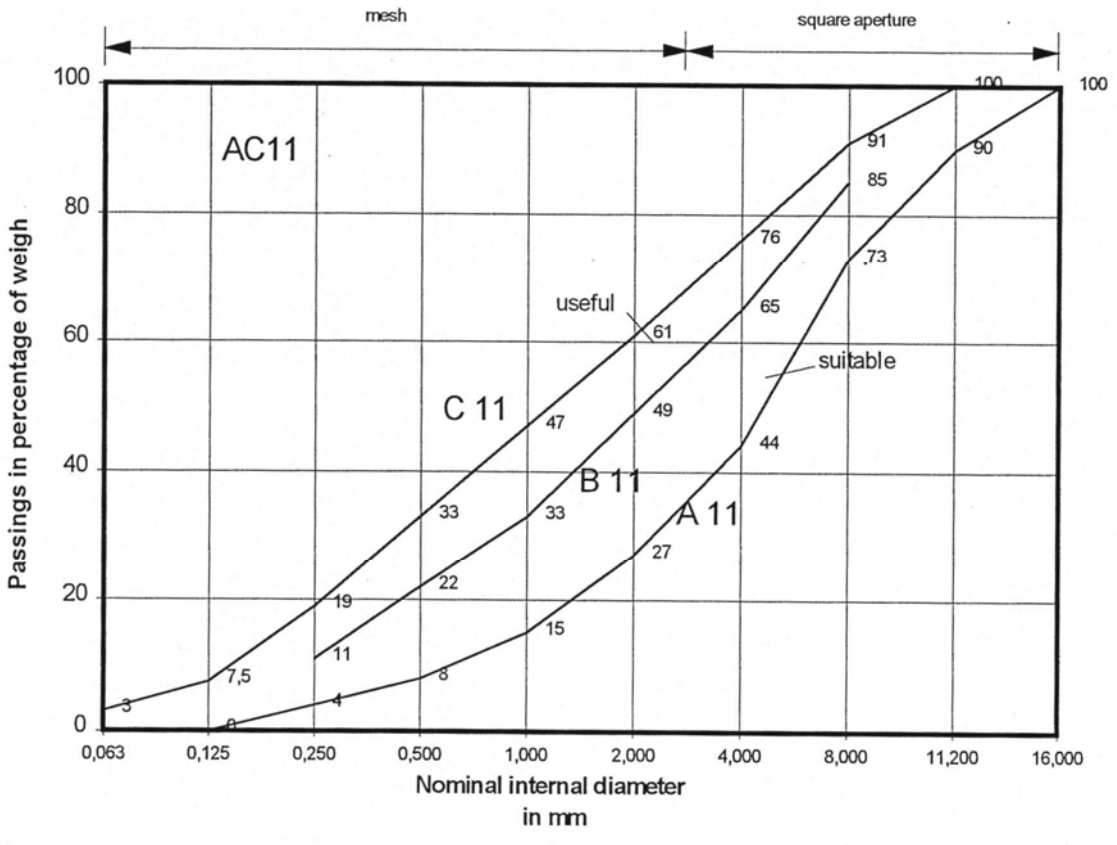
c) The amount of fine particles under 0.1 mm grain size shall not exceed 2% of the total mixture.

d) The maximum size of the aggregates shall not exceed 11 mm.

e) The grain size distribution shall be between the lines A and C preferably near line B as shown in FIG. 7.1.

f) Frozen aggregates must not be used. Minimum temperature of the aggregates shall be 5° Celsius plus.

g) During rainy and cold weather periods the aggregates shall be stored under cover for at least 48 hours before being used, in order to reduce the water content.



Figures in the table refer to passing in percentage of weight.

FIG. 7.1 Grain size distribution of aggregates

2.3.7.2.2.3 ACCELERATING ADMIXTURES

a) The no-alkali accelerating admixtures shall be compatible with the cement used. Powder or liquid type admixtures may be used. The compatibility shall be tested in the laboratory and in

field trials to achieve the required properties for setting and strength development as specified in Chapter 2.3.7.2.6 of this specification.

b) The dosage rate to be used is evaluated following the suitability tests carried out in compliance with the requirements of Chapter 2.3.7.2.6 of this specification. Any addition to this dosage rate shall not exceed 1% of the cement content of the mix design by weight. The dosage rate may be reduced if required for downhand and vertical spraying positions. Automatic device shall be used to add the accelerating admixture. Actual dosage shall be decided by laboratory tests.

2.3.7.2.2.4 ADDITIVES

a) Additives for the improvement of performance, workability etc. may be added, with the approval of ENGINEER.

b) Additives intended to be used shall be included in the tests as described in Chapter 2.3.7.2.6 of this specification.

2.3.7.2.3. MIX DESIGN

The mix for shotcrete shall be designed by laboratory tests and field trials as indicated hereafter to meet the requirements for strength development and final strength. The following factors shall be taken into consideration:

- *Cement type and content*
- *Accelerating admixtures*
- *Water-cement ratio*
- *Setting and strength development*
- *Temperature of mix*

2.3.7.2.3.1 CEMENT CONTENT

For the dry shotcrete process the quantity of cement shall not be less than 350 kg/m³ dry mix.

The cement content shall be designed to meet the strength requirements of shotcrete applied in the field.

For the wet shotcrete process the minimum cement content shall comply with the standard mix of MB 25 concrete.

2.3.7.2.3.2 WATER CEMENT RATIO

a) Dry process:

The water content shall be controlled by the nozzle man to suit the conditions of the shotcreting surface and location of application. An indication that the water/cement ratio is in the correct range will be, that the shotcrete will seem to have a slightly shining appearance immediately following application.

b) Wet process:

Field trials shall be carried out to determine and establish the suitable water/cement ratio.

2.3.7.2.3.3 SETTING AND STRENGTH DEVELOPMENT

a) Accelerating admixtures or special "cement-binders" shall be used to meet the requirements for setting and strength development of shotcrete applied in-situ.

b) In order to determine a suitable dosage rate of accelerating admixtures suitability tests shall be carried out.

c) The compressive strength of shotcrete in situ (taken from the tunnel lining or panels sprayed in the tunnel) shall develop progressively to a final strength according to the minimum requirements specified below. Uniaxial compressive tests shall be done in accordance with the provisions stipulated in Chapter 7.2.6.

d) The strength development due to suitability tests must exceed the specified in-situ strength by a factor of 1/0.85 (=1.18)

e) The 28-day-strength of shotcrete shall be minimum 25 N/mm². The strength development of shotcrete shall be such to meet the following requirements:

- o *0.1 – 0.2 MPa* *after 2 minutes (not more than 0.2 MPa)*
- o *0.2 – 0.5 MPa* *after 6 minutes*
- o *approx. 1.0 MPa* *after 1 hour*
- o *approx. 2.0 MPa* *after 2 hours*
- o *2.0 – 5.0 MPa* *after 6 hours*

For tunneling under buildings or shallow cover (Rock Mass Type SCC) the strength development of young shotcrete shall be such to reach 12 N/mm² after 24 hours.

2.3.7.2.4. BATCHING, MIXING AND TRANSPORTATION

Truck mixers to be used for the transport of shotcrete underground must be fitted with approved exhaust filters.

2.3.7.2.4.1 DRY SHOTCRETE PROCESS USING NO-ALCALI ACCELERATING ADMIXTURES

a) Cement and aggregates shall be batched in the proportions specified and designed. Measurement shall be done by weight. At the time of batching all aggregates shall have been dried or drained sufficiently to result in a stable moisture content, which shall not exceed 7 %.

b) Mixing of cement and aggregates shall be performed mechanically with a pan type mixer. Shotcrete shall not be used unless placing can be completed within a period of 90 minutes from the time of mixing. The time span shall be kept as short as possible, especially at seasons with high air temperatures and high humidity.

c) The mixing time shall be not less than 3 minutes.

d) A system of delivery notes shall be introduced to record the date, the time of mixing, design mix number, quantity, delivery point, time of delivery and completion of placing. The delivery notes shall be available to the ENGINEER for approval.

e) For the dry process, powder or liquid type accelerating admixtures shall be added to the dry-mix. The powder type accelerator shall be proportioned and added just before the dry mix enters the shotcrete machine trough a mechanical device (dispenser). Liquid type accelerator is delivered by a special dosage pump and added to the dry-mix at or near the nozzle. Dosage pump and the hoses to the nozzle shall be kept in good order.

f) During cold weather periods provisions shall be made to maintain the setting properties of the shotcrete either by means of heating the water or the aggregates or both, depending on the temperature. Relevant standards shall be applied.

g) During hot weather periods the water content of the aggregates for the dry process shall be kept above 4% , in order to avoid cement loss at the rotor of the shotcrete machine.

2.3.7.2.4.2 WET SHOTCRETE PROCESS USING NO-ALCALI ACCELERATING ADMIXTURES

h) See also Section Work with Cement Concrete- of SPECIAL TECHNICAL CONDITIONS.

i) Only liquid types of accelerators apply to the wet process; these shall be added at or near the nozzle. The delivery from the accelerator pump must be controlled to be proportional to the output of the concrete pump. The nozzle must be such as to ensure a homogeneous mixture of the accelerator with the wet-mix.

2.3.7.2.4.3 SPECIAL CEMENT-BINDER

Basically there are 2 possibilities for applying shotcrete with special cement-binder:

- *using dry aggregates with a water content less than 0.8 % the aggregates can be mixed with the cement-binder already before application.*
- *using moist aggregates with a water content of less than 4 % aggregates and cement-binder will be mixed just before spraying.*

2.3.7.2.5. PLACING OF SHOTCRETE

a) Rock or previously applied shotcrete surfaces to be shotcreted shall be carefully cleaned of all loose material, rock and other contaminations. It shall be cleaned using compressed air or a water jet if the rock is not sensitive to water.

b) The optimum distance between nozzle and surface of application is 1.0 to 1.3 meter. The nozzle shall be positioned at right angles to the surface of application. Two nozzles shall be used at least for regular tunnel heading.

c) The maximum thickness of shotcrete to be applied at once shall not exceed 15 cm. If the thickness must be increased, subsequent layer(s) must not be applied before the previous layer has developed sufficient strength to support the additional layer(s). These additional layers shall be completed within a period not exceeding three days.

d) Steel ribs, roof ties, wire mesh and other reinforcement shall be embedded in shotcrete as shown on the drawings. The minimum cover of wire mesh and re-bars applied at the inner side of a tunnel lining shall be 2 cm or as shown on the drawings.

e) If more than one layer of reinforcement is used, the second layer shall not be positioned before the first one is embedded and covered with shotcrete.

f) In sound rock the shotcrete shall follow the rock surface with proper rounding of notches and corners. At projections of sound rock the actual shotcrete thickness may be locally reduced to two thirds of the specified thickness. This shall apply to Support Class A2 and B1 only.

g) Rebound shall be removed immediately after finishing of each shotcrete application. In particular at horizontal shotcrete connections due to separate excavation sequences and at all construction joints the rebound shall be removed, if necessary by pneumatic hammers, prior to further application of shotcrete.

h) Under no circumstances shall rebound material be worked back into the construction. The work shall be continuously kept free of rebound material.

i) Curing: required, where necessary.

j) Measures to establish the total thickness of shotcrete shall be set up by the CONTRACTOR and approved by the ENGINEER. These may include visual guides installed prior to shotcreting or holes drilled after completion of shotcreting.

k) Surface Preparation for Waterproofing Membrane

Shotcrete sealing shall be used as surface preparation and backing for the waterproofing membrane in accordance with Section 2.3.8.

l) To avoid an excess load of the shotcrete lining in heavy squeezing rock, deformation slots have to be placed in the shotcrete lining. Ordinary the slots have an opening width of 20 to 40 cm. and have to be boarded radial. The actual position of the gaps depends on the geotechnical conditions.

2.3.7.2.6. TESTING OF SHOTCRETE

a) Suitability tests and quality control of shotcrete shall be carried out in accordance with the Austrian "Sprayed Concrete Guideline – Chapter 12", unless otherwise specified in this Section.

b) Type and number of suitability tests for mix design are listed in TAB. 7.1.

c) Type, number and frequency of tests required for quality control during construction are listed in TAB. 7.2

2.3.7.2.6.1 SUITABILITY TESTS

a) The compatibility of accelerating admixtures and cement shall be tested in the laboratory by checking setting times and whether the addition of the accelerator leads to an excessive reduction in the long terms compressive strength of the shotcrete.

b) Field trials shall be carried out to determine setting and strength development and establish the suitable range of accelerator dosage of shotcrete applied in the field.

c) For each type of accelerating admixture found suitable by preceding laboratory tests a trial mix shall be sprayed into test panels (3 Nos. 500x500x200 mm per trial mix), cured under site conditions and shall be subjected to tests. As described hereunder, at least three different dosages of each type of accelerating admixture shall be tested. The range of accelerator dosage rates shall vary between 2% and 7% of the cement in weight.

d) The ambient temperature for the test shall be in accordance with the actual conditions in the tunnel.

2.3.7.2.6.2 TESTING OF FRESH SPRAYED CONCRETE (EARLY STRENGTH CLASS)

7.2.6.3.1 Penetration needle method (Measuring range 0 to 1.2 MPa)

The strength development up to 1.2 N/mm² can be determined by the Penetrometer using a plunger of 3 mm diameter, depth of penetration shall be approximately 15 mm. This test has to be carried out according to "Sprayed Concrete Guideline".

7.2.6.3.2 Bolt-driving method

a) Measuring range 1 to 8 MPa

Bolt screws are shot into the concrete and the depth of penetration is determined. The penetration depth is the parameter used to determine the compressive strength. A HILTI DX 450 L bolt-setting unit with white cartridges is used to drive the bolt screws into the concrete. Test has to be carried out according to Austrian "Sprayed Concrete Guideline".

b) Measuring range 3 to 16 MPa

Bolt screws are shot into the concrete and the depth of penetration is determined. Then the bolt screws are removed and the pull-out force is measured. The ratio of pull-out force to penetration depth is the parameter used to determine the compressive strength. A HILTI DX 450 L bolt-setting unite with green cartridges is used to drive the bolt screws into the concrete. The pull-out force is determined by means of a pull-out device (e.g. HILTI Tester 4). Test has to be carried out according to Austrian "Sprayed Concrete Guideline".

c) Measuring range 16 to 56 MPa

HILTI bolt screws, type M6-8-52 D12 (overall length 60 mm) are shot into the concrete and the depth of penetration is determined. Then the bolt screws are removed and the pull-out force is measured. The ratio of pull-out force to penetration depth is the parameter used to determine the compressive strength. A HILTI DX 450 L bolt-setting unite, set to position 2, with yellow cartridges is used to drive the bolt screws into the concrete. The pull-out force is determined by means of a pull-out device (e.g. HILTI or ETIRIP). Test has to be carried out according to Austrian "Sprayed Concrete Guideline".

2.3.7.2.6.3 TESTING OF SPRAYED CONCRETE

The development of the compressive strength shall be tested by the crushing of cylindrical shotcrete specimens at the age of 7 and 28 days. The specimens shall be prepared by means of core drilling from the test panels which shall be cured under similar condition to those in the tunnel and shall have a diameter of 100 mm and be cut to a height of 100 mm. The cores shall be drilled not earlier than 48 hours after spraying. A minimum distance of 100 mm shall be kept from the edges of the test panel.

Five cores shall be tested at each shotcrete age specified for assessment of compressive strength. The average value of the five test results shall comply with the strength requirements specified.

The permeability of shotcrete shall be tested in accordance with the Austrian Standard ÖNORM B 3303. The penetration depth of water shall not exceed 35 mm. Three core samples with a diameter 200 mm and a height of 120 mm shall be tested at an age of 28 days.

2.3.7.2.7. QUALITY CONTROL

To ensure the specified quality of shotcrete during construction, the aggregate gradation, cement, additives (e.g. fly ash), accelerating admixtures, strength development of "young" shotcrete and shotcrete strength at 7 and 28 days age shall be tested as shown in TAB. 7.2.

2.3.7.2.7.1 COMPRESSIVE STRENGTH FAILURES

This Clause deals with the course of action to be taken in case the strength requirements as specified in Clause 2.3.7.2.3.3 of this specification are not met.

a) Failure of pull-out test at 24 hours or cores on 3 day tests:
   - *Inform the ENGINEER*
   - *Immediate examination of tunnel lining in suspect area*
   - *Immediate examination of elements concerned in making, transporting and placing of shotcrete*
   - *Continuous monitoring*
   - *Prepare to take further tests at three days*
   - *Take further test panels as soon as possible and institute penetrometer test, pull-out tests and compression test on core samples as specified above*

b) Failure of cores on 7 day tests :
   - *Inform the ENGINEER and DESIGNER*
   - *Install a measurement section*
   - *Monitor as per specification (Section 10 of this Specification)*
   - *If monitoring results show instability of the respective section additional rock support shall be installed*
   - *If the interpretation of deformation measurements is such that additional support is not required, further tests shall be carried out at 28 days.*

c) Failure of cores at 28 days :
   - *Inform the ENGINEER and DESIGNER*
   - *Cores to be taken from the tunnel lining*
   - *Establish the suspect area*
   - *Cores to be then tested and if failure ?*
   - *Prepare proposals for strengthening of the respective area in co-operation with the DESIGNER*
   - *Submit proposals for the approval of the ENGINEER before remedial work is done.*

   If the required 28-days-strength of shotcrete is not achieved the ENGINEER may require that the theoretical thickness of shotcrete ds is increased by the value d1, calculated with the following formula:
   - *d1 = ((F/M) - 1) * ds*
   - *F - required 28-days-strength in N/mm²*
   - *M - measured actual strength of shotcrete lining in N/mm²*
   - *d1 - additional thickness of shotcrete to be sprayed in cm*
   - *ds - theoretical thickness of shotcrete lining in cm*

Alternatively the ENGINEER may require the failed shotcrete to be cut out and the rock support re-installed in accordance with the Rock Mass Type specified.

d) It should be noted that the ENGINEER may require additional strengthening measures to be taken at any time after failure of 3 day cores.

e) Failures of compressive strength as described above are the responsibility of the CONTRACTOR. Required strengthening or reinforcement of the installed rock support due to failed quality control tests will not be measured for payment.

2.3.7.3 REINFORCING STEEL

2.3.7.3.1. WIRE MESH (WELDED WIRE FABRICS)

2.3.7.3.1.1 MATERIAL

a) Welded wire fabric shall comply with the provisions of Section of SPECIAL TECHNICAL CONDITION, unless otherwise specified in this Section.

b) The welded wire fabric shall be made of steel quality MAG 500/560.

c) A mesh 150 x 150 mm or 100 x 100 mm, 5 - 6mm dia shall be used depending on the approval of the ENGINEER.

2.3.7.3.1.2 INSTALLATION

a) Welded wire fabrics shall be installed such that it follows as closely as possible the irregularities of the excavation surface or previous layers of shotcrete. It shall be firmly fixed to prevent vibration and change of position during spraying of shotcrete. Welded wire fabrics shall be installed in the longest practical length. The overlap for welded wire fabrics applied in the shotcrete lining shall be at least twice the pitch distance in circumferential and one pitch distance in longitudinal direction.

b) The installation of the wire mesh shall be such to ensure a concrete cover of minimum 3,0 cm.

2.3.7.3.2. REINFORCING STEEL BARS

For tunnel support purposes, reinforcing steel bars (re-bars) are required as an additional reinforcement in heavily stressed areas such as portal areas, junctions of tunnels and cross passages depending on the local ground conditions and as shown on the design drawings.

2.3.7.3.2.1 MATERIALS

a) Re-bars shall comply with the provisions of Section of SPECIAL TECHNICAL CONDITION, unless otherwise specified in this Section.

b) Re-bars shall be made of steel RA 400/500.

2.3.7.3.2.2 INSTALLATION

a) Reinforcing steel bars shall be attached securely to the previously placed shotcrete layer or wire mesh.

b) Overlaps shall be arranged as shown on relevant drawings.

2.3.7.4 STEEL RIBS

2.3.7.4.1. GENERAL

a) This part of Section 2.3.7 applies to the supply and installation of the steel ribs required and used as support in underground excavations. They shall be effective as primary support immediately after excavation and shall subsequently act as reinforcement and load distributing members for the shotcrete lining.

b) The steel ribs shall be manufactured to meet the geometrical requirements for the excavation geometries in each Rock Mass Type including the relevant tolerances.

2.3.7.4.1.1 SUBMISSION

a) According to Chapter 2.3.7.1.2. of this specification.

b) Shop Drawings.

Prior to the beginning of the work, the following shall be submitted:

- *Complete fabrication details of the steel ribs*
- *Installation procedures and layout*
- *Details of joints, rib connections, rib spacers, geometry etc.*
- *Certificates of compliance of the materials.*

2.3.7.4.2. TYPES OF STEEL RIBS

2.3.7.4.2.1 H - PROFILE ARCHES

H - Profile Arches shall consist either of HEB or GI hot rolled profiles of dimensions as shown on the tunnel support drawings.

2.3.7.4.2.2 TH - PROFILE AND E - PROFILE ARCHES

a) TH - Profiles and E - Profiles originating from mining are hot rolled and have a bell shaped cross section. The connections of the rib sections are done with an overlap of the profiles fitting into each other and are connected with clamps. These type of connections allow large deformations due to friction in the clamp connections.

b) In ground conditions with expected large deformations, TH - profiles and E - Profiles shall be used.

2.3.7.4.2.3 LATTICE GIRDERS

a) Lattice girders are three dimensional, lightweight steel frames manufactured of round steel bars in compliance with the required excavation geometry of the tunnel.

b) In case of fabrication on site, the CONTRACTOR shall submit a detailed method statement for approval to the ENGINEER.

2.3.7.4.3. MATERIALS

a) Hot rolled profiles (H, TH and E profiles) shall consist of structural steel with minimum yield strength of 240 N/mm².

b) Lattice girders shall be manufactured of reinforcing bars with minimum yield strength of 400 N/mm².

2.3.7.4.4. MANUFACTURING OF STEEL RIBS

2.3.7.4.4.1 GEOMETRY

The steel ribs shall be manufactured to meet the geometrical requirements of each of the support classes requiring their use as shown on the design drawings.

2.3.7.4.5. WELDING

a) The manual metal-arc welding process shall be employed. The manufacturer shall be responsible for ensuring that the capacity of the welding plant and ancillary equipment is adequate for the welding procedure to be used and for maintaining all welding plant and ancillary equipment in good working order.

b) Covered electrodes complying to German Standard DIN 1913 shall be used. Electrodes shall be selected with regard to the particular application (welding position, joint design). Electrodes shall be stored in their original containers in a dry, preferably heated place adequately protected from the effects of the weather and in accordance with the manufacturer's specification.

c) Surfaces to be welded shall be dry. Fusion faces and the surrounding surfaces shall be free from heavy scale, moisture oil, paint or any other substance which might affect the quality of the weld. Slag shall be removed from each run of weld metal before a further run is superimposed. The most favorable welding position for each case shall be chosen.

d) For the cutting of the steel profiles the manual flame cutting process may be employed. Also sawing is permitted.

e) Further preparation of joint and fusion faces shall be done by grinding.

f) Parts to be welded shall be assembled such that the joints are easily accessible and visible to the operator.

g) Slag shall be removed from all welds in order to allow visual inspection.

h) Welding operations shall be supervised by a suitably trained supervisor who shall have particular production experience. The welding supervisor is responsible for the following duties listed hereunder:

- *employment of the welders or skilled operators and supervision of their work.*
- *selection, use and storage of suitable welding filler metals and auxiliary materials.*
- *selection and use of satisfactory welding apparatus, welding plant and welding fixtures.*
- *visual and dimensional checking of the weld seams as described under (l).*

i) Welders shall pass the acceptance test as described under (j).

j) Prior to commencement of each welding connection type three nos? of joints shall be manufactured by each welder under conditions of the regular manufacturing process for inspection. These joints shall be inspected by the ENGINEER.

k) Routine inspection of welded joints shall be done by spot checking of not less than 10 per cent of the welded joints in compliance with (l) by the ENGINEER.

l) Acceptance Test and Routine Inspection shall be done in accordance to the criteria as described in the table below. Visible defects exceeding the limits as shown in the table shall be removed and replaced by adequate means.

undersize welds	0.1 "a" permitted (10 %)
undercut	permitted to a limited extent
visible pores	some,10% by area
visible slag inclusions continuous	permitted to a limited extent not
Open end craters	slight depressions permitted
lack of fusion continuous areas	permitted, but no large and no
Cracks permitted	individual small local cracks
excessive asymmetry of welds	side ratio < 1:0.6

2.3.7.4.6. INSTALLATION

a) Steel ribs shall be erected to the lines and levels as indicated on the drawings. The exact excavation levels will however be determined by the CONTRACTORto match best his equipment and construction method subject to the approval of the ENGINEER.

b) Hardwood footblocks and wedges shall be used to bring the steel ribs to the required line and level. Tie bars shall be provided to connect the rib to the adjacent steel rib and fix it securely in place.

c) Steel ribs shall be embedded in shotcrete, in order to get contact between rock and steel rib by a solid shotcrete packing which shall have a minimum cover to steel of 20 mm.

d) The steel ribs shall be erected perpendicular to the tunnel axis.

e) The joints of the ribs shall be such that the static efficiency of the cross section is maintained.

f) In the case of TH - profiles, the trough shall be oriented towards the tunnel in order to enable load transfer and to avoid cavities behind the steel profile. Contact between ground and steel shall be obtained as in (c) above.

2.3.7.5 FOREPILING (FOREPOLING)

Forepiling is a pre-excavation support element required for the tunnel excavation works. Forepiling shall be applied in rock and soil conditions, which tend to produce overbreak, collapses or material inflows immediately following excavation. Forepiling may be applied locally or systematically as the circumstances require for the safety of the works and to prevent overbreak which is always in connection with erection of steel ribs. The length of the steel pipes or rod shall be at least 1 m longer than the instructed length of round.

2.3.7.5.1. INJECTED FOREPILING PIPES

2.3.7.5.1.1 MATERIAL

Injected forepiling pipes are self drilling pipes with lost pit. The pipe consist of a continuous cold rolled drill rod thread. Stell pipes with a minimum outer diameter of 32 mm and drill hole with a diameter of 20 mm and a minimum steel grade of St 37-3U (ENV 1993 – S 235 J0) should be used. Grouting openings in a distance of 25 cm should reach from the pipe peak up to 1 m before the pipe end.

Grout mortar shall comply with Chapter 7.7.4.1 of this specifications.

2.3.7.5.1.2 INSTALLATION

a) Forepiling shall be applied as shown on the drawings or as instructed by the ENGINEER.

b) The pipes should be grouted through the flushing hole immediately after completion of the drilling operation.

c) Forepiling shall be properly supported by the steel rib and the shotcrete above the steel rib. Therefore the shotcreting of the gap between rib and rock in the portions of forepiling shall be completed after the installation of forepiling.

d) Spacing between consecutive forepiling pipes or bars around the crown of the excavation profile must comply with the distance specified on the drawings, but must be adopted to the prevailing geological conditions of the tunnel face.

2.3.7.5.2. DOWELS

2.3.7.5.2.1 MATERIAL

Dowels are steel bars with a minimum steel grade of St 37-3U (ENV1993 – S 235 J0) and a minimum diameter of 26 mm. Dowels are bedded in mortar according to chapter 7.7.2.5.

2.3.7.5.2.2 INSTALLATION

a) Forepoling shall be applied as shown on the drawings or as instructed by the ENGINEER.

b) Mortar has to be filled in to the predrilled holes from the bottom to the top.

c) Dowels shall be inserted into the predrilled holes from the face of the drivage towards the unexcavated ground.

d) Forepiling shall be properly supported by the steel rib and the shotcrete above the steel rib. Therefore the shotcreting of the gap between rib and rock in the portions of forepiling shall be completed after the installation of forepiling.

e) Spacing between consecutive forepiling pipes or bars around the crown of the excavation profile must comply with the distance specified on the drawings, but must be adopted to the prevailing geological conditions of the tunnel face.

2.3.7.6 DRIVEN STEEL LAGGING

Steel Lagging (sheet piles) shall be employed mainly in weak ground with low cohesion with the purpose of preventing the collapse of material during and immediately after excavation. The use of lagging will always require the erection of steel ribs.

2.3.7.6.1. MATERIALS

a) Lagging sheets with a thickness of 4 to 6 mm shall be used.

b) Lengths shall be chosen in accordance with the length of excavation and the support requirements beyond the face.

c) Length of steel lagging is 1.5 to 2.0 m.

d) Width of the sheet metal has to be between 180 mm and 225 mm

2.3.7.6.2. INSTALLATION

a) Lagging sheets shall be driven at distances shown on the drawings. They shall be driven in advance of excavation of the respective round to a depth extending a minimum length of 0.8 metres beyond the face into the ground.

b) Voids and gaps behind the lagging sheets shall be either filled with shotcrete or by contact grouting with a suitable cement mortar.

2.3.7.7 ROCK BOLTS

2.3.7.7.1. GENERAL

a) The provisions contained hereunder apply to all rock bolts installed either locally or in a systematic pattern in the roof, side walls, and invert of the tunnels. Rock bolts are part of the primary support, with the purpose of activating the composite action between the surrounding rock and the shotcrete, contributing to the load bearing capacity of the primary tunnel lining. Rock bolts occasionally required for the support of the tunnel face during the advance are covered likewise under these provisions.

b) Rock bolts shall be installed according to the lengths and rock bolt patterns shown on the drawings for each relevant standard support system unless otherwise determined by the CONTRACTOR'Sand ENGINEER'S representative classifying the encountered rock conditions.

2.3.7.7.1.1 DEFINITIONS

a) SN-Bolts are made of deformed steel bars and fully bonded with the surrounding rock by cement mortar. The hole is filled with grout before insertion of the bolt. The abbreviation SN descends from the mine "Store Norfors" where applied first.

b) PG - bolts (post - grouted or injection bolts) are made of deformed steel bars with a hose attached. Grouting is done after installation of the bolt through the hose .

c) IBO-bolts (injection-bore-bolts) are a combined system of rock bolt and drill rod. During drilling, the bolt is used as the drill rod fixed with a drill bit. Rod and bit remain in the hole as a rock bolt, which is grouted through the flushing hole. In case of collapsing boreholes, this system still enables the installation of rock bolts.

d) Swellex Rockbolts (friction anchored rock bolts) are mechanically folded steel tubes. High water pressure inflates the tube and adapts its shape to the irregularities of the borehole.

2.3.7.7.2. MATERIALS

2.3.7.7.2.1 SN-BOLTS AND PG-BOLTS

a) Bolts shall have a minimum diameter of 28 mm for steel grade RA 400/500.

b) The specified breaking load shall also apply to the thread, nut, anchor plate and coupling, if any.

c) Rock bolts shall be made of deformed reinforcing steel with a corrugated surface (ribbed rod). The ripped steel of the steel rod should have a related rip area (fR) according to DIN 488 Part

3, between 0,02 and 0,03. Usually are used diameters of 24 mm, the condition above corresponds to a rip distance of approx. 25 mm to 50 mm depending on rip height and inclination. Longitudinal rips have to be avoided. Bolts have to be approved by the ENGINEER.

d) One end of the rod shall be fitted with a suitable thread which is to receive an anchor plate and fixing nut.

e) Anchor plates on all types of bolts with a size of 150 x 150 mm and a thickness of 8 mm shall be used unless instructed otherwise by the DESIGNER and approved by the ENGINEER based on support necessities. The shape shall allow a uniform seat, even if the bolt is not installed exactly perpendicular to the surface below.

f) Washers and nuts shall allow the secure transfer of the anchor force to the anchor plate.

2.3.7.7.2.2 IBO-BOLTS (SELF DRILLING BOLTS)

a) IBO-bolts shall have a minimum breaking load of 250 kN.

b) The breaking load shall also apply to threads , nuts, anchor plates and couplings.

c) The steel rods shall have a corrugated surface.

2.3.7.7.2.3 SWELLEX AND SUPER SWELLEX ROCKBOLTS

a) Super Swellex Rockbolts for systematic rock bolt patterns shall have a minimum breaking load of 200 kN.

b) For local bolting and for rock bolting of construction stages, bolts with a breaking load of 110 kN ("Standard" Swellex) may be used.

c) Bolt face plates shall be such as to allow transfer of the anchor force at the head of the rock bolt to the shotcrete, steel rib or rock surface.

d) (For inflation of bolts, equipment as recommended by the manufacturer of the bolts shall be used.

2.3.7.7.2.4 COUPLINGS FOR BOLTS

Couplings have to be from the same or better material as the bolts itself. The coupling diameter should allow grouting the whole anchor length from the deepest point of the drill hole.

2.3.7.7.2.5 CEMENT - MORTAR GROUT

a) The cement mortar grout shall consist of sand, cement and water or neat cement and water.

b) Ordinary Portland Cement shall be used.

c) Sand for grouting purpose shall be clean, mineral sand, uniform in quality and from an approved source. This material should be approved by the ENGINEER.

d) Water shall be clean, free from oil, acid, alkaline, organic and other deleterious substances.

e) Additives for the improvement of workability may be used.

f) The cement mortar grout shall be mechanically mixed to produce a uniform consistency.

g) Expanding additives are imperative.

2.3.7.7.3. <u>EXECUTION</u>

2.3.7.7.3.1 SN-BOLTS

a) Boreholes for all rock bolts shall be drilled to the depths as required by the lengths of rock bolts specified for the support of the respective Rock Mass Types and at diameters, which ensure best workability for grouting, coupling and installation. The minimum diameter of the boreholes shall be 10 mm larger than the diameter of the rock bolts/ couplings installed.

b) The boreholes shall be cleaned of all drill cuttings, sludge and debris. The installation of rock bolts shall follow the drilling and preparation of the borehole within 3 hours.

c) Prior to the installation of the rock bolt, the entire borehole shall be filled with cement mortar by inserting the grout hose to the full depth of the hole and withdrawing as the grout is pumped in.

d) The nozzle shall be kept buried in the grout as the pipe is withdrawn so that air is displaced as the hole is filled. The bolt is then pushed into the hole.

e) The nut of the grouted rock bolts shall be tightened not later than 2 rounds behind the face or 12 hours after installation to achieve a force at the anchor plate of approx. 20 kN. This force shall be applied by a calibrated torque wrench.

f) In case of confined working space and/or great length of rock bolts, coupling shall be permitted. The number of coupled parts shall be kept to a minimum. However, the load capacity of such coupled rock bolts shall not be less than that of a standard integral rock bolt. Special attention shall be paid to the grouting procedure in order to ensure full embedment of the bolt by grout.

2.3.7.7.3.2 PG – BOLTS

a) In case of coupled rock bolts or partly collapsed boreholes, grouting may be done after installation of the bolt. The hole is then grouted by a special attachment which allows the mouth of the borehole to be sealed whilst the grout is pumped in. Air is displaced from the hole via a tube, which is attached to the full length of the rock bolt as it is installed. Grout is then pumped in and the hole can be seen to be full, when grout escapes from the end of the tube.

b) Same as Chapter 7.7.3.1, except paragraph (c) of it.

2.3.7.7.3.3 IBO- BOLTS

a) IBO-bolts shall be used in ground conditions where the effective installation of other types of rock bolts is impossible.

b) IBO-bolts shall be placed by drilling the rod into the ground without withdrawing the rod.

c) IBO-bolts shall be grouted through the flushing hole immediately after completion of the drilling operation.

d) The grout mix, grouting pressure and quantity shall be determined by the CONTRACTOR according to the ground conditions encountered and approved by the ENGINEER.

2.3.7.7.3.4 SWELLEX ROCKBOLT

a) Boreholes for the rockbolts shall be drilled to the depths as required. The boreholes shall be cleaned of all drill cuttings, sludge and debris.

b) The installation of rock bolts shall be done not later than two hours after drilling of the borehole.

c) Installation and inflation of the bolts shall follow the manufacturer's recommendations. Specific inflation plant shall be used. The rockbolt shall be drained after inflation.

2.3.7.7.4. TESTING

2.3.7.7.4.1 GROUT MORTAR

a) Prior to acceptance tests of rock bolts, tests with available cements and sands shall be carried out to determine an appropriate mix design to achieve the specified strength and a proper workability in association with the grouting equipment used.

b) Additives may be used to improve workability. The influence of the additive to the strength development shall be followed by tests as described under this clause.

c) The grout mortar shall be tested on cubes 5x5x5 cm. The cubes shall be cured in water.

d) Five numbers of cubes shall be prepared for each compressive strength test. The resultant strength is the average evaluated from the three remaining values after elimination of the highest and the lowest.

e) During construction, cube sample shall be taken weekly at each five bolts drivage from the grouting hose at the nozzle. Preparation and evaluation shall follow the procedure as described above.

f) Required compressive strength of grout mortar

- *after 24 hours* — *8 N/mm²*
- *after 28 days* — *20 N/mm2*
- *w/c = 0.25 – 0.30* — *pure cement*
- *w/c = 0.50 – 0.60* — *cement-sand mixture (0-5 mm)*

2.3.7.7.4.2 PULL OUT TESTS ON ROCK BOLTS

Pull-out tests shall be performed on basis of ISRM Doc.2, Part 1 "Suggested Method for Rockbolt Testing".

a) Proof Tests

A detailed test program set up on basis of above mentioned document shall be approved by the ENGINEER prior to all testing work.

Deviations from the ISRM suggested method shall be approved by the ENGINEER.

A test report shall be issued immediately after completion of the tests. It shall be submitted for approval to the ENGINEER.

For each type of rock bolt submitted information shall comprise

- *type of bolts, testing equipment, location and installation records*
- *applied testing loads and records of deformation*
- *the evaluation of test results as specified in ISRM's document*
- *interpretation and suggested action for failed pull-out tests*

Proof tests shall be carried out for all types of bolts to be used for this project prior to the commencement of tunneling to demonstrate the effect and the service capacity of the bolts in the field.

The tests shall be performed in similar geological ground conditions as expected during tunnel drivage. The location of the bolts to be tested shall be selected by the ENGINEER.

A minimum of five bolts of each type shall be tested. Depending on the testing procedure and the test results the ENGINEER may require further bolts to be tested.

Adequate testing equipment, as specified in the above mentioned ISRM document shall be provided to record bolt elongation, movement of the bolts and tension forces.

The maximum load to be applied is 250 kN or as otherwise approved.

b) Testing during Tunnel Driving

The ENGINEER will select rock bolts for testing of production bolts. For each type of rock bolts five bolts will be selected from the first 100 bolts placed in the tunnel. From the remaining bolts five per 200 bolts will be selected for testing purpose. The testing force to be applied has to be at least 80% of the bolt breaking load.

Bolts which fail the tests or which are pulled out shall be replaced.

For each failure, the ENGINEER shall require further bolts to be tested in the vicinity.

Otherwise as Chapter 7.7.4.2 (a) of these specifications.

2.3.7.7.4.3 INSTALLATION RECORDS.

Comprehensive records about details of the installation of rock bolts during drivage, such as grout consistency, drilling depth, length and type of rock bolts, deviations from the theoretical position, type and time of grouting, time of tightening, special observations, etc. shall be kept for each round by the CONTRACTORand countersigned by the ENGINEER´S supervisory personnel. Copies of these records should be submitted to the ENGINEER.

2.3.7.8 LSC (LINING STRESS CONTROLLER)

2.3.7.8.1. GENERAL

To manage large deformations occurring during tunnel excavation in rock with unfavourable characteristics, the tunnel lining is divided into segments by means of longitudinal gaps. To make better use of the lining capacity, yielding elements (LSC) made of mild steel are installed in the deformation gaps in the circumferential direction. These elements have a defined resistance over the required shortening path.

The LSC is used to achieve controlled ductility of the tunnel lining. By limitation of normal forces developing in the lining overstressing is prevented and adequate bearing capacity of the support ensured.

2.3.7.8.2. SYSTEM

The LSCs (Lining Stress Controllers) inserted between two pressure plates arranged at its end sides consist of multiple steel pipes in a concentric assembly.

In order to limit inward and outward buckling the load tube is coaxially arranged between two supporting tubes shorter than the load tube. To allow for a smooth initial load development, special provisions have to be foreseen (weakening at the ends of the load tube). The minimum shortening dlp to reach the design load Fp is 60 mm.

The variation of the actual load from the design load (tolF) shall not exceed +/- 15% of the design load Fp .

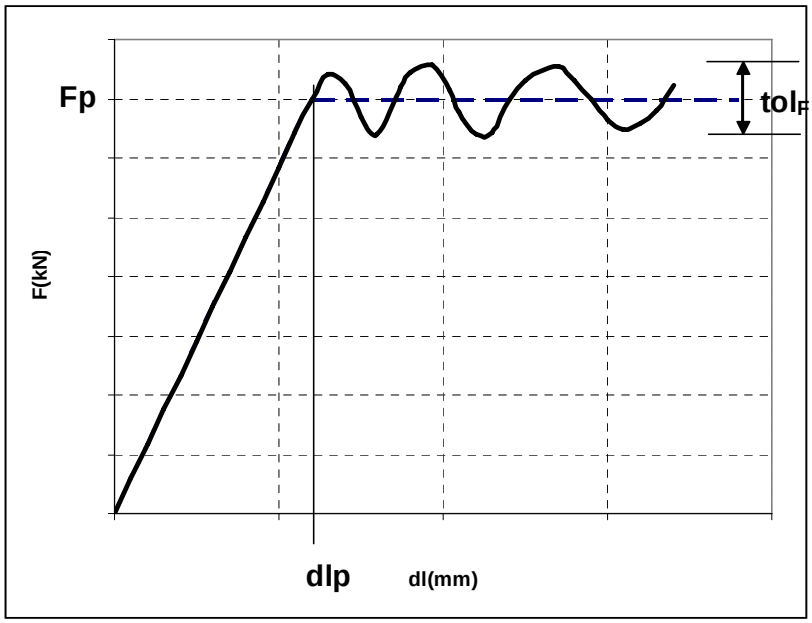


Figure 1. Load line of a LSC. Dashed line is the design load line, solid line actual load line; Fp design load; dlp shortening to design load; tolF tolerance of actual load to design load

In order to optimize the bearing capacity of the lining especially of a shotcrete lining multi-stage systems can be used. Multi-stage system is a unit consisting of at least two LSCs with the same height (L1) and one or more shorter units (L2) which are activated after a certain deformation. In this case bearing capacity of the element unit is stepwise increased.

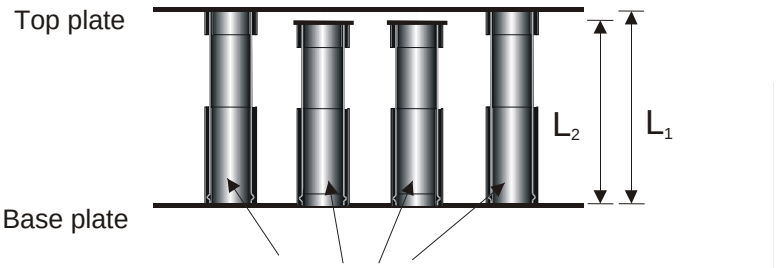


Figure 2. Group of 4 yielding elements; two elements in this group are shorter for later activation

Single elements are grouped. Different combinations of LSC types and lengths of elements are possible, to optimally adjust to displacements and development of shotcrete properties.

Depending on the necessity of the project the following LSC types or combinations thereof can be used:

	1*Fp (kN)	tolF (%)	dlp min (mm)
LSC A-I	**200**	**+/- 15**	**45**
LSC A-II	**550**	**+/- 15**	**45**
LSC A-III	**750**	**+/- 15**	**40**
LSC B-I	**900**	**+/- 15**	**45**
LSC B-III	**1600**	**+/- 15**	**55**

The length of the yielding elements has to be designed to the requirements of the project. Common lengths are between 400 to 450 mm.

2.3.7.8.3. CONSTRUCTION

Each LSC unit consists of a combination of several LSCs with an upper and lower base plate. Installation is done prior to shotcreting. The elements are fixed to the steel arches with appropriate fixing devices (hooks or similar).

Special care must be taken to properly align the elements to the lining. Functionality must not be affected by the assembly, transport and installation.

Refers to shotcrete support:

Before shotcreting the elements have to be covered by a timber board or similar at the tunnel side to avoid penetration of shotcrete into the space of action of the LSCs.

After shotcreting and ensuring that the functionality of the adjacent elements will not be affected when the works continue, the cover can be removed.

2.3.7.9 PIPE ROOF

A pipe roof, consisting of steel tubes, is installed in case of low rock cover (up to 2 to 3 tunnel diameters) in order to reduce settlements and to increase excavation and face stability. Normally, pipe roofs are used in soil and very weak rock (decomposed or completely weathered, completely sheared, fractured or mylonized rock).

In loose ground or soil, the steel pipes can be used as „manchette tubes„ for pressure grouting the ground between and around the pipes.

2.3.7.9.1. MATERIAL

a) Perforated steel pipes with a minimum steel grade St 37-3U (acc. to DIN 2448) (ENV 1993 – S 235 J0) with a minimum outer diameter of 114 mm shall be used.

b) The wall thickness should not be below 6 mm.

c) The steel pipes are generally installed in lengths of 15 m. The overlap shall be 4 – 5 m.

d) Grout mortar shall comply with chapter 2.3.7.7.4.1 of this specification. The water cement ratio has to be adapted to the requirements of the surrounding rock. The ring space and the volume in the pipe has to be grouted from the dippiest borehole area with low pressure grouting (max. 10 bar).

e) Pipes have to be provided with opposite situated grouting holes pairs in a minimum distance of 1m. Grouting holes have to be shifted for 90 degrees.

2.3.7.9.2. INSTALLATION

a) The pipe roof shall be installed as shown on the drawings or as instructed by the ENGINEER. The drilling has to be executed with an accuracy of 1%.

b) The steel pipes shall be inserted into the predrilled holes from the face of the drivage towards the unexcavated ground. In unstable boreholes th steel pipes may be used as casing for drilling.

c) Spacing between the steel pipes in the crown of the excavation profile must comply with the distance specified on the drawings, but must be adopted to the prevailing geological conditions of the tunnel face.

d) After drilling the steel pipes shall be cleaned by using compressed air prior to low pressure grouting.

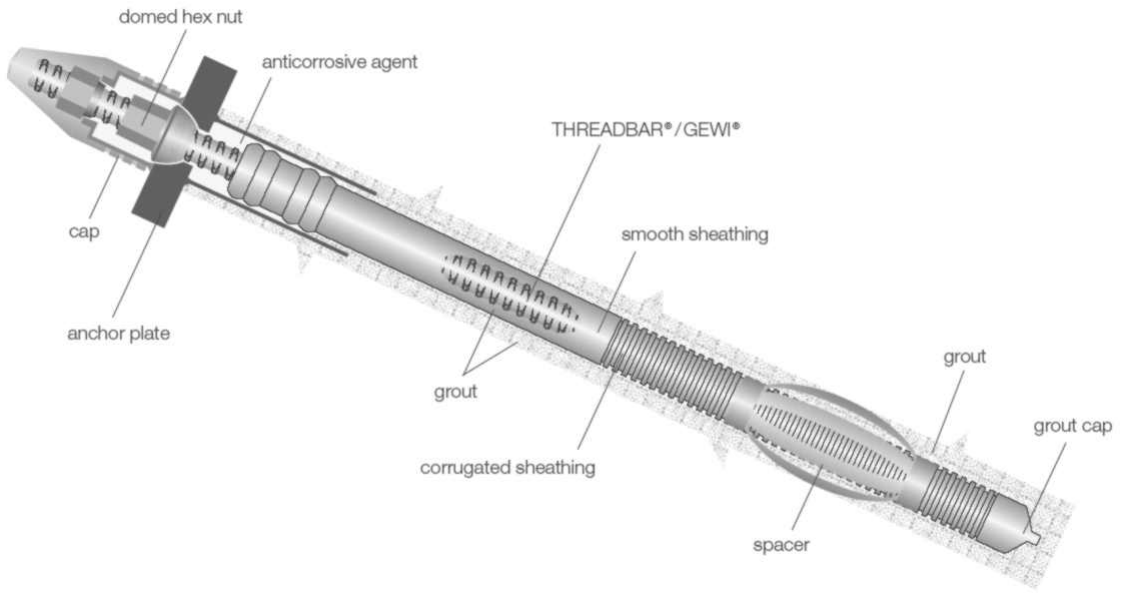
2.3.7.10 BAR ANCHORS

2.3.7.10.1. GENERAL

a) This part of Section 3 applies to the supply and installation of prestressed bar anchors required and used as additional support of cavern.

b) All works shall be carried out in accordance with the following standards:

- *SIA 191 (1996)*



2.3.7.10.2. MATERIALS

2.3.7.10.2.1 GENERAL

Anchors shall not contain materials that are mutually incompatible with each other and the surrounding environment.

2.3.7.10.2.2 PRESTRESSING BARS

a) The prestressing steel shall consist of prestressing steel bars according to OENORM B 4258. The distance between the bar and plastic tube shall be sufficiently large to provide for faultless embedding in cement or mortar or in the permanently plastic corrosion protection material. The bars shall be made of high, tensile steel.

b) The mechanical properties and technical characteristics shall comply with:

- *Steel bars St 835/1030 MPa*
- *Double corrosion protection*

2.3.7.10.2.3 GROUT

a) BAS «Grouting and Injecting Work»

b) Grout shall consist of Portland cement, water and admixtures, if required. The cement shall not contain (by weight) more than 0.02% chlorides or 0.10 % sulfides. The admixtures shall not harm bars or grout properties. The water/cement ratio shall be kept as low as possible. In no case it shall exceed 0.45. The grout mix shall not be subject to bleeding in excess of 0.5 percent by volume 3 hours after mixing or 1 % maximum when measured at 20° C in a covered glass or metal cylinder of 100 mm diameter and with a grout depth of approximately 100 mm.

c) At prestressing the compressive strength of the grout shall be at least 20 N/mm².

2.3.7.10.2.4 PROTECTIVE TUBES

a) The free length of the bars shall be encased in a smooth HDPE-tube. The HDPE shall be homogeneous and free of voids. No regenerated material is allowed. Thickness of the tube-wall shall be at least 3 mm.

b) The bond length of the bars shall be encased in a corrugated tube with a minimum wall thickness of 1 mm.

2.3.7.10.2.5 ANCHOR HEAD

The strength of the anchor head shall be at least the same as of the bars.

2.3.7.10.3. SYSTEM REQUIREMENTS

2.3.7.10.3.1 CORROSION PROTECTION

a) The corrosion protection of anchoring system has to be made according to SIA 191 (1996).

b) This includes all parts such as anchor head, packer, free anchor length and bond length of the bar and the distant end of the anchor.

c) The bond length is principally corrosion protected by cement suspension and one corrugated HDPE tube. Grouting of the cement suspension is performed before or after anchor installation, depending on application.

d) The bond length shall be determined by suitability tests.

2.3.7.10.3.2 SYSTEM COMPONENTS

a) The system shall be designed to provide an ultimate load holding capacity of not less than s x Pw (Pw.....working load). The safety factor according to SIA 191 (1996) is specified as follows:

- *against failure of tendon*

- o *against yield tendon*
- o *against limited creep load*
- o *against failure of grout body*

b) The anchor shall be designed to allow monitoring of the load (e. g. with hydraulic load cells or equivalent)

c) The stressing anchorage shall be designed to enable release of load in the case that the working load is considerably exceeded due to ground movements

2.3.7.10.4. ANCHOR INSTALLATION

2.3.7.10.4.1 DRILLING

a) Anchor length is to be such, that boreholes can be drilled with normal face drilling rigs. Borehole diameters for anchors shall be 80 mm, depending on the rock quality respectively and is given in drawings.

b) In ground likely to collapse, the sides of the boreholes shall be supported by suitable casing tubes.

c) Before insertion of the anchor the drill hole shall be washed clean.

d) A drilling record, containing all relevant information such as drilling method, borehole depth, flushing medium, flushing return, drilling speed, kind of rock drilled etc. shall be taken by the CONTRACTORgeologist for each hole drilled. The records shall be made immediately available to the ENGINEER.

2.3.7.10.4.2 WATER PRESSURE TESTS

a) Water pressure tests shall be carried out in defined boreholes only in rock that is not sensible on water. The first three boreholes in each typical geological section shall be tested to 4 bar. After the experience of these tests it shall be decided by the ENGINEER if the water pressure tests shall be continued or can be omitted for the subsequent anchors at each location. Every 15th borehole shall be tested routinely.

b) If loss of water exceeds 5 liter per minute over a period of 5 minutes in the bond section of the anchor at a water pressure of 3 to 4 bars in the test section, the borehole shall be pregrouted, redrilled and tested again.

c) A full record of water pressure tests shall be taken by the CONTRACTORand submitted to the ENGINEER.

2.3.7.10.4.3 INSERTION OF ANCHOR

a) The anchor shall be inserted as soon as practicable after but at most within 12 hours of completion of the drilling.

b) The anchor shall be positioned in the center of the borehole by use of spacers and the bearing plate shall be at a right angle to the borehole axis. To achieve the latter it may be necessary to cut out pockets in the rock.

2.3.7.10.4.4 GROUTING

a) The grouting procedure shall ensure that there are no air or water pockets left in the grouted zone.

b) Grouting shall proceed at a slow, steady rate and continue until grout of the same composition and consistency as mixed can be seen emerging from the outlet of the vent pipe for at least one minute.

c) A record giving full details of the grouting operation for each anchor shall be submitted by the CONTRACTORto the ENGINEER.

d) Grouting of the free anchor length shall be done after prestressing of the anchor.

2.3.7.10.5. ANCHOR TESTING PROCEDURES

Anchor testing procedures should follow standards as SIA 191 (1996) as well as BAS.

2.3.7.10.5.1 SUITABILITY TESTS

Suitability tests are carried out on anchors constructed under similar conditions as for the working anchors. These tests indicate the results, which shall be obtained subsequently from the working anchors by the routine acceptance tests. Considerable and significant changes of the conditions for the working anchors e.g. geological conditions, require the execution of suitability tests.

2.3.7.10.5.2 ACCEPTANCE TEST

a) In the course of the acceptance test each anchor will be stressed to the relevant test load. In cohesive soils the creep-values shall be determined as well.

b) Test programme:

   A cyclic loading and unloading procedure shall be carried out with the load being increased from a initial load in successive cycles by load steps until a specified maximum load. At each load increment the displacement of the bars at the anchor head relative to a fixed point in the environment shall be observed at constant load according to the schedule set up.

2.3.7.11 CABLE ANCHORS

2.3.7.11.1. GENERAL

a) This part of specifikations applies to the supply and installation of prestressed cable anchors required and used as additional support for the bored pile wall in the open cut sections.

b) All works shall be carried out in accordance with the following standards:

   - *SIA 191 (1996)*
   - *BAS*

2.3.7.11.2. MATERIALS

2.3.7.11.2.1 GENERAL

Anchors shall not contain materials that are mutually incompatible with each other and the surrounding environment.

2.3.7.11.2.2 PRESTRESSING STRANDS

a) The prestressing steel shall consist of prestressing steel strands according to OENORM B 4258. The distance between the individual strands shall be sufficiently large to provide for faultless embedding in cement or mortar or in the permanently plastic corrosion protection material. The strands shall be made of high, tensile steel.

b) The mechanical properties and technical characteristics shall comply with the code OENORM B 4258, as follows:

   - *steel strands with seven wires, low relaxation ST 1570/1770*
   - *nominal steel area 100 mm^2*

2.3.7.11.2.3 GROUT

a) BAS «Grouting and Injecting Work»

b) Grout shall consist of Portland cement, water and admixtures, if required. The cement shall not contain (by weight) more than 0.02% chlorides or 0.10 % sulfides. The admixtures shall not harm strands or grout properties. The water/cement ratio shall be kept as low as possible. In no case it shall exceed 0.45. The grout mix shall not be subject to bleeding in excess of 0.5 percent by volume 3 hours after mixing or 1 % maximum when measured at 20° C in a covered glass or metal cylinder of 100 mm diameter and with a grout depth of approximately 100 mm.

c) At prestressing the compressive strength of the grout shall be at least 20 N/mm².

2.3.7.11.2.4 PROTECTIVE TUBES

a) The free length of the strands shall be encased in a smooth HDPE-tube. The HDPE shall be homogeneous and free of voids. No regenerated material is allowed. Thickness of the tube-wall shall be at least 3 mm.

b) The bond length of the strands shall be encased in a corrugated tube with a minimum wall thickness of 1 mm.

2.3.7.11.2.5 ANCHOR HEAD

The strength of the anchor head shall be at least the same as of the strands.

2.3.7.11.3. SYSTEM REQUIREMENTS

2.3.7.11.3.1 CORROSION PROTECTION

a) The corrosion protection of anchoring system has to be made according to SIA 191 (1996).

b) This includes all parts such as anchor head, packer, free anchor length and bond length of the strands and the distant end of the anchor.

c) The bond length is principally corrosion protected by cement suspension and one corrugated HDPE tube. Grouting of the cement suspension is performed before or after anchor installation, depending on application.

d) The bond length shall be determined by suitability tests.

2.3.7.11.3.2 SYSTEM COMPONENTS

a) The system shall be designed to provide an ultimate load holding capacity of not less than s x Pw (Pw.....working load). The safety factor according to SIA 191 (1996) is specified as follows:

b) against failure of tendon

c) against yield tendon

d) against limited creep load

e) against failure of grout body

f) The anchor shall be designed to allow monitoring of the load (e. g. with hydraulic load cells or equivalent)

g) The stressing anchorage shall be designed to enable release of load in the case that the working load is considerably exceeded due to ground movements

2.3.7.11.4. ANCHOR INSTALLATION

2.3.7.11.4.1 DRILLING

a) Anchor length is to be such, that boreholes can be drilled with normal face drilling rigs. Borehole diameters for anchors shall be 130 mm, depending on the rock quality respectively and is given in drawings.

b) In ground likely to collapse, the sides of the boreholes shall be supported by suitable casing tubes.

c) Before insertion of the anchor the drill hole shall be washed clean.

d) A drilling record, containing all relevant information such as drilling method, borehole depth, flushing medium, flushing return, drilling speed, kind of rock drilled etc. shall be taken by the CONTRACTOR'Sgeologist for each hole drilled. The records shall be made immediately available to the ENGINEER.

2.3.7.11.4.2 WATER PRESSURE TESTS

a) Water pressure tests shall be carried out in defined boreholes only in rock that is not sensible on water. The first three boreholes in each typical geological section shall be tested to 4 bars. After the experience of these tests it shall be decided by the ENGINEER if the water pressure tests shall be continued or can be omitted for the subsequent anchors at each location. Every 15th borehole shall be tested routinely.

b) If loss of water exceeds 5 liter per minute over a period of 5 minutes in the bond section of the anchor at a water pressure of 3 to 4 bars in the test section, the borehole shall be pregrouted, redrilled and tested again.

c) A full record of water pressure tests shall be taken by the CONTRACTOR and submitted to the ENGINEER.

2.3.7.11.4.3 INSERTION OF ANCHOR

a) The anchor shall be inserted as soon as practicable after but at most within 12 hours of completion of the drilling.

b) During installation the anchor shall be handled with care. The anchor shall be installed with an injection pipe and an ventilation pipe.

c) The anchor shall be positioned in the center of the borehole by use of spacers and the bearing plate shall be at a right angle to the borehole axis. To achieve the latter it may be necessary to cut out pockets in the rock.

2.3.7.11.4.4 GROUTING

a) The grouting procedure shall ensure that there are no air or water pockets left in the grouted zone.

b) Grouting shall proceed at a slow, steady rate and continue until grout of the same composition and consistency as mixed can be seen emerging from the outlet of the vent pipe for at least one minute.

c) A record giving full details of the grouting operation for each anchor shall be submitted by the CONTRACTORto the ENGINEER.

d) Grouting of the free anchor length shall be done after prestressing of the anchor.

2.3.7.11.5. ANCHOR TESTING PROCEDURES

Anchor testing procedures should follow standards as SIA 191 (1996) as well as BAS.

2.3.7.11.5.1 SUITABILITY TESTS

Suitability tests are carried out on anchors constructed under similar conditions as for the working anchors. These tests indicate the results, which shall be obtained subsequently from the working anchors by the routine acceptance tests. Considerable and significant changes of the conditions for the working anchors e.g. geological conditions, require the execution of suitability tests.

2.3.7.11.5.2 ACCEPTANCE TEST

a) In the course of the acceptance test each anchor will be stressed to the relevant test load. In cohesive soils the creep-values shall be determined as well.

b) Test programme:

A cyclic loading and unloading procedure shall be carried out with the load being increased from a initial load in successive cycles by load steps until a specified maximum load. At each load increment the displacement of the strands at the anchor head relative to a fixed point in the environment shall be observed at constant load according to the schedule set up.

2.3.7.12 ANCHOR BEAMS

2.3.7.12.1. GENERAL

For specification of concrete works and steel reinforcement see Section 2.3.9 - CONCRETE WORKS AND REINFORCEMENT.

2.3.7.13 MEASUREMENT

2.3.7.13.1. SHOTCRETE

a) Shotcrete lining applied in tunnels, parking bays, cross passages and niches will be measured for each nominal thickness by square meter along "Line 2 (as shown on FIG. 4.3). The length of the tunnel (or each round) will be measured along the center line.

b) Additional shotcrete required for refilling cavities between roof pipes will not be measured for payment.

c) Additional shotcrete required due to the widening of the cross section under the pipe roof will not be measured for payment separately.

d) Additional shotcrete required for temporary footings will be measured by linear meters of footings.

e) Deformation gaps will be measured by linear meters.

2.3.7.13.2. WIRE MESH

a) Welded wire fabrics applied in tunnels, parking bays, cross passages and niches will be measured by weight along "Line 2" (as shown on FIG. 4.3). The length of the tunnel (or each round) will be measured along the center line. Overlap, waste material, additional material necessary for temporary footings and auxiliary material for fixing will not be measured.

b) Additional reinforcement required due to the widening of the cross section under the pipe roof will not be measured for payment and shall be included in the relevant Unit Prices.

2.3.7.13.3. RE-BARS

Re-bars used for tunnel support will be measured by weight.

2.3.7.13.4. STEEL RIBS

Steel ribs for rock support will be measured by weight along "Line 2" (as shown on FIG. 4.3). Auxiliary material such as spacer bars between the ribs, steel plates at connections, bolts for connections etc. will not be measured for payment.

2.3.7.13.5. FOREPILING

Forepiling pipes or bars (dowels) will be measured by pices for different lengths. Drilling will not be measured separately.

2.3.7.13.5.1 INJECTED FOREPOLING PIPES

The unit price has to include the lost pit, boring, injection grouting up to a solid cement usage of 10 kg per m.

2.3.7.13.5.2 DOWELS

The unit price has to include boring, fabrication of the peak of the rod and mortar.

2.3.7.13.6. STEEL LAGGING

Lagging sheets will be measured by weight.

2.3.7.13.7. ROCK BOLT

Rock bolts will be measured by "pieces" for the various types and lengths. Drilling, grouting and inflation (Swellex) will not be measured separately. Auxiliary material, such as anchor plates, washers, nuts, couplings will not be measured for payment.

2.3.7.13.8. LSC (LINING STRESS CONTROLLER)

LSC (Lining Stress Controller) will be measured by "pieces" for the various types. Transmission plates will not be measured for payment. The deformation gaps a separately item is intended in bill of quantities and will measured by length.

2.3.7.13.9. PIPE ROOF

a) Steel pipes will be measured by pieces. Drilling and low pressure grouting will not be measured separately.

b) Additional consuption of breakout material, wiremesh, shotcrete and waterproof membrane due to widenings in pipe roof sections will not be measured and payed with separate item.

2.3.7.13.10. BAR ANCHORS

Bar anchors will be measured by pieces for the various length, types and working loads designed. Installment and supply material, such as anchor plates, packings, nuts and joints shall be included in the Unit Price.

2.3.7.13.11. CABLE ANCHORS

Cable anchors will be measured by pieces for the various length, types and working loads designed. Installment and supply material, such as anchor plates, packings, nuts and joints shall be included in the Unit Price.

2.3.7.13.12. ANCHOR BEAM

a) Concrete will be measured in cubic meter according Section 9.6. Form work for construction of the concrete beams will not be measured in the Unit price for concrete.

b) Reinforcement for concrete beams will be measured by weight for actual quantities (t) installed as shown on the drawings.

2.3.7.14 PAYMENT

2.3.7.14.1. GENERAL

a) The Unit Prices for the various pay items shall include all labour, equipment and materials required for the complete execution of the work, including face support, testing and quality control.

b) Payment for installation of additional support elements in a distance of more than 50 m behind the respective excavation face will be calculated by separate pay items but not for cross passages and niches.

2.3.7.14.2. FOREPOLING

Forepoling pipes or bars (dowels) will be measured by pices for different lengths. Drilling will not be measured separately.

2.3.7.14.2.1 INJECTED FOREPOLING PIPES

The unit price has to include the lost pit, boring, injection grouting up to a solid cement usage of 10 kg per m.

2.3.7.14.2.2 DOWELS

The unit price has to include boring and fabrication of the peak of the rod.

2.3.7.14.3. ANCHORS

a) The Unit Prices for the different pay items shall include all labour, equipment and materials required for execution of the works, including coupling, grouting of free anchor length, prestressing, quality control and testing. Drilling and grouting of bond length will be paid separately.

b) The Unit Price for anchors of different length than specified will be calculated by linear interpolation or extrapolation.

c) Drilling for anchors will be paid for at the Unit Price per linear meter considering the respective total length of the bore hole.

d) The unit price should also cover the installment of anchors over head in inclined direction.

2.3.7.14.4. ANCHOR BEAMS

a) The Unit Prices for the different pay items shall include all labour, equipment and materials required for execution of the works.

b) According to Section 9 - Shuttering and scaffolding required for the construction of the anchor beams shall be included in Unit Price for concrete.

2.3.7.14.5. PIPE ROOF

a) Steel pipes will be measured by pieces. Drilling and low pressure grouting will not be measured separately.

b) Additional consumption of breakout material, wire mesh, shotcrete and waterproof membrane due to widening in pipe roof sections will not be measured and paid with separate item.

Suitability tests for shotcrete Tab 7.1

Test items	Properties	Testing Method	Samples	Age at Test
Young Shotcrete	Early Strenght	Penetration needle Kaindl-Meyco	Test panels	5', 15', 30', 1h, 3h, 6h, 9h, 24h
Shotcrete	Compressive strenght	Core samples	Dia 100 mm, Height 100 mm, from panels 5 core samples each	7d, 28d
	Permeability	ÖNORM B3303 penetration 35 mm	3 Core samples Dia 200 mm, Height 120 mm	28d
Cement	Specific surface, initial setting, Compressive strenght 1d, 28d	Specific surface (Blaine), Vicat needle, ÖNORM B3310	2kg	
Agregates	Grain size distribution	ÖNORM B3304	10kg	
	Moisture content	ÖNORM B3304	10kg	
Accelerating Additives (powder or liquid)	Content of alcali	Authorized Laboratory	2l	
	Initial setting	Guideline on Shotcrete, Part 2; Chapt. 1.2	800 cm^3	>45sec<180sec
	Decrease in Compressive Strenght	Guideline on Shotcrete, Part 2; Chapt. 1.2	Prism sample 4x4x416 cm made from Mortal	7d

Remark:

1) The requirements and specifications for suitability tests are valid for shotcrete application in tunnel and for slope protection at portal cuts

2) Suitability tests shall be carried out by an Authorized Laboratory.

Quality control for shotcrete Tab7.2

Test items	Properties	Testing Method	Location of Testing Samples	Age at test	Frequency of Sampling and Tests	Test type
Young Shotcrete	Early Strenght	Penetration needle Kaindl-Meyco	Shotcrete lining	5', 15', 30', 1h, 3h, 6h, 9h, 24h	1x /500m^2	A
Shotcrete	Compressive strenght	Core samples	Dia 100 mm, Height 100 mm, drilled from Shotcrete lining	7d, 28d	1x /50m^2 or 1x /250m^2 or min. 3 samples	B
	Permeability	ÖNORM B3303	3 core samples Dia 200 mm, Height 120 mm	min. 28d	1 X month	B
	Deformation Modulus	ÖNORM B3303	Dia 100 mm, Height 200 mm	3d, 7d, 28d, 56d	1 x for each mix	B
Shotcrete without accelerator	Compressive strenght, Reduction of Compressive strenght	Austrian Guideline on Shotcrete, Part. 2; Chapter 2.2		28d	1 x 2month	B
Cement	Specific surface, initial setting, Compressive strenght 1d, 28d	Specific surface (Blaine), Vicat needle, ÖNORM B3310	5kg	Immediately after taking samples from the site	1 x 250t	B
Fly - Ash	Specific surface	ÖNORM B3303	1kg	Immediately after taking samples from the site	1 x 2month	B

2.3.8 WATERPROOFING AND PERMANENT GROUNDWATER DRAINAGE

Attached Figure:

Figure 8.1: Requirements on surface irregularities of shotcrete

2.3.8.1 WATERPROOFING AND PROTECTIVE FELT

2.3.8.1.1. GENERAL

This section covers the waterproofing for all tunnel structures by means of a continuous waterproofing membrane installed to the outside of the final concrete lining. It does not include provisions for other elements such as waterstops in concrete, sealing of joints etc.

The waterproofing shall be such, that all underground structures are watertight. In case of leakage, provision shall be made for these to be repaired.

2.3.8.1.1.1 DESCRIPTION

a) The purpose of the membrane waterproofing to underground structures is to prevent leakage of groundwater or mountain water into the tunnels and to protect the final concrete lining against deleterious chemical influences. Waterproofing shall be applied to crown and sidewalls above footing or invert arch level. The waterproofing membrane shall always be located between shotcrete support and final concrete lining. As the underground structures referred to are not immersed below a distinct groundwater table no membrane waterproofing will be provided for tunnel inverts.

b) The waterproofing system shall consist of two layers: the first shall consist of a protective felt fastened to the shotcrete surface; the second layer shall be the actual waterproofing membrane properly fixed by special means as recommended by the manufacturer.

c) While the sealing function shall be provided by the membrane, the layer of felt is required to protect the waterproofing membrane against damage from contact with the shotcrete surface, to prevent interlocking between concrete and shotcrete in case of differential movements of shotcrete support and final lining, and to provide a drainage layer allowing to drain off groundwater into the longitudinal lateral drainage pipes, thus preventing a build-up of hydrostatic pressure on the tunnel lining.

d) In case of ground water it is necessary to use design solutions, which are forseen by ENGINEER.

2.3.8.1.1.2 SUBMISSION

The following submissions shall be furnished for approval in accordance with the contract requirements:

a) Certificates of compliance attesting that the materials meet specification requirements.

b) Manufacturer's instructions for installation of felt backing and waterproofing membrane, including procedures for preparation, fixing, welding and splicing, flashing etc.

c) Manufacturer's and installer's qualifications to include evidence of experience of the manufacturer and the installers, as well as resume of lining installation supervisors.

d) Samples as listed hereafter:

- *Membrane: one square meter of each type membrane.*
- *Protective felt: one square meter of each type of felt.*
- *Welded splice: 1 m of welded membrane splice for each type of membrane.*
- *Fixings and fittings: 10 samples from different lots of rondels and nails,*
- *2 samples of sealing flanges for projections passing through the membrane.*

e) Shop drawings shall be submitted for approval showing all necessary installation details for felt and waterproofing membrane, including installation sequence, position of joints, treatment of projections, connection to water stops, connection to waterproofing of structures in open cut, local reinforcements etc.

2.3.8.1.1.3 QUALITY ASSURANCE

a) General

Supply and install suitable products designed and manufactured specifically for application in tunnels under conditions similar to those encountered on this project and having had acceptable performance.

b) Manufacturer's Qualifications

Select a manufacturer (or manufacturers) who is (are) regularly engaged in the production of similar materials for tunnel structure and has demonstrated successful application on at least five recent projects of comparable nature.

c) Supervision and Training

Manufacturer's representative shall be present at least during the first 10 working days of installation and later as often as necessary.

Execute all installation and testing under the direct supervision of an individual with recent, continuous, acceptable experience in the installation of tunnel membrane linings.

Provide all personnel involved in lining installation and testing with adequate training prior to beginning of the lining work.

d) Installation records shall be submitted to the ENGINEER for approval with all relevant data for all seam checks etc. These records shall form part of the submission to obtain approval to proceed with the installation of the inner concrete lining, see also Section 9 of this Specification.

2.3.8.1.2. MATERIALS

2.3.8.1.2.1 PROTECTIVE FELT

The protective felt shall be a continuous filament non-woven poly-propylene geotextile of uniform thickness and surface texture meeting the requirements listed below.

Property	Specified Value	Standard
Unit weight	500g/m^2 min	DIN 53854
Thickness at 0.02 bar	3,9 mm min	DIN 53855/3
Thickness at 2.0 bar	1,7 mm min	DIN 53855/3
Tensile strength	1000 N/50 mm	DIN 53857/2
Extension at break	70 % min	DIN 53857/2
Extension at 30% of tensile strength	20 % min	DIN 53857/2
Permeability in plane		
at 0.02 bar	5x10-1 cm/s min	*
at 2.00 bar	5x10-2 cm/s min	*
Resistance against acid and alkaline solutions, pH 2-13	Loss of strength 10% max.	SN 640 550 DIN 53857/2
Resistance to Punching	2000 N	DIN 54307

Test according to Franzius Institute, Hannover, BRD

2.3.8.1.2.2 WATERPROOFING MEMBRANE

The waterproofing membrane shall be made of one of the following materials, or similar and shall meet the requirements listed below.

The membrane shall be supplied with a signal layer, i.e. a thin sheeting of different colour, bonded to one side, which is intended to facilitate the detection of damages.

ECB Waterproofing Membrane (ethylene-copolymer bitumen)

Property	Specified Value	Standard
Thickness	2.0 mm min	DIN 53370
Tensile strength	10 N/mm^2 min	DIN 53455
Elongation at failure	500% min	DIN 53455
Compressive strength at 20% strain	2.5 N/mm^2 min*	DIN 53454
Tear propagation strength	150 N/mm min	DIN 53363
Resistance under water pressure	Waterproof at 10 bar for 10 hours	DIN 16726
Strength of welded seam	7.2 N/mm^2 min	DIN 16726
Dimensional stability after accelerating ageing	+/- 2% max	DIN 16726
Material characteristics during and after storage at 80^o C:		DIN 16726
- General appearance	no blisters	
- Dimensional stability, long. and transverse	<-3%	
- Variation of tensile strength, long. and transverse	<$\pm$10%	
- Variation of elongation at failure, long. and transverse	<$\pm$10%	
- Folding at a temperature of -20 degrees C	no fissures	
Water absorption	1% max	DIN 53495
Behavior after storage in acid and/or alkaline solutions:		DIN 16726
- Variation of tensile strength, long. and transverse	<$\pm$20%	
- Variation of elongation at failure, long. and transverse	<$\pm$20%	
- Folding at a temperature of -20 degrees C	no fissures	
Shear strength of splice with bitumen	100N/50 mm	DIN 16726
Behaviour during perforation test	no perforation at 750 mm height of fall	DIN 50014

* Cubic specimen with edge length of 10 mm.

PVC Waterproofing Membrane (poly-vinyl-chloride)

Property	Specified Value	Standard
Thickness	2.0 mm min	DIN 16726
Tensile strength	12 N/mm^2 min	DIN 16726
Elongation at failure	250% min	DIN 16726
Compressive strength at 20% strain	2.5 N/mm^2 min*	DIN 53454
Tear propagation strength	100 N/mm min	DIN 53363
Resistance under water pressure	waterproof at 10 bar for 10 hours	DIN 16726
Tensile strength of welding seam Welding factor (90 % of tensile strength)	10,8 N/mm^2 min	DIN 16726
Dimensional stability after accelerating ageing	+/- 2% max	DIN 16726
Material characteristics during and after storage at 80^o C:		DIN 16726
- General appearance	no blisters	
- Dimensional stability, long. and transverse	<-3%	

- Variation of tensile strength, long. and transverse	<±20%	
- Variation of elongation at failure, long. and transverse	<±20%	
- Folding at a temperature of -20 degrees C	no fissures	
Water absorption	1% max	DIN 53495
Behaviour after storage in acid and/or alkaline solutions:		DIN 16726
- Variation of tensile strength, long. and transverse	<±20%	
- Variation of elongation at failure, long. and transverse	<±20%	
- Folding at a temperature of -20 degrees C	no fissures	
Shear strength of splice with bitumen	100N/50 mm	DIN 16726
Behaviour during perforation test	no perforation at 750 mm height of fall	DIN 50014
Behaviour in fire	B 1	ÖNORM B3800/1

* Cubic specimen with edge length of 10 mm.

2.3.8.1.2.3 ACCESSORIES

Fixing material, flashing, reinforcement for expansion joints, sealing flanges and preparation of corners and intersections shall be made as recommended by the manufacturer of the membrane.

2.3.8.1.3. EXECUTION

2.3.8.1.3.1 SURFACE PREPARATION

a) All surfaces to which waterproofing is to be applied shall be sufficiently clean, smooth and free from deleterious materials and projections.

b) The following treatment of surfaces shall be performed prior to the installation of waterproofing:

- *For the fixing of the protective felt and the waterproofing membrane, a minimum shotcrete cover of 5 cm to rock is required.*
- *Irregularities of the shotcrete lining surface shall be eliminated by means of additional shotcrete. The ratio of the diameter to depth of irregularities shall be not less than 5:1 (see FIG.8.1). Rounding at rock bolts, etc. shall have a min. radius of 0.3 m.*
- *Transitions and intersections of tunnel profiles shall be rounded off with a minimum radius of 50 cm.*
- *Protruding steel bars, wires, spacers, pipes etc. shall be cut off unless treated with additional shotcrete cover.*
- *Exposed steel parts such as rock bolts, if not intended to remain accessible, shall be covered with shotcrete.*
- *All shotcrete surfaces shall finally be smoothened with fine-graded shotcrete backing (rounded aggregates, grain size 0 - 8 mm), applied in a layer of 3 to 5 cm thickness.*

2.3.8.1.3.2 APPLICATION

Prior to the application of the waterproofing, all surfaces to which it shall be applied, shall be inspected and approved by the ENGINEER.

The application shall follow the written instructions of the manufacturer. Generally procedures are the following:

a) Preparations

Special preparations will be required for waterproofing at tunnel intersections and for projections passing through the membrane. They shall be carried out according to the manufacturer's recommendation.

b) Fixing of Felt

The protective felt shall be attached to the shotcrete surface using suitable fixings specified by the manufacturer. Depending on the location 2 to 4 nos. fixing elements shall be used per square meter. The felt shall be laid with sufficient slack to avoid overstress during concreting. Adjacent sections of felt shall be overlapped by 10 cm and joined by point welding or similar suitable method. Along the bottom of the tunnel side walls the felt shall extend sufficiently to cover the lateral drainages as shown on the drawings.

c) Fixing of Waterproofing Membrane

The waterproofing membrane shall be installed to cover the felt and shall be attached to the felt fixings by means of thermal welding. No perforation of the membrane shall be allowed for installation purposes. The waterproofing membrane shall be laid with the signal layer towards the inside and with sufficient slack to prevent overstressing during concreting. Adjacent sheets of waterproofing shall be joined by a double weld. Along the bottom of the tunnel side walls the membrane shall extend sufficiently to cover the lateral drainages as shown on the drawings. Connections to waterstops and to the waterproofing of structures in open cuts shall be carried out according to drawings to be furnished by the SUPPLIER.

2.3.8.1.3.3 PROTECTIVE MEASURES

Every care shall be taken not to damage the waterproofing membrane during or after installation. Any damages occurred shall be repaired and tested before the casting of the final concrete lining.

2.3.8.1.4. QUALITY CONTROL OF EXECUTION

2.3.8.1.4.1 TESTING OF SEAM

All seams shall be tested and records of these tests shall be submitted by the CONTRACTOR to the ENGINEER.

a) Seam Test with Compressed Air

For seams between adjacent sheets of waterproofing membrane the testing for tightness shall be carried out by means of compressed air pumped into the test channel which is formed by the double welded joint. Initial test pressure shall be 2 bar for a test period of 5 minutes or 1.5 bar for a test period of 10 minutes. The joint shall be considered waterproof if the loss of air pressure is in both cases not more than 20%.

b) Seam Test with Vacuum Equipment

For the testing of areas of membrane of limited size such as special con-figurations of joints or local repairs with patches, vacuum equipment may be employed. This consists of a vacuum bell which, after being fitted tightly over the area to be tested, is evacuated by pumping in order to detect leaks in the membrane.

2.3.8.2 PERMANENT GROUND WATER DRAINAGE

This clause applies to the installation and maintenance of the permanent groundwater drainage system in the tunnels. If during construction ground water is encountered below the designed level of the longitudinal groundwater drainage system then a further permanent drainage system will be designed to deal with it.

2.3.8.2.1. GENERAL

a) This section covers requirements for the permanent groundwater drainage system inside the tunnels, consisting of slotted, tunnel-shaped pipes above the abutments on either side, revision niches, inspection shafts underneath the roadway, connection pipes between revision niches and inspection shafts, and the tunnel main drainage pipe.

b) The revision niches and the inspection shafts for the tunnel main drainage pipe shall be installed at the designed spacing.

c) A separated drainage system for groundwater and waste water (from the carriageway) shall be executed inside the tunnels.

d) This section does not include provisions for the road drainage system and waste water treatment outside the tunnels. The roadway drainage system inside the tunnels consists of slotted prefabricated kerb stones. The reinforced concrete kerbs are layed on cement mortar and sealed with elastic silicon mastic.

2.3.8.2.2. MATERIALS

a) The longitudinal ground water drainage shall consist of PE-HD double layered ribbed pipes as shown on the drawings. The total area of the slots for water intake shall be more than 200 cm^2 per metre length of pipe depending on hydrological conditions in the rock mass.

b) Porous no-fines concrete shall be composed of ordinary Portland cement and natural, 32 mm single size aggregate. The ratio of aggregate to cement shall be 8:1 by volume or 10:1 by mass.

c) Cross connection shall consist of PE-HD double layered corrugated, unperforated pipes of minimum inner diameter 200 mm.

d) The tunnel main drainage shall be made concrete pipes (MB 30) as shown on the drawings.

e) Kerbs for dewatering of roadway are made of concrete (MB 40), reinforced and shall be waterproof layed, joints are sealed with elastic silicon mastic. Kerbs have to be prefabricated in steel formwork.

2.3.8.2.3. EXECUTION

a) The water appearing and/or collected behind the waterproofing membrane shall be diverted permanently by longitudinal drainage pipes installed at both sidewalls of the tunnels.

b) The longitudinal ground water drainage pipes shall be covered and protected by no-fines porous concrete between the inspection niches inside the tunnel.

c) Inspection niches shall be installed in the inner concrete lining for permanent maintenance (flushing) of the drainage system as shown on the drawings.

d) The CONTRACTORshall ensure that the permanent ground water drainage system is used only for the control of groundwater. Throughout the construction and maintenance periods regular inspection and servicing shall be provided.

e) All drainage pipes for control of the ground water shall be installed to line and grade as shown on the drawings.

f) The no-fines concrete shall be mixed by machine or by hand to a uniform colour and consistency before placing. The quantity of water used shall not exceed that required to coat all of the aggregate particles without forming excess grout.

g) The no-fines concrete shall be compacted by hand only.

2.3.8.3 MEASUREMENT

2.3.8.3.1. WATERPROOFING MEMBRANE

a) The waterproofing membrane applied in traffic tunnels, parking bays and cross passages will be measured by square meter along "Line 2" (as shown on Figure 4.3). The length of the tunnels will be calculated along the centre line.

b) Necessary enlargements of tunnel cross sections for smaller niches (emergency call niches, niches for electrical facilities, fire fighting niches, drainage inspection niches, spaces under pipe roof, etc.) will not be measured for the waterproofing membrane.

c) The penetration of the waterproofing membrane in the water distribution niche will not be measured for payment and shall be included in the relevant Unit Price.

2.3.8.3.2. LONGITUDINAL GROUNDWATER DRAINAGE

a) The executed works for the longitudinal drainage pipes and cross connection pipes to the revision (inspection) shafts will be measured by linear meter of each drainage pipes. Protection of the longitudinal drainage pipes by no-fines concrete will not be measured separately.

b) Construction of inspection shafts will be measured separately.

c) Main dewatering system for mountain and roadway water will be measured in meters (m^1).

2.3.8.4 PAYMENT

2.3.8.4.1. WATERPROOFING MEMBRANE

The Unit Price for the waterproofing membrane shall include all labour, equipment and materials required for execution of the works, including quality control and testing.

2.3.8.4.2. LONGITUDINAL GROUNDWATER DRAINAGE

The Unit Price for the longitudinal groundwater drainage system shall include all labour, equipment and materials required for execution of the works.

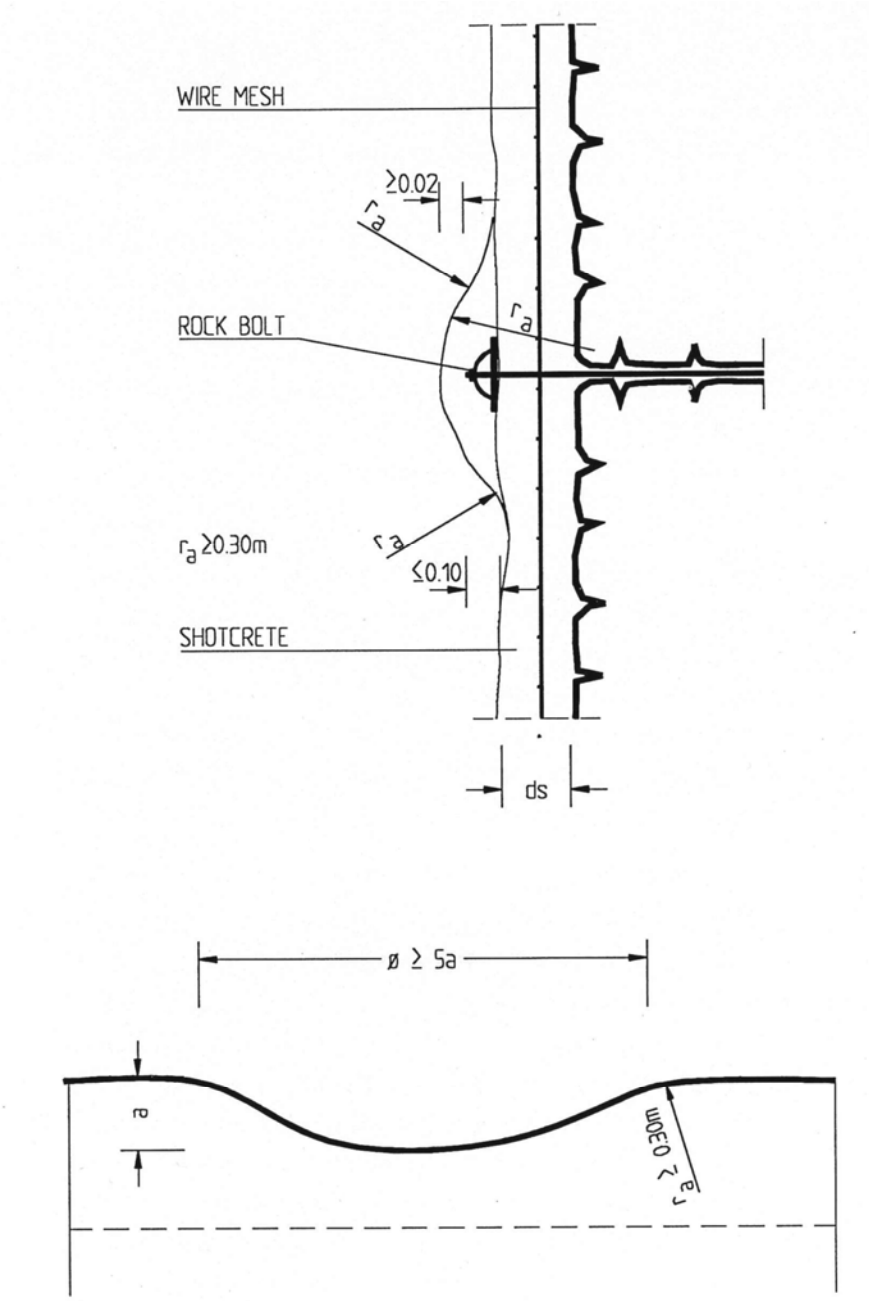


Figure 8.1: Requirements on surface irregularities of shotcrete

2.3.9 CONCRETE WORKS AND REINFORCEMENT

Attached Figures:

FIG. 9.1 Lines for Measurement and Payment of Inner Concrete Lining

FIG. 9.2 Lines for Measurement and Payment of Filling Excessive Overbreak with Inner Concrete Lining

FIG. 9.3 Lines for Measurement for Concrete at Niches

2.3.9.1 GENERAL

This section contains specifications for the construction of the final tunnel lining, the foundation beams, the concrete invert arch and precast concrete components as well as concrete works in cut-and-cover tunnel sections, for the Concrete Arch and for retaining structures. Structures of the mined tunnel are predominantly unreinforced, but they may also be reinforced locally, as designed and approved by the ENGINEER, while cut-and-cover tunnel sections, the Concrete Arch and retaining structures are generally reinforced.

2.3.9.1.1. DESCRIPTION

a) SPECIAL TECHNICAL CONDITIONS, unless otherwise specified in this section.

b) The final tunnel lining, a cast-in-situ concrete lining, increases the safety factor of the tunnel lining system, provides a uniform interior surface and improves the watertightness of the tunnel lining. A smooth interior surface is required for air flow, aesthetic, lighting and maintenance reasons.

c) The foundation beams form the abutments for the final tunnel lining. Cable ducts and side walks are generally placed on these longitudinal concrete beams.

d) The invert arch forms the ring closure of the tunnel lining (tunnel tube) where poor geological conditions prevail.

e) The formwork or shutters for the foundation beams, invert arch and roof arch provide the necessary tools for the construction of the final tunnel lining. They shall be designed and constructed of steel in such a manner that the shape, dimensions and surface finish of the concrete are obtained, as specified.

f) Precast concrete elements form the lateral boundaries of the road surface (kerb stones) and are also used for cable duct slabs.

g) Contact grouting is the injection of grout material under pressure to fill voids between in-situ concrete lining and the shotcrete or the membrane lining (waterproofing). A systematic contact grouting shall be carried out in the roof section of the tunnel after hardening of the concrete lining. Provision shall be made in the roof arch shutter for fixing of the necessary pipes (or casting openings) for contact grouting. Positioning of these grout holes shall be approved by the ENGINEER.

h) Coating of the concrete surface of the inner lining will be necessary for protection of concrete and to facilitate cleaning.

i) The cast-in-situ reinforced Concrete Arch forms the roof of a mixed tunnel/cut&cover-method. The Concrete Arch transfers the forces, induced by the backfill, into the lateral load bearing rock mass. In the protection of the Concrete Arch, the tunnel can be mined by conventional methods.

2.3.9.1.2. SUBMISSIONS

a) Working drawings shall be submitted showing the camber of formwork as required for compensation of deflection by concrete placing operation.

b) The CONTRACTORshall submit detailed shop drawings of the formwork for approval by the ENGINEER.

c) Separate shop drawings for the formwork of the tunnel cross section, cross passage, niches, Concrete Arch and cut-and-cover shall be submitted by the CONTRACTORfor approval by the ENGINEER.

d) Test reports shall be submitted for the concrete to be used in accordance with Section 5.3 of the SPECIAL TECHNICAL CONDITIONS.

e) Prior to fabrication of precast concrete components the CONTRACTORshall submit references of the manufacturer to the ENGINEER.

f) Method statement, plant and material description for contact grouting shall be submitted to the ENGINEER for approval before commencement of inner lining concreting works.

g) Test reports and examples of material used for coating shall be submitted by the CONTRACTORfor approval by the ENGINEER.

2.3.9.1.3. JOB CONDITIONS

a) The inner concrete lining in the tunnel shall not be placed until the rate of displacement at any position on the tunnel periphery and perpendicular to the periphery is less than 4 mm per month, unless otherwise approved by the ENGINEER.

b) The inner concrete lining shall not be placed before the reprofiling results have been accepted and approved by the ENGINEER.

c) The inner concrete lining in the tunnel shall not be placed before the waterproofing system installed is accepted and approved by the ENGINEER.

d) The placement of the precast concrete components shall not be executed prior to approval by the ENGINEER.

e) Coating of the concrete surface shall not be executed before the surface of the inner concrete lining has been approved by the ENGINEER.

2.3.9.2 MATERIAL

Materials shall comply with the provisions of SPECIAL TECHNICAL CONDITIONS, unless otherwise specified in this Section.

2.3.9.2.1. FORMWORK

a) SPECIAL TECHNICAL CONDITIONS.

b) The shape of the Concrete Arch has to be modeled with a steel formwork or the excavated material is used to create an earth form for the Concrete Arch.

c) Formwork shall be sufficiently rigid to maintain the forms in their correct position, shape and profile so that the final concrete structure is within the limits of tolerances.

d) The formwork for tunnel lining shall be made of steel and suitable for repetitive use.

e) The formwork for tunnel lining shall be provided with openings along each side wall and in the crown. The opening shall be designed to permit the use of vibrators for compacting the concrete, to permit inspection of the concrete during placing and of the hardened concrete surface prior to the striking or the removal of the formwork. The size of the openings shall be minimum 600 mm square. Openings for pouring of concrete shall be located at such heights as to prevent segregation of the concrete. Joints in the forms shall be sufficiently tight to prevent leakage of grout and absorption of water from concrete.

f) The forms shall be maintained at all times in good condition as accuracy of shape, strength, rigidity, water tightness and smoothness of surface is warranted. All forms shall be kept clean, free of corrosion and in good repair.

g) The upper sector of the lining formwork shall have facilities for mounting external vibrators at regular intervals to ensure thorough compaction of the arched soffit.

h) The steelform shall be furnished with suitable devices for the erection of stop ends and to enable chamfers along the periphery at the start/end of each concreting section in order to produce a regular surface between pours where the tunnel is on curve.

2.3.9.2.2. CONCRETE

a) SPECIAL TECHNICAL CONDITIONS, unless otherwise specified in this Section.

b) The concrete grade for tunnel lining, abutment, invert arch, Concrete Arch and cut-and-cover shall be MB 30.

c) Maximum aggregate size is to comply with the SPECIAL TECHNICAL CONDITIONS.

d) The consistency of the mix shall be chosen to allow placing of concrete by pumping.

e) Plasticizers may be used in the concrete mix to improve flow and compaction. Details of such additives shall be submitted to the ENGINEER for approval prior to their use.

2.3.9.2.3. PRECAST CONCRETE COMPONENTS

a) SPECIAL TECHNICAL CONDITIONS, unless otherwise specified in this Section.

b) The concrete grade for precast concrete components shall be MB 40.

c) Precast concrete elements shall be produced with a dimension tolerance of $\pm$ 2 mm.

2.3.9.2.4. GROUT FOR CONTACT GROUTING

a) Grout shall be based on a mixture of cementious materials and water, but may contain additives to improve the performance, subject to the ENGINEER'S approval. All sources of water to be used with cement shall be approved by the ENGINEER. If at any time during construction, water from an approved source becomes unsatisfactory, the CONTRACTORshall provide satisfactory water from other main sources.

b) Cement shall conform to current Standards. The grout shall be a uniform mixture of which the consistency shall be sufficiently fluid to ensure that the grout flows freely under pressure into all parts of the void.

c) The grout mix shall have low or no bleedability and low shrinkage characteristics. When set, the grout should have the lowest permeability possible.

2.3.9.2.5. STEEL REINFORCEMENT

For the inner concrete lining steel reinforcement is necessary in heavily stressed areas such as cut-and-cover tunnel sections, sections under houses and shallow cover (excavation sequence SCC), portal areas, niches, junctions of tunnels and cross passages, depending on the local ground conditions and as shown on the design drawings. Furthermore, the concrete inner lining may be reinforced in areas of heavy installations inside the tunnel, for example where ventilation fans are fixed.

Steel reinforcement is required for the Concrete Arch as well and the precast concrete elements as well.

2.3.9.2.5.1 MATERIALS FOR WIRE MESH (WELDED WIRE FABRICS)

a) Welded wire fabric shall comply with the provisions of SPECIAL TECHNICAL CONDITION, unless otherwise specified in this Section.

b) The welded wire fabric shall be made of steel quality MAG 500/560.

2.3.9.2.5.2 MATERIALS FOR RE-BARS

a) Re-bars shall comply with the provisions of SPECIAL TECHNICAL CONDITIONS, unless otherwise specified in this Section.

b) Re-bars shall be made of steel RA 400/500.

2.3.9.2.6. COATING

a) The quality of the coating material shall be in accordance with the valid provisions in the Austrian provision RVS 8.29.4.

b) Testing shall be done by an authorised testing institute.

c) The material consists of an two-component mixture based on epoxy resin.

d) The adhesion value tested by cutting a grid of 5 mm x 5mm (in accordance with RVS 8.29.4) shall be at least 85 %.

2.3.9.3 EXECUTION OF CONCRETE WORKS

Execution of Concrete Works shall comply with the provisions of SPECIAL TECHNICAL CONDITIONS, unless otherwise specified in this Section.

2.3.9.3.1. PREPARATION OF FORMWORK BEFORE CONCRETING

a) SPECIAL TECHNICAL CONDITIONS, unless otherwise specified in this Section.

b) The inside surface of forms shall be coated with an approved nonstaining mould oil to prevent adhesion of the concrete.

c) Release agents shall be applied strictly in accordance with the manufacturer's instructions and shall not come into contact with reinforcement.

d) The composition of the release agent shall be such that it will not interfere with future surface treatments.

e) Before concreting, all forms shall be thoroughly cleaned. Faces of formwork in contact with concrete shall be free from adhering foreign matter, projecting nails and the like, splits or other defects.

f) The formwork shall be erected and anchored in such a way that it rigidly retains its shape and position during concreting and that surface irregularities in the concrete are avoided.

g) Formwork shall be erected to such levels as to make allowance for anticipated deflection of the formwork under load.

h) In case an earth form is used for the Concrete Arch, the earth form has to be covered with a separation membrane prior to placement of the reinforcement, in order to avoid bond between earth and concrete.

2.3.9.3.2. PREPARATION FOR PLACING CONCRETE

Before the concrete tunnel lining is cast the CONTRACTORshall thoroughly clean the invert, sides and roof of the excavation of loose or unsound fragments of rock, mud, debris, standing water, oil and any other foreign matter.

2.3.9.3.3. PLACING OF CONCRETE

a) SPECIAL SPECIFICATION, unless otherwise specified in this Section.

b) The CONTRACTORshall submit full details of his proposed tunnel concrete placing methods, including a description of the equipment to be used.

c) The method of transporting and placing concrete shall be approved by the ENGINEER. Concrete shall be transported and placed in such a way, that contamination, segregation or the loss of the constituent materials does not occur.

d) Concrete shall not be placed in any part of the structure until the ENGINEER´S approval has been given.

e) Concrete shall be placed by a displacement type pump or by such method as may be approved by the ENGINEER. The method of placing concrete shall be such that the concrete is not introduced into the formwork at a high velocity and shall be such that segregation of the concrete does not occur, the concrete pump shall produce a continuous stream of concrete without air pockets.

f) The casting of the foundation beams and the structural invert shall be done in separate operations before placing the inner lining arch of the tunnel. The method of placing concrete in the invert shall be subject to approval of the ENGINEER.

g) The concrete beams on each side shall be used as abutments for the rails which are necessary for moving the tunnel formwork. They shall be cured for at least 7 days before the formwork for the inner lining arch is allowed to be placed.

h) Concrete shall be pumped into the formwork through suitable temporary openings.

i) Concrete in the walls and crown of tunnels shall be brought up in horizontal layers not exceeding 50 cm, evenly distributed over the concreting section.

j) Maximum level differences shall not exceed the values as specified by the manufacturer of the formwork.

k) Concrete shall not be pumped into the crown of the arch and allowed to flow down into the walls and invert. Therefore it is not allowed to pump concrete in the crown before the concrete level has reached the height of the openings in the formwork. Concrete shall be forced into all irregularities in the ground or initial support surface by submersive vibrators to fill the void between that surface and the formwork.

l) Particular care shall be taken to ensure the complete filling of the crown of the tunnel arch. The CONTRACTORshall include with his details of tunnel concrete placing methods proposals for satisfying this requirement. Air pockets in the tunnel roof shall be relieved by ventilation hoses where necessary beyond the relevant stop-end of the formwork.

m) Cold joints in final lining shall be avoided where practicable. A standby concrete pump and placement line shall be provided during concreting operations. In the event of continuous placing being interrupted by equipment breakdown or for any other reason, the CONTRACTOR shall thoroughly consolidate the concrete at such joints to a reasonably uniform and stable slope while the concrete is plastic and any concrete which remains unconsolidated shall be removed.

n) Final lining for tunnels shall be cast in sections of maximum 12 meters length measured along the tunnel axis. Each section shall be cast in one continuous operation without interruption and construction joints. All construction joints at the ends of the sections shall be perpendicular to the gradient.

o) For hot and cold weather concreting refer to SPECIAL TECHNCIAL CONDITIONS.

2.3.9.3.4. COMPACTION OF CONCRETE FOR FINAL LINING

a) All concrete shall be compacted to produce a dense homogeneous mass.

b) The concrete shall be compacted by vibrators anchored to the formwork and immersion vibrators operated through the inspection openings in the formwork.

c) Vibrators shall not be applied to the reinforcement. Where vibrators of the immersion type are used, contact with reinforcement and all inserts shall be avoided.

d) The operating time of the external vibrators shall be kept short in order to avoid segregation.

e) Concrete shall not be subjected to vibration after 4 hours after casting.

2.3.9.3.5. REMOVAL OF FORMWORK

a) Section of the SPECIAL TECHNICAL CONDITIONS, unless otherwise specified in this Section.

b) The ENGINEER shall be informed in advance when the CONTRACTORintends to strike any formwork.

c) The time at which the formwork is struck shall be the CONTRACTOR'Sresponsibility.

d) Formwork shall be so designed as to permit easy removal without resorting to hammering or levering against the surface of the concrete or injuring the concrete.

e) Any damages occurring during striking of the formwork shall be made good by the CONTRACTOR.

f) Form removal shall not be started until the concrete has attained a strength so that most unfavorable load conditions do not cause any damages to the structure. The strength of the concrete shall be measured after removal of the stop-end shutter in the tunnel roof. The minimum strength for removal of the formwork must satisfy the structural requirements for

"dead load" of the lining. This strength shall be checked by a Schmidt pendulum type hammer, or similar approved, for low strength concrete, with a piston of 40 mm diameter.

The following equipment or similar shall be used:

Manufacturer: Wykeham Farrance, Slough, England

Model N0. : WF 53932

2.3.9.3.6. CURING OF CONCRETE

a) Sections 5.3.4.8 and 5.3.4.9 of the SPECIAL TECHNICAL CONDITIONS, unless otherwise specified in this Section.

b) Immediately after the installment concrete shall be protected for at least 7 days harmful effects of weather, including rain, rapid temperature changes, frost and from drying out. The methods used shall be subject to the approval of the ENGINEER.

c) The method of curing used shall minimize the loss of moisture from the concrete.

d) The sealing agent shall not interfere with the bonding of any subsequent surface treatment.

e) Curing can be omitted if the humidity and shrinkage measurements prove that no effect is attained by curing measures.

f) It is under the responsibility of the CONTRACTORto avoid or minimize shrinkage cracks with careful work and proper workmanship. In reinforced concrete linings the width of shrinkage cavities is limited to 0,3 mm. Wider cracks shall be filled with resin or mortar. Shrinkage cracks in non reinforced linings with a width exceeding 1,0 mm shall be filled with mortar or resin or treated as instructed by the ENGINEER.

2.3.9.3.7. REMEDIAL TREATMENT OF SURFACES

a) Any remedial treatment of surfaces shall be agreed with the ENGINEER, following inspection immediately after removing the formwork and shall be carried out without delay.

b) Any concrete, the surface of which has been treated before being inspected by the ENGINEER, shall be liable to rejection.

2.3.9.3.8. PRECAST CONCRETE COMPONENTS

a) Precast concrete components shall be placed with a tolerance of ± 10 mm, related to the theoretical position.

b) Precast elements shall be embedded in mortar with a minimum thickness of 30 mm.

c) The standard length of the precast concrete elements shall be 100 cm (e.g. cable duct slab, kerb stone)

d) The reinforcement for the precast concrete elements used for cable duct slabs shall be min. 5 kg/m.

e) The joints between precast concrete elements shall be sealed (using permanently elastic material).

2.3.9.3.9. CONTACT GROUTING

a) Prior to the commencement of inner lining works, the CONTRACTORshall submit to the ENGINEER for his approval full details of the working method and equipment to be used.

b) At all times the CONTRACTORshall ensure that the grouting operation is under the direct control of skilled and experienced operatives. The maximum pressures to be used shall be approved by the ENGINEER.

c) Grouting and ventilating pipes shall be positioned prior to concreting.

d) Upon completion of grouting, the CONTRACTORshall cut off all surplus lengths of pipes.

e) The CONTRACTORshall provide the ENGINEER with records of areas grouted, injection pressures, grout consumption and mix details as the ENGINEER may so require.

f) The ENGINEER will require tests to be carried out to confirm that the grout mix and its constituent materials are in accordance with the specification. The CONTRACTORshall carry out such tests and submit the results for the ENGINEER'S approval when required.

g) Where dry premixes of grout of an acknowledged manufacturer are used, they shall be mixed to the manufacturer's recommended water/solids ratio. All grout mixes shall be prepared using high speed, high shearing action mixers.

h) The CONTRACTORmay choose to propose a method of concreting in order to eliminate contact grouting of the tunnel lining.

2.3.9.3.10. COATING

a) Execution of coating works shall comply with the provisions of austrian directives RVS 8.29.4 unless otherwise specified in this section.

b) Prior to the commencement of the coating work the concrete surface has to be smoothened and cleaned.

c) Shrinkage cavities shall be filled with synthetic modified mortar.

d) Coating of the concrete surface shall be executed in two layers. The first layer can be sprayed but the second layer has to be rolled on.

e) Contaminations caused by coating works shall be removed.

2.3.9.4 EXECUTION OF REINFORCEMENT WORKS

2.3.9.4.1. WIRE MESH (WELDED WIRE FABRICS)

a) Welded wire fabrics shall be installed in the longest practical length. The overlap for welded wire fabrics shall be at least twice the pitch distance in circumferential and one pitch distance in longitudinal direction.

b) The installation of reinforcement shall be such to ensure a concrete cover of minimum 4,0 cm.

c) The CONTRACTORshall pay utmost attention not to damage the waterproofing membrane during the construction of the reinforcement.

2.3.9.4.2. REINFORCING STEEL BARS

Reinforcing steel bars shall be attached securely to the previously wire mesh. Overlaps shall be arranged as shown on relevant drawings.

2.3.9.5 QUALITY ASSURANCE

a) Quality and Quality Control of Concrete Works shall comply with the provisions of Section 5.3 of the SPECIAL TECHNICAL CONDITIONS.

b) Quality and Quality Control of Formwork shall comply with the provisions of the SPECIAL TECHNICAL CONDITIONS.

c) Quality and Quality Control of Reinforcement shall comply with the provisions of of the SPECIAL TECHNICAL CONDITIONS.

d) Quality and Quality Control regarding precast concrete components shall comply with the provisions of of the SPECIAL TECHNICAL CONDITIONS.

e) Quality and Quality Control of Coating material and works shall comply with the provisions of austrian directives RVS 8.29.4.

2.3.9.6 MEASUREMENTS

The work specified in this Section will be measured as follows:

a) The inner concrete lining in the tunnel will be measured in cubic meter, comprising the theoretical thickness of the inner lining (d_i) inside the "Line 3", as shown on FIG. 9.1. Quantities for the inner concrete lining outside of "Line 4" will not be measured, except for filling of excessive overbreaks due to unfavourable geologic conditions.

b) In case the average value of the actual deformation in a specific section is smaller than the agreed deformation tolerance measurement for additional inner concrete will be made in cubic meter, provided the difference "c" is bigger than 10 cm. The quantity of additional concrete will be calculated between "Line 3" and "Line 4". Actual average deformations will be derived from geotechnical measurements.

c) Filling of excessive overbreak with inner concrete will be measured in-situ by actual quantities provided the required concrete quantity exceeds 2 cubic meters (as shown on FIG. 9.2).

d) Inner concrete lining of niches will be measured by cubic meter, as shown in FIG. 9.3.

e) Inner concrete lining in the invert arch and the foundation beams will be measured in cubic meters inside „Line 2„, according to FIG. 9.3.

f) Additional concrete for inner lining due to the widening of the cross section under the pipe roof will not be measured for payment.

g) Wire mesh and re-bars applied in concrete lining of mined tunnels, cross passages, niches, cut&cover tunnels and in retaining structures will be measured by weight considering actual quantities. Auxiliary material for fixing will not be measured.

h) Hindrances due to the protection of the waterproofing membrane during the construction of the reinforcement will not be measured separately and shall be included in the relevant Unit Prices.

i) Curing of concrete (e.g. refilling of cracks) will not be measured for payment and has to be included in the relevant Unit Price.

j) Precast concrete components will be measured by linear meters.

k) Preparing and coating of the concrete surface will be measured by square meters along the inner surface of the lining. Cleaning of the surface shall be included.

2.3.9.7 PAYMENT

a) The Unit Prices for the various pay items shall include all labour, equipment and materials required for the complete execution of the work, including sampling, testing and quality control. Formwork, scaffolding and the shutters are to be included in the Unit Prices of relevant pay items.

b) In case aggressive components are detected in the seepage water during tunnel drivage, the inner concrete lining in these tunnel sections has to be executed as "sulfate-resistant" concrete. All labour, equipment and materials necessary have to be included in the additional payment for "sulfate-resistant" concrete.

c) The Unit Prices for precast elements shall include all labour, equipement and materials required for the complete execution of the work, including reinforcements and sealing of joints, as well as the transport to the site.

d) The Unit Prices for coating shall include all labour, equipment and materials required for the complete execution of the work.

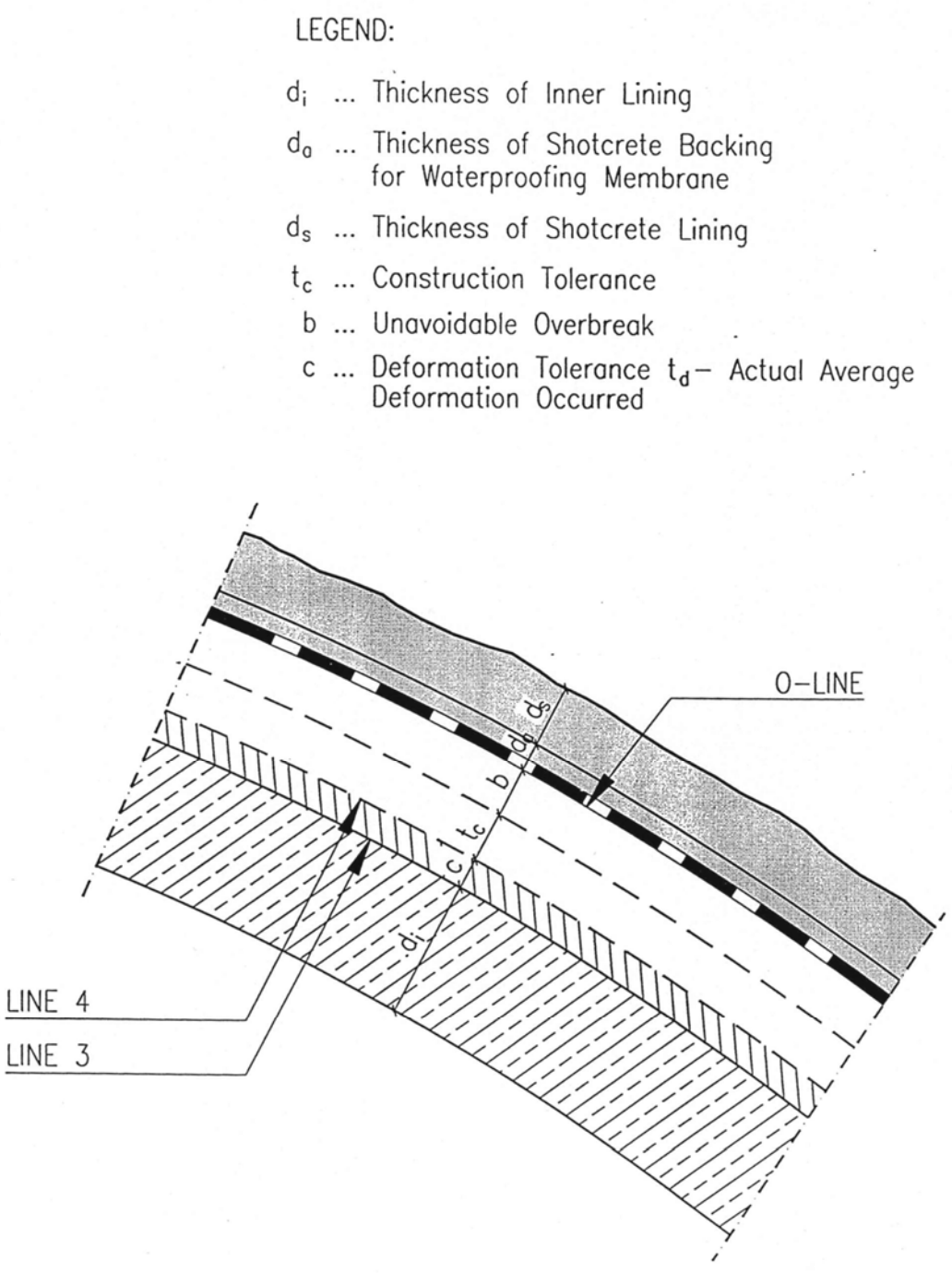


FIG. 9.1 Lines for Measurement and Payment of Inner Concrete Lining

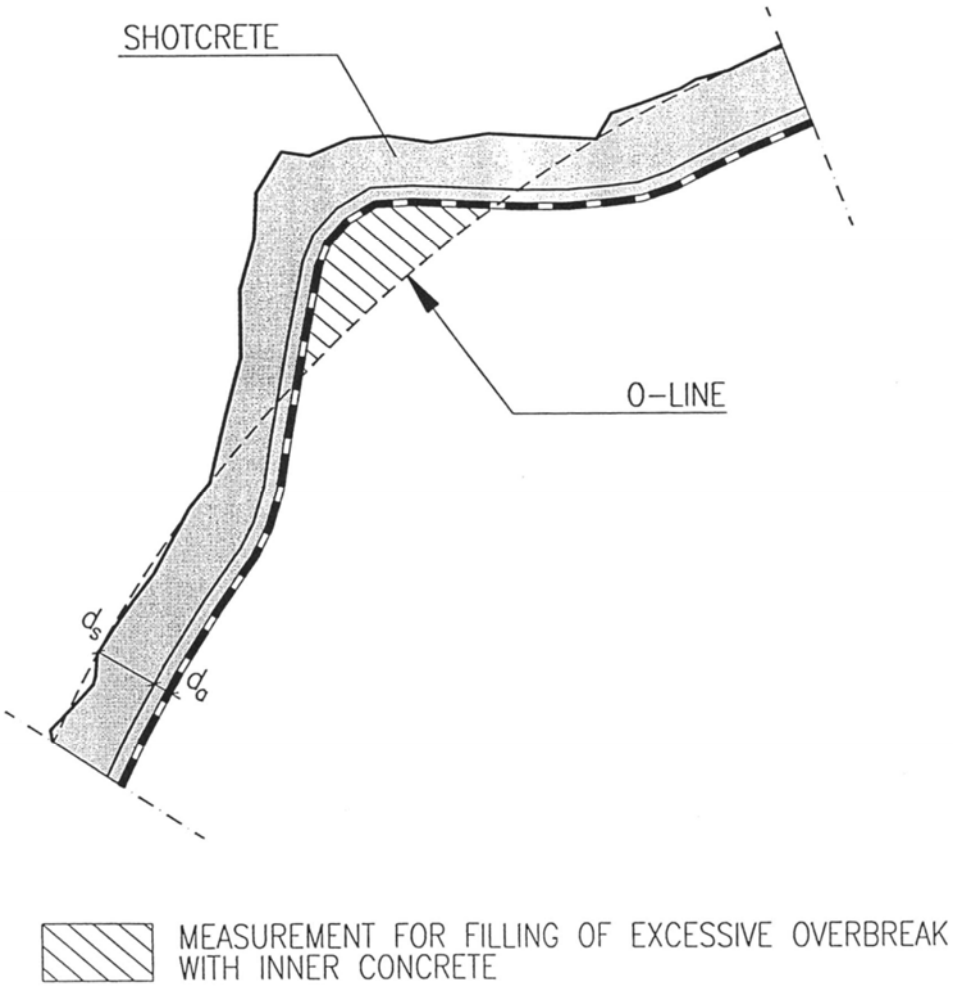


FIG. 9.2 Lines for Measurement and Payment of Filling Excessive Overbreak with Inner Concrete Lining

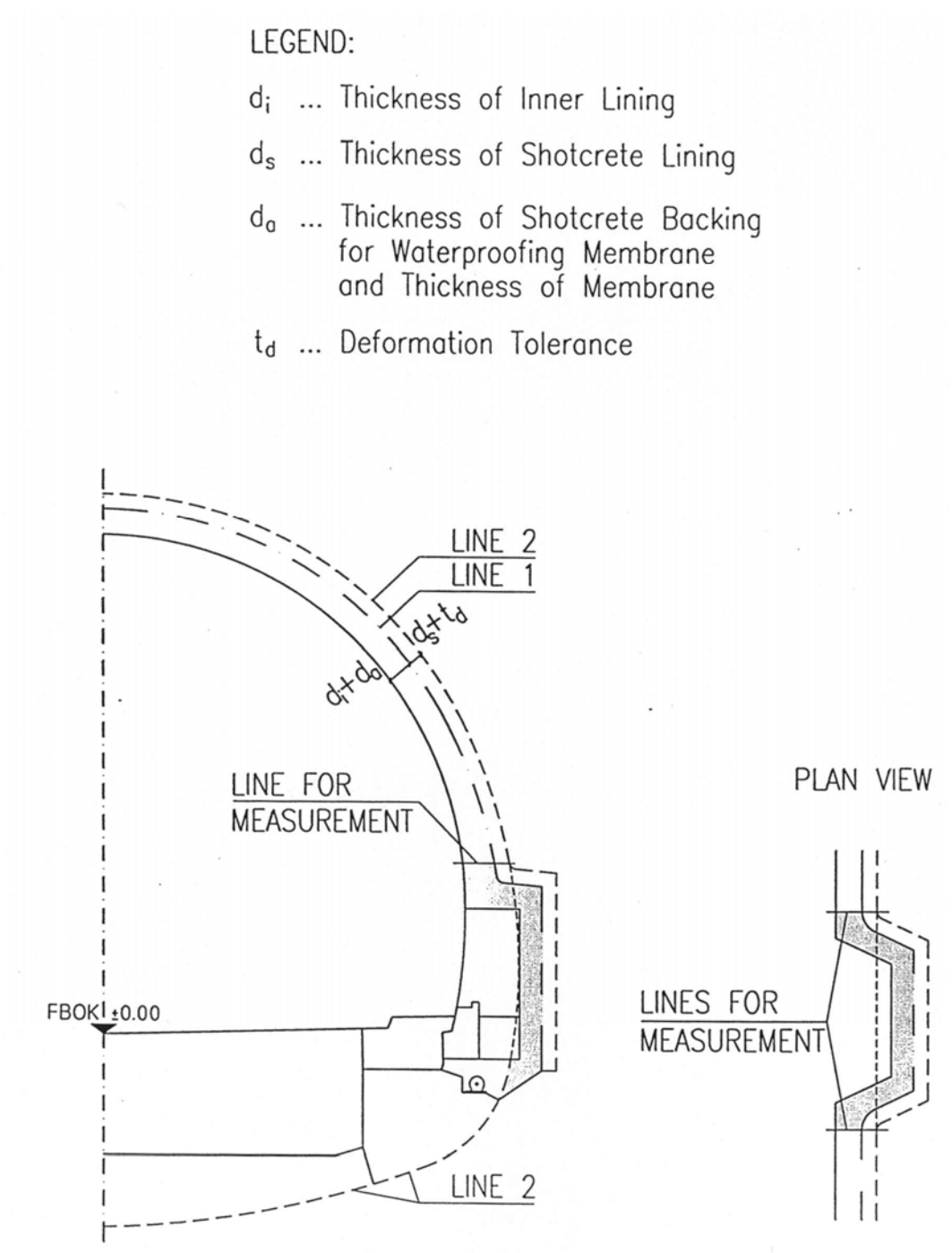


FIG. 9.3 Lines for Measurement for Concrete at Niches

2.3.10 GEOTECHNICAL MEASUREMENTS AND GEOLOGICAL MAPPING

2.3.10.1 GENERAL

2.3.10.1.1. SCOPE

a) This section specifies the requirements for the geotechnical measurements in tunnels and at the surface above tunnels designed according to the NATM for the purpose of observing and recording deformations, settlements and load variations on supporting elements and in the adjacent rock.

b) As part of the safety concept 3-dimensional (3-D) deformations of the tunnel lining shall be monitored by means of optical methods. The points to be observed are marked by targets or reflectors mounted on standard convergency bolts.

c) Measurements shall be carried out with a free-stationed high precision electronic theodolite with integrated coaxial EDM device. The flow of data shall be fully automatic. The software shall allow determination of displacements in an absolute coordinate system with an accuracy of +/- 1 mm in minimum.

d) The works for geotechnical measurements include the installation of geotechnical instrumentation and devices.

e) Necessary conclusions shall be drawn from the geotechnical measurements, from their magnitude, alterations and tendencies about stability of the primary lining and surrounding rock, performance of the initial support applied and utilization of the supporting elements.

f) The locations and spacing between geotechnical measurement sections depend on geological conditions, frequency of geological alterations, rock mechanical behaviour, length of tunnels, primary stress conditions, size of tunnels. The location of measurement sections shall be decided during tunnelling according to the local geological conditions and the experience gained during tunnel driving and as required by the DESIGNER or ENGINEER.

g) Reading of instruments, interpretation and evaluation of monitoring results as well as geological mapping during excavation will be carried out by the DESIGNER.

2.3.10.1.2. DESCRIPTION OF INSTRUMENTS FOR GEOTECHNICAL MEASUREMENTS

a) Level points are fixed markers, pins or bolts placed in the roof and invert and/or sidewalls of the tunnels, linings and are measured by optical survey methods to determine vertical, horizontal and longitudinal displacements.

b) Surface level points are fixed markers, pins or bolts placed in small shafts at the surface above shallow tunnels or on beams, at houses or other structures (e.g. bridges) above shallow tunnels and pre-excavation area. Measurements are done by optical survey methods to determine ground surface displacement or displacements of houses and other structures and performed as spatial displacement vectors.

c) Convergence pins are pins or bolts installed in the tunnel lining. The bolts must have a minimum length of 250 mm and a minimum diameter of 20 mm. Measurements are made by optoelectronic method to determine absolute displacements of the tunnel lining or tunnel opening in general. Convergence measurements by tape extensometer rendering only relative displacements can be used in exceptional cases to replace the optical readings depending on the approval by the ENGINEER.

d) Targets or reflectors suitable for optoelectronic high precision measurements are fixed on the pins described above.

e) Borehole extensometers are used to measure displacements of the surrounding rock at various depths. The extensometer readings inform about the absolute amount of displacements around a tunnel and the depth and pattern of the deformations in the rock environment of the tunnel.

f) Inclinometers made at the same time also as piesometers serve for rock displacement measurements by depth. Before installation an orientation of inclinometer pipes should be determined considering requirements by ENGINEER and DESIGNER and in dependence of morphologic and geotechnical conditions for a given area. After installation of inclinometers geodetic survey of each inclinometer head should be done with the aim to ensure measurements of absolute displacements.

g) Measurement anchors are used to measure strains in different depths. Measurement readings inform about stresses and loads in the anchors for specific chosen support system. Results have to allow controlling and determining needed limit load of installed anchors.

2.3.10.1.3. SUBMISSIONS

a) Samples of convergence pins, targets or reflectors, strain meters and extensometers.

b) Specifications and catalogues for the instrumentation and readout devices intended to be used.

c) Complete layout of instrumentation sections: Instrumentation equipment for main and secondary measuring sections, location of sections, distances ,monitoring schedule.

d) A description of the software necessary for the calculation of the three-dimensional deformations and presentation of results.

e) Description of installation, fixing and protection of pins.

f) Basic characteristics of software package for evaluation of geotechnical measurements and reference file of original and compiled data in choose format.

g) Prior the CONTRACTOR has to do trigonometric measurement of original state, which should be used as a reference

h) All submissions are subject to the approval of the ENGINEER.

2.3.10.2 MATERIALS

2.3.10.2.1. LEVEL POINTS

For the determination of elevation of tunnel crown or at other points only approved pins or bolts shall be used.

Leveling of the tunnel crown and other specific points (invert, sidewalls etc.) shall be done during tunnel excavation to monitor vertical settlements and bottom heaves and to be able to interpret and figure out the absolute amount of displacements together with extensometer and convergence readings.

The method of performing the level measurements shall be such as to ensure an accuracy of $\pm$ 1 mm.

2.3.10.2.2. CONVERGENCY BOLTS

Convergence bolts or pins shall consist of ribbed bars protected against corrosion with a minimum length of 250 mm. The pins shall be securely attached to the exposed rock or shotcrete surface. After installation the convergence pins shall be protected by a protective cap.

2.3.10.2.3. TRAGETS OR REFLECTORS

For the optoelectronic measurements bolts shall be provided with a plastic cap with a predetermined breaking point serving as an adapter for the mounting of a reflector with marked centre point. This device shall be designed for high precision measurements with two axes of rotation and to be observable from both sides.

The plastic reflector can be replaced by a positive centered prism (target) providing the same standard as the reflector above.

2.3.10.2.4. THEODOLITE

An optoelectronic theodolite (DISTOMAT) with integrated coaxial electronic distance meter (EDM) shall be used. The equipment shall be such as to ensure an accuracy of 3^{cc} for directions as well as an accuracy of $\pm$ 0,5 mm for distances.

The measuring arrangement shall include further equipment as follows:

- *Illuminated 4-line matrix display*
- *Numeric and alphanumeric input options*
- *Plug-in data recording module with 2000 data blocks*
- *Required theodolite has to be provided to the CLIENT's surveyor for time of construction*

2.3.10.2.5. TAPE EXTENSOMETER

When no optoelectronic measurements are possible the reading of convergences shall be done by means of a tape extensometer of a recognized manufacturer. The equipment and measuring procedure shall be such as to ensure an accuracy of +/- 0,3 mm. Handling and maintenance of the equipment shall be done according to the manufacturer's recommendations, which shall include a daily calibration. A suitable calibration frame consists of a rigid steel frame with permanently attached pins or bolts at both ends of the same type as used in the tunnel. Minimum tape length shall be 20 meters.

Specifications and instructions for use shall be supplied to the ENGINEER.

Required tape extensometer has to be provided to the CLIENT's surveyor for the time of construction.

2.3.10.2.6. BOREHOLE EXTENSOMETER

Borehole extensometers shall be multiple position rod type or single rod type with mechanical anchors at fixed points. The remaining length of each rod or wire shall be in a pipe so as to be able to move freely. Multiple rod type extensometers shall be designed to read at least at three positions along the rod. The instruments shall be resistant to corrosion. The diameter of the bore hole for installation of the extensometers depends on the type (single/multiple rod type) and it shall be in accordance with the manufacturer's recommendations.

The readings shall be done by a dial gauge or by using electrical transducers for remote reading. The accuracy of the extensometer readings shall be 0.05 mm.

The manufacturer's literature, specification and instructions shall be supplied to the ENGINEER.

2.3.10.2.7. INCLINOMETER

Inclinometer pipe with four longitudinal guidance should be injected in borehole in such a manner that inclinometer probe can be moved in two mutual perpendicular directions. When inclinometer serves also as piesometer the inclinometer pipe is perforated so the water could undisturbed pass through to surrounding rock and probe moving is easier.

Inclinometer probe is made for measurements of pipes' inclination changes on determined 0.5 meter- or 1.0 meter- intervals along the pipes. Probe is connected to the portable digital data receiver that records data between each measurement.

Measuring pipe may be inclined from vertical axis $\pm$30 degree; its length may be max. 200 m. Probe sensitiveness should be in range from 0.010 to 0.175 mm/m. Inclinometer to be calibrated every three month.

2.3.10.2.8. MEASUREMENT ANCHORS

Measurement anchors are anchors, which are adapted to measure changes in deformations and stresses along depth. Generally they are combination of anchors and extensometers. Anchors are able to determine the depth of increased deformation, which are caused by excavation works, advance rate, geological tectonic changes, and quality of installation works. It is also possible to determine level of loads on each anchor in different rock masses and consequently the required length and capacity in each category. Forces on each measurement anchor head will be measured with hydraulic or electronic cells.

2.3.10.3 EXECUTION

2.3.10.3.1. GENERAL REQUIREMENTS

a) The instruments shall be installed at locations and in accordance with a schedule as agreed by the DESIGNER or ENGINEER.

b) The geotechnical instrumentation and monitoring program may always be subject to alterations and modifications if required by the actual geological or geotechnical conditions.

c) Installation of all major instrumentation shall be supervised by the ENGINEER.

d) All instrumentation shall be installed in accordance with the manufacturer's recommendations and with the additional requirements specified in this section.

e) The installation of all instrumentation and devices shall be carried out close to the face within the last round of excavation.

f) The installed measuring instrumentation as well as the required space for measuring must be kept free and accessible until fixation of the water proofing membrane.

g) All instruments shall be protected against damage by blasting and tunnel traffic. Where required protective covers or housings may be used to prevent damage of the instruments.

h) Damaged instruments due to construction operations shall be replaced immediately without additional costs.

i) Readout units as high precision theodolite shall be available at any time during tunnel construction. Spare parts and spare units shall be maintained on site.

j) The CONTRACTORshall provide, arrange and maintain all the equipment throughout the construction period which is required for the installation and monitoring of the measuring sections.

k) All instruments and equipment used and required for the geotechnical measurements shall be made available to the DESIGNER and to the ENGINEER throughout the construction period as requested.

l) It is necessary to be present at least two times daily at every face and benches. Maping have to be in accordance with ISRM and supplements.

m) It is necessary to be present at every face during predrilling: geological logging of debris and records of gas and water

n) After installation, a record have to be made with all important data about installation; record has to confirm representative of the Engineer, which controlled the installation.

2.3.10.3.2. READING, PLOTTING AND INTERPRETATION

a) Reading, plotting and interpretation of the instruments and measuring results will be carried out by qualified personnel of the CONTRACTOR

b) For the optical displacement monitoring a software package shall be used which allows a direct data flow. This software shall include features as follows:

- *Free stationing of the theodolite and calculation of standard deviation in all three coordinate directions.*
- *Automatic target identification and recognition of new zero readings.*
- *Calculation of 3D-coordinates and displacements of any desired point and its radial distance to the theoretical profile.*
- *Correction of errors based on physical effects.*
- *Transformation of coordinates after control measurements.*
- *Measurement results shall be tabulated and presented in graphs.*

c) The numeric representation has to be stored in ASCII – file format in such a manner that the export of values is possible to data base programs. Submitted ASCII-files are subject to the approval of the GEOTECHNICAL ENGINEER.

d) Calculation of 3D-coordinates and displacements of any desired point and Evaluation and representation of measurement results: The evaluation of data has to be carried out with the program "Tunnel Monitor" or the like. The software has to support following sorts of diagrams.

- *State diagram (influence lines).*
- *Path/Time diagrams*
- *Deformation path cross section (Vector Diagram)*
- *development of measuring results versus time related to the progress of the excavation headings*
- *development of measuring results versus distance of the measuring sections from the excavation face*
- *development of measuring results versus distance of the measuring sections relating to different work phases in the tunnel.*

e) Following values have to be supported by the diagram types stated above:

- *Relative displacement between any two measuring points*
- *Certain Coordinate Components or any value derived by the components (e.g. Tangens Vertical / Horizontal – Displacement).*

f) The software used shall enable (only for geodetic surveys) the smoothing of graphic curves for the execution of control measurements or repeated placing of measurement points.

g) The CONTRACTORshall provide and maintain adequate lighting, ventilation and platforms including operator for access to all instruments for the personnel carrying out the readings. This requirement applies to all ENGINEER'S personnel as deemed necessary by the ENGINEER.

h) The first measurements (zero-readings) shall, for each measuring instrument, be made immediately after installation or as soon as the particular instrument may allow. Complex measurement profiles (extensometers, measurement anchors) have to be installed at last 24 hours after excavations.

i) The frequency of the further measurements or readings for normal behaviour of surrounding rock can be envisaged for each measuring section as follows:

- *Up to 40 m behind excavation face: daily*
- *40 to 100 m behind excavation face: every second day*
- *200 m behind excavation face: once per week*
- *more than 200 m behind excavation face: monthly*
- *Visible stabilization of settlements monthly and bimonthly*

The actual frequency of readings will however be influenced by the construction stages top heading/bench heading in one tunnel and by the staggered parallel driven tunnels and is subject to the ENGINEER.

When the bench is approaching the instrumentation section installed during top heading, reading frequencies shall be increased again. When the parallel tunnel tube approaches the station of an instrumentation section installed in the first tunnel tube, readings shall be activated again and reading frequencies increased respectively.

The frequency increased at any location during and after installation of any support elements or excavation, according to Engineer approval.

j) At sections where increasing rates of deformation occur, readings shall be taken frequently (at least once per day) until the rate of deformation decreases with time.

k) Measurements shall continue until construction work at the inner lining stops the taking of measurements.

l) At least till 14h00 every day the CONTRACTORshall send the geofiles – electronic diagrams of measuring results to the DESIGNER and the ENGINEER. In the case of geodetic surveys the diagrams shall include:

- *date and time of measurements,*
- *names and coordinates of measuring points.*

m) The coordinates of measuring points shall be given in the relative coordinate system, which consists of: longitudinal coordinate of the tunnel axis, cross deviation from the tunnel axis and the height difference from the tunnel axis.

n) The format of the electronic diagrams shall be approved by the ENGINEER.

2.3.10.3.3. GEOLOGICAL MONITORING AND MAPPING

The GEOLOGIST nominated by the CONTRACTOR will carry out geological mapping during execution of portal cuts and tunnel excavation. There will be a Geologist during day shift and during night shift. The CONTRACTORshall provide access and any necessary support for geological mapping to the GEOLOGIST. The GEOLOGIST will provide an on site geological model. The GEOLOGIST will perform on site weekly and monthly progress meetings for presenting interim work results and for preparing future work program details for site investigation.

Predicted services:

- *Daily geological mapping faces and benches according to the approval of Engineer, supplied with fotodocumentation and the following itmes:*
  - *lithology*
  - *level of weatherness*
  - *level of joints*
  - *joints and fault zones*
  - *orientation of faults, geometrical measurement of discontinuities*
  - *morphological characteristics of joints*
  - *strength of rockmass with simple on-site tests*
  - *GSI classification*
  - *Water inflow, volumes, Ph factor, measurement of conductivity and temperature*
- *Monitoring predrilling, included photo documentation;*
- *Sampling laboratory, terrain and geophysical investigations and evaluations of rock mass;*
- *Daily mapping and drawing geological model in the cross section and plan view M 1:100 (supplementing documentation at the site);*
- *Weekly geological interpretation of collected data in the form of layout and longitudinal profile, both in scale of 1:500; (also electronically)*
- *Weekly geological report with prognosis for next week;*
- *Making of résumé of zero state at the water sources*
- *Evaluating GSI and RMR indexes and collaboration at determining the rock mas classification according to ONORM 2203;*
- *Finding level of water aggressiveness to concrete and metal (chemical analysis on water);*
- *Recording of overbreaks, their volumes and statement of causes, record of over profiles and statement of causes;*

- *Geological profile and plan view M 1:100 have to be up-to-date daily;*

2.3.10.4 MEASUREMENT

The works specified in this Section will be measured as follows:

- *Installation of monitoring devices and instrumentation will be measured by actual quantities within the framework of the Bill of Quantities in the tender documents.*

2.3.10.5 PAYMENT

a) The Unit Price per measuring section shall include all labour, equipment (e.g. theodolite and tape extensometer) and materials (e.g. reflectors for optical measurements) required for the execution of the services for the whole period of construction.

b) Results that are not handed over in time will not be paid.

c) Installation of monitoring devices will be paid for at the Unit Prices of the contract. The Unit Prices shall include all labour, equipment and materials necessary for the complete installation and maintenance of the instrumentation.

d) The Unit Prices for the instrumentation shall also include all necessary drilling and grouting work, auxiliary materials and small handworks.

e) Obstructions caused by geological mapping of the tunnel face after each step shall be included in the unit price for excavation.

2.3.11 PRE-DRILLING AND GROUTING

2.3.11.1 PRE-DRILLING

Drilling ahead of the tunnel face for dewatering and ground investigation purposes is termed „pre-drilling„.

For dewatering purposes, Section 4.2 of the SPECIAL TECHNICAL CONDITIONS shall apply, unless otherwise specified in this Section.

2.3.11.1.1. GENERAL

a) In tunnel sections as indicated in the "Geological and Geotechnical Report" the CONTRACTORshall always probe ahead of the face with 20 to 30 m long pre-drillings to prove or investigate the ground to be encountered and to search for water and gas sources. The probing shall be repeated and overlapped so that at no time a single probe is less than 10 m ahead of the tunnel face.

b) The number of probes and their positions and angles shall be governed by the type of ground and available site investigation data. Radial probes may also prove necessary.

c) At locations where excessive ground water flow is expected or occurs, pre-drilling ahead of the tunnel face in order to reduce the water pressure at the tunnel face is proposed.

2.3.11.1.2. SUBMISSIONS

a) All probing details shall be approved or instructed by the ENGINEER.

b) In case unexpected conditions are met during tunnel drivage, such as confined ground water, suspicious color or smell of the water, floor heave, cavities or gas the conditions ahead of the face shall be observed carefully and documented properly. The ENGINEER has to be informed immediately.

2.3.11.1.3. EXECUTION

The CONTRACTORis responsible for the validity of the information gained by pre-drilling, especially regarding additional costs owing to inadequate and inaccurate infomation gained by pre-drilling.

2.3.11.2 GROUTING

This section must be read and applied in conjuntion with the applicable parts of Section 5.6 of the SPECIAL TECHNICAL CONDITIONS, unless otherwise specified in this Section.

2.3.11.2.1. GENERAL

a) „Strata Grouting„: This term refers to grouting of materials under pressure in rock strata for consolidation of fractured rock or for filling of cavities and voids in the rock surrounding the tunnel. Strata grouting does not cover injections for loose ground areas.

b) „Consolidation Grouting„: This term refers to grouting of loose material by means of bentonite, cementitious or chemical grouting.

2.3.11.2.2. SUBMISSIONS

a) The CONTRACTORshall prepare a detailed grouting specification, since grouting works are manifold and a wide range of methods and techniques are available for ground improvements to suit best the actual conditions encountered. This grouting specification shall be submitted to the ENGINEER for approval unless otherwise agreed or directed by the ENGINEER.

b) The CONTRACTORshall submit to the ENGINEER full details of his proposed grouting procedures including details of grouting equipment, location, depth and orientation of grout holes, grout methods, grout composition, grouting pressures and a time scaled program for each sequence of grouting operation. The depth and means of drilling shall be such that the holes can be located accurately along the zones to be grouted.

2.3.11.2.3. NECESSITY OF GROUND TREATMENT DRILLINGS

The need for ground treatment in addition to the ground treatment indicated on the drawings shall be based, after consultation between the ENGINEER and the CONTRACTOR, on soil investigations, probes, the amount of water at the face, or other indications that the ground to be excavated is soft, fissured or heavily water bearing, together with the information contained in the contract.

2.3.11.2.4. GROUT HOLES AND GROUND TREATMENT DRILLINGS

Grout holes for primary and secondary grouting shall be drilled to a distance and to a pattern into the zone to be treated and grout injected under pressure, all subject to the agreement of the ENGINEER. Gauges shall be installed adjacent to the point of injection and used to measure the pressure of the grout. The design pressure of the grouting proposed by the CONTRACTOR and agreed by the ENGINEER shall not be exceeded without the consent of the ENGINEER.

2.3.11.3 MATERIAL

The grout may consist of

- *chemical grout*
- *cement mortar grout (cement/sand)*
- *cement grout with clay or bentonite*

a) Ordinary Portland Cement shall be used.

b) Sand for grouting purpose shall be a clean, mineral sand, uniform in quality and from an approved source.

c) Water shall be clean, free from oil, acid, alkaline, organic and other deleterious substances.

d) Additives for the improvement of grouting performance may be used.

2.3.11.4 EXECUTION

2.3.11.4.1. TESTING

a) The CONTRACTORmay be required to carry out grouting tests to satisfy the ENGINEER that the ground treatment proposals are acceptable. Such tests shall be so designed as to allow visual inspection of the treated mass, and to demonstrate that the required ground improvement has been achieved.

b) Water acceptance tests of grout holes shall be carried out before grouting as directed by the ENGINEER and in a manner that shall permit the measurement of the volume of water at various pressures.

c) On completion of grouting the area grouted shall be tested by a method to be agreed by the ENGINEER.

2.3.11.4.2. DRILLING

a) Grout holes shall be drilled either with percussion type or rotary type drilling equipment.

b) The diameter at the bottom of the grout holes shall not be less than 35 mm. For percussion drill holes the diameter of the drilling bit shall be at least 8 mm larger than the diameter of the couplings used for the drill rods.

c) Only dry drilling shall be applied unless otherwise directed by the ENGINEER. All holes shall be thoroughly cleaned immediately after drilling using air under pressure. After cleaning, downward holes shall be kept plugged until the commencement of grouting operation.

2.3.11.4.3. MIXING OF GROUT

a) All grout mixes shall be prepared using high speed, high shearing action mixers to produce a grout of uniform homogenous consistency.

b) When, prior to pumping, mixed grout is to be stored for short periods, purpose made agitator tanks shall be used.

c) When clay or bentonite additives are used, separate mixing tanks shall be provided for mixing and agitation.

d) Water meters shall be provided for accurate measurement of water used for mixing. Pressure gauges, safety valves, by-pass valves etc. shall be provided where required on mixers, agitators, pumps and injection hoses.

2.3.11.4.4. GROUTING OPERATION

a) All hoses and piping should be of a small diameter to ensure a high velocity flow without segregation.

b) Grouting operation shall be performed without major interruptions .

c) In case of an interruption before completion of grouting (plant breakdown), the hole shall be washed with clean water.

d) Until experience of the ground conditions is gained, grouting shall proceed with caution. Safety valves shall be tested before each application.

e) Grouting in the tunnel shall be performed in a manner that pressures are equally distributed and do not overstress the initial tunnel lining.

f) In case of no pressure building up when using a sand/cement mix, grouting shall be stopped and the hole washed. After a few hours, grouting shall recommence using a sand/cement grout until the desired pressure builds up.

g) In case of any grout communicating between holes, grouting shall be done simultaneously or holes where grout issues shall be plugged.

h) Grouting is completed, when the required pressure can be kept constant over a period of 10 minutes.

i) Records of all details of grouting works such as location, inclination, diameter of boreholes, drilling time, equipment used, water pressure tests, mix, quantity, pressure of grouting, development of and special events during grouting operation etc. shall be kept by the CONTRACTOR, countersigned on site by the Engineer's supervising personnel and submitted to the ENGINEER.

2.3.11.5 QUALITY ASSURANCE

Quality and Quality Control of Grouting Works shall comply with the provisions of the SPECIAL TECHNICAL CONDITIONS.

2.3.11.6 MEASUREMENT

2.3.11.6.1. PRE-DRILLING

Drilling works shall be measured by linear meter considering the actual length of drill holes.

2.3.11.6.2. GROUTING

The executed work shall be measured according to SPECIAL TECHNICAL CONDITIONS.

2.3.11.7 PAYMENT

2.3.11.7.1. PRE-DRILLING

a) Predrilling shall be paid for at the Unit Prices according to the Bill of Quantities.

b) Necessary equipment, materials and auxiliary constructions are to be included in the Unit Prices, as well as hindrance of other works.

2.3.11.7.2. GROUTING

Payment for the executed work shall be calculated according to Chapter 5.6.8 of the SPECIAL TECHNICAL CONDITIONS.

2.3.12 EARTHING IN TUNNELS

2.3.12.1 GENERAL

a) This section specifies both material and installation of the main earthing steel flat bars to be laid in the tunnel abutment, their connection underneath the invert arch and the connections to the earthing cables in the cable ducts and to the steel reinforcement of the shotcrete lining.

b) For details of the laying and connection of the earthing bars refer to the relevant drawings.

c) This section will not deal with the earthing system in the portal areas and the Distribution Buildings, which is covered by the Electrical Specifications.

d) The CONTRACTOR will be responsible for the connection of the tunnel earthing system, as well as for the testing and function of all earthing facilities. The CONTRACTOR has to submit a comprehensive testing program as well as record of the obtained results to the ENGINEER.

2.3.12.2 MATERIALS

a) The main earthing bars in the tunnel tubes, both the longitudinal and transversal bars , shall consist of 25x4 mm FE-Zn bars.

b) All necessary connections between earthing bars have to be executed by means of 2 connection bolts M8 with their correspondent nuts and washers, all made of brass.

2.3.12.3 EXECUTION

a) The main longitudinal earthing flat bars must be installed in the tunnel abutments on either side and cast in together with this structural element.

b) Transversal bars have to be installed between both longitudinal earthing bars. These transversal bars will have to be laid in the invert concrete or sub-base course of each carriageway. At the transversal connection the earthing bars must be connected with the wire mesh of the shotcrete. Spacing of the transverse bars is about 50 m.

c) At each connection point between longitudinal and transversal earthing bars in the tunnel abutment a vertical lance, consisting of the same material, has to be executed, which must outcrop from the abutment so as to enable the connection of the cable duct earthing conductor laid in the precast walkway duct with the main earthing bars. Length of this vertical bars must be minimum 80 cm.

d) In accordance with the available length of flat Fe-Zn bars the CONTRACTOR will have to provide the necessary quantity of connection elements specified in Clause 2.3.12.2. (b) so as to allow intermediate connections of transversal and longitudinal bars.

e) At each final portal chainage of both tunnel tubes the main longitudinal earthing bars located in the tunnel abutments, as above specified, will end. In correspondence with this points vertical lances, as stated under Clause 2.3.12.3.(c), must be connected, which will guarantee the further connection of the tunnel earthing system with the distribution buildings through the portal area earthing cables.

2.3.12.4 MEASUREMENT

Measurement of the longitudinal and transversal flat bars and the vertical lances will be done by linear meter.

2.3.12.5 PAYMENT

Payment for the flat bars will be made for at the Unit Price per linear meter. All labour, equipment and materials required for installation of the flat bars shall be included in the Unit Price.

2.3.13 ELECTRICAL AND MECHANICAL EQUIPMENT

2.3.13.1 TECHNICAL CONDITIONS

2.3.13.1.1. QUALITY OF MATERIALS AND WORKMANSHIP

For all the products, materials, apparatus, installations, and equipment installed in accordance with the present design, the CONTRACTOR shall submit suitable evidence (such as certificates) and approving professional assessments and measurements to demonstrate the quality of apparatus, installations, and equipment as well as of the workmanship and operational reliability. All the devices, installations, and workmanship shall be of the highest quality and shall comply with the relevant standards as indicated in this design.

All the conducting equipment in the tunnel shall have the seismic resistance in accordance with the class V.L.3, with the shifting amplitude below 8 to 9 Hz, and with the shifting of less than 1.5 mm, as well as with the acceleration amplitude above 8 to 9 Hz, and with the acceleration of less than 0.5 g according to the TABLE 1, classes for low-frequency oscillations of the relevant European standard EN 60654-3 (IEC 60654-3 1983) "Operational conditions for the equipment for measuring and monitoring the industrial processes – Part 3 Mechanical impacts". On motorways and inside buildings all the controlling equipment shall have seismic resistance in compliance with the class V.L.2, with the shifting amplitude for oscillation below 8 to 9 Hz, with the shifting of less than 0.75 mm, and the acceleration amplitude above 8 to 9 Hz with the acceleration of less than 0.2 g.

The equipment, its arrangement, and workmanship shall be the best possible, all to be approved by the Engineer.

All the installations, devices, and equipment shall be adequately finished for the anticipated working and operating conditions. At certain tunnel locations, appropriate temperature conditions are between -30°C and +70°C, with 100 % relative humidity, and wind speed of up to 25 m/s in any direction.

All the products with a trademark shall be approved by the Engineer, while the CONTRACTORis liable to delays arising from the fact that unacceptable materials might have been submitted for approval. Wherever different materials are introduced, electrochemical reactions (electrolytic corrosion) between these different materials (e.g. copper/steel, copper/aluminium, aluminium/steel, etc.) shall be taken into account. Any electrochemical reactions shall be prevented by suitable measures.

"Stainless steel sheet and profiles" shall be Cr-Ni-Mo-Ti alloy of material grade 1.4571 according to the DIN 17440. " "Stainless fixing materials" shall be of Cr-Ni-Mo alloys of material grade 1.4401 according to the DIN 17440, or of epoxy resins of adequate mechanical resistance complying with the DIN 4102 concerning the fire resistance.

"Aluminium alloy" indicated in these specifications as the material to be used shall be Al.Mg-Si 05 according to the DIN 1725 with the strength F25 and H14 according to the DIN 1748 for profiles, and Al.Mg3 according to the DIN 1725 for aluminium sheet. "Aluminium" is an aluminium alloy complying with the above-mentioned specifications unless specified otherwise.

The aluminium alloy shall always be "sandblasted" as indicated in the further text unless specified otherwise. Galvanized steel shall only be used where this is explicitly defined. It shall always be zinc hot-dip galvanized steel.

2.3.13.1.1.1 PAINT COATS

The colour shade of individual paint coats shall be in accordance with the Engineer's decision using the RAL standard colour shades, without any cost modification.

Preliminary treatment of metal:

The metal surface shall be treated in accordance with the DIN 55928, Part 4: steel surfaces to be cleaned from rust, aluminium surfaces to be ground or suitably sandblasted).

Paint coat system:

2 layers of priming coat in a dry film thickness of approximately 40 μm each, 2 layers of top coat in a dry fim thickness of approximately 60 μm each. The total dry film thickness shall amount to approximately 200 μm

Quality of paint coats:

All the paint material shall be a two-component one, with a high meshed polymerization and a low rate of developing the capillarity, suitable to the tunnel environment, resistant against saline water, highly resistant to ultraviolet light, resistant to oil, acids, and alkalis, insensible to grease, and not containing heavy metals. It shall be suitable for the temperature range between –30°C and 120°C.

Quality references:

The density of porosity according to the DIN 4681, Part 3, with electric insulation of at least 4,000 V at 100 μm of paint coat thickness. Adhesion test by cutting a mesh in the dry film according to the DIN 53151: the Gt0 grade is required for both steel and aluminium.

2.3.13.1.1.2 DOCUMENTS

Execution drawings as well as descriptions of materials and equipment shall be submitted. These documents shall provide the dimensions, details, and arrangement of equipment, installation and testing methods, lists of materials, and all other information enabling the Engineer to verify the adequacy of the proposed installation.

2.3.13.1.2. CABLE CONNECTIONS

Cables without halogen may only be used.

The insulation of all feeding cables for ventilating fans, emergency lighting, and emergency feeding for electro-niches and emergency call niches in a tunnel shall be fire resistant E30/FE180. The same applies to all the cables to which such devices and elements are connected that have to operate reliably in case of fire or to preserve their function in case of fire for at least 120 minutes. The methods of cable termination and the proposed system of cable labelling shall be submitted. Only approved types and labels may be used. Cable terminations shall be clearly and durably marked in compliance with the schemes of cable connections so that checking of circuits is simplified. Each cable contains a durable label or plate firmly fixed next to each termination, indicating the reference number of the particular cable in accordance with the indications in the cable lists. Cables shall be led into cases (except where switchboards with the protection IP 40 or less are in question) by means of sealing inserting elements where all the cores have to be thoroughly arranged and safely fixed to prevent pests to enter the case, and to disburden the clamps from the cable weight. The clamps shall be coded and labelled in accordance with the interconnection schemes and cable designations, so that a correct interconnecting of all the cables is facilitated. Cable clamps shall be resistant to vibrations. Special insulation shall be ensured. The nominal current shall be at least the same as that of the cable, which will be connected to the clamps.. Metal elements under tension shall be so executed as to be located at a safe distance or protected from coincidental touch. Where the clamps are used for controlling, signalling, or communication cables, additional spare locations and possibilities for installation of additional clamps shall be foreseen. All the equipment and connecting cases shall have separated clamps for each wire, including spare cores. Over the entire installation, the arrangement of adequate cables and corresponding clamps shall be strictly adhered to as agreed with the Engineer. The cables shall be brought to the site on drums, and the coiled-up cable must remain intact. Broken coils or cables with knots or abrasions must not be used. Vertically placed cables (in grooves in the tunnel walls or at other locations) shall be suitably mechanically disburdened by means of standard relieving sockets and supports placed at every 30 cm. In addition, the cables placed in vertical grooves shall be adequately protected with a thermal isolation (refer to detail). All the indicated cable lengths are approximate only. The Contractor is responsible to establish the correct length at site prior to ordering the cables. Cables may only be placed along the foreseen cable routes. The Contractor is fully responsible for the protection of the cables against damage during storing, laying, etc. The Contractor shall prepare and submit for approval adequate cable lists for each system, indicating the type, cross-section, quantity, route, and methods of connecting for each cable.

2.3.13.1.3. OVER-VOLTAGE PROTECTION

The Contractor shall take all the necessary and appropriate measures to prevent impacts and damages, which might occur due to a stroke of lightning and other types of over-voltage on electrical equipment and installations. All the low-voltage cables and communication cables consisting of metal cores entering into power stations or electro-niches or control centre, shall be protected from over-voltage by means of special over-voltage protection devices suitable for control cables. The Contractor shall submit a detailed design of the over-voltage protection to the Engineer and the CLIENT for approval.

2.3.13.1.4. EARTHING AND POTENTIAL EQUALIZING

All the visible metal surfaces of the structure, and metals not forming a part of electric circuits including casing for equipment and cable supports, shall be interconnected and earthed. Metal earthing shoes and bolts (however not of iron) for connecting the cable coats or adjacent equipment shall be installed. Where several electrical cabinets are placed together forming an integral unit, a connecting strip shall be laid without any interruption to ensure an adequate interconnection of all the cabinets. The earthing connectors are copper screws (bolts) or sockets. These requirements apply irrespective of the working voltage and purpose of the equipment. .

The Contractor shall carry out all the necessary connections for earthing and equalizing the potentials where appropriate.

All the over-voltage protection devices which must be capable to sustain defect conditions shall be installed. All the cable coats shall be interconnected and attached to the earthing body. Special attention shall be paid to correct connection and earthing of coats of single-core cables. Tests and measurements of Ohm resistance on basic and eventual supplemental and earthing systems shall be carried out as directed by the Engineer. Protocols with the results shall be submitted to the Engineer. The design of the system shall include lightning protection, the protection against all the effects of stray currents, etc., due to defects occurring in the adjacent circuits, which might cause damage or incorrect functioning of the equipment.

The earthing bath for low-voltage equipment shall be permanently connected to the main earthing bath.

2.3.13.1.5. MINOR WORKS TO BE TAKEN INTO CONSIDERATION

All the mechanical and electrical elements shall be suitably protected to ensure safety of all humans in the vicinity of the devices and installations.

In areas accessible to public, the equipment shall be completely closed, the casing shall be robust to sustain deliberate damage, and shall have smooth outer surfaces, without unnecessary irregularities and rifts where dust and moisture could accumulate. Cabinets, desks, boxes, etc. shall be of high quality and strong structure. The doors and covers enabling access shall have adequately finished and shaped edges to ensure appropriate strength. All scrapings shall be removed, and all the welds shall be perfect, clean, and smooth. Printed circuit plates shall be carried out on stable insulating materials, where the printed circuit shall remain durably connected with the plate in all conditions. Both plate and printed circuit shall be protected from weather impacts, dirt, moisture, etc., by means of approved techniques of final treatment. The number of types and size of relays, contactors, switches, etc., shall be as small as possible, the relays being coded and "with keys" to ensure inserting of relays into the correct socles and proper arranging of the contacts. The contacts of different voltages on the same relay shall be arranged in voltage groups – one group for each voltage – and shall be mechanically and electrically separated. Magnetic contact surfaces of relays, contactors, circuit breakers, circuit breakers, switches, etc., shall be made of stainless material and arranged in such a way that the quantity of dust accumulated on the contacts is as small as possible, when the cover of a relay or a contactor has to be removed. Hermetic relays, except those with hermetic contactors, shall have a transparent case to enable monitoring of the operation of relay contacts. In all the contractual works, all the elements of the equipment shall be fitted with nameplates as described below, to enable the identification for the operation and maintenance purposes. All the nameplates shall be clearly readable, perfectly visible, and fixed with nails, screws, or rivets.

- *Circuit breakers, switches, contactors, relays, clamps, etc.:*

  These elements shall be marked and numbered on the element itself as well as on the element bearing plate, while the functional scheme shall be fixed on the inner side of the doors. For fuses and circuit breakers the nominal values of both current and voltage shall be indicated. Functional schemes shall be prepared in a way as approved by the Engineer. They shall be clearly drawn in ink, and protected with transparent plastic material.

- *Constituent parts:*

  In case that more than one product of the same or similar kind is mounted in a casing or cabinet, each of them shall be fitted with a plastic nameplate indicating its function.

- *Distribution cabinets:*

  Each cabinet shall be equipped with engraved plastic or metal nameplate indicating the function and the identification number of the particular cabinet.

All the equipment shall be provided with damping of radio interference to prevent disturbance of functioning of other equipment, notwithstanding the disturbance occurs due to radiation, induction, or conduction. Prevention of radio interference shall comply with the CENELEC EN 55014 and EN 55015, as well as with the CISPR 14 and 15 publications.

All the plates to indicate danger and warning signs shall be made of durable material, fixed by means of bolts, screws, or rivets, with clear and readable letterings in both local and English language. The word "DANGER" shall be written with letters bigger than other writings to catch one's eye. The letter size and the nature of the warning shall be approved by the Engineer. All the letters shall be of red colour. Identical components within the sets of equipment shall be of the same size and mutually replaceable. All the equipment shall have correct blockades to ensure that only regular procedures of switching and operating. The Contractor shall foresee his own measures to protect all the installed elements and the stored goods from damage and stealing. All the fixing material, anchors, bolts, etc. inside and outside tunnel shall be made of stainless steel No. 1.4401 according to DIN 17440, or of epoxy materials of adequate mechanical strength complying with the DIN 4102 standard concerning the fire resistance. Inside the tunnel only suitable epoxy fixing clips are admitted to fasten the temperature sensitive cable of the fire line detector and aerial cable of tunnel radio device, as metal clips may cause certain interference. Anchor bolts inside the tunnels shall be filled up with epoxy resin. The Contractor shall perform all the testing and measurements, and shall provide professional assessments by authorized institutions, which are required after completion and take-over of works, including ensuring the necessary equipment, manpower, and specialists. Drawings showing grooves and other structural elements in the walls (openings, recesses, foundations, pipes, etc.) shall be included in these specifications. The Contractor shall review those drawings and shall make sure that all the grooves in or through the walls, elements, and structures, which are indispensable for the contractual works, i.e. installation of electrical equipment, devices, and apparatus, have been taken into consideration.

In case the Contractor should require any additional grooves and/or openings, the latter may only be approved at locations as agreed with the Engineer. Any costs that might arise shall be born by the Contractor. All the openings or recesses, particularly those, which extend through fire safety zones, shafts, access openings, etc., shall be filled up with foam or similar and approved incombustible material (FLAMRO) after completion of the cable works. Boring or cutting of concrete walls, pavements, and other structures may only be carried out after receiving appropriate approval by the Engineer.

2.3.13.1.6. SURFACE DAMAGES

All the construction machinery working in the vicinity of finalized surfaces, or brick or concrete surfaces, shall be such as to prevent depositing of dirt, oil, and other harmful substances. All the machinery shall be suitably placed and adjusted to fulfil the above condition.

2.3.13.1.7. PACKING

Goods, materials, devices, and equipment shall be thoroughly packed for transportation and storing purposes, so that they are protected from improper handling, vibrations, and weather impacts, thus being transported to the site and stored at site without any damage. All the contact surfaces, sensitive finalized surfaces, edges, etc. shall be suitably protected, which, however, must not have any effect on the general character of the above-mentioned requirements.

2.3.13.1.8. WARRANTY, MAINTENANCE, SPARE PARTS

The Contractor shall submit a warranty as provided by the contract between the CLIENT and the CONTRACTOR. In addition, the Contractor shall ensure a complete maintenance service, i.e. a routine maintenance and the maintenance upon cutout, including all the necessary spare parts, up to the expiry of the liability period. The contract price shall include the complete maintenance services including the necessary spare parts for the entire liability period. When any goods, material, or equipment cannot be repaired at the site, all the costs relating to returning those goods, material, or equipment to factories or plants for repair shall be included in the contract price. Prior to issuing a statement on completion of the works, the CONTRACTOR shall submit to the Engineer for approval the detailed lists of tools, adjusting devices, accessories, apparatus, and testing equipment, which are indispensable to ensure proper performance of the above-mentioned maintenance services. The CONTRACTOR shall indicate the local companies and institutions, which will be available to carry out the maintenance works. For all the equipment foreseen for individual systems or subsystems, the tenderer shall, of his own choosing, submit a list of the necessary spare parts with prices, which shall be included in the final tender price. The tenderer shall also indicate the maintenance costs for all the systems and for the complete duration of the liability period and for additional two years of operation, separately for materials and works. The CONTRACTOR shall indicate the prices for spare parts, which are specified in the List of works. In addition, the CONTRACTOR shall submit a separate list of spare parts he recommends for the period after the expiry of the liability period. For those spare parts, informative or fixed amount shall be indicated in the List of works. The CLIENT shall specify such a period. For this list of spare parts, the prices shall be indicated by the SUBCONTRACTOR. The spare parts shall be ordered by the CLIENT of his own choosing. The prices of spare parts shall be fixed up to the time as specified by the CLIENT after the expiry of the liability period. The price of spare parts shall be broken down to delivery costs and work costs (installation and testing). The CONTRACTOR shall indicate a minimum period in which he can guarantee the delivery of spare parts. This period, however, must not be less than ten years after expiry of the liability period.

The prices of the same spare parts indicated in the list for the liability period and in the list after the liability period shall not differ one from the other.

The CONTRACTOR shall provide instructions for cleaning the equipment and rooms. The first cleaning shall be carried out by the CONTRACTOR prior to handing-over of the structure, while the subsequent cleanings, i.e. after the take-over, shall be executed by the user.

2.3.13.1.9. STANDARDS

Unless other standards are provided by these specifications, all the materials, calculations, and tests shall comply with the above-mentioned standards, or with such current standards of the country of the producer/manufacturer, which, according to the Engineer's opinion, ensure at least the same quality level. In case the CONTRACTOR offers such materials, equipment, design calculations, or testing, which comply with other standards than with the above-mentioned ones, he shall submit all the details demonstrating the differences between the proposed and the specified standard, if such differences affect the design and the equipment capacity. The works and all the devices, equipment, and materials, which are a part of these specifications, shall be in all aspects in compliance with the rules and regulations of the country of the producer/manufacturer/supplier, or with the regulations provided by any other parties being authorized to perform any part of the Works.

2.3.13.2 TESTING AND MEASUREMENTS

2.3.13.2.1. GENERAL

Tests and measurements are generally divided in three groups. The factory acceptance tests (F.A.T.) shall be performed prior to delivering the equipment, the site acceptance tests (S.A.T.) shall take place at the site, while the final acceptance tests shall be carried out after completion of the Works. The CONTRACTOR shall submit adequate pamphlets covering the entire equipment, and the list of tests proposed for each individual component of the equipment. These documents shall include a general review of the documentation and a description of individual tests. None of aforementioned descriptions or documents shall restrict the CONTRACTOR's obligations to carry out all the tests as specified and required to demonstrate sufficient capacity of the system. Testing methods and timing for each individual test shall be prepared on the basis of preliminarily submitted detailed description of the particular test, including a final offer of the system, and after obtaining the Engineer's approval. Without the latter, no deviations are admitted whatsoever.

The CONTRACTOR shall submit to the Engineer for approval all the detailed testing procedures and time programmes for the testing at least eight week prior to commencement of the factory acceptance testing. Proposal of testing shall be submitted, and the Engineer shall approve such a proposal. The CONTRACTOR shall indicate when such proposals of testing shall be submitted. In case that any deficiency is found out during the particular test, this shall be explained in detail to the Engineer. On the basis of such an explanation, the Engineer shall decide, whether the deficiency can be considered as a minor one, or if it has to be made good prior to continuing the testing. Minor defects are deficiencies, which are discovered during the testing, and which do not affect negatively the function of the system in broader sense; therefore they need not be made good before continuing the testing, and such testing can be successfully completed. If, however, an important deficiency is in question, the Engineer shall decide, which part of the test or tests has to be repeated. The Engineer has the right to require a repetition of all the tests, if, in his opinion, the particular deficiency might have considerable consequences. All the costs relating to any repeated testing shall be born by the CONTRACTOR, including the costs of both Engineer and CLIENT. The Engineer or his representative has an unlimited access to the CONTRACTOR's and SUPPLIER's premises for the purpose of inspecting and testing at any time. The CONTRACTOR shall inform his SUPPLIER or SUBCONTRACTOR of this requirement..

All the costs that might occur in connection with the transportation and lodging of persons, who are authorized to attend and supervise the testing, shall be born by the CONTRACTOR. The equipment shall also be subjected to further and special tests as specified in the technical specifications, attached Lists of works, or any other parts of the specification.

2.3.13.2.2. FACTORY ACCEPTANCE TESTS (F.A.T.)

The factory acceptance tests (F.A.T.) are divided in three groups:

- *environment impact tests,*
- *technical tests,*
- *system tests.*

The CONTRACTOR shall distribute the tests in groups to minimize the travelling costs to the smallest possible extent, in case that the Engineer and/pr the CLIENT intends to attend these tests. The factory acceptance tests shall be carried out under the supervision of both Engineer and CLIENT. After completion of all the tests, the results, which have to be approved by the CLIENT or his representative (provided that he attends any of such tests), shall be submitted to the Engineer. After the Engineer has received the results and has made sure of successful testing carried out on the equipment, he shall give a written notice to the CONTRACTOR, and the latter will be free to supply the equipment. In case the Engineer decides that the equipment does not comply with the specifications, he has the right to reject it and to inform the CONTRACTOR of reasons for the rejection within appropriate time period..

The Engineer shall inform the CONTRACTOR in writing of any ascertained minor deficiencies, and which of these deficiencies have to be made good prior to delivery to the site.

2.3.13.2.2.1 FACTORY TESTS OF ENVIRONMENT IMPACTS

The tests of environment impacts shall be performed on one piece of the indicated equipment, sufficiently early prior to the factory acceptance tests. The environment impacts to be tested comprise at least the heat, frost, and vibrations.

General:

Three tests are described in this section. The equipment shall successfully stand all of the mentioned tests. A statement shall be submitted as prescribed by an authorized testing institution, demonstrating that the equipment has successfully passed all the environment impact tests. The CLIENT and the Engineer reserve the right to modify any test or all the tests during the equipment acceptance testing. The CONTRACTORs shall indicate a programme of these modified tests.

Unless stated otherwise, the environment impact testing shall be carried out on the equipment in its usual housing and under full loading.

Dry heat:

In such test, a single piece of lamp, TV camera, traffic light, traffic lane marking light, and variable traffic sign is placed into the chamber, where it is exposed to radiating heat in the cycle as mentioned below:

20°C for 9 hours, then the temperature is approximately linearly increased up to 40°C for the equipment in tunnels and buildings, and up to 50°C for other external equipment, all in the period of 5 hours. Both temperatures, i.e. 40°C and 50°C shall be maintained for 5 hours, and then the temperature is lowered approximately linearly up to 20°C for the next 5 hours. During the testing, all the equipment shall be turned on and shall be kept under full operational load.

Frost:

In such test, a single piece of lamp, TV camera, traffic light, traffic lane marking light, and variable traffic sign shall successfully pass the frost test by gradual temperature variation. The initial temperature prior to recovery shall amount to – 15°C, while the exposure time at that temperature shall be 16 hours. The equipment shall operate in compliance with the specification:

- *prior it is placed into the testing chamber,*
- *after expiry of on hour, and 16 hours after the commencement of the – 15°C stage,*
- *after the recovery period.*

Vibrations:

A single piece of lamp, TV camera, traffic light, traffic lane marking light, variable traffic sign, and longitudinal ventilating fan shall be tested. The test shall be carried out in compliance with the requirements indicated in section 2.03.13.01.01 "Quality of materials and workmanship" dealing with the seismic resistance for installation inside tunnels. The endurance test shall last for 6 hours within the range of 5 Hz to 35 Hz, and with uniform distribution in the direction as mentioned below. The equipment shall be mounted in its usual operating position, and shall be subjected to vibrations in the vertical plane and in each of both main horizontal planes. The endurance test at resonance frequencies shall last for 10 minutes. The equipment shall operate in compliance with the specifications during the entire test.

2.3.13.2.2.2 TECHNICAL FACTORY ACCEPTANCE TESTS AND MEASUREMENTS

Unless provided otherwise by the specification, complete functional tests shall be performed, including appropriate standard tests, on at least one lamp, UPS device, and transformer to demonstrate that they comply with the technical conditions of the specification. Hardware and software, as well as the remote control equipment, including peripheral apparatus, shall also be tested.

2.3.13.2.2.3 SYSTEM FACTORY ACCEPTANCE TESTS AND MEASUREMENTS

The system functional tests shall be carried out on a characteristic part of the system to demonstrate that the system fully complies with the specified technical and operational requirements. Unless specified otherwise, the CONTRACTOR shall submit details on the number

and type of equipment to be inserted into the system. Long cable connections shall be simulated by means of simulating cable cabinets (testing device). The systems foreseen for transmission via optical fibres shall be tested by means of transportable cable in the full length coiled up on a cable drum.

2.3.13.2.2.4 SITE ACCEPTANCE TESTS AND MEASUREMENTS

On each section of the installed equipment, site acceptance test shall be carried out. At least 6 weeks prior any site testing, the CONTRACTOR shall submit to the Engineer for approval the details of tests and testing equipment he proposes for the execution of such testing. The CONTRACTOR is obliged to provide the Engineer with one of each type of instruments for site testing of the current, voltage, resistance, and insulation within the ranges and levels of impedances, as may be necessary for a safe testing of the equipment. Simultaneously with the progress of the installation works, the insulating resistance of cables shall be controlled and recorded. The identification of cable cores shall be approved on both sides of the cables, while in case of communication, alarm, and control cables this shall be done on both sides of each circuit. The executed tests on the cables shall be approved by the Engineer prior to commencement of testing the appurtenant equipment. The CONTRACTOR shall carry through all the necessary tests as may be required by the law and for the insurance purposes, including the programmes for such testing, inspections by authorized institutions, persons, or insurance companies. He shall also submit certificates in prescribed and approved forms, which are necessary to allow commissioning of installations and equipment. zvajalec izvede vse potrebne preizkuse, ki so zahtevani po zakonu in zaradi sklenitve zavarovanj, vključno s programi za take preizkuse, preglede s strani pooblaščenih organov, oseb ali zavarovalnic, in predloži potrdila v predpisanih in odobrenih oblikah, ki so potrebna, da se omogoči dajanje instalacije in opreme v obratovanje.

Tests and measurements upon commissioning at the site shall demonstrate, to complete satisfaction of the Engineer, the following:

a) all the equipment, cable connections, distributions, etc. are electrically and mechanically safe;

b) all the blockades, insulators, and protective mechanisms on the doors and covers are properly mounted and adjusted;

c) all the visible metal components are correctly interconnected and earthed, and all the connections and locations for which earthing is required due to safety and satisfactory operation are adequately earthed in accordance with the manufacturer's requirements;

d) all the cables, conductors, and terminals are correctly executed, safe, properly installed, and painted;

e) all the phases, poles, neutral in common cables are correctly connected, as it is necessary for the adequate electric power at all the points, and the voltage and frequency are correct and in compliance with the operational requirements for the complete equipment;

f) all the feeding cables shall be properly secured by means of fuses or in any other appropriate way to ensure a satisfactory selective protection and a safe turning off in conditions of failure;

g) all the contacts are properly levelled and not exposed to excessive wear and tear or corrosion,

h) all the protective covers are properly mounted, all the warning and marking plates are executed correctly, and the interior of all the cabinets and boxes is clean and without waste pieces of cables or cable coats;

i) if necessary, batteries shall be installed and attached, and the battery feeders work correctly;

j) the insulation resistance of all the cable connections and equipment amounts to at least the

value as indicated in the regulations;

k) the resistance of loops of individual circuits does not exceed the value, which ensure proper function of the power strokes;

l) interconnection of metal masses is demonstrated by measurements (continuity of galvanic connections);

m) the earthing resistance does not exceed the resistance of the earthing network;

n) all the instruments and measuring apparatus are switched on with a correct polarity, and they function properly,

o) all the indicators and alarms of troubles operate properly;

p) in addition to all operational tests required for satisfactory handing-over of the works, the following shall also be verified to full satisfaction of the Engineer: all the blockades, sequences, and protections, as well as the adjustment of the protection against overload and short circuits, which are not in use during normal operation.

Site tests and measurements upon commissioning shall be carried out under the Engineer's supervision. Authorized institutions may only perform site tests and measurements. Final acceptance tests shall commence after successful completion of all the site hand-over tests and making good all the deficiencies found out during these tests. The tests shall comprise complete functional testing of the works as a whole, and certain selected technical tests of the entire equipment or some parts of the equipment. After completion of the site acceptance tests, the CONTRACTOR shall submit the test results to the Engineer. After receiving the test results and making sure that the particular device has passed the tests, the Engineer shall inform the CONTRACTOR in writing that the acceptance tests may be considered as successful. During the site acceptance tests, the Engineer shall inform the CONTRACTOR of ascertained minor deficiencies, and which of them shall be made good before commencing the tests after completion of the works.

2.3.13.2.3. TESTS AND MEASUREMENTS AFTER COMPLETION OF WORKS

The CONTRACTOR shall inform the Engineer of when the tests after completion of works shall commence. Prior to begin of the tests after completion of the works, all minor defects discovered during the preceding tests shall be made good to complete satisfaction of the Engineer. The system shall be fully capable to operate perfectly. The Engineer shall direct such testing as may be appropriate in his opinion. During these periods the entire system shall be at the Engineer's disposal. Suitable supervisory inspections shall be carried out as well.

2.3.13.3 TRAINING OF CLIENT'S PERSONNEL

2.3.13.3.1.1 GENERAL

During the contract period, the CONTRACTOR shall provide facilities and equipment for the training of the CLIENT's personnel at the tunnel location. Such training shall ensure that the CLIENT's personnel foreseen for the particular project can acquire knowledge of and acquaintance with all the aspects of the project, daily operation, maintenance, repairs, diagnosing the failures of the power supply, traffic control furniture, ventilation system, hardware, and software. For the training of CLIENT's personnel, five months in total shall be foreseen per person (member of educational staff).

The CLIENT shall nominate his personnel, who will attend the training courses, and the CONTRACTOR shall enable the personnel a reasonable access to the design data and documents, so that the personnel can be fully acquainted with all the system aspects. The facilities and equipment to be provided by the CONTRACTOR also include appropriate offices and accommodation.

The CONTRACTOR shall nominate qualified instructors, and the Engineer has the right to approve or reject any of the proposed instructors. All the equipment that is indispensable to a complete and

successful training of the personnel (video-players, TV, projectors, etc.) shall be provided by the CONTRACTOR. The CONTRACTOR is obliged to provide accommodation, transportation, and food for all the trainees on his own cost.

Not later than two months after award of the contract, the CONTRACTOR shall submit to the Engineer a detailed training programme for approval.

2.3.13.4 DOCUMENTS

2.3.13.4.1. STAGES OF DOCUMENTS

The documents shall be submitted in four different design stages:

- *execution design,*
- *documents during contract implementation,*
- *as-built design ,*
- *operation and maintenance instructions.*

All the documents shall be in local language.

2.3.13.4.2. EXECUTION DESIGN

The purpose of the execution design is to provide a complete base for the execution of contractual works. Until the Engineer approves the execution design for the system, the CONTRACTOR must not order any equipment or commence the production of any equipment components. The execution design shall be submitted to the Engineer for approval within four mounts after award of the contract. The highest priority of the CONTRACTOR is to provide a sufficient number of skilled personnel to implement the works in accordance with the programme. The execution design shall include detailed information and drawings of the following:

- *all the 20 kV feeding equipment*
- *all the 400/230 V feeding equipment,*
- *all the emergency feeding equipment,*
- *all the lighting equipment,*
- *all the ventilating equipment,*
- *all the traffic control equipment including adequate cable connections,*
- *fire alarm system,*
- *anti-burgle system,*
- *all other systems not mentioned herein,*
- *TV control system and its components,*
- *radio installation in the tunnel,*
- *software for traffic control system, as well as for controlling the lighting, ventilation of power installations, and all the systems not mentioned herein,*
- *a method of the processor system control,*
- *take-over testing,*
- *a list and presentation of documents,*
- *data transfer equipment and communication equipment.*

2.3.13.4.3. SOFTWARE EXECUTION DESIGN

Software execution design includes flowcharts and description of the entire configuration of the software, with an explanation of functioning and interconnections of different computer programs. It also specifies all the operational functions and interfaces to be provided in each processor

system. Interfaces between component programs and data structures shall be foreseen. Special software for all the interfaces within the system shall be specified. Critical time courses shall be evaluated and presented. For each function, a specification of the time distribution and allocation of RAM shall be indicated. The report shall focus on the preparation and description of the integral system design, with unified systems of data variation, etc. If standard programs are in question, it is necessary to provide detailed documents for each of them, and a standard reference system shall be adopted. This includes a functional description of the program with flowcharts, tabular configurations, interfaces, definitions, time controls, saving protocols, and source protocols. For the program packages on regular sale, which shall be a part of the finalized application software, a detailed seller's documentation shall be submitted. Controlling software on regular sale, which shall be a part of the finalized application software, a detailed seller's documentation shall be submitted. Controlling software shall be supported by an on-line assistance to the operator.

2.3.13.4.4. EXECUTION DESIGN OF PROCESSOR SYSTEM HARDWARE

The execution design of the hardware shall be worked out together with the standard items for modular processor and appurtenant peripheral devices. Should any hardware be designed or modified, technical details shall be specified. The design shall include a detailed description of the processor system, the method of connecting peripheral devices and of information transfer, including a system for the data transfer. A complete specification of the equipment shall be submitted, including a physical layout (in plan), as well as arrangements of interconnections and power feeding.

2.3.13.4.5. ACCEPTANCE TESTS AND MEASUREMENTS

All the specifications of tests as well as the programmes of these tests, which shall be carried out at different stages, are described in item 10.03.02 and shall be finalized at the execution design stage. These specifications represent a base for the preparation of detailed testing procedures.

Hardware testing:

Time programmes of hardware testing shall be defined. Such programmes shall include a review and, if necessary, modifications of the CONTRACTOR's standard factory tests. Standard diagnostics shall be verified.

Software and system testing:

The software and system testing comprises all the acceptance tests carried out on individual computer programs and on the system as a whole. Detailed specifications of testing and time programmes for all the tests to demonstrate the capacity and proper function of the system shall be submitted. In addition, the sequence of tests as well as forming of equipment groups for each individual test shall be defined.

2.3.13.4.6. DOCUMENTS DURING THE CONTRACTUAL WORKS

To maintain the contact between the Engineer and a SUBCONTRACTOR, for each executed work and for each individual part of the specifications adequate documents shall be prepared in such a form that they can be immediately issued, not waiting for the preparation of the as-built design. The CONTRACTOR shall propose a modular method of preparation of such documents.

Chapters issued during the contractual works shall be considered as a draft, as the works, which follow, will inevitably affect the already executed works, and a modification will be unavoidable. It is essential to submit the documents, notwithstanding several new issues will be required.

The CONTRACTOR's design shall also include a statement indicating references and bases used for the preparation of design documents. Attention shall be paid to the fact that the documents, issued during the contractual works, are such as to be suitable for the final as-built design. A set of copies of standard authorial documents delivered according to the particular contract shall be submitted not later than six months after award of the contract. It is acceptable that such a standard documentation is submitted as a part of the execution design.

2.3.13.4.7. EXECUTION DOCUMENTS – MANUALS FOR SYSTEMS

The execution documents (manuals for systems) consists of the following:

- *software manuals,*

- o *programming manual,*
- o *hardware and maintenance manuals, which also includes all the equipment outside the station,*
- o *manual for tunnel operators.*

Where appropriate, the final manuals for systems shall include both standard and design documents submitted during the contract period.

Not later than six months prior to commencement of the site acceptance tests, the CONTRACTOR shall submit to the ENGINEER for information and approval three copies of the draft of the final manual for the system. The draft shall consist of the same number of parts and shall have the same form as the final manual for the system. Renewed issues shall be submitted if required for commissioning and site testing. After being approved, a copy of the draft of these documents including all the modifications shall be returned to the CONTRACTOR. Six complete sets of final manuals for the systems shall be submitted together with six copies of the complete index of notions prior to issuing the acceptance certificate. In addition, four copies of maintenance manuals for the local station equipment indicated in item 2.03.13.04 shall be submitted as well.

2.3.13.4.8. SOFTWARE MANUAL

All the software shall be oriented towards the design. A standard detailed aid for programming shall be incorporated in the programming manual. Therefore, a software manual shall comprise system programmes and protocols of system data. The information shall comply with the specification of the execution design of the system.

The manual shall explain the complete configuration of the software with flowcharts, where special attention shall be paid to items to which the subsequent users' programmes can be linked. It is essential to explain the complete configuration of the function, irrespective of details of the executive programme, so that it can be easily understood, in particular by the competent software engineer, who intends to specify or incorporate a new programme into the system. In the general description a specification of allocation of RAM and the time to individual functions shall be indicated, including mentioning the upper limits of the spare capacity. Then, a detailed description of each task within the operational system shall follow, including executive, controlling, and users' programmes. Each programme shall comprise a general description with a flowchart and actual protocol with comments if appropriate. The format of data structures shall be given in the second part of the manual. Data records, variables, etc., shall be provided in a form compatible with the system of the data updating. The original protocols for all the supplied software including a booklet of standard and application programmes, form a part of this manual, except for software packages, which can be purchased on regular sale and for which only the right of use can be bought.

2.3.13.4.9. MANUAL FOR HARDWARE AND MAINTENANCE OF THE PROCESS SYSTEMS

The manual shall include a description and maintenance procedures of the complete hardware system. The maintenance procedure for a tunnel shall comprise a statement that, in case of maintenance works or an accident, the traffic shall be directed by the control centre personnel. For the standard equipment, a copyright documentation shall be incorporated. The description of the equipment shall commence with the general configuration of the system, i.e. with the arrangement plans showing the location of each unit, with block schemes and explanation of functioning. The function of constituent units shall be explained in detail. Block schemes showing the flow and interaction of data, logical diagrams. circuit schemes with component values, and general arrangement schemes including cable connection schemes shall be submitted. In addition, lists of components and schemes of their interconnection shall be submitted as well; such details, however, must not make more difficult the comprehension of the description of functioning. The maintenance procedures comprise the diagnosis of defects, testing and adjusting, replacement of units, hardware routine maintenance, and operation of testing equipment. The use of testing software shall be explained, and suitable instructions for its use by individual steps shall be provided; a detailed list of programmes shall be submitted separately. Steps required for the replacement of plugs of the computer system, including adjusting and verifying the feeding voltage etc, where appropriate. Regular hardware maintenance shall be comprised.

Chapters dealing with the following equipment shall be bound up into separate volumes to make the use by the maintenance staff easier:

- *20 kV system for power feeding,*
- *400/230 V system for power feeding,*
- *system of emergency power feeding,*
- *lighting system,*
- *ventilation system,*
- *traffic signs and traffic lights, traffic control,*
- *system of measuring the CO concentration, the visibility, and air flow,*
- *video system equipment and automatic detection of the traffic,*
- *fire alarm system,*
- *anti-burgle system,*
- *radio device in the tunnel,*
- *control system,*
- *fire water system,*
- *other signalling,*
- *control centre and data transfer equipment.*

2.3.13.4.10. MANUAL FOR THE TUNNEL OPERATOR

Such a manual shall be specially prepared for the tunnel operators in all the control centres. It shall contain a set of specific procedures and instructions as may be necessary for successful managing of the system. Instructions for handling with different traffic configurations with the help of the system shall be included. The manual for the control centre and subordinate control stations shall comprise the following:

- *instructions provided by individual steps for the conditions of defects, fire alarm, and any other alarm,*
- *instructions provided by individual steps for the use of all the equipment on control desks including TV monitoring.*

The manual shall be suitable for permanent use.

2.3.13.4.11. FORM OF DOCUMENTS

All the documents shall be in local language.

All the documents shall be fitted with the number and the date of issue.

All the documents shall contain tables of contents, with a complete index of notions in the final manuals.

All the documents shall be prepared in uniform format in compliance with the CLIENT's requirements. All the schemes relating to the design documents shall fit the size (height) of the page, bound up, and marked by a correct reference to the text. For simpler use, they shall be folded in such a way that the text is visible. The execution design shall be bound into durable solid outer binding. The latter shall be in a form of free sheets, enabling easy replacement of pages. Each folder shall be clearly marked with a well readable lettering, which may be applied to either front or back page. Special attention shall be paid to the fact that the experts are not necessarily acquainted with the system, which shall be taken into consideration when elaborating the documents. Certain difficulties may be expected in the application of control panels, activation of locking devices, and plugs. 7 copies of each document shall be submitted.

2.3.13.4.12. CONTRACTOR'S DRAWINGS

From time to time the CONTRACTOR shall submit to the ENGINEER for approval the required copies of all the drawings, schemes, and details of the complete equipment or a part of it. Such drawings shall be at the ENGINEER's disposal at any time. Interconnection schemes and other such drawings, which are, according to ENGINEER's opinion, not final until satisfactory installation and testing is performed, shall be approved on principle. The CONTRACTOR shall submit a block scheme showing the method of fulfilling the functional requirements provided by this specification; he shall also submit a general arrangement of cable connections including an estimated total quantity of the cables. All the drawings shall be based on actual dimensions of the structure, such dimensions to be verified by the CONTRACTOR. Within a month after signing the contract, the CONTRACTOR shall submit a programme of his designing activities, including detailed information relating to numbering, categories, and lists of drawings. During performing the contractual works, such a programme will serve for the preparation, submission, and approval of the drawings and any other documents as may be necessary to the ENGINEER. The above-mentioned programme shall comply with the specifications relating to production, supply, and installation of contractual devices and equipment to implement the contractual provisions, and shall consider reasonable time to be at the ENGINEER's disposal to study and approve all the drawings, calculations, and graphs submitted (and, if necessary, re-submitted) by the CONTRACTOR.

The CONTRACTOR is obliged to ensure that the contractual works are satisfactorily completed and that all the operational conditions are implemented, notwithstanding the ENGINEER has approved any of the drawings. Without any delay and not later than 12 weeks after signing the Contract, the CONTRACTOR shall provide information of dimensions of the equipment to be placed in the foreseen rooms, the details of cable routes and necessary breakthroughs, the methods of bringing the equipment in the foreseen rooms, etc.

2.3.13.4.13. ENGINEER'S DRAWINGS

The intention of such drawings is to show the general arrangement.

The CONTRACTOR shall inspect all the construction works before commencing the installation of the equipment.

2.3.13.4.14. AS-BUILT DRAWINGS

The as-built drawings are a constituent part of these specifications. The as-built drawings are reviewed drawings of the execution design showing the works actually performed. The CONTRACTOR shall submit the as-built drawings in such original that can be copied. The drawings shall contain the names of signatories on behalf of the CLIENT, ENGINEER, and CONTRACTOR. After being signed, five copies of those drawings shall be submitted to the ENGINEER. Together with the as-built drawings, the CONTRACTOR shall submit six copies of booklets of as-built drawings of reduced dimension (A3). All the details, dimensions, etc. in the drawings shall be clearly visible and readable even though the size of the drawings has been reduced. The CONTRACTOR shall complete the as-built drawings, obtain the approval by the ENGINEER, and finally submit the approved drawings including the A3 booklets not later than within three months after receiving a certificate on completion of the works. All the costs relating to the submittal of the above-mentioned drawings shall be included in the contract price.

In general, the as-built drawings comprise the following:

- *For mechanical equipment:*
  - *structural drawings, ,*
  - *operation instructions,*
  - *functional block schemes.*
- *For electrical installations:*
  - *installation drawings including numbers of circuits and an exact indication of the types of all the equipment installed,*

- *distribution schemes including numbers of circuits,*
- *measurements to demonstrate the correctness of protective measures and adjustment of the selectivity of the protective system,*
- *measurements of energy consumption,*
- *precise numbering of types of apparatus (including the equipment supplied by others, which shall be connected to any of the above-mentioned installations),*
- *earthing systems.*

o *For switching apparatus:*

- *structural drawings,*
- *circuit schemes and operation schemes,*
- *additional circuit schemes as may be appropriate,*
- *exact lists of any equipment installed, including a precise description of such equipment,*
- *ranges of adjusting the switches, etc.*

o *For the equipment:*

- *structural drawings,*
- *circuit schemes,*
- *functional block schemes,*
- *lists of quantities, etc.*

o *For main and secondary cable connections:*

- *drawings of electric wires including dimensions.*

For these drawings, cable types of standard cross-section and of the indicated lengths shall be used.

2.3.13.4.15. OPERATION AND MAINTENANCE INSTRUCTIONS

In addition the sections from 2.03.13.04.07 to 2.03.13.04.13, the CONTRACTOR shall submit to the CLIENT all the remaining operation and maintenance instructions for all the systems, devices, and installations.

2.3.13.5 SPARE PARTS AND MAINTENANCE

For all the equipment of individual systems or sub-systems, the tenderer shall, on his own choosing, indicate a list of necessary spare parts and their prices, which shall be included in the final tender price. The tenderer shall also indicate the maintenance costs over the complete liability period plus two years of operation, separately for the material and for the work.

2.3.14 LIST OF TYPICAL WORK

ITEM No.				DESCRIPTION OF ITEM
01				**PRELIMINARY WORKS**
01	01			Stacking-out and survey
01	01	05		Stacking-out and survey in portal cuts,cut & cover and mined tunnel sections (left and right tube)
01	02			Clear felling and removal
01	02	05	12111	Clearing work and removal, trunk diameter up to 15 cm
01	03			Cutting trees and removal
01	03	05	12112	Cutting trees, trunk diameter 15 - 50 cm, CLIENTs property
01	04			Stump-grubbing
01	04	05		Stump grubbing, diameter 15 - 50 cm, deposit
01	05			Standstill of entire tunnel construction
01	05	05		Standstill of site due to force majeur or as directed by the Engineer more than 1 week
02				**EARTH WORKS AT PORTALS**
02	01			Top soil stripping, deposit lateral
02	01	05	21 111	Top soil stripping, deposit lateral for later use
02	02			Bulk excavation
02	02	05	21 211	Bulk excavation of soil with low bearing capacity
02	02	10	21 212	Bulk excavation of light soil
02	02	15	21 213	Bulk excavation of heavy soil
02	02	20	21 214	Bulk excavation of soft rock
02	02	25	21 215	Bulk excavation of hard rock
02	02			Bulk excavation for Concrete Arch
02	02	05	21 211	Bulk excavation of soil with low bearing capacity
02	02	10	21 212	Bulk excavation of light soil
02	02	15	21 213	Bulk excavation of heavy soil
02	02	20	21 214	Bulk excavation of soft rock
02	02	25	21 215	Bulk excavation of hard rock
02	02			Bulk excavation for Concrete Arch
02	02	05	21 211	Bulk excavation of soil with low bearing capacity
02	02	10	21 212	Bulk excavation of light soil
02	02	15	21 213	Bulk excavation of heavy soil
02	02	20	21 214	Bulk excavation of soft rock
02	02	25	21 215	Bulk excavation of hard rock
02	03			Transport of excavated material
02	03	05		Transport of excavated material on a distance of 13 km

02	03	05		Transport of excavated material on a distance of 5 km
02	04			Excavation of foundation
02	04	05	21 323	Exc. pits width up to 1,0 m and 1,0 - 2,0 m depth in heavy soil
02	04	10	21 363	Exc. pits width 1,0 - 2,0 m and 1,0 - 2,0 m depth in heavy soil
02	05			Excavation of building pits
02	05	05	21 413	Excavation up to 1,0 m depth in heavy soil
02	05	10	21 423	Excavation from 1,0 - 2,0 m depth in heavy soil
02	05	15	21 433	Excavation from 2,0 - 4,0 m depth in heavy soil
02	05	20	21 443	Excavation over 4,0 m depth in heavy soil
02	07			Backfilling
02	07	05	42212	Backfilling with natural heavy soil
02	07	10	42212	Backfilling and compaction with natural heavy soil
02	11			Backfilling (Concrete Arch)
02	11	05		Backfilling and compaction
03				**RETAINING STRUCTURE AND SLOPE SUPPORT**
03	01			Bored piles excavation
03	01	10		Excavation and execution of bored piles, diameter 100 cm
03	02			Bored piles, anchor head and beam
03	02	05	53 244	Crown beam execution dim. 0.5 x 1.1 m (0.5 x 1.5 m)
03	02	10	53 615	Anchor vertical beam execution dim 0.4 x 1.0 m (0.85 x 0.85 m)
03	02	15	53 831	Anchor beam execution dim 0.7 x 0.8 m (0.85 x 0.85 m)
03	03			Shotcrete
03	03	05		Shotcrete d = 5cm
03	03	10		Shotcrete d = 10cm
03	03	15		Shotcrete d = 15 cm
03	03	20		Shotcrete d = 20 cm
03	06			Reinforcement for shotcrete
03	06	05		Steel wire mesh type MAG 500/560 - Q 189
03	06	10		Construction steel re-bars type RA 400/500
03	06	15		Protection fence H = 1.85 m (wiremesh)
03	06	20		Rocky bricketing lining, humus filling Kamnita betonska zložba, debeline 0.6 m
03	06	25		Rocky bricketing wall, thickness 0.6 m Dostopna pot širine 4 m, tampon 0.5 m
03	06	30		Access road, width 4 m, tampon 0.5 m
03	06			Concrete arch
03	06	05		Steel wire mesh type MAG 500/560 - Q 503
03	06	10		Concrete MB 30
03	06	15		PVC foil + fleece politlak 300
03	06	20		SN anchor 32 mm, L = 9 m, F = 250 kN, distance 0.3 m
03	06	20		SN anchor 32 mm, L = 6 m, F = 250 kN, distance 0.3 m

03	06	25	SN anchor 32 mm, L = 4 m, F = 250 kN, 1 pce/4 m2
03	06	30	Polyester anchor, L = 4.0 m, 1 pce/4 m2
03	04		Shotcrete for Concrete Arch
03	04	05	Shotcrete d = 5cm
03	04	10	Shotcrete d = 10cm
03	04	15	Shotcrete d = 15 cm
03	04	20	Shotcrete d = 20 cm
03	11		Drainage drillings without casing up to D = 100 mm
03	11	05	Drillings without casing 0 - 10 m
03	11	10	Drillings without casing 10 - 20 m
03	11	15	Drillings without casing 20 - 30 m
03	12		Drainage drillings with casing up to D = 100 mm
03	12	05	Drillings with casing 0 - 10 m
03	13		Perforated PVC pipes D = 50 mm
03	13	05	Perforated PVC-pipes 0 - 10m
03	14		Vertical core drilling min. D = 80 mm
03	14	05	Core drilling, 0 - 10 m
03	14	10	Core drilling, 10 - 20 m
03	14	15	Core drilling, 20 - 30 m
03	15		Horizontal or inclined core drilling D = 80 mm
03	15	05	Core drilling 0 -10 m
03	15	10	Core drilling 10 - 20 m
03	15	15	Core drilling 20 - 30 m
03	15	20	Core drilling 30 - 40 m
03	16		Additional payment for cementation of core drilling
03	16	05	Core drilling 0 -10 m
03	16	10	Core drilling 10 - 20 m
03	16	15	Core drilling 20 - 30 m
03	16	20	Core drilling 30 -40 m
03	17		SN - bolts
03	17	05	SN-bolts, ultimate load min. 250 kN length 4,0 m
03	17	10	SN-bolts, ultimate load min. 250 kN length 6,0 m
03	17	15	SN-bolts, ultimate load min. 250 kN length 9,0 m
03	18		IBO - bolts
03	18	05	IBO - bolts, ultimate load min. 250 kN length 3,0 m
03	18	10	IBO - bolts, ultimate load min. 250 kN length 4,0 m
03	18	15	IBO - bolts, ultimate load min. 250 kN length 6,0 m
03	21		Permanent cable anchor
03	21	05	Anchor, working load min. 700 kN, length 21 m (free portion 10 m, fixed portion 11 m)

03	22	05	Anchor, working load min. 700 kN, length 24 m (free portion 10 m, fixed portion 14 m)
03	28	05	Anchor, working load min. 450 kN, length 24 m (free portion 10 m, fixed portion 14 m)
03	29	05	Anchor, working load min. 700 kN, length 23 m (free portion 10 m, fixed portion 13 m)
03	45		Dewatering during construction (Concrete Arch)
03	45	05	Temporary channel
03	45		Dewatering (Concrete Arch)
03	45	05	PEHD drainage pipe 100 mm
03	45	05	Drainage course - tampon 16-32 mm, thickness 30 cm
03	46		Dewatering-channels around the portal
03	46	05	Channels
03	46	05	Concrete tube 500 mm (up to Bolska)
03	46	05	Dewatering channel protected with shotcrete
03	46	05	Concrete tube 300 mm
03	46	05	PEHD tube 250 mm
03	46	05	PEHD tube 100 mm
03	46	05	PEHD tube 125 mm
03	46	05	Temporary concrete shaft 1.0m/100cm
03	46	05	Revision shaft 0.8 m/150 cm
03	46	05	Temporary reservoir 3 x 1.5 x 1 m
03	46	05	Sedimentary basin
03	47		Water pressure test (Lugeon)
03	47	05	Water pressure test with single packer
03	47	10	Water pressure test with double packer
03	48		Measurement
03	48	05	Triple extensometer (7, 14 and 20 m) furnish and install
03	48	10	Vertical inclinemeter - 4 pieces, furnish and install, depht up to 35 m
03	48	15	Hydraulic disk load cells, working load 1000 kN
03	48	20	Measuring rock bolt, 6 m
03	48	25	Measuring rock bolt, 9 m
03	48	30	Geodetic points - level points on surface, beams, houses and other structures
03	48	35	Monitoring station for measuring initial stress conditions
04			**TUNNEL EXCAVATION (UNDERGROUND EXCAVATION)**
04	01		Top heading excavation (ascending heading)
04	01	20	Top heading excavation rock class B2
04	01	30	Top heading excavation rock class C2
04	01	35	Top heading excavation rock class C3
04	01	40	Top heading excavation rock class C5
04	01	45	Top heading excavation rock class PC
04	01	50	Top heading excavation rock class SCC
04	01	60	Top heading excavation rock class CA
04	01	65	Top heading excavation class Parking bay niche

04	01	70	Top heading excavation rock class SWG - ALTERNATIVE INSTEAD OF SCC
04	02		Top heading excavation (descending heading)
04	02	20	Top heading excavation rock class B2
04	02	30	Top heading excavation rock class C2
04	02	35	Top heading excavation rock class C3
04	02	40	Top heading excavation rock class C5
04	02	60	Top heading excavation rock class SCC
04	02	65	Top heading excavation class Parking bay niche
04	02	70	Top heading excavation rock class SWG - ALTERNATIVE INSTEAD OF SCC
04	03		Bench excavation (ascending heading)
04	03	20	Bench excavation rock class B2
04	03	30	Bench excavation rock class C2
04	03	35	Bench excavation rock class C3
04	03	40	Bench excavation rock class C5
04	03	45	Bench excavation rock class PC
04	03	50	Bench excavation rock class SCC
04	03	60	Bench excavation rock class CA
04	03	65	Bench excavation class Parking bay niche
04	03	70	Top heading excavation rock class SWG - ALTERNATIVE INSTEAD OF SCC
04	04		Bench excavation (descending heading)
04	04	20	Bench excavation rock class B2
04	04	30	Bench excavation rock class C2
04	04	35	Bench excavation rock class C3
04	04	40	Bench excavation rock class C5
04	04	50	Bench excavation rock class SCC
04	04	65	Bench excavation class Parking bay niche
04	04	70	Top heading excavation rock class SWG - ALTERNATIVE INSTEAD OF SCC
04	05		Invert excavation with longitudinal subdivision (ascending heading)
04	05	05	Invert excavation (maximal length of round 12 m)
04	05	10	Invert excavation rock class Parking bay niche (max. length of round 12 m)
04	06		Invert excavation with longitudinal subdivision (descending heading)
04	06	05	Invert excavation (maximal length of round 12 m)
04	06	10	Invert excavation rock class Parking bay niche (max. length of round 12 m)
04	07		Invert excavation without longitudinal subdivision (ascending heading)
04	07	05	Invert excavation (maximal length of round 6 m)
04	07	10	Invert excavation rock class Parking bay niche (max. length of round 6 m)
04	08		Invert excavation without longitudinal subdivision (descending heading)

04	08	05	Invert excavation (maximal length of round 6 m)
04	08	10	Invert excavation rock class Parking bay niche (max. length of round 6 m)
04	09		Invert excavation (shotcrete invert) ascending heading
04	09	05	Invert excavation
04	09	70	Top heading excavation rock class SWG - ALTERNATIVE INSTEAD OF SCC
04	09		Invert excavation (shotcrete invert) descending heading
04	09 a	05	Invert excavation
04	09	70	Top heading excavation rock class SWG - ALTERNATIVE INSTEAD OF SCC
04	10		Excavation of temporary invert in top heading
04	10	05	Excavation of temporary invert
04	11		Excavation of temporary footings
04	11	05	Excavation of temporary footings
04	12		Top heading and bench excavation for cross passages
04	12	05	Top heading and bench excavation for cross passages
04	13		Further excavation
04	13	05	Invert excavation for cross passages
04	13	10	Excavation of niches
04	13	15	Excavation of niches and cross passages
04	13	20	Excavation of reshaping tunnnel profile due to unexpected high deformations, including demolition of shotcrete
04	14		Additional payment on excavation for hindrance due to waterinflow > 10 l/s, top heading
04	14	05	Additional payment due to waterinflow > 10 l/s
04	15		Additional payment on excavation for hindrance due to waterinflow > 10 l/s, bench
04	15	05	Additional payment due to waterinflow > 10 l/s
04	16		Additional payment on excavation for hindrance due to waterinflow > 10 l/s, invert
04	16	05	Additional payment due to waterinflow > 10 l/s
04	17		Temporary water control in in descending headings
04	17	05	Pumps, capacity 5 - 10 l/s
04	17	10	Pumps, capacity 10 - 15 l/s
04	18		Transport of excavated material to embankment or disposal site
04	18	05	Transport of excavated material from eastern portal to disposal site on a distance of 1 km
04	18	10	Transport of excavated material from western portal to disposal site on a distance of 4 km

04	20		Interruption of excavation work
04	20	05	Interruption of excavation work 6 - 12 h
04	20	10	Interruption of excavation work > 12 h
04	20	15	Standstill due to high gas concentration 2 - 12 h
04	20	15	Standstill due to high gas concentration > 12 h
07			**TUNNEL SUPPORT**
07	01		Shotcrete for top heading, bench and niches
07	01	15	Shotcrete d = 15 cm
07	01	20	Shotcrete d = 20 cm
07	01	25	Shotcrete d = 25 cm
07	01	30	Shotcrete d = 30 cm
07	01	30	Shotcrete d = 35 cm
07	01		Shotcrete for top heading, bench and niches
07	01	15	Shotcrete d = 15 cm
07	01	20	Shotcrete d = 20 cm
07	01	25	Shotcrete d = 25 cm
07	01	30	Shotcrete d = 30 cm
07	01	30	Shotcrete d = 35 cm
07	01		Microfibre reinforced shotcrete for top heading, bench and niches
07	01	15	Microfibre reinforced shotcrete for top heading, bench and niches
07	02		Shotcrete for invert
07	02	00	Shotcrete d = 20 cm
07	02	05	Shotcrete d = 30 cm
07	02	10	Shotcrete d = 35 cm
07	02		Shotcrete for invert
07	02	00	Shotcrete d = 20 cm
07	02	05	Shotcrete d = 30 cm
07	02	10	Shotcrete d = 35 cm
07	03		Shotcrete for temporary invert top heading
07	03	05	Shotcrete d = 20 cm
07	03	10	Shotcrete d = 25 cm
07	03		Shotcrete for temporary invert top heading
07	03	05	Shotcrete d = 20 cm
07	03	10	Shotcrete d = 25 cm
07	04		Shotcrete for temporary footings
07	04	05	Shotcrete d = 20 cm
07	05		Shotcrete for face support
07	05	05	Shotcrete d = 3 cm
07	05	10	Shotcrete d = 5 cm

07	05	15	Shotcrete d = 10 cm
07	06		Filling cavities with shotcrete
07	06	05	Shotcrete
07	07		Reinforcement for shotcrete
07	07	00	Steel wire mesh Q189
07	07	05	Steel wire mesh Q283
07	07	10	Construction steel re-bars type RA 400/500
			Armatura za brizgani beton
07	07		Reinforcement for shotcrete
07	07	00	Steel wire mesh Q189
07	07	05	Steel wire mesh Q283
07	07	10	Construction steel re-bars type RA 400/500
07	08		Additional payment for sulfate-resistant shotcrete
07	08	05	Additional payment for sulfate-resistant shotcrete,dimension of cu is m2x thickness in m = m3
07	09		Additional payment for installation of support elements more than 50 m behind tunnel face
07	09	05	Shotcrete d = 10 cm
07	09	10	Shotcrete d = 15 cm
07	09	15	Shotcrete d = 20 cm
07	09	20	Steel wire mesh MAG 500/560
07	10		SN-bolts
07	10	05	SN-type rock bolts,ultimate load min. 250 kN, length 3.0 m
07	10	10	SN-type rock bolts,ultimate load min. 250 kN, length 4.0 m
07	10	15	SN-type rock bolts,ultimate load min. 250 kN, length 6.0 m
07	10	20	SN-type rock bolts,ultimate load min. 250 kN, length 9.0 m
			SN - sidra
07	10		SN-bolts
07	10	05	SN-type rock bolts,ultimate load min. 250 kN, length 3.0 m
07	10	10	SN-type rock bolts,ultimate load min. 250 kN, length 4.0 m
07	10	15	SN-type rock bolts,ultimate load min. 250 kN, length 6.0 m
07	10	20	SN-type rock bolts,ultimate load min. 250 kN, length 9.0 m
07	11		injection - bolts
07	11	05	Grouting-drilling bolts, type-IBO, ultimate load min. 250 kN, length 3.0 m
07	11	10	Grouting-drilling bolts, type-IBO, ultimate load min. 250 kN, length 4.0 m
07	11	15	Grouting-drilling bolts, type-IBO, ultimate load min. 250 kN, length 6.0 m
07	11	20	Grouting-drilling bolts, type-IBO, ultimate load min. 250 kN, length 9.0 m
07	12		Swellex bolts
07	12	05	Swellex bolt, length 3.0 m, ultimate load min. 100 kN
07	12	10	Swellex bolt, length 3.9 m, ultimate load min. 100 kN
07	12	15	Superswellex bolt, length 3.0 m, ultimate load min. 200 kN
07	12	20	Superswellex bolt, length 3.9 m, ultimate load min. 200 kN

07	13		Additional payment for bolts in cross passages due to narrow spacings
07	13	05	SN - bolts
07	13	10	IBO - bolts
07	13	15	Swellex bolts
07	14		Steel ribs
07	14	05	Steel arches TH - 21
07	14	10	Lattice girderALWAG PS 70/20/30 (ALTERNATIVE in B2)
07	14	15	Steel arches TH -24
07	14		Steel ribs
07	14	05	Steel arches TH - 21
07	14	10	Lattice girderALWAG PS 70/20/30 (var. in B2)
07	14	15	Steel arches TH -24
07	15		Laggings
07	15	05	Steel laggings, d = 6.0 mm ,1.6 m length
07	15	10	Steel laggings, d = 6.0 mm ,2.0 m length
			Injektirane cevi - sulice
07	16		Injected forepiling pipes
07	16	05	Injected Forepiling pipes, 1 1/2" 2.0 m length
07	16	10	Injected Forepiling pipes, 1 1/2" 3.0 m length
07	16	15	Injected Forepiling pipes, 1 1/2" 4.0 m length
07	17		Grouted forepiling (re-bars D = 28 mm)
07	17	05	Grouted forepiling 2.0 m length
07	17	10	Grouted forepiling 3.0 m length
07	17	15	Grouted forepiling 4.0 m length
07	18		Driven forepiling pipes
07	18	05	Driven forepiling pipes, 1 1/2" 3.0 m length
07	18	10	Driven forepiling pipes, 1 1/2" 4.0 m length
07	19		Forepiling using IBO - bolts
07	19	05	Forepiling 3.0 m length
07	19	10	Forepiling 4.0 m length
07	20		Additional payment for tunnel support installed at a distance of more than 50 m behind tunnel face
07	20	05	SN-bolts (6 and 9 m)
07	20	10	IBO-bolts (6 and 9 m)
07	22		Micropiles
07	22	05	Grouting-drilling bolts, type IBI or equivalent, length 4,0 m
07	22	10	Grouting-drilling bolts, type IBI or equivalent, length 6,0 m
07	22		Micropiles
07	22	05	Grouting-drilling bolts, type IBI or equivalent, length 4,0 m
07	22	10	Grouting-drilling bolts, type IBI or equivalent, length 6,0 m

07	23			Roof pipes
07	23	05		Steel pipes D=4" length 15 m
07	23	10		Steel pipes D=4" length 15 m, drilled from pre-cut
07	23			Roof pipes
07	23	05		Steel pipes D=4" length 15 m
07	23	10		Steel pipes D=4" length 15 m, drilled from pre-cut
08				**WATER PROOFING AND DRAINAGE WORKS**
08	01			Water proofing for mining sections
08	01	05		Water proofing for tunnels (incl. one layer of geotextile)
08	01	10		Shotcrete backing for sealing (3 - 5 cm)
08	01	15		Waterproofing for crosspassages (incl. one layer of geotextile)
08	01	20		Shotcrete backing for sealing (3 - 5 cm) in cross passages
08	02			Water proofing for cut and cover sections
08	02	05	57621	Water proofing for cut and cover sections (incl. two layers of geotextile)
08	02	10	53511	Shotcrete backing for water proofing membrane protection (10 cm)
08	03			Water proofing for joints
08	03	05		Joint rubber ribbon built into concrete
08	03	10		Joint rubber ribbon for construction joint
08	04			Drainage collecting pipe
08	04	05		Drainage collecting pipe (cut and cover section) D = 300 mm of concrete MB 30
08	04	10		Drainage collecting pipe (mined tunnel section) D = 300 mm of concrete MB 30
08	05			Cross connection of drainage
08	05	05		Drainage collecting pipe (cut & cover section) D = 200 mm
08	05	10		Drainage collecting pipe (mined tunnel section) D = 200 mm
08	06			Sidewall drainage
08	06	05		Sidewall drainage (cut and cover section) D = 200 mm
08	06	10		Sidewall drainage (mined tunnel section) D = 200 mm
08	07			Collection of water in mining section by pipes
08	07	05		Flexible PVC-pipes 1 1/2 "
08	08			Soft PVC pipe, half shells
08	08	05		Soft PVC pipe D = 100 mm
08	08	10		Soft PVC pipe D = 200 mm
08	09			Drainage pipes PVC including filter, D = 4 cm
08	09	05		Drainage pipes
08	10			Drainage drillings mined section (acc. item 0809)
08	10	05		Drainage drillings mined section

08	11			Connection of PVC pipes with sidewall drainage
08	11	05		PVC-pipes D = 50 mm
08	11	10		PVC-pipes D = 75 mm
08	11	15		PVC-pipes D = 100 mm
08	12			Shafts
08	12	05		Cleaning shaft for slotted kerbs
08	12	10		Revision shaft on tunnel main drainage pipe D=300 mm on pavement (C&C and mined tunnel), D=100 cm, h=140cm
08	13			Shaft covers of cast iron
08	13	05		Revision niche cover INOX on the main tunnel drainage in C&C and mined tunnel section VA4, 145x205 cm
08	13	10		Shaft cover for rev. shaft tunnel for slotted kerb 500 kN of cast iron 700x700 mm
08	13	15		Shaft cover on main drainage collecting pipe 500 kN of cast iron D=660 mm
08	14			Drainage section waste water reservoir
08	14	05	43 132	Execution of sewerage of plastic pipes, placed on underlaid course of cement concrete of diam. 20 cm
08	14	10		Execution of sewerage of plastic pipes, placed on underlaid course of cement concrete of diam. 15 cm
08	14	10	44 172	Execution of shaft of cement concrete, circular section of diameter 100 cm, and of depth 100 to 150 cm
08	14	15	44 173	Execution of shaft of cement concrete, circular section of diameter 100 cm, and of depth 150 to 250 cm
08	14	25		Execution of lid of cast iron for 25 Mp type D, of D= 600 mm
08	14	30		Execution of lid of cast iron for 25 Mp type D, of dim. 600/600 mm
08	14	35		35 kg steel anchor for fixation of steel construction
08	14	40	58 624	Climbing iron
08	14	45	59 361	Top coat of epoxides on concrete surface, thickness of 0,3 mm
08	14	50	59412	Protection of hot - dip galvanizing average thickness 43 micrometers
08	15			Temporary drainage
08	15	05		Temporary drainage
09				**CONCRETE WORKS AND REINFORCEMENTS**
09	01			Structural reinforced concrete (C&C)
09	01	05	53244	Preparation and placement of mixtures of reinforced cement concrete MB 30
09	01	10	53254	Preparation and placement of mixtures of reinforced cement concrete MB 30
09	02			Abutment concrete (C&C)
09	02	05		Abutment beam MB 30
09	03			Lean concrete above foundation slab (C&C)
09	03	05	53 124	Preparation and placement of mixtures of ordinary cement concrete MB 10

09	04			Subgrade concrete (C&C)
09	04	05	53114	Preparation and placement of mixtures of ordinary cement concrete MB 10
09	05			Structural reiforced concrete (Concrete arch)
09	05	05		Preparation and placement of reinforced cement concrete MB 30
09	06			Concrete for invert arch (mined tunnel)
09	06	05		Concrete for invert arch MB 30
09	06	10		Concrete for invert arch MB 30, cross passages
09	07			Lean concrete above invert arch (mined tunnel)
09	07	05		Lean concrete MB 15
09	07	10		Lean concrete MB 15, cross passages
09	08			Abutment concrete (mined tunnel)
09	08	05		Abutment concrete MB 30
09	08	10		Abutment concrete MB 30, cross passages
09	09			Inner lining concrete
09	09	05		Inner-lining concrete MB 30
09	09	10		Inner-lining concrete MB 30, cross passages
09	10			Reinforced inner lining concrete
09	10	05		Reinforced inner lining concrete MB 30
09	11			Lining concrete for niches
09	11	05		Lining concrete for niches MB 30
09	12			Additional payment for sulfate-resistant concrete, inner lining
09	12	05		Additional payment for sulfate-resistant concrete
				Črpanje betona v zruške
09	13			Pumping concrete for excessive overbreaks
				Črpanje betona
09	13	05		Pumping concrete
09	14			Precast concrete (C&C and mined tunnel)
09	14	05		Precast concrete for kerb stone MB 40 (standard length 100 cm), including reinforcements and sealing of joints (using permanently elastic material)
09	14	10		Precast concrete for kerb stone MB 40 (standard length 100 cm), cross passages
09	14	15		Precast concrete for slotted kerb stone MB 40 (standard length 100 cm), including reinforcements and sealing of joints (using permanently elastic material)
09	14	20		Precast concrete for cable duct slab MB 40 of standard length 100 cm, width 75 cm and thickness 12 cm including reinforcement (min. 5 kg/m1) and sealing of joints (using permanently elastic material)
09	14	25		Additional pay item for kerb stone - connecting cross passage MB 40 (curve blocks) including reinforcements and sealing of joints (using permanently elastic material)

09	14	30		Steel cover slab for cable duct openings (140 x 74 cm), thickness designed for a single load of 100 kN
09	14	35		Precast concrete for kerb stone (type 1) MB 40 (standard length 100 cm), parking bay niche including reinforcements and sealing of joints (using permanently elastic material)
09	14	40		Precast concrete for slotted kerb stone MB 40 (standard length 100 cm), parking bay niche including reinforcements and sealing of joints (using permanently elastic material)
09	14	45		Precast concrete for kerb stone (type 2) MB 40 (standard length 100 cm), parking bay niche
09	14	50		Precast concrete for cable duct slab MB 40 (standard length 100 cm), parking bay niche, including reinforcement (min. 5 kg/m) and sealing of joints (using permanently elastic material)
09	15			Concrete components (C&C and mined tunnel)
09	15	05		Lean concrete MB 10 in and underneath cable ducts
09	15	10		Concrete slab MB 15, cross passages
09	16			Reinforced concrete for E-niche partition wall, mined section
09	16	05		Reinforced concrete wall d = 10 - 15 cm
09	17			Extra concrete for filling of cavities due to unfavourable geological conditions
09	17	05		Concrete MB 30
09	18			Extra concrete on account of not occured rock deformation Beton MB 30
09	18	05		Concrete MB 30
09	19			Reinforcement (Concrete arch)
09	19	05		Prepar. and install. of ribbed wire (RA 400/500 - 2, diam. 14 mm and more) for demanding reinforcement
09	20			Reinforcement (C&C)
09	20	05	52 222	Prepar. and install. of ribbed wire(RA 400/500,diam. to 12 mm) for medium demanding reinforcement
09	20	10	52 232	Prepar. and install. of ribbed wire(RA 400/500-2,diam. to 14 mm and more) for medium demanding reinforcement
09	20	15	52 312	Preparation and installation of nets from rolled steel (CBM-50 - MAG 500/560, diam.4-12mm) weight over 2 to 3 kg/m2
09	20	20	52 314	Preparation and installation of nets from rolled steel (MAG 500/560, diam.4-12mm) weight over 4 to 6 kg/m2
09	20	25	52 315	Preparation and installation of nets from rolled steel (MAG 500/560, diam.4-12mm) weight over 6 kg/m2
09	22			Reinforcement mined tunnel (niches)
09	22	10		Wire mesh MAG 500/560 - type Q 385
09	22	15		Steel re-bar RA 400/500
09	23			Coating of concrete surface
09	23	05		Preparation of concrete surface
09	23	10		Double coating sidewalls (up to + 0,2 m)

09	23	15	Double coating roof (above + 2,0 m)
09	24		Slots in inner lining
09	24	05	Slots in inner lining 23cm x 13cm
09	24	10	Slots in inner lining 5cm x 5cm
09	25		Cable pipes embedded in concrete
09	25	05	Cable pipes D = 5 cm
09	26		Cross connection PVC pipes
09	26	05	Cross connection PVC pipes D = 110 mm
09	27		Cross connections of cable ducts
09	27	05	Cross connections with PVC pipes of cable ducts under the pavement D=120 mm (3 per niche)
09	28		Electro shafts located at portals
09	28	05	Electro shaft dimensions of 80 x 80 cm and depth up to 1 m
09	29		Shaft cover
09	29	05	Shaft cover for shaft 500 kN of cast iron 800x800 mm
10			**GEOTECHNICAL MEASUREMENTS**
10	01		Pins for convergence measurements and targets
10	01	05	Pins for convergence measurements and targets (reflector)
10	02		Bore hole extensometer (triple rod) furnish and install
10	02	05	Measuring head and anchor for triple rod extensometer (2, 4 and 6 m)
10	02	10	Measuring head and anchor for triple rod extensometer (3, 6 and 9 m)
10	03		Measuring bolts furnish and install
10	03	05	Measuring bolt, ultimate load 250 kN, length 6 m
10	03	10	Measuring bolt, ultimate load 250 kN, length 9 m
10	04		Radial pressure cell
10	04	05	Contact stress cell (for radial stress)
10	04	10	Contact stress cell (for tangential stress)
10	05		Strain meter
10	05	05	Concrete cell (for tangential stress)
10	06		Laboratory test on shotcrete specimen
10	06	05	Laboratory test
10	07		Execution of measurement
10	07	05	Measuring section MS - I
10	07	10	Measuring section MS - II
10	07	15	Measuring section MS - III
10	07	20	Measuring section MS - IV
10	07	25	Measuring section MS - V

10	07	30	Measuring section MS - VI
10	08		Settlement pins
10	08	05	Settlement pins on houses
10	08	10	Settlement pins on surface
10	09		Execution of ground water monitoring (taking samples - chemical analysis)
10	09	05	Execution of ground water monitoring
10	10		Interpretation and evaluation of geotechnical measurements regarding the Engineer's order
10	10	05	Interpretation and evaluation
11			**PREDRILLING AND GROUTING**
11	01		Injection hose
11	01	05	Injection hose 4 m
11	01	10	Injection hose 6 m
11	01	15	Injection hose 9 m
11	02		Pressure grouting and injecting
11	02	05	Cement suspension PC 275
11	02	10	Cement suspension PC 375
11	02	15	Bentonit additive
11	03		Core drilling
11	03	05	Core drilling 0 - 10m
11	03	10	Core drilling 10 - 20m
11	03	15	Core drilling 20 - 30m
11	04		Additional payment for casing
11	04	05	Core drilling 0 - 10m
11	04	10	Core drilling 10 - 20m
11	04	15	Core drilling 20 - 30m
11	05		Additional payment for cementation and redrilling
11	05	05	Core drilling 0 - 10m
11	05	10	Core drilling 10 - 20m
11	05	15	Core drilling 20 - 30m
11	06		Drilling without casing
11	06	05	Drilling without casing 0 - 5m
11	06	10	Drilling without casing 5 - 10m
11	06	15	Drilling without casing 10 - 20m
11	07		Additional pay item for cementation and redrilling
11	07	05	Drilling without casing 0 - 5m
11	07	10	Drilling without casing 5 - 10m
11	07	15	Drilling without casing 10 - 20m

11	08		Drilling with casing (without core) up to 80 mm
11	08	05	Drilling with casing 0 - 10m
11	08	10	Drilling with casing 10 - 20m
11	09		Additional pay item for ascending drilling with casing
11	09	05	Drilling with casing 0 - 10m
11	09	10	Drilling with casing 10 - 20m
11	10		Water pressure test (Lugeon)
11	10	05	Water pressure test with single packer
11	10	10	Water pressure test with double packer
11	11		Core drilling in concrete / shotcrete
11	11	05	Core drilling in concrete /shotcrete
11	12		Execution of cased borehole D = 250 mm for firefighting waterworks between surface and distribution waterworks niche in tunnel
11	12	05	Execution of cased borehole D = 250 mm
12			**EARTHING IN TUNNEL**
12	01		Earthing
12	01	05	Fe - Zn earthing 40 x 4 mm strip, complete with supports and joints for the main foundation earthing system
12	01	10	Fe - Zn earthing 25 x 4 mm strip for cross connections of main earthing strips and connection strips in cable ducts
13			**ROAD CONSTRUCTION WORK (PAVEMENT)**
13	01		Sub base courses
13	01	05	Mixture of gravel stabilized with cement 20 cm
13	01	10	Layer of bitumen and gravel 5 cm
13	02		Pavement work
13	02	05	Concrete slab 24 cm
13	02	10	Cast asphalt 3 cm
14			**MANPOWER AND MASHINERY**
14	01		Work outside the tunnel
14	01	05	Skilled worker on surface
14	01	10	Trained worker on surface
14	01	15	Unskilled worker on surface
14	02		Mined tunnel
14	02	05	Skilled workers in mined tunnel section
14	02	10	Trained workers in mined tunnel section
14	02	15	Unskilled workers in mined tunnel section
14	03		Construction equipment
14	03	05	Truck up to 1,5 to hook capacity

14	03	10	Truck up to 3,0 to hook capacity
14	03	15	Truck, dump truck up to 5,0 to hook capacity
14	03	20	Truck, dump truck up to 7,0 to hook capacity
14	03	25	Truck, dump truck up to 10,0 to hook capacity
14	03	30	Back hoe 1,0 m3 bucket
14	03	35	Crawler loader 60 - 90 PS
14	03	40	Crawler loader 90 - 130 PS
14	03	45	Wheel loader 60 - 90 PS
14	03	50	Wheel loader 90 -130 PS

15 BIOTECHNICAL REPLANTING

15	01		Replanting
15	01	05	Supplying and planting of forest plants
15	01	10	Humusing 15 cm
15	01	20	Grass seeding
15	01	25	Slope stabilization by using willows
15	01	30	Reinforced earth
15	01	40	Planting in drilled holes