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1. RETAINING STRUCTURES AND SLOPE SUPPORT

1.1 GENERAL REQUIREMENTS

a) 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.

1.1.1 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.

1.1.2 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 shall 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.
c) Specifications for concrete and reinforcement according to the Chapter for Concrete Works and Reinforcement.

1.2 SHOTCRETE

a) For specification of shotcrete see Section TUNNEL SUPPORT.

1.3 ROCK BOLTS

a) For specification of rock bolts see Section TUNNEL SUPPORT.

2. UNDERGROUND EXCAVATION

2.1 GENERAL

2.1.1 DESCRIPTION

a) 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.
b) 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 3.1.2. of this specification or other procedure as agreed with the DESIGNER and approved by the ENGINEER.
c) The CONTRACTOR shall carry out excavation and support work so as to accomplish the requirements of the particular support class agreed and to minimise the deterioration and loosening of the rock mass surrounding the excavation, to restrict overbreak and to prevent damage to the initial lining previously installed.
d) Excavation sequences and subdivision of excavation headings shall be in accordance with tender drawings, specifications and detailed design drawings prepared by the Designer.

2.1.2 SUBMISSIONS

a) Prior to commencement of any underground excavation, the CONTRACTOR shall submit to the ENGINEER for approval descriptions of proposed excavation methods and sequences, including necessary site drainage, safety measures and the results of test programmes carried out in accordance with Albanian 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 tunnelling works by CONTRACTOR.
c) Based on the rock support classification system as specified in Section 5 the CONTRACTOR shall submit to the ENGINEER for approval a detailed schedule of the working cycle for excavation and support in each support category 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:
    a. Drilling pattern, hole diameters, spacing, depth and inclination.
    b. 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.
    c. Distribution of the charge in the holes and priming of each hole.
    d. 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.
    e. Stemming of holes and matting or covering of blast area.
    f. 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.

2.2 EXECUTION

2.2.1 EQUIPMENT

a) Any mechanical equipment for underground excavation works and transportation shall be suitable for the works specified with respect to performance and current Albanian 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.

2.2.2 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) Distance between lamps along constructed tunnel and cross passages should be able to provide illumination of 50 lx or more. Areas around works (excavation faces, around working machines, etc.) should be iluminetaed with 150 lx or more.

2.2.3 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 - 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 (CO2, CO, NO, NO2). 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.

2.2.4 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.3.1).
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.3.1) to compensate for radial deformation for the various rock mass types considers allowances for deformation (deformation tolerance tD). The values given on related drawings or in the tender documents for expected deformations " tD" may be adjusted to suit actual deformations as experience is gained during excavation. Adjustments shall be suggested by the CONTRACTOR 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.

2.2.5 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:
    a. natural overbreak which cannot be avoided by careful work and proper workmanship.
    b. Overbreak caused by prevailing unfavourable geological conditions.
c) The average order of magnitude of the so-called "unavoidable overbreak" is estimated for all support categories and indicated on the drawings in the tender documents and is defined as value "b" (see FIG. 3.1).
d) Excessive overbreak (see FIG.3.2.) may be caused by extremely un-favourable 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 unfavourable geological conditions.
e) In the event of excessive overbreak, support shall be installed immediately as required to stabilize the ground. The ENGINEER shall be informed. Remedial works shall be discussed and agreed between the CONTRACTOR and 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.
f) 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.

2.2.6 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 lay 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 arches 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 lay bay niches shall be carried out by widening the regular cross section of the main tunnel during tunnel driving with an inclination of 40° or less, depending on the CONTRACTOR's technology. 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 lay 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.

2.2.7 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.

2.2.8 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 support category A and B1).

2.2.9 DRAINAGE DURING CONSTRUCTION

2.2.9.1 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 CONTRACTOR shall 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.

2.2.9.2 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 CONTRACTOR shall ensure that the sumps installed are kept clean and the drainage system maintained so that all water during the construction period is adequately controlled.

2.2.9.3 EXPLORATORY BOREHOLES

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

2.2.9.4 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 metres.
b) Ponding 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.

2.2.9.5 SITE TRAFFIC ON INVERT SUPPORT

a) No site traffic shall be allowed to run on unprotected invert structures, temporary or final, concrete or shotcrete.
b) 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 MEASUREMENT FOR EXCAVATION

a) Excavation of the all tunnel profilesin all support categories will be measured by cubic meter (in-situ) along "Line 2" (equal to D-Line) as shown on FIG. 3.3, FIG. 3.4 and FIG. 3.5. 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 support categories will be measured by cubic meter along "Line 2" (equal to D-Line) as shown on FIG. 3.3 and FIG. 3.7.
c) Excavation of niches will be measured for payment by cubic meter along "Line 2" according to FIG.3.6.
d) Over profile, estimated as unavoidable overbreak ("b") inside the O-Line will not be measured for payment (see Figure 3.2).
e) Excessive overbreak beyond (outside) the O-Line due to unfavourable geological conditions will be measured in-situ by actual quantities, provided the volume of the overbreak exceeds 2 cubic meter per 1 m of running tunnel per excavation phase. Overbreaks less than 2 m3 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 for payment.
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 5 l/sec per face, 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 per face 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 CONTRACTOR and will not be measured for payment.
m) Initial rock support including shotcrete, wire mesh, steel arches, rock bolt, sealing of the face and forepiling will be measured separately (see Section 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 will be measured by cubic meter solid (in-situ) rock mass (not considering loosening of excavated material).

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 CONTRACTOR to 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.
r) Interruptions of excavation work up to 2 hours due to geotechnical measurements will not be measured for payment.

2.4 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. face support, 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, temporary water control in ascending headings, hindrances of excavation work due to seepage water, 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 3.3.
b) Underground excavation for the various rock mass types will be paid for at the Unit Price per cubic meter
c) Interruptions of excavation work exceeding 6 hours due to heavy water inflow, large overbreaks or other uninteded 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.
d) 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.
e) The Unit Price for excavation shall include all labour, equipment and materials necessary for monitoring and dilution of gas concentrations during tunnel drivage.
f) 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).
g) Over profile (“b”) is estimated for each Support category and shown on the drawings. Contractor shall consider over profile in the unit price of excavation along “Line 2” (equal to D-Line).
h) The Unit Price for transport of excavated material (intact rock) to embankments or disposal sites beyond a distance of 300 m from the respective tunnel portal shall include all labour and equipment required for loading, transport and unloading of the material. Loading and unloading of material at temporary disposal sites under maintainance of the dewatering system shall also be included in the Unit Price for transport.
i) 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.
j) Final excavation levels (formation level) for pavement construction shall be included in the Unite price for excavation and will not be extra paid.

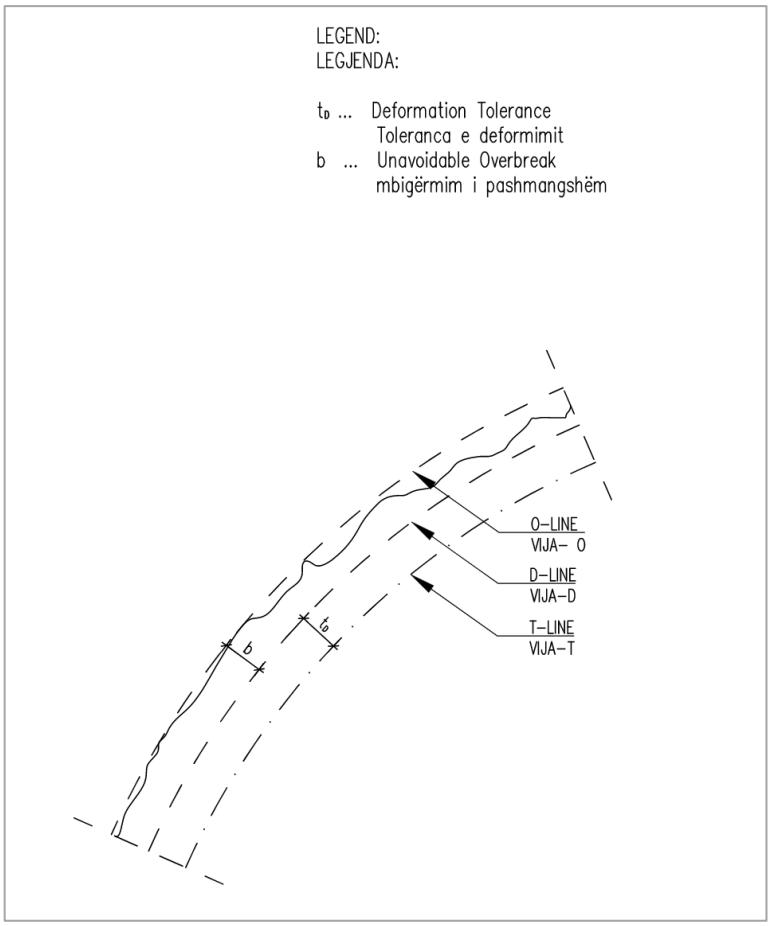

Figure 1 Definition of Excavation and Deformatin lines

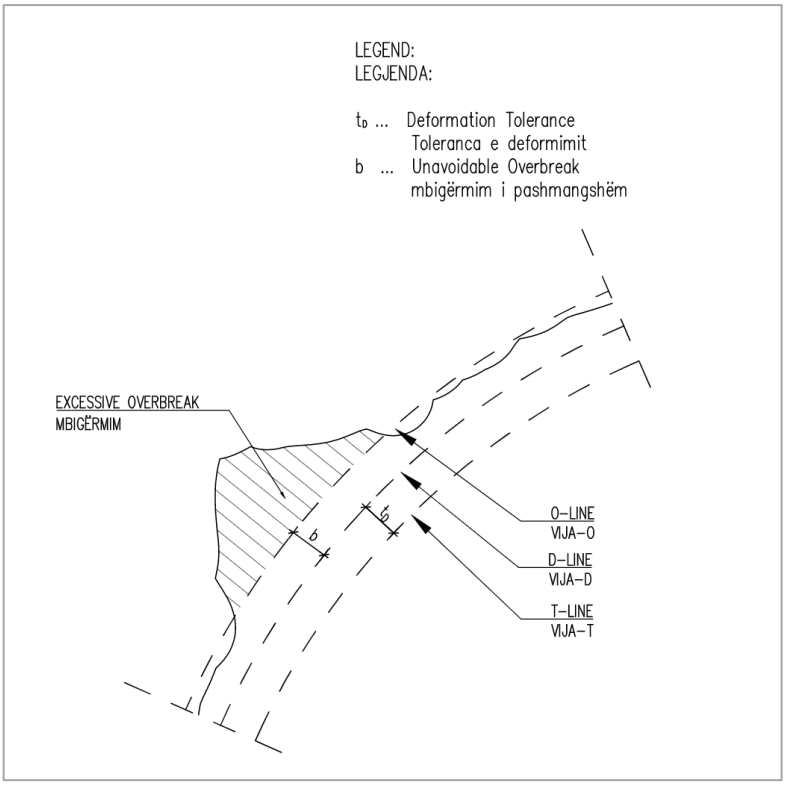

Figure 2 Definition of overbreak due to particular geological conditions

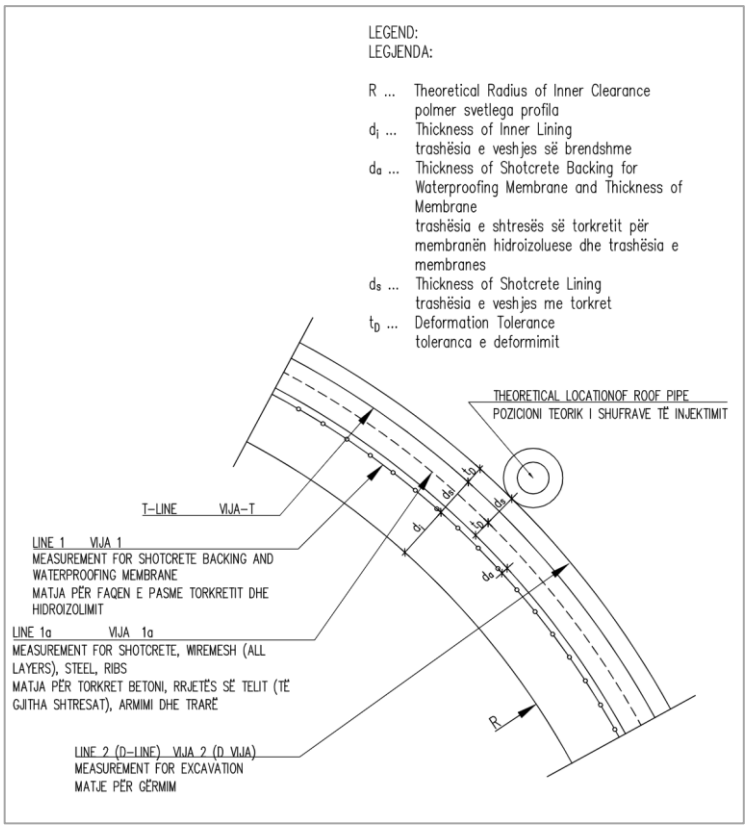

Figure 3 Definition of lines for measurement and payment

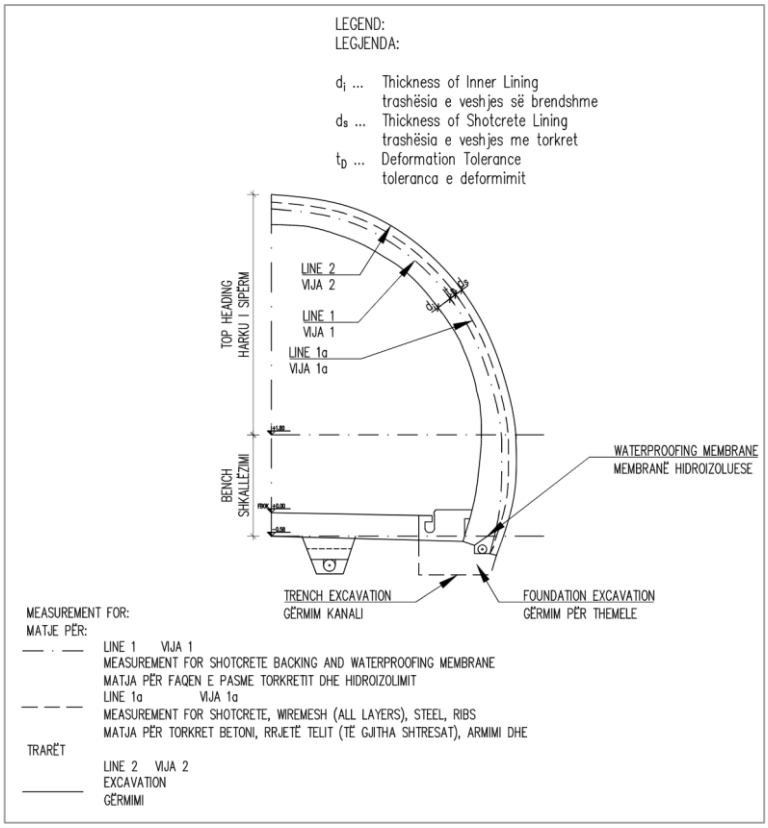

Figure 4 Definition of lines for measurement and payment for cross section without invert

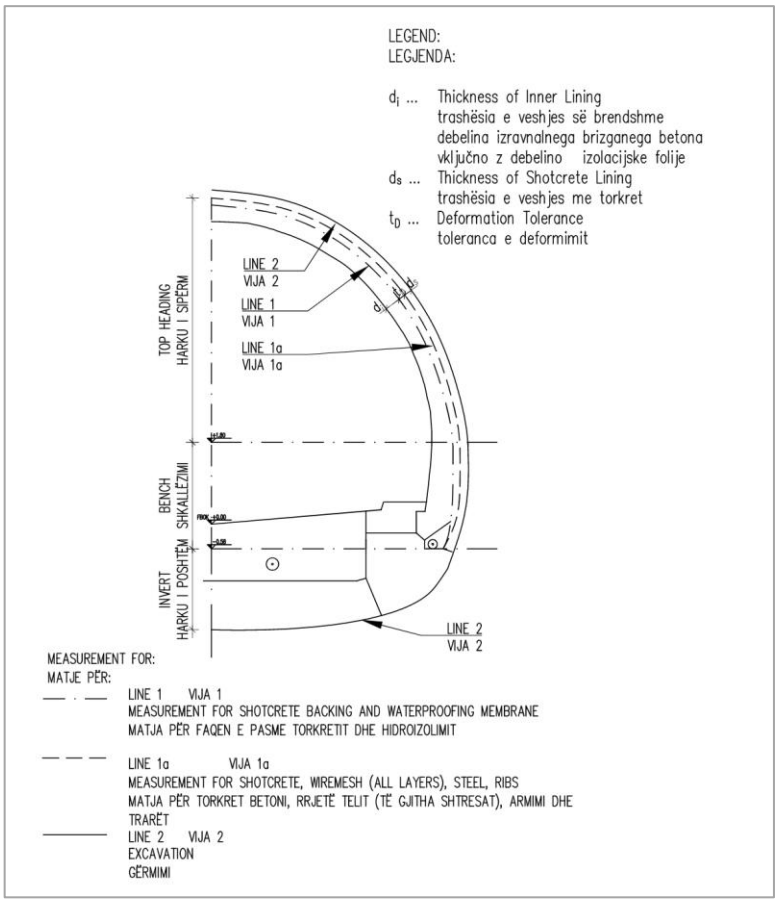

Figure 5 Definition of lines for measurement and payment for cross section with invert

2.5 TRANSPORT OF EXCAVATED MATERIAL

2.5.1 GENERAL

a) Excavation material adequate for construction of embankments shall be transported to embankment sites as stated in the designer's specification of quantities.
b) Material not suitable for construction of embankments shall be transported to a disposal as stated in the designer's specification of quantities.

2.5.2 MEASUREMENT

a) Transport of excavated material from the site to an embankment site or deposit will be measured by cubic meters (in-situ).
b) Hindrances due to coordination problems with other construction sites (e.g. traffic) shall be included in transport costs and will not allow the CONTRACTOR to claim for additional payment.

2.5.3 PAYMENT

a) Transport of excavation material from temporary disposal in portal area (300m) to embankments or disposal sites measured from the respective temporary tunnel portals will be paid by cubic meter (measured in-situ). Loading, unloading and dewatering of material at temporary disposal sites shall be included in the unit price for transport of excavated material.

3. PROFILE CONTROL AND TOLERANCES

3.1 PROFILE CONTROL

3.1.1 SCOPE

a) 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.

3.1.2 METHOD OF PROFILE CONTROL FOR FINAL CONCRETE LINING

a) Clearance control of executed profile of tunnel tube is performed with the help of 3D measurements
b) CONTRACTOR is solely responsible for the setting out for longitudinal abutments and correct and accurate mounting/fixing of rails on each side of the tunnel for the steel formwork.
c) It is the CONTRACTOR'S responsibility to ensure that the minimum clearance for the final lining as shown on the drawings is provided. For the purpose of providing the required clearance profiles, the Contractor shall perform measurements of the surfaces and provide to the Engineer graphical presentation of the results.

3.1.3 EXECUTION

a) The checking of the final clearance shall not be performed before the geotechnical measurements show that the displacements have stopped.
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 conform with the minimum thickness of the inner lining as indicated on the drawings.
c) 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.
d) The CONTRACTOR shall submit a proposal for the remedial works to the ENGINEER.
e) No reshaping of the tunnel support shall be carried out without the approval of the ENGINEER.
f) Geotechnical measurement stations shall not be removed and abandoned without the approval of the ENGINEER.

3.1.4 RECORDS

a) Records shall be kept for each stage of remedial measures.
b) Any Surface Surveying shall be performed using terestrial laser scanning techique 3D measurements which serve for quality control of execution of performed works in the tunnel. The following measurments shall be implemented:
    - after installation of the regulating layer for the waterproofing membrane
    - after the construction of the inner lining of the tunnel
c) The measurements are performed by the Contractor.
d) The quality control system for the performed work in the tunnel consists of a recording device for tunnel profile, software tool for absolute positioning of measurements and software equipment for evaluation and display of measurement results:
    - The measured point cloud that shall be georeferenced. With further processing the results can be displayed as a 3D model or in 2D format (surface along perimeter plot or profile).
    - The system for determining the absolute position of the tunnel shall be in the coordinate

system where the recording accuracy is determined by a resolution of at least 1x1 cm at distance of 10 m from the place of measurement. The accuracy of the point unit must not exceed 11 mm of standard deviation from the test points at a distance of 10 m. Accuracy of the system must be proven by an authorized service certificate.

- The reference system for geodetic and geotechnical measurements shall be established in the tunnel as a polygon network. The polygon network is being upgraded and corrected throughout the construction of the tunnel by means of control measurements. The control and correction measurements are carried out as independent measurements.
- Monitoring of tunnel geometry is carried out between the theoretically given geometry and the actual (constructed) geometry. A 3D image is required for proper comparison. Theoretical geometry is defined in the project and consists of simple geometric shapes. The actual geometry reflects the current state of the measurement and is the basis for the comparison.

e) Criteria for measuring and presenting the surface of the regulating layer for waterproofing membrane (before installing the membrane) are given as the following values:
   - Green: Measurement measured outside the theoretical line of regulating shotcrete to the rock side of the tunnel
   - Yellow: Measurement measured shows the value between the theoretical line extrados line of inner lining concrete and extrados line +2cm
   - Orange: No measurement is given for this criteria
   - Red: Measurement measured outside the theoretical line of inner lining concrete on the rock side, which less then 2 cm

f) Criteria for measuring and presenting the surface of the inner lining are given with the following values:
   - Green: Measurement measured outside the theoretical line of inner lining (inner radius). Deviation to the rock or tunnel side to a maximum of 3 cm.
   - Yellow: No measurement is given for this criteria
   - Orange: Measurement measured outside the theoretical line of the inner lining (inner radius). Deviation to the rock or tunnel side and is more than 3 cm and less than 10 cm
   - Red: Measurement measured outside the theoretical line of the inner lining (inner radius). Deviation to the rock or tunnel side and is more than 10 cm.

g) The clearance profil shall approved by the ENGINEER

h) The final clearance profile shall be recorded at intervals in longitudinal direction and points along the periphery of the tunnel as proposed by the CONTRACTOR and approved by the ENGINEER.

3.2 CONSTRUCTION TOLERANCES

3.2.1 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 arches 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.

3.2.2 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.

3.2.3 TOLERANCES FOR THE INNER CONCRETE LINING

3.2.3.1 SURVEY TOLERANCES

a) 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.

3.2.4 Formwork tolerances

a) 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.

3.2.4.1 EFFECT OF CURVES:

a) 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:

b) $C = R + B/2 \quad - ((R + B/2)2 – (L/2)2)1/2$ [in mm]

3.2.4.2 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.

d) 4.2.3.5 Other tolerances

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

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

4. ROCK SUPPORT CATEGORIES

4.1 SUPPORT CATEGORY DRAWINGS

a) Support measures and lengths of excavation steps are provided in the design drawings for each Support Category. The support categories are developed on the basis of Rock Mass Types and the expected behavior of the rock mass versus tunnel excavation and support system under certain boundary conditions like overburden, water conditions, direction of excavation, etc.

b) The Support Categories distinguish primarily between:
- Advance length
- Thickness of shotcrete and reinforcement
- Number and length of rock bolts
- Number and length of spiles
- Face support
- Without or with invert

c) For the regular cross section 6 different Support Categories are provided in the design documents:

d) Support Category A
- Advance length: 2.20m
- Thickness of shotcrete and reinforcement: Fibre reinforce shotcrete ds=15cm
- Number and length of rock bolts: SN bolts 4m long, pattern 2.00x2.20
- Number and length of spiles: none
- Face support: generally not required
- Without or with invert: without invert

e) Support Category B1
- Advance length: 1.70m
- Thickness of shotcrete and reinforcement: 15cm, 1 layer of mesh reinforcement Q189, lattice girder 70/20/30
- Number and length of rock bolts: SN bolts 4m long, pattern 1.70x2.00
- Number and length of spiles: 29 pc l=4.0m
- Face support: if required
- Without or with invert: without invert

f) Support Category B2
- Advance length: 1.70m
- Thickness of shotcrete and reinforcement: 20cm, 2 layers of mesh reinforcement, 2 layers of wire mesh Q189, lattice girder 70/20/30; deformation slots (if necessary due to delayed deformation behaviour)
- Number and length of rock bolts: SN bolts l=4.0m pattern 1.70x1.50
- Number and length of spiles: 29 pc l=4.0m
- Face support: shotcrete
- Without or with invert: without invert

g) Support Category C1
- Advance length: 1.30m
- Thickness of shotcrete and reinforcement: ds=25cm, 2 layers of wire mesh Q283, lattice girdeer 95/20/30
- Number and length of rock bolts: SN bolts l=4.0m pattern 1.30x1.50
- Number and length of spiles: 31 pc, l=3.0m
- Face support: Shotcrete

- Without or with invert: without invert

h) Support Category C2
- Advance length: 1.30m
- Thickness of shotcrete and reinforcement: 25cm, 2 layers of wire mesh Q283, lattice girdeer 95/20/30
- Number and length of rock bolts: SN bolts l=4-6m, pattern 1.30x1.25
- Number and length of spiles: 39 pc, l=3.0m
- Face support: Shotcrete
- Without or with invert: with shotcrete invert

i) Support Category D
- Advance length: 1.0m
- Thickness of shotcrete and reinforcement: 30cm, 2 layers of wire mesh Q283, lattice girdeer 95/20/30
- Number and length of rock bolts: SN bolts l=6m, pattern 1.00x1.25
- Number and length of spiles: 39 pc, l=3.0m
- Face support: Shotcrete, wiremesh and face dowels, ecvavation in pockets (if required)
- Without or with invert: with invert

j) In a similar manner Support Category drawings are provided for the sections of Layby-niches, Cross Passages and Emergence Escape Tunnel.

k) The support measures shown in the drawings for each Support Category shall be understood to as preferred guideline, but subject to adjustments during construction to local needs arising from the behaviour of the rock mass and rock mass / support interaction under specific circumstances.

4.2 RELATION OF ROCK SUPPORT TO ROCK MASS TYPES AND BEHAVIOUR

a) The design of the Support Categories has considered various factors influencing the required measures to excavate and support the tunnel. The primary factor is the Rock Mass Type (RMT) defined in the Geotechnical Report. Four different RMT are distinguished in this project: L1, L2, L3 and F, refer to Table 1. The L types differ primarily in the degree of fracturing of the limestone. The F type characterizes a cataclastic fault zone, which may appear in limited length.

Ground type	Rock type	Description	Properties of rock mass: Weathering grade	RQD	RMR	Properties of discontinuities: JRC	bedding thickness	discontinuity spacing	block size	Geological strength index	Properties of intact rock (prevailing): Strength R (MPa)	Abrasivity
			5 4 3 2 1 0	[%]	[-]	1 2 3 4 5 6 7 8 9 10	[cm]	[cm]	[cm]	GSI	0 1 2 3 4 5 6 7	CAI
			residual soil / completely / highly / moderately / slightly / fresh	<20 / 20-40 / 40-60 / 60-80 / 80-100	V (<21) / IV (21-40) / III (41-60) / II (61-80) / I (81-100)	0-2 / 2-4 / 4-6 / 6-8 / 8-10 / 10-12 / 12-14 / 14-16 / 16-18 / 18-20	<0.6 / 0.6-2 / 2-6 / 6-20 / 20-60 / 60-200 / >200	<2 / 2-6 / 6-20 / 20-60 / >200	<6 / 6-20 / 20-60 / 60-200 / >200	min / applied / max	0.6-1 / 1 - 5 / 5 - 12.5 / 12.5 - 25 / 25 - 50 / 50 - 100 / 100 - 250 / >250	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	
L1	limestone	slightly fractured limestone, thick bedding								60 70 80		laboratory tests pending
L2	limestone	moderately fractured limestone								40 50 60		
L3	limestone	highly fractured limestone								20 30 40		
F	cataclastic limestone, fault gouge	cataclastic fault zone					not applicable			0 10 20		

prevailing subordinate

(1) ground type designation
(2) rock types/lithologies relevant for particular ground type
(3) typical appearance of rock mass types, based on information from surface mapping, core photos and borehole data
(4) typical range of weathering grades, based on keyoutcrop documentation
(5) typical range of RQD, based on borehole data
(6) rock mass rating system after Bieniawski 1989
(7) joint roughness coefficient after Barton & Choubey 1977
(8) typical range of bedding thickness, based on key outcrop documentation
(9) typical range of disconitnuity spacing, based on key ouctrop documentation
(10) typical range of block size, based on key ouctrop documentation
(11) GSI classification (applied for RocLab parameter assessment)
(12) strength range of intact rock based on key outcrop documentation and laboratory test results

Table 1: Characteristics of project-specific Rock Mass Types

a) In addition to the RMT, the primary stress, orientation of the discontinuities and influence of water will mainly govern the behavior during tunneling. To cope with these influences,
   - Support Category B2 provides deformation slots for tunneling in high stress, where the deformation takes considerable time and distance to cease (and hard shotcrete may crack)
   - Support Categories C2 and D provide inverts to close the ring
   - Support Category D provides a toolbox of typical soft ground tunneling measures

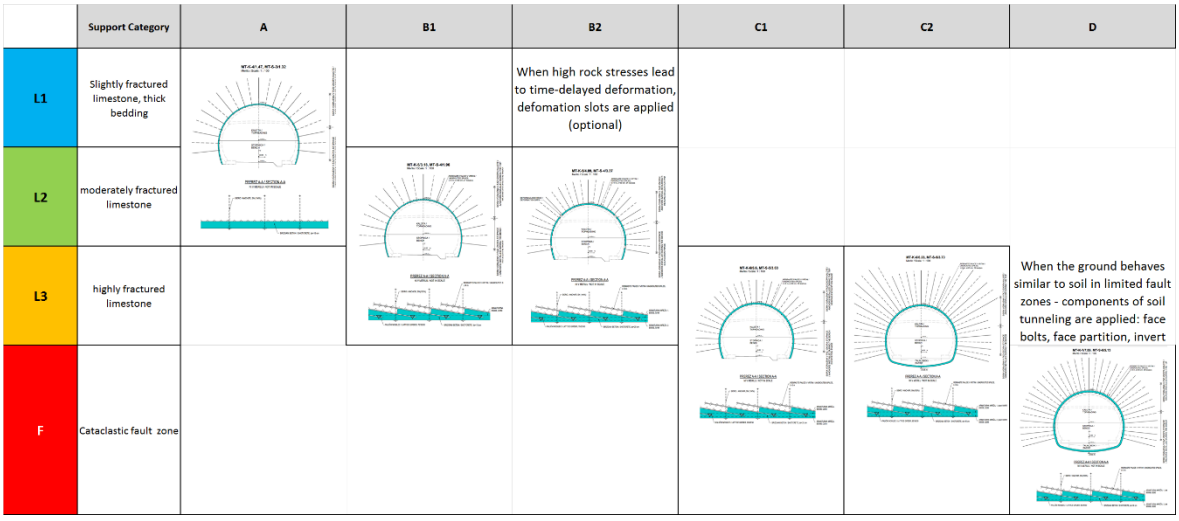

Figure 1: Correlation between Rock Mass Types and Support Categories (for Main Tunnel Section)

4.3 DECISION PROCESS FOR SUPPORT CATEGORIES

4.3.1 PARAMETERS FOR THE DECISION PROCESS

a) The decision on a predetermined support type and possible potential deviations, any additional measures and the sequence of excavation and installation of support measures must be based on:
- Encountered Rock Mass Type, or variation thereof
- Ability to control the excavation profile and to avoid undesired overbreak
- Interpretation of the results of geotechnical and geodetic measurements in the area of influence; Amount of deformation and time-dependency
- Previous experience with the tunnel system behaviour (interaction of rock mass with tunnel support) in similar geological-geotechnical conditions.

4.3.2 DAILY REVIEW MEETING (DRM)

b) The monitoring instrumentation shall be read on a regular basis – as per Drawings and monitoring plan – and the results made available for a daily review meeting (DRM) attended by the senior members of the Contractor's and the Engineer's staff. Input into the meeting shall also include current geotechnical investigations, face logs and any recent non-conformance reports relating to the tunnel construction.

c) The DRM shall be held daily during the excavation of the tunnels unless otherwise agreed by the Contractor and the Engineer. At the meeting the Contractor shall present the current results of monitoring of the tunnels, together with trends in these results and comparison with the deformations predicted by the calculations.

d) The outcome of the meeting shall be a report, the Required Excavation and Support Sheet (RESS), agreed by the Contractor and the Engineer, which states that tunnelling may continue as proposed, or gives the requirements for modifications to the tunnelling (e.g. shorter advances, smaller headings).

e) If no agreed report is available by a specified time each day then the tunnel shall be made safe and tunnelling be stopped.

f) All records from these meetings including face logging and monitoring results shall be kept and be available for inspection until the termination of the contract.

4.3.3 THE REQUIRED EXCAVATION AND SUPPORT SHEET: RESS

a) • Based on the design and the evaluation of the results of monitoring, a RESS will be issued as the outcome of the Daily Review Meeting (DRM). In the absence of any approved changes, the RESS will reflect exactly what is shown on the relevant design drawings.

b) The RESS shall be prepared and endorsed by the Contractor's Site Manager responsible for the tunnelling works and the Engineer on site. Unless both signatures are obtained, the proposals indicated on the RESS shall not be implemented.

c) The RESS shall address, but not necessary be limited to, the following matters:
- the tunnel section(chainages) to which the RESS is applicable
- the support to be installed
- the excavation sequence
- the method of working related to ground support including staging of application of sprayed-concrete layers and lapping of reinforcement
- monitoring to be installed in the tunnel section in question
- measures to be taken during stoppage of works
- other instructions relevant to the tunnel section in question
- reference to relevant Design Drawings

- predrilling (if any)

d) A copy of the RESS will be given to the foreman in charge of the work in the tunnel and shall be kept at the working face.
e) A RESS is required for every metre of the length of the tunnels.
f) If for any reason the approved design method of working is changed, then this will be reviewed prior to the DRM and, subject to acceptance by the Engineer, a new RESS will be issued.

5. TUNNEL SUPPORT

5.1 GENERAL REQUIREMENTS

a) 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.

5.1.1 CONSTRUCTION METHOD

a) 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.

5.1.2 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.

5.1.3 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 categories 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.
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.

5.1.4 CONSTRUCTION TOLERANCES

a) See Section 5 of this Specification.

5.1.5 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.

d) 6.1.6 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 Albanian 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 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 support categories indicated on the drawings and according to the work programme.

5.2 SHOTCRETE

5.2.1 GENERAL

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

b) Wet-mix shotcrete shall be used. Dry-mix shotcrete is not permited.

5.2.2 MATERIALS

5.2.2.1 CEMENT

a) Cement used for preparation of shotcrete shall be in accordance with EN 197-1:2011.

b) Only portland cement types CEM I and CEM II/A-D of strength class 42.5 or higher (according to EN 196-1:2016) are allowed for preparation of shotcrete. To achieve high early strengths, use of type R (rapid) cements is permitted. Only exception to this clause is in areas with increased chemical reactivity of underground waters where use of cement type CEM III/A is allowed.

c) Minimum fineness of cement as measured with Blaine's air permeability test shall exceed 350 m2/kg, but shall not exceed 700 m2/kg

d) Maximum chloride content in cement shall not exceed 0.1% as per EN 197-1:2011. This limit can be breached only when type CEM III/A cement is used.

e) Use of sulphate resistant cements is required in areas with increased chemical reactivity of underground water as shown in the Drawings. Sulphate resistant cement CEM I-SR 0 shall have the total content of tricalcium aluminate (3CaO Al2O3 or C3A) 0% and sulfate content in form of SO3 lower than 3%. Alternatively may sulphate resistant shotcrete be prepared with blast furnace cement of type CEM III/A, having maximum amount of blast furnace slag shall below 30%. Maximum chloride content shall not exceed 0.2%.

5.2.2.2 AGGREGATES

a) Within this Document, terms »aggreggates« and »stone aggreggates« apply to the same material.
b) Normal weight stone aggregate shall comply with EN 12620:2002. Lightweight and recycled aggregates made of crushed concrete are not permitted.
c) Aggregates shall be obtained only from sources that demonstrate capability of producing the quantities required for the Works at a consistent quality. If supplier of aggregates or supplying location (quarry) is to be changed, Engineer shall be notified at least 28 days in advance and pre-construction tests performed.
d) Aggregates shall be free from earth, clay, loam and soft, clayey, shale or decomposed stone, organic matter and other impurities, and shall be hard and dense. Minimum required density 25 kN/m3.
e) Aggregates shall be stored and handled in a way that prevents contamination with other materials or other sizes or types of aggregate and allows free drainage of water.
f) Aggregates shall be clean and checked for potential chemical reactions and deleterious organic materials according to EN 1744-1:2010. If the analysis indicates potential problems, the source of the aggregate shall be changed or, if this is not possible, its use must be approved by the Engineer, after evaluation of its influence on the quality and durability of the shotcrete.
g) Aggregates shall not contain a total mass of reactive alkali greater than 2.0 kg/m³ of concrete or other matter likely to affect the long-term durability.
h) Aggregate shall be uniformly well graded and shall not exhibit extremes of variation.
i) Grading of aggregate for preparation of shotcrete for the Works shall lie within the envelope of the following table
j) ISO sieve (mm) Min % by mass Max % by mass

k) ISO sieve (mm)	Min % by mass	Max % by mass
0.125	4	12
0.25	11	26
0.5	22	50
1.0	37	72
2.0	55	90
4.0	73	100
8.0	90 (plain shotcrete) 100 (fibrecrete)	100

Table 1 Grain size distribution for shotcrete

l) Coarse aggregates (4-11.2 mm) shall not contain larger amount of long angular grains i.e. maximum grain size shall not exceed 11.2 mm in any dimension.
m) Coarse aggregate to be tested for drying shrinkage characteristics. Drying shrinkage shall not exceed 0.1%.
n) Maximum grain size for plain shotcrete shall not exceed 11 mm and 8 mm for fibre-reinforced shotcrete unless otherwise approved by the Engineer.
o) Both fine and coarse aggregates shall be tested for potential aggregate cement reactivity.
p) Stone aggregates shall be stored in covered area to be protected from rainfall and cold weather minimum of 48 hours before being used in shotcrete production.

5.2.2.3 MINERAL ADDITIVES

a) The most commonly used cementitious additives in shotcrete are fly ash (PFA), ground granulated blast furnace slag (GGBS) and silica fume.
b) The maximum level of additives by weight of cement shall not exceed the following: PFA 15%, GGBS 30% and silica fume 20% by total weight of cement in the shotcrete mix.
c) Fly ash to be used for preparing shotcrete for the Works shall have equal to or more than 60% by total weight of dry mass composed of three main chemical components (SiO2, Al2O3, Fe2O3). Content of SiO2 shall exceed 30%.
d) Calcium content (CaO) in fly ash shall be equal to or higher than 15%, but not above 25%. (testing as per EN 451-1:2017).
e) Alkali content of fly ash shall not exceed 3% Na2O Eq uivalent if aggregates used do not exhibit alkali-silica reactivity and shall be limited to 1.5% if there is potential for alkali-silica reactivity of aggregates.
f) The sulphate content in fly ash shall not exceed 2% by weight of dry mass.
g) The unburned carbon content in fly ash shall not exceed 4%.
h) Fineness of fly ash shall exceed 500 m2/kg.
i) Ground granulated blast furnace slag (GGBS) shall have SiO2 content higher than 35% by weight of dry mass. Also CaO content shall be higher than 35% by weight of dry mass. The ratio by mass (CaO + MgO)/(SiO2) shall exceed 1.0.
j) Fineness of GGBS shall exceed 450 m2/kg.
k) The optimum content of cementitious additives shall be determined during site trials.

5.2.2.4 CHEMICAL ADMIXTURES

a) This Section sets forth the requirement for use of set accelerators and other chemical admixtures to improve fresh and hardened characteristics of the shotcrete.
b) All chemical admixtures shall comply with EN 934, parts 1, 2 and 5.
c) Admixtures containing chlorides shall not to be used. Chloride ion content shall not exceed 0.1% by mass of the chemical admixture.
d) Admixtures which negatively affect durability of shotcrete shall not be used.
e) Handling with chemical admixtures shall fully comply with manufacturer’s instructions and recommendations. Liquid admixtures shall be stored according to manufacturer's instructions to prevent their evaporation or freezing. It is strictly prohibited to use any admixture which shelf life had expired, it was frozen, or its characteristics do not comply with manufacturer’s description of the material.
f) Admixture suppliers are required to provide all necessary information and data on recommended admixture dosage, suitability of admixture for intended use and its effect on shotcrete characteristics, including previous experience, references to projects where admixture had been used and comprehensive safety data (MSDS).
g) Only alkali-free set accelerators, i.e. Na2O equivalent content shall be less than 1% and pH in range of 3-8%, shall be used. Use of alkaline accelerators shall be strictly forbidden.
h) Alkali-free set accelerators shall comply with EN 934-5:2008.
i) Only liquid alkali-free set accelerators shall be used for all wet-mix spraying operations for the Works.
j) Only the minimum quantity of accelerator necessary shall be permitted in the normal spraying operations to fulfil requirements of this Document with regards to early strength development. Optimum quantity shall be determined by the pre-construction site trials.
k) At no stage in the strength development course shall the strength of the accelerated mix drop below 0.9 times the strength of the un-accelerated shotcrete. This requirement has to be proved by laboratory and site tests for each proposed mix design.
l) Accelerator dosage can be reduced from the optimum dosage determined by site trials for spraying

downwards from horizontal plane (inverts), subject to approval by the Engineer.

m) m.)

n) The stability of accelerators during storage shall be visually inspected at regular intervals. Storage times and temperature ranges shall be in accordance with the manufacturer's recommendations to ensure specified behaviour.

o) Plasticisers i.e. water reducing agents, workability retaining agents, hydration control (retarders), mix stabilizers, thixotropic and internal curing agents may be used for the preparation of shotcrete for the Works. All admixtures shall be trial tested prior to construction to evaluate performance, compatibility between the different admixtures and their overall effect on the concrete quality and durability. Optimum dosages of these admixtures shall be determined during these site trials and shall not exceed the maximum dosage recommended by the manufacturer or limits in next clauses (whichever is stricter).

p) Usage of abovementioned chemical admixtures in regular spraying operations is subject to approval by the Engineer.

q) Addition of new admixtures, change of type of already permitted admixtures or change in their dosage is not allowed without written consent of the Engineer. Any considerable change in the mix design requires new acceptance tests outside the area of the Works.

r) For reduction of mixing water in the fresh shotcrete mix, only high range water reducing agents based on the modified polycarboxylic ether (PCE) shall be used. Maximum dosage of high range water reducing agent shall not exceed 1.5% by weight of cementitious materials.

s) Workability retaining agents may be used to extend the workability of shotcrete treated with high range water reducing agents. Maximum dosage of hydration control agents shall not exceed 1.0% by weight of cementitious materials.

t) Hydration control agents may be used to control the hydration of the mix i.e. to increase the pot life of the fresh shotcrete. Maximum dosage of hydration control agents shall not exceed 1.0% by weight of cement per m3 of shotcrete. Maximum pot life of shotcrete treated with hydration control agents shall be determined by site trials.

u) Stored shotcrete treated with hydration control agents shall be re-mixed thoroughly before use and be protected against evaporation in order to avoid any change in the initial quality and consistency.

v) Selected hydration control agent shall have no negative influence on the accelerator dosage i.e. due to the addition of hydration control agents the maximum accelerator dosage cannot be exceeded.

w) Mix stabilizers may be used to improve pumpability of the fresh mix, reduce bleeding and segregation. Effectiveness of proposed substance shall be verified by thecomparison to untreated shotcrete during site trials.

x) Thixotropic admixtures may be used to reduce rebound and prevent sagging of fresh shotcrete. Effectiveness of proposed substance shall be verified by the comparison to untreated shotcrete during site trials.

y) Internal curing compounds may be used to help with curing of shotcrete when thin layers of shotcrete need to be applied in hot weather conditions. Effectiveness of proposed substance shall be verified by the comparison to untreated shotcrete during site trials. Site trials shall also verify that proposed substance has no deleterious effects on the long term strength of hardened shotcrete (with internal curing agent treated shotcrete shall exhibit increase of compressive strength by at least 5% from 28-day to 56-day test).

5.2.2.5 FIBRES

a) Steel or synthetic fibres can be used for fibre-reinforced shotcrete. Steel fibres shall comply with EN 14889-1:2006 and synthetic fibres with EN 14889-2:2006.

b) Steel fibres shall be of cold drawn wire type i.e. type I according to EN 14889-1:2006, with an aspect ratio of 40 to 70 and of a single length ranging from 30 mm to 40 mm. Minimum tensile strength of 1200 N/mm2.

c) Steel fibres shall have bent or deformed ends for improved anchorage. Straight or continuously corrugated fibres shall not be used for the Works.
d) Synthetic fibres shall be of type II according to EN 14889-2:2006. Both, virgin and recycled polypropylene macro-synthetic fibres can be used.
e) Synthetic fibres shall be of a single length ranging from 45 mm to 65 mm with continuous embossing anchorage. Aspect ratio of synthetic fibres to be used shall be in range 50 - 100. Minimum tensile strength of 500 N/mm2. Minimum elastic modulus of 6 GPa. Fibres with lower tensile strength and/or lower elastic modulus may be used, subject to approval by the Engineer if flexural toughness of minimum of five (5) consecutive tests exceeded required values for compressive strentgh and flexural toughness requirements prescribed with these specifications
f) .
g) e.)f.) Glass fibres are not permitted.
h) f.)g.) Fibre-reinforced shotcrete shall be only applied by the wet-mix process.

5.2.3 MIX DESIGN

5.2.3.1 GENERAL REQUIREMENTS

a) The Contractor is responsible for the design of shotcrete mixes and for the quality of installed shotcrete.
b) Any shotcrete mix shall be designed to allow the required design life of underground structures, to achieve or exceed the specified compressive / flexural strength and other specified properties below, using materials which comply to the requirements provided in Section 6.2.2.
c) Shotcrete mix shall be first developed by laboratory compatibility tests and optimized by site trials as specified in this Section. Each shotcrete mix to be used shall further successfully pass the pre-construction acceptance test.

5.2.3.2 MIX PROPORTIONING

a) Selected shotcrete proportions shall satisfy the requirements for fresh and hardened shotcrete listed in this Document.
b) Cement content shall be defined based on the required early and long-term compressive strength development of shotcrete to be used for the Works.
c) Minimum total cement content shall be 350 kg/m3 for any shotcrete mix to be used for the Works.
d) Water-to-cement ratio shall be lower than 0.45 (including water in the admixtures or silica fume slurry) and shall be low enough to allow reaching the required final compressive strength. The natural moisture content of aggregates shall be taken into consideration when determining the water demand of the shotcrete mix.
e) High range water reducing agents (also referred to as hyperplasticisers) shall be used to reduce the total amount of required mixing water in the fresh mix to reduce bleeding and segregation of fresh shotcrete during transport and pumping and reduce shrinkage of hardening shotcrete.
f) Workability of fresh shotcrete used for the Works shall be:
g) Recommended slump in range of 150 – 200 mm for slump test according to EN 12350-2:2009. Slump shall not be outside of the range 120 – 240 mm.
h) Recommended flow diameter in range of 550 – 620 mm for flow table test according to EN 12350-5:2009. Spread diameter shall not be outside of the range 500 – 650 mm.
i) Dosage of the fibres used in fibre-reinforced shotcrete for the Works shall be sufficient to meet the required flexural toughness as specified in this specification.
j) While use of silica fume is optional for the plain shotcrete, it is recommended for the fibre-reinforced shotcrete to allow for sufficient anchorage of fibres in the cement matrix. Dosage of silica fume in combination with fibres shall allow reaching the required flexural toughness requirements.
k) For the environmental reasons, the amount of soluble water admixtures shall be reduced to

minimum and replaced with non-soluble admixtures

5.2.3.3 COMPRESSIVE STRENTGH AND FLEXURAL TOUGHNESS REQUIREMENTS

a) Shotcrete used for the Works shall have an early strength development corresponding to the red line in Figure 6 as follows:
- 0.3 MN/m² after 3 minutes
- 0.6 MN/m² after 30 minutes
- 3.0 MN/m² after 6 hours
- 10 MN/m² after 24 hours

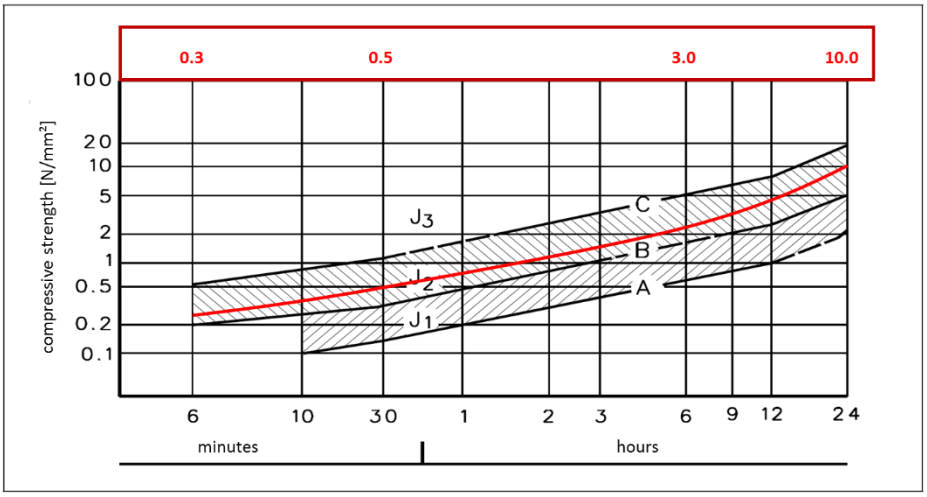

Figure 6: Early strength requirement for shotcrete

b) Long-term compressive strength development (after 24 hours) shall conform with the specific concrete grade.

c) To exclude detrimental effect of chemical admixtures on the long term shotcrete strength, compressive strength of shotcrete after 56 days shall exceed the 28-day strength by minimum of 5% as tested on core samples. One core from the set tested can be below this margin, but its 56-day strength shall be above 28-day result provided that both cores were taken from the same panel.

d) Flexural strength of the fibre-reinforced shotcrete to be used for the Works as tested with panels in accordance with EN 14488-5 and expressed in terms of the energy absorption capacity shall be Class EV700.

5.2.3.4 SITE TRIALS

a) Site trials shall be performed in a place outside the Works with ambient temperatures and humidity similar to the expected conditions in the Tunnels. Site trials shall be performed in presence of the Engineer.

b) Site trials shall employ the wet-mix shotcrete spraying equipment which will be used during the Works. The trials will establish whether the selected spraying equipment is capable of efficiently mixing shotcrete, accelerator and air at the nozzle.

c) For shotcrete mixes, site trials shall determine:
   a. early and long-term compressive strength development of proposed mixes under field conditions using actual spraying equipment that will be used;
   b. optimum water-to-cement and water-to-binder ratios;
   c. compatibility of water reducing agents and hydration control agents with cement and accelerator used in proposed shotcrete mixes;
   d. optimum dosage of water reducing and hydration control agents to achieve planned properties of fresh shotcrete (workability, pot life);

e. design range of slump or flow table spread diameter;
f. optimum dosage of accelerator to achieve planned early strength development of placed shotcrete;
g. effect of accelerator on the long-term strength development of proposed shotcrete mixes;
h. effectiveness of mix stabilizers, thixotropic admixtures and internal curing compounds by the comparison to untreated shotcrete (if used in proposed mixes);
i. effect of internal curing compound on the long-term strength (if used in proposed mixes);
j. flexural toughness and fibre-count for fibre-reinforced shotcrete.

d) Dosing chemical admixtures by hand into the mixing type transmixer is exceptionally allowed during the site trials to be able to explore their effect on the properties of fresh and hardening shotcrete. The dispersion of additive in the mix shall be forced with thorough mixing.
e) Once 28-day compressive strengths and flexural toughness results were obtained, final recipes of shotcrete mixes with optimized dosages of cement, cementitious additives and chemical admixtures can be derived. These final recipes shall be submitted to the Engineer for approval. Engineer shall either approve or reject mixes within 5 days. Approved mixes can proceed to the pre-construction acceptance testing stage.

5.2.4 THE CONTRACTOR's INTERNAL QUALITY CONTROL

5.2.4.1 GENERAL REQUIREMENTS

a) Programme of the Internal Quality Control of shotcrete consists of continuous regular construction testing and as directed construction testing of shotcrete as required by the Engineer.
b) Programme of the Internal Quality Control of shotcrete includes the following tests:
   1) workability of fresh shotcrete mix,
   2) testing of early strength development (up to 10 MPa),
   3) testing of long-term strength development (above 10 MPa) of samples either drilled from purpose-sprayed panels or in-situ drilled from primary lining,
   4) testing of flexural toughness of fibre-reinforced shotcrete samples either drilled from purpose-sprayed panels or in-situ drilled from primary lining,
   5) fibre count in fresh and sprayed shotcrete.
c) Programme of the Internal Quality Control of shotcrete is of sole responsibility of the Contractor and shall be executed throughout the Works with frequency specified in this Document. All test listed above shall be executed according to the provisions of respective standards and provisions of this Document. Whenever in conflict, provisions of this Document take precedence.
d) Programme of the Internal Quality Control of shotcrete includes complete process of shotcrete testing:
   1) (samples from panels) fabrication of suitable panels, spraying shotcrete into panels, execution of on-site tests, curing and manipulation with panels on site;
   2) (in-situ samples from primary lining) coring of samples from primary lining;
   3) transport of panels with shotcrete to the Accredited Testing Agency;
   4) coring of suitable cylindrical samples from received panels (for testing long-term compressive strength);
   5) appropriate curing of samples;
   6) testing of samples and
   7) preparation of formal testing report with the specified content.
e) If requested, the Engineer and External Quality Control shall be allowed to witness the execution of any phase in the process of shotcrete testing, including all activities in the Accredited Testing Agency.
f) Traceability of shotcrete is also part of Internal Quality Control programme. Shotcrete delivery tickets with required information shall be required for all shotcrete to be used for the Works.

g) Required workability and early strength testing of shotcrete (Penetrometer, Shooting Test) shall only be performed by properly trained and skilled personnel to ensure execution of tests according to the provisions of referenced standards and requirements of this Document.
h) Required coring of samples from in-situ shotcrete for testing of long-term compressive strength and flexural toughness shall only be performed by properly trained and skilled personnel to ensure suitability of samples according to the provisions of referenced standards and requirements of this Document.
i) 6.2.4.2 Required testing programme
    1) Workability of fresh shotcrete mix
        a.) Workability of shotcrete shall be confirmed performing slump test according to EN 12350-2:2009 or flow table test according to EN 12350-5:2009.
        b.) Slump tests shall be applied only to slumps lower than 220 mm; from 220 mm onwards the flow table test shall be used.
        c.) Workability shall be determined for each 10th batch delivered to the site or produced on site or on demand of the Engineer. If slump or spread diameter are outside of the confirmed design range, shotcrete shall not be used.
        d.) Obtained slump or flow table spread diameter shall be recorded on the Shotcrete Delivery Ticket and in the Shift Report, if a regular construction test was performed.

5.2.4.2 EARLY COMPRESSIVE STRENGTH DEVELOPMENT OF APPLIED SHOTCRETE (UP TO 10 MPA)

a) Early compressive strength development of shotcrete for the Works shall be tested using the Penetration Needle Method and Bolt Driving Method Pull-out Test (measuring range 2 to 16 N/mm2 - green cartridge) in accordance with EN 14488-2:2006.
b) Early strength testing shall be performed on a shotcrete layer of a minimum thickness of 100 mm.
c) Execution of early strength testing within regular periodic testing shall only be performed on shotcrete sprayed in suitable panels. Shotcrete shall be sprayed in panels in one pass. If problems had occurred during spraying e.g. blockage of pipes or nozzle, shotcrete in panel shall be discarded and panel sprayed again.
d) Penetration Needle Method measures the force needed to drive a needle into freshly sprayed shotcrete; the force obtained is correlated to compressive strength of a cube. Measuring range of 0.2 to 1.0 N/mm2. Mechanical or digital penetrometers can be used as long as the needle diameter and tapered tip comply with the requirements in EN 14488-2:2006.
e) Penetrations shall be performed evenly along the tested surface of a panel or patch, distance between penetrations within one set of penetrations and offset to the edge of a panel or patch shall exceed 50 mm. If the tip hits a larger grain of aggregate, the result shall be discarded and additional penetration tests taken in the vicinity.
f) Regular construction testing: Minimum of three (3) valid sets of 10 penetrations shall be performed for each panel i.e. minimum of three strength points within the measuring range of penetrometer shall be obtained for the strength development curve. Based on the previous experience with respecitve mix, schedule testing at such times that one reading is obtained at roughly 0.35 N/mm2, one at around 0.60 N/mm2 and one as close to 1 N/mm2 as possible.
g) Reporting: for each regular construction testing only field testing data to the Penetration Needle Test report with the following content:
    a. designation of shotcrete mix used,
    b. Shotcrete Delivery Ticket number of shotcrete used,
    c. type of accelerator and its dosage,
    d. workability of shotcrete (slump or spread diameter),
    e. ambient temperature and temperature of shotcrete in a panel,
    f. date and exact time when spraying of a panel was completed,

g. Tunnel, heading, drift, chainage, excavation round and layer where shotcrete was applied,
h. Nozzleman that furnished the panel,
i. results of 10 valid penetrations for each set of penetrations, time lapse from spraying, mean value of readings, derived cube strength in [N/mm2],
j. chart showing calibration curve and connection average value of penetration readings through the calibration curve to strengths.

h) Bolt driving pull-out test (further referred to as Shooting Test) allows determination of strength development in the range of 2 – 16 N/mm2 using green cartridge. Stud-bolts are driven into the shotcrete, offset measured and pulled out measuring the force. Compressive strength of a cube is derived based on a ratio of pull-out force to the penetration depth using the conversion line.
i) For the Works, Shooting Test shall be used for the determination of shotcrete strength development in the range of 2 – 10 N/mm2. Shooting Test shall be used for regular production testing and to verify the blasting requirement.
j) Verification of the blasting requirement: as required strength is at the borderline of the method's range, the results obtained with shooting test are not 100% reliable. Long 105 mm stud-bolts, one at the time, shall be fired into the hardening shotcrete in regular time intervals based on the previous experience with strength development of the respective mix. Bolts shall be placed at minimum spacing of 80 mm and minimum of 150 mm from the edge of a panel. When protruding length exceeds 1/3 of the stud-bolt's length, shoot another 2 bolts at different locations. If offset on both is minimum of 1/3 of length, shotcrete has sufficient strength to pull the trigger on a blast. Otherwise continue with the procedure described herein..
k) Regular construction testing: 10 stud-bolts at minimum distance of 80 mm and minimum of 150 mm from the edge of a panel shall be fired into the hardening shotcrete for one test. At least two Shooting Tests shall be performed per single regular construction testing i.e. minimum of two strength points within the allowed measuring range shall be obtained for the strength development curve. Based on the previous experience with the respective mix, schedule testing at such times that one reading is obtained at roughly 3 N/mm2 and other one around 7 N/mm2. In general, 2 Shooting Tests shall be performed minimum of three (3) hours apart.
l) Reporting: for each regular construction testing only (not required for verification of the blasting requirement), fill testing data to the Shooting Test report with the following content:
    a. designation of shotcrete mix used,
    b. type of accelerator and its dosage,
    c. workability of shotcrete (slump or spread diameter),
    d. ambient temperature and temperature of shotcrete in a panel,
    e. date and exact time when spraying of a panel was completed,
    f. Tunnel Project, heading, drift, stationing, excavation round and layer where shotcrete was applied,
    g. Nozzleman that furnished the panel,
    h. mean time lapse from spraying,
    i. table with results of 10 valid stud-bolt tests for shooting test including stand-offs, penetration depth, pull out load, calculated ratio of pull-out force to the penetration depth,
    j. chart showing calibration curve and connection of calculated ratio of pull-out force to the penetration depth through the calibration curve to strengths.
m) Reporting: The Penetration Needle Test report and all Shooting Test reports shall be attached to the Daily Contractor's Report. Results of early strength testing shall be also presented in graphic form which shall include the chart of early strength requirements from EN 14488-2:2006, added long-term strength requirements and obtained strength development curve of shotcrete.
n) Penetration Needle Test report and all Shooting Test reports shall be submitted within one (1) day of testing.
o) Shotcrete shall be considered compliant if less than 15% of obtained data points on the strength

development curve up to 10 MPa is below the required early class curve.

5.2.4.3 LONG-TERM COMPRESSIVE STRENGTH DEVELOPMENT OF APPLIED SHOTCRETE (ABOVE 10 MPA)

a) Test panel size for testing long-term compressive strength development of shotcrete shall be minimum of 600 mm square (bottom of panel) by minimum depth of 115 mm. Panels shall be made with sloped 1:1 sides to allow escape of rebound.
b) Three panels shall be sprayed inside the heading with ambient temperatures and humidity similar to the face. Panels shall be placed at 60° angle from horizontal on stable surface and secured against movements. Panels shall be sprayed in same manner as spraying operations for the Works (distance and angle of the nozzle to the receiving surface). The shotcrete in all test panels shall adhere well to the formwork, be properly compacted, free of rebound and exhibit no sagging.
c) Test panels shall be clearly marked for later identification in the laboratory (minimum required information: mix designation, location, date and exact time of shotcrete placement, consecutive identification number of test and panel number). Waterproof marker on plasticized tag shall be used.
d) Panels shall not be moved within 24 hours after spraying for J2 and J3 class shotcrete or 48 hours for J1 class shotcrete and shall be stored without disturbance. Exception: panels can be moved within given time span for all classes of shotcrete, if it has been unambiguously proved that compressive strength of shotcrete in panels has exceeded 10 N/mm2.
e) Test panels or cored samples from these panels shall be cured in accordance with EN 12390-2:2009, but in ambient temperatures and humidity representative to the tunnels. Test panels or cores shall not be submerged in water.
f) When the compressive strength of shotcrete in panels exceeded 10 N/mm2, a minimum of six (6) full depth, 100 mm diameter cores shall be cored from each panel as per EN 12390-1:2013. No core shall be taken from within 150 mm of the upper edge of a test panel (50 mm from the bottom edge). Specimens shall be cut to a length equal to the diameter and marked from which panel they were cut.
g) Cores shall be visually inspected and graded. Good quality photos of cores shall be taken.
h) Prior to testing, each specimen shall be clearly marked with the batch and specimen number of sufficient size that will be clearly seen on the photos.
i) Compressive tests according to EN 12390-3:2009 shall be performed on minimum of three (3) cores at 1 day for J2 and J3 class shotcrete and 3 days for J1 class shotcrete, 7, 28 and 56 days after spraying. For any test at a given time, cores from different panels shall be selected.
j) Additional set of cores shall be tested at 28 days if previous tests exhibited non-compliance of shotcrete to the required strength.
k) Mechanical rebound hammers shall not be used to obtain the indirect compressive strength of shotcrete.
l) Bolt driving method pull-out test (measuring range 17 to 56 N/mm2 – yellow cartridge) according to ÖBV Guideline “sprayed concrete” shall not be used for the determination of the long-term compressive strength of shotcrete for the Works.
m) Reporting: attach to the Daily Contractor’s Report the Shotcrete Compressive Strength Testing report issued by the Accredited Testing Agency which shall include:
    a. consecutive identification number of test,
    b. identification numbers of specimens including panel number,
    c. shotcrete mix designation,
    d. date and time of shotcrete application ,
    e. Shotcrete Delivery Ticket number of shotcrete sprayed for test,
    f. date and time when specimens were tested,
    g. age of specimens,
    h. curing procedures,

i. dimensions of specimens prior to test,
j. grades of samples,
k. load-deformation curve for specimens from same batch on a single chart,
l. calculated compressive strength for each specimen and average compressive strength of all specimens from the same batch,
m. average compressive strength of cubes: multiply average compressive strength of cylinders with 0.80 as per Eurocode 2,
n. type of failure for each specimen,
o. good quality photos of intact and broken specimens with clearly visible identification numbers.

n) Shotcrete Compressive Strength Testing report shall be submitted within one (1) day of testing.
o) Average compressive sterngth of tested specimens shall exceed required compressive strength at a given time with no individual specimen having compressive strength of less than 85% of the required value to consider shotcrete acceptable.
p) Flexural strength and toughness of the fibre-reinforced shotcrete to be used for the Works shall be tested in accordance with EN 14488-5.
q) The fibre content in the shotcrete shall be established in accordance with EN 14488-7.

5.2.5 EQUIPMENT

5.2.5.1 HANDLING, STORAGE, PREPARATION AND BATCHING

a) Deliver, store and handle materials to prevent cross-contamination and segregation of constitituents, and damage of packaging.
b) Store cementitious materials in dry, protected enclosures and in accordance with manufacturer's recommendation.
c) Storage conditions and handling of admixtures shall fully comply with the manufacturer's recommendations. Store admixtures at all times in clearly marked and labelled watertight containers to guard against dampness, evaporation, freezing, and contamination. If not stored in original containers, label on container shall including admixture name, type, storage requirements, and use-before date as of minimum. Any admixture failing to comply with these requirements shall not be used for the Works.
d) Only batching equipment that proportions entry constituents (stone aggregate, cement, mix water and cementitious additives) by weight shall be utilized for the Works. Batching by volume shall not be permitted. Only liquid chemical admixtures are allowed to be measured by volume. Measuring or dosing admixtures by hand at the batch plant or transmixers shall not be allowed, except for the site trials. Calibration of scales and flow meters used at the batch plant(s) shall take place at regular intervals.
e) The batching facility and proportioning devices shall be capable of providing the exact required mix ingredients in proportions as accepted by the Engineer based on the results of site trials. The measurements of cement, aggregates, water and cementitious additives shall be within ±3% and ±5% accuracy for admixtures dosed at less than 5% of cement weight as per EN 206-1:2013.
f) Shotcrete for the Works shall be prepared in a stationary or mobile batch plant that can provide sufficient volumes of fresh shotcrete mix for the Works and complies with the requirements of this Document. Ready-mix plant and further batching in the batching type transmixers or use of screw type batch plant shall not be allowed.
g) Each batch plant producing fresh shotcrete mix for the Works shall be certificated as per EN 206:2013. If batch plant does not possess a valid certificate, Contractor may obtain Project certificate for batch plant that allows respective batch plant to supply fresh shotcrete mix.
h) Adding water or chemical admixtures to the fresh shotcrete mix after it was discharged from the batch plant i.e. into the transmixers or hopper of the spraying equipment is strictly prohibited,

except for the site trials. Once discharged from the batch plant, only approved workability retaining agent can be added to the fresh shotcrete mix to extend working time of plasticisers provided that the mixing and not agitating type of tranmixers are used. Addition of the chemical shall be clearly marked on the Shotcrete delivery ticket.

i) To enforce the traceability of shotcrete, the Shotcrete Delivery Tickets for all shotcrete used for the Works shall be daily submitted to Engineer within the Shift Report. Shotcrete Delivery Ticket shall contain the following information:
   a. date and exact time when the shotcrete was discharged from the batch plant,
   b. name of supplier,
   c. name of batching plant and location,
   d. batch number at batch plant,
   e. serial number of Shotcrete Delivery Ticket,
   f. mix design designation,
   g. the strength of the mix of shotcrete being delivered,
   h. amount of water added and water-to-binder ratio,
   i. chemical admixtures used and their quantity,
   j. amount of shotcrete delivered,
   k. slump or spread diameter of delivered shotcrete at site,
   l. place where it was sprayed (Tunnel, heading, drift, excavation round and chainage) and volume applied,
   m. exact time when delivered shotcrete was used up,
   n. added chemicals after finished batching (type, quantity, batching time and exact time when added),
   o. volume of discarded shotcrete and reason for it (shotcrete timed out, low slump/ spread diameter, etc.).

5.2.5.2 TRANSPORT OF FRESH SHOTCRETE

a) For road transport of the wet-mix shotcrete from the batch plant to the active heading only mixing or agitating type concrete transporters (transmixers) shall be allowed. Transport of shotcrete shall not adversely alter specified properties with regards to workability, air entrainment, and homogeneity.
b) Transmixers shall be regularly inspected to assure that they are clean and in condition to mix/agitate to deliver a uniform mix.
c) Pumping of shotcrete from the batch plant or temporary storage stations to the active heading may be allowed, subject to approval by the Engineer based on the submitted documents showing setup and detailing procedures.
d) Shotcrete shall be delivered directly from the transmixer into the hopper of spraying equipment with a pump that delivers shotcrete to the nozzle if utilizing wet-mix technology.

5.2.5.3 SPRAYING EQUIPMENT

a) Shotcrete transport pipes and hoses shall be laid straight or in gentle curves and shall be free of any dents or kinks between the shotcrete machine and the nozzle to allow for uniform shotcrete delivery. The transport pipes shall have a uniform diameter appropriate to the characteristics of shotcrete mixes to be used for the Works.
b) Shotcrete delivery equipment shall be leak-proof with respect to all materials and shall be thoroughly cleaned of lumps of hardened shotcrete at least once per shift to prevent blockages of transport pipes or nozzle.
c) The tunnel air and water supply system shall be capable of supplying the spraying equipment at pressures and volumes recommended by the manufacturer of the machine. Air supply systems that deliver air contaminated by oil shall not be used.

d) Spraying equipment is subject to approval by the Engineer. List of equipment to be used and maintenance plan for it shall be made available to the Engineer prior to commencement of site trials. Contractor shall submit to the Engineer maintenance logs for spraying equipment on a weekly basis.
e) If the equipment requirements have not been met and shotcrete cannot be placed to the specified quality, the Engineer can halt spraying operations until all requirements are fulfilled. Additional test panels and test cores shall be provided by the Contractor to demonstrate that the equipment is functioning properly during spraying operation if required by the Engineer based on the observed irregularities in performance of shotcrete equipment or shotcrete quality. Contractor shall not be entitled to compensation for lost time, potential loss of materials and required additional testing due to poor equipment performance.
f) Selected spraying equipment shall be of an adequate capacity for the volumes to be applied depending on the size of a drift.
g) To prevent uneven distribution of accelerator in the applied shotcrete, the shotcrete equipment shall be capable of steady delivery of shotcrete without pulsation i.e. at a regular rate and propelling shotcrete from the nozzle at velocities that will allow adherence of the shotcrete to the surface being shotcreted with a maximum adhesion and density and minimum rebound. For the wet-mix shotcrete application, the use of positive displacement pumps equipped with hydraulic or mechanically powered pistons shall be required, with compressed air added at the discharge nozzle.
h) Selected shotcrete equipment shall have a possibility of delivering air and water to the nozzle so that the Nozzleman may use any combination of the two to prepare receiving surfaces for shotcreting or to clean the completed surfaces or support elements.
i) For any size of drift on the Project shall selected size and configuration of shotcrete equipment allow positioning of the nozzle perpendicular to the surface receiving shotcrete at distance of 1 – 2 m in such manner that all enables sufficien compaction of shotcrete with maximum adhesion and density and minimum rebound.
j) Selected spraying equipment shall allow Nozzleman unobstructed view of receiving surface at any given time (cordless remote control of the spraying arm is preferred).
k) The addition of liquid accelerator into the shotcrete stream shall be computer controlled; accelerator shall be added into the air stream inside the nozzle assembly prior to joining the shotcrete stream. Proportioning of accelerator shall be computer controlled with respect to the measured volume of shotcrete being pumped from the hopper to the nozzle and selected percentage. Amount of accelerator added, flow rates of shotcrete and accelerator shall be displayed on the purposive screen on the robot. Dosing of accelerator by hand shall not be permitted.
l) Selected head and nozzle assembly shall allow for the sufficient mixing of accelerator with the shotcrete stream. Air ring and injection holes shall be checked after each spraying operation. Also, the spray nozzle shall be regularly checked for wear and replaced if required.
m) Accelerator delivery system shall be cleaned at least once per week to prevent crystallization of the accelerator inside the hoses and allow for a sufficient flow. Accelerator delivery system shall be cleaned whenever insufficient discharge of accelerator becomes apparent. Calibration tests to confirm specified delivery of accelerator through the delivery hoses shall be performed monthly or at Engineer's request to prove compliance of actual flow with values on the display.
n) Use of on-board compressors on spraying equipment may be allowed if clean air, free of oil at sufficient and consistent pressure and volume can be provided, subject to approval by the Engineer.
o) Standby spraying equipment meeting aforementioned requirements shall be provided on site, maintained in good working order and operation ready at all times for the duration of Works

5.2.6 APPLICATION

5.2.6.1 PREPARATION OF RECEIVING SURFACE

a) Water used for washing of surfaces before the application of shotcrete or used to remove rebound, overspray and/or surface laitance shall be free of oil and chemical or organic impurities deleterious to shotcrete bond.
b) Ground: excavated ground to the required line and grade, and scale surfaces. Surfaces to receive shotcrete shall be free of loose material, mud and other foreign matter. A combination of water and high velocity air jet shall be used provided that the specified cleaning may not cause undue erosion of the surface. Inverts: all groundwater and cleaning water shall be removed from areas to receive shotcrete before spraying. Spraying into ponding water is strictly prohibited.
c) Shotcrete: remove all deteriorated, loose, unsound material or contaminants that may inhibit bonding by a combination of water and high velocity air jet. All shotcrete surfaces to receive shotcrete shall be saturated surface dry immediately prior to placement of shotcrete i.e. surface is damp, free water on surfaces to receive shotcrete is not permitted.
d) Construction joints in lining: circumferential joints shall have edges tapered to approximately 45 degrees to prevent trapping of rebound. Longitudinal joints shall have square edges, perpendicular to intrados of tunnel lining. Overspray and rebound in these areas shall be chipped away using pneumatic or hydraulic hammers.
e) Structural reinforcement: the surface shall be free of deleterious materials that inhibit bonding, including mud, tunnel spoil or rebound. For new construction, reinforcement laps shall be separated with a clearance of at least three times the diameter of largest aggregate. Reinforcement shall be secured to prevent movement and vibration during spraying. Hardened overspray shall be removed from exposed reinforcement using pneumatic or hydraulic hammers to provide sufficient overlapping of the reinforcement.
f) Form work: if formwork is to be used during spraying operations, the effects of vibration shall be minimized by proper securing of the formwork members. Formwork shall be constructed to allow escape of placement air and rebound.
g) Water leaks: control groundwater inflow and seepage to prevent dissolution of cement and fine aggregates in freshly sprayed shotcrete which would adversely affect quality of the shotcrete layer and inhibit bonding. Any water inflows that might cause deterioration of the shotcrete or prevent adherence, shall be diverted to the bottom of the drift using approved methods such as channels, geo-composite strip drains, pipes or other appropriate means.
h) The following requirements shall be met prior to placement of shotcrete into structural layer:
    a. all receiving surfaces prepared as per requirements of this Section,
    b. structural reinforcement properly installed and at adquate spacing to allow for complete encasement (including contact of steel arches and wire mesh),
    c. construction joints were properly cleaned and free of rebound or other foreign material (mud, tunnel spoil),
    d. receiving surface of preceding shotcrete properly cleaned and damp without free water,
    e. formwork of drainage openings for release of water throught the primary lining to the longitudinal sidewall drainages where required.

5.2.6.2 PLACEMENT REQUIREMENTS

a) Spraying operations for the Works shall be performed only by experienced Nozzlemen.
b) Only shotcrete mixes approved by the Engineer on the pre-construction acceptance shall be used for spraying operations.
c) Sequence of shotcrete installation shall follow the Drawings. Thickness of shotcrete indicated in the

Drawings is the minimum thickness at any point.

d) Rebound material shall not be covered with shotcrete or incorporated into the initial lining.
e) In case of mechanized spraying, an adequately sized robot for the size of a drift to be sprayed is required. To enforce adequate quality of placed shotcrete only mechanized spraying shall be allowed for application of.
f) Working areas for spraying operations shall be well illuminated to provide Nozzleman with good visibility of surfaces to receive shotcrete.
g) The optimum distance between the nozzle and the surface receiving shotcrete shall be 1 - 2 m to ensure placement of shotcrete to the required quality (density and compaction) and proper encasement of reinforcement where present.
h) Compressed air velocity and applied distance of the nozzle from receiving surface shall be the optimum for maximum shotcrete adherence and compaction. If shotcrete is being displaced by further flow (provided proper accelerator dosage and flow for the given shotcrete volumes), nozzle distance shall be increased to allow for good compaction. The relationship between air velocity, accelerator and concrete stream shall be constantly observed during spraying operations.
i) The nozzle shall, in general, be aimed perpendicular to the application surface. In corners, nozzle shall be directed at approximately 45-degree angle or bisect the corner angle.
j) Shotcrete shall emerge from the nozzle in a steady uninterrupted flow. Should the flow become intermittent for any cause, the Nozzleman shall direct nozzle away from the receiving surface until steady flow resumes or stop spraying operations to investigate the cause of intermittent flow.
k) If it is apparent that the accelerator flow is obstructed for any cause and placed shotcrete does not bond to the receiving surface or it is severely displaced by the further flow, the Nozzleman shall direct the nozzle away from the receiving surface until the accelerator flow resumes or stop spraying operations to investigate the cause.
l) Monitor the air ring at spraying robot's head for signs of blockage of individual air holes. Stop spraying and clean air ring if non-uniform discharge of accelerator becomes apparent.
m) For every stage, start application of shotcrete from the bottom and continue upwards to avoid the inclusion of rebound in the lining. Place shotcrete first in corners, recesses and other areas where rebound or overspray cannot escape easily. Maintain a tapered leading edge towards the face, encase steel arches completely.
n) Big cavities (overbreaks) shall be carefully built up in layers up to Line O before the application of the structural layer. Accelerator dosage for these backfilling operations can be altered from optimum dosage.
o) Apply shotcrete properly so sagging or sloughing does not occur. Where movement of shotcrete has occurred adjacent to a slough-off, the affected shotcrete shall be completely removed.
p) Do not apply shotcrete on surfaces submerged in water or water running from substrate. For the inverts: removal of all groundwater and cleaning water from the surface to receive shotcrete is required before the spraying operations can commence.
q) The thickness and profile of shotcrete shall be defined by steel arches, guide wires, depth pins or other means as approved by the Engineer (if steel arches are used in the top heading and not in bench with invert, guide wires, depth pins or other approved means shall be used in invert with bench). All members for thickness and profile control shall be surveyed in place. Maximum distance between points of known thickness and position (including line with final thickness of initial lining on previous excavation rounds) shall not exceed 1.5 m in any direction. Use of modern scanning techniques for profile control during spraying is allowed only if the results are instantly (i.e. in real-time) available to the Nozzleman during spraying so that sufficient lining thickness can be applied with sufficient smoothness.
r) Shotcrete shall be built up to the specified layer thickness by making the minimum number of passes commensurate with control of the applied mix in respect of sag and finished density to reduce lamination of finished product. However, maximum thickness of shotcrete applied in one

session shall not exceed 150 mm. Before proceeding with the next layer, the applied shotcrete shall gain sufficient strength to be able to withstand the weight of succeeding layer without inhibiting the adhesion to the receiving surface. Prior to spraying, loose material, laitance and rebound shall be removed with a blast of air.

s) Shotcrete shall be applied to the full required thickness also at the construction joints, especially at the longitudinal joints between excavation stages, subject to compression loads.

t) Do not reuse rebound, sprayed fibres, overspray or defective shotcree. All scrap shotcrete and its constituents shall be removed from the working area and shall not be further used in later batches for the Works.

u) Surfaces and objects not intended for shotcrete placement (e.g. geotechnical instrumentation cords and boxes) shall be adequately protected from deposit of rebound and overspray or impact from the nozzle stream. If they got coated with shotcrete, they shall be cleaned immediately after spraying (when shotcrete is still soft) to prevent further damage that would occur by chipping away hardened shotcrete.

v) Encasement of reinforcement (wire mesh, steel arches, additional reinforcement): place shotcrete to completely encase reinforcing steel. Encase reinforcement by shooting with sufficient velocity, angles, distance and plasticity of shotcrete so material flows around and behind the reinforcement. Front face of the reinforcement shall remain clean during encasement to prevent obstruction of shotcrete flow. Minimum shotcrete cover of reinforcement shall exceed 20 mm at the intrados of primary shotcrete lining and 50 mm at the extrados of primary shotcrete lining.

w) Spraying shotcrete through more than one layer of bar reinforcement or wire mesh is strictly prohibited. Where initial lining requires more than one (1) layer of wire mesh, each layer of wire mesh has to be completely encased in shotcrete before installation of successive layer.

x) Rebound and overspray shall be removed from exposed overlapping reinforcement at joints as much as possible immediately after completion of spraying to prevent breakage of dowels during execution of subsequent construction stages. Use of compressed air or mechanical means is allowed. Finished surface of shotcrete shall not be eroded if using compressed air.

y) Hardened rebound and overspray on the joints and connection dowels shall be completely removed during the execution of subsequent construction stage using hydraulic or pneumatic hammers. Construction joints shall be properly shaped. Spraying structural layer shall be halted by the Engineer until the abovementioned requirements have been met.

z) Shotcrete shall be left in its natural finish without further working except as required to trim excess thickness or overspray. Shotcrete shall be allowed to gain sufficient strength before being trimmed with an approved cutting screed.

aa) Freshly applied overhead shotcrete shall be considered as a safety hazard. Until the shotcrete hardens the potential of the breakouts of the shotcrete placed in the roof of the tunnel exists. Workers are allowed to enter the Fresh shotcrete exclusion zone only when shotcrete has exceeded a compressive strength of 0.5 N/mm2 as tested by the Penetration Needle Method.

bb) Blasting shall be only allowed when the adjacent shotcrete lining has reached at least 1.5 N/mm2 to prevent the development of micro-cracks in the lining.

cc) Backfilling of invert shall only be allowed once shotcrete in backfill area exceeded compressive strength of 1 N/mm2.

dd) The fresh shotcrete mix shall be used in 90 minutes after batching.

ee) Dust formation shall be minimized by selection of appropriate spraying equipment and by maintaining it in good order, and by means of additional ventilation, negative pressure ventilation or water sprays.

5.2.6.3 SHOTCRETE APPLICATION IN EXTREME WEATHER CONDITIONS

a) Extreme weather conditions are defined as the ambient temperature or surface temperature to receive shotcrete being outside of the range of 5° to 32°. Outside of the abovementioned range are

spraying operations are allowed only with the application of special measures as described herein.

b) The temperature of fresh wet-mix shotcrete at the time of placement shall be in the range of 10° to 27°C. Shotcrete falling outside these boundaries shall be discarded.

c) Being the major component of the concrete mix, aggregates have the major influence on the temperature of the mixed concrete. Under high or low ambient temperature conditions, aggregates shall be stored in suitably protected areas and shall be either cooled or heated to keep the concrete mix temperature within the specified range. Frozen aggregates or aggregates containing frozen lumps shall not be used. Minimum required temperature of aggregates is +5°C. Contractor shall secure adequate amounts of aggregates for potential cold periods in winter time. Maximum temperature of stone aggregates shall not exceed 32°C.

d) Hot weather application: mix, place, and protect shotcrete as follows:
   a. Cool ingredients by chilling water and/or replacing portion of mixing water with ice to maintain shotcrete temperature at time of placement below 27 °C for wet mix, 38°C for dry mix.
   b. Internal curing compounds may be used to help with curing of shotcrete when thin layers of shotcrete need to be applied in hot weather conditions.
   c. Lower temperature of reinforcing steel and receiving surfaces below 32°C before applying shotcrete by atomized fog spray.
   d. When relative humidity in the tunnel decreases below 75%, and for all open-air applications, maintain the shotcrete surfaces in a moist condition by spraying water, covering the surface with an absorptive mat that is kept continuously wet or covering with impervious sheet material for the duration of the curing period i.e. until shotcrete had reached 10 N/mm2.

e) Cold weather application: Protect shotcrete work from physical damage or reduced strength caused by frost, freezing and low temperatures according to the following requirements:
   a. Do not use frozen materials or materials containing ice or snow for preparation of shotcrete mix.
   b. Shotcrete shall be protected from freezing until the shotcrete has obtained a compressive strength of 5 N/mm2.
   c. Potential methods to address cold weather applications include use of warm water in the mixture to a maximum of 60° or heating aggregates, thermal insulation using blanket covers or other measures proposed by the Contractor and approved by the Engineer.
   d. Without applying special measures, spraying operations can commence as soon as the ambient temperature reaches 5°C and has a rising trend. Spraying operations shall be ceased if ambient temperature reaches 5°C and has a trend of decreasing, unless special measures are applied.
   e. Do not place shotcrete on frozen surfaces or surfaces containing frozen materials.
   f. It is strictly prohibited to increase the accelerator dosage above optimum dosage when spraying in low temperature conditions to make up for possible low temperature of fresh shotcrete or low ambient temperature.
   g. If shotcrete does not achieve the required design strength, the Contractor shall cease tunnelling activities until the required strength can be achieved, subject to the approval of the Engineer.

5.3 OTHER STRUCTURAL SUPPORT ELEMENTS

5.3.1 GENERAL REQUIREMENTS

a) Load, transport, unload and store all structural support materials so that they remain clean from mud and protected from damage.

b) Structural support materials shall be stored on well drained platforms, skids or other supports above the ground surface.
c) Heavy corrosion or pitting of steel structural elements shall be cause for rejection. Light rust that has not resulted in pitting is acceptable, subject to approval by the Engineer.
d) Damaged structural support materials shall be clearly marked and removed from site immediately at no cost to the Owner. Use of damaged structural support materials for the Works is strictly prohibited.
e) Contractor is required to maintain on site a stock of bar and wire mesh reinforcement, suitable steel arches, rock bolts, spiles, and grouts, with all required accessories that is sufficient for minimum of 14 days of Works. Consumption shall be calculated based on the forecasted Support categories and on a progress rate equal or greater than the average rate achieved or the rate assumed in the Construction schedule, whichever is greater.
f) Any voids longer than 100 mm in individual borehole for installation of steel structural elements or water inflow larger than 0.5 l/s and lasting for more than 1 hr after drilling shall be immediately reported to the Engineer. Decision on the grouting, backfilling and/or dewatering approach shall be mutually determined by the Engineer and Contractor.
g) Drilling equipment shall be equipped with MWD (»Measurement While Drilling«) technology as per EN ISO 22476-15:2016 i.e. have the capability of recording torque, rotational speed and drilling rate at minimum interval of 100 mm per individual support element.
h) Drilling equipment used for installation of support measures should preferably be total station and computer controlled and should be able to automatically determine the position of a drilling boom to allow for proper line and grade of installed bolts, spiles and pipes.
i) Drilling equipment for installation of radial rock bolts, face dowels and spiles shall be equipped with man basket with control in the bascet. Use of ladders for manipulation with aformentioned steel structural elements shall be strictly forbidden.
j) Rotary percussion drilling shall be utilized for drilling steel structural elements to ensure good directional stability. Drilling with water shall be required. When drilling with water, the penetration rate and water consumption shall be adjusted to the encountered ground conditions to minimse the damage to the rock mass.

5.3.2 LATTICE GRIDERS

5.3.2.1 SUMMARY AND DEFINITIONS

a) Steel arches are part of the passive support of an underground opening and are primarily used for the profile control, for supporting freshly sprayed shotcrete allowing application of thicker layers and to support tails of spiles.
b) Lattice girders are lightweight, three-dimensional welded steel truss state-of-the-art support arches used in modern tunnelling as they allow proper encasement with shotcrete without shadowing.

5.3.2.2 GEOMETRY AND MATERIAL REQUIREMENTS

c) Each individual part of steel arches shall be considered as the construction material, but not fabricated steel arch as a complete unit. Fabricated steel arch shall fully comply with the requirements of this Document.
d) Steel arches shall be designed and fabricated to meet minimum clearances for the applied Support type and under consideration of inaccuracy of placement during construction, material and construction tolerances.
e) Geometry of steel arches shall follow precisely the required contour of the theoretical excavation line. Allowable tolerance for curvature radii is ±30 mm.
f) Size of an arch shall be determined based on the required Line D for the applied Support category including the over-excavation requirement (b). Minimum embedment with shotcrete of 20 mm on

the intrados shall be observed, including any other required reinforcement to be installed on the intrados of the girder e.g. second layer or final wire mesh if required.

g) Circumferential lattice girders will be delivered to the site in segments with plate connections on either side, butt joints will be bolted together at the face. Contractor shall choose the position of butt joints to accommodate its means and methods of construction, subject to approval by the Engineer. As of minimum, butt joints shall be located at each longitudinal construction joint.

h) The circumferential length of a complete lattice girder shall not deviate from the theoretical length by more than 50 mm.

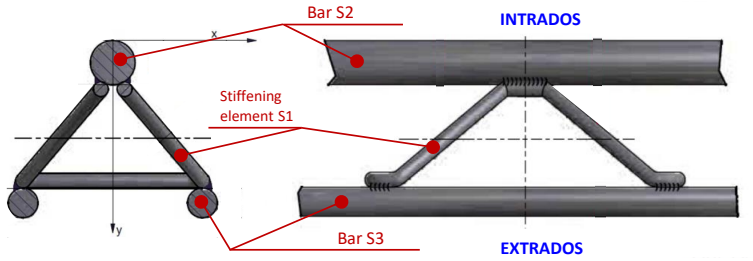

Fig 2: Allowable geometry of lattice girder on the project

i) All circumferential lattice girders shall consist of three primary reinforcing bars (S2 and S3 as shown on Fig 2) arranged in a triangle, connected by stiffening elements – S1. Lattice girders with four reinforcing bars shall not be used on the Project.

j) Lattice girders shall be designed in a way to allow maximum penetration of shotcrete into and behind the girder, thereby minimizing the creation of spray shadows. Therefore, a larger diameter S2 bar shall be on the intrados and two smaller diameter S3 bars on the extrados.

k) All lattice girder members i.e. primary reinforcing bars and stiffener elements shall be ribbed to provide good quality bonding between the steel and shotcrete, in order to form a composite, continuous shotcrete lining. Smooth elements shall not be allowed.

l) Each of the primary reinforcing bars and stiffening elements shall be composed of only one piece of high strength steel having minimum yield strength of 500 N/mm2 and a minimum ultimate elongation of 5% (steel grade B 550 B according to EN 10080:2005 as of minimum). Butt joints for any of the lattice girder's members shall not be allowed.

m) Minimum diameter of stiffening elements shall be 10 mm for a height of a girder H < 160 mm and 12 mm for H > 160 mm.

n) The maximum centreline spacing of stiffening elements shall be less than three times the height of the girder to ensure stability against buckling, with a tolerance of ±25 mm.

o) A minimum of 5 percent of the moment of inertia shall be provided by the stiffening elements. This percentage will be calculated as an average along a repeatable length of the lattice girder.

p) Welded connections of stiffening elements to the reinforcing bars shall have adequate capacity to withstand foreseen loads. As of minimum, all welds parallel to the reinforcing bars shall have a minimum length of 25 mm. Quality and dimensions of welds shall be constant for each type of lattice girders.

q) Lattice girder butt joints: to provide better encasement of lattice girders in shotcrete, flat steel connection plates (butt plates) shall be used for an effective span of tunnel less than 6 m and maximum length of lattice girder segment of 6 m. Angle connection shall be used in lattice girder joints for larger effective spans or longer segments. Minimum thickness of butt and angle plates 10 mm, minimum grade S235. Minimum width of angle plates shall be 80 mm on the bolts side and 120 mm on the girder side. Minimum width of butt plates depend on the height and width of the individual lattice girder: add minimum of 10 mm on each side of the reinforcing bars to allow for quality fillet welding. Butt plate connection shall be used at all longitudinal construction joints between excavation stages where connection will be completed at a later time (base plate), use of

angle plates is not allowed in this spot.

r) Angle plates shall be welded to a reinforcing bar along the whole length. Butt plates shall be welded with a fillet weld along the full perimeter of a reinforcing bar. Spot welding shall not be allowed for fixing connection plates to the reinforcing bars.

s) Butt plates shall be bolted together with minimum of 3 bolts and angle plates with minimum of 4 bolts, M20 or larger, grade 8.8 or higher. Bolted lattice girder connections with steel connection plates shall have the same bearing capacity as the regular lattice girder section.

t) Connection of lattice girder segments without angle or butt plates can only be used for inverts utilizing wire rope clips, subject to approval by the Engineer. Minimum of three clips shall be used for connection of each reinforcing bar at minimum centre-to-centre distance of 200 mm and 100 mm from the end of each bar. Stiffening elements shall start no further than ½ of stiffener length from the boundary clip.

u) Lattice girders shall be produced in a specialized factory or mechanic shop with appropriate equipment and conditions, where continuous control of all processes is established according to EN 1090-2.

v) Lattice girders to be used on the Project shall exhibit ductile behaviour that shall be either proved by the certificate of performance issued by the established manufacturers of lattice girders for tunnels or proved by the ductility performance test as described in Section e for lattice girders fabricated elsewhere.

w) Manufacturer shall only be considered as established if the respective manufacturer can provide references for minimum of 5 projects where their lattice girders had been used and fabrication of lattice girders is subject to the internal quality control programme that includes the ductility performance test.

5.3.2.3 HANDLING AND EXECUTION

a) Prevent bending, scraping, or overstressing of lattice girders at all times. Protect parts vulnerable to bending or damage during handling e.g. nuts for spacer bars, butt and angle plates.

b) Ensure tight connection of all segments when constructing full arch from segments. All required bolts at all joints shall be placed and tightened.

c) Erect an arch in a safe way; uncontrolled movement of arch during lifting shall be prevented using braces and straps.

d) Steel arches shall be erected to a position as shown in the Drawings and shall follow the line and grade of a tunnel. Steel arches shall be erected within ±100 mm of the longitudinal positions shown on the Drawings unless otherwise approved by the Engineer. Steel arches shall be always placed perpendicular to the tunnel axis.

e) Steel arches shall not deviate towards the inside from the theoretical position defined on the Drawings by more than 15 mm.

f) Position of steel arches shall be checked using approved surveying methods. Spraying of shotcrete shall not be allowed if position of a steel arch has not been checked by the Site Surveyor.

g) Secure lattice girder segments by means of temporary wood blocks/wedges or other approved means to maintain position during application of shotcrete. It is forbidden to place base plates on top of the muck. Remove temporary blocking prior to continuing shotcrete lining into the next excavation stage. No wood material is permitted to permanently remain within the primary shotcrete lining.

h) Insert spacer bars in bolt nuts welded to the outer rim of steel arches and secure them with tie wire.

i) Cover base plates with Styrofoam or similar material to prevent them to be sprayed in during spraying operations. Covering base plates with muck or rebound shall not be allowed.

j) Clean and level muck around butt plates and longitudinal joint to remove obstacles for shotcrete application i.e. to ensure proper angle and distance of a nozzle to receiving surface.

k) If base plate was ripped off or damaged during the excavation or cleaning of the connection,

approved welder shall weld new base plate according to the above listed requirements of weld lengths and distances to the edge of plates to allow for the accurate positioning of the subsequent steel arch segment. Connecting lattice girders segments with heavy wire or custommade mock-ups shall not be allowed.

5.3.2.4 PRE-CONSTRUCTION SUBMITTALS

a) As part of the Method statement for underground works, Contractor shall submit the following documents and Technical documentation for steel arches for Engineer's approval:
   a. shop drawings for any type of steel arches to be used, including specifications and fabrication details, details of all connections between segments to be used for the Works and details of accessories (bolts, bolt nuts, spacer bars, clamps, etc.) for each type of steel arches to be used;
   b. (1) certificates of products if steel arches and required accessories for the Works will be obtained from the established manufacturer of steel arches for tunnelling or (2) certificate of factory or mechanic shop that its procedures and quality control comply with EN 1090-2 if steel arches and required accessories will be manufactured elsewhere;
   c. Work Plan for steel arch installation, including procedure and equipment used for erection of a steel arch for each of drifts and details of wood blocking/wedging and
   d. detailed procedure for alignment of steel arches according to the requirements listed herein.
b) Contractor shall submit the following mock-ups of steel arches to be used for Engineer's approval:
   a. 3 No. of 2.20 m long sections of each type of lattice girders, to be used for the Works, if the lattice girders will not be supplied by the established manufacturers of lattice girders for tunnelling, subject to approval by the Engineer, or if the manufacturer's certifications of lattice girder performance are not provided;
   b. mock-up of fully representative connections for each type of steel arches to be used for the Works (total length of mock-up shall be 0.5 m, except for the mock-up of connection using wire rope clips which shall be 1.0 m long) and
   c. 2 samples of each type of accessories used (bolts, bolt nuts, spacer bars, clamps, etc.).
c) As part of the Method statement for underground works shall Contractor submit the Work Method Statement for steel arch installation for Engineer's approval.

5.3.2.5 QUALITY ASSURANCE

a) Lattice girders shall be tested for their ductility performance prior to the commencement of the Works unless certifications of lattice girder performance issued by established supplier have been provided.
b) Ductility performance test shall be performed on the specimens provided by the Contractor. Test shall be performed on simply supported element having both spot supports at 1.5 m distance (one support fixed, other sliding). Sample shall be placed centrally on both supports with stronger reinforcing bar (S2 bar) facing upwards.
c) Load shall be applied in increments to the upper i.e. S2 bar in the middle of a span between both supports where deflection shall be measured constantly. Load shall be increasing until a failure in a single point flexure. Deflection shall be measured on the bottom side of a specimen in the middle between both supports. Results shall be presented in a force-deflection chart.
d) The Engineer representatives shall be allowed to witness the tests if requested.
e) Behaviour of the stiffening elements and welds shall be constantly monitored during the loading.
f) Reporting: Accredited Testing Agency shall submit the Lattice girder ductility testing report to the Engineer and External Quality Control including:
   a. date and time of testing,
   b. type of tested lattice girder,

c. photos of failed samples,
d. corresponding force-deflection charts and
e. observations of behaviour of stiffening elements and welds.

g) Different types of lattice girders used for the Works shall sustain the characteristic force at yielding strength of material within required range as shown below. Minimum required moment of resistance is given in Table 2.

Lattice girder type	Characteristic force Fc [kN]	Deflection at Fc [mm]	Moment of resistance Wx,min [cm^3]
70/20/30	30.6 – 37.4	16	50
95/20/30	33.3 – 40.7	18	65

Table 2 Lattice girder types

h) All lattice girders shall be rejected if any one sample fails to meet the specified requirements and Contractor shall provide substitute product from different manufacturer.
i) Provided connections and accessories shall be checked by the Engineer for conformance with the requirements specified herein. Butt connections not complying with requirements listed herein shall be rejected.
j) Engineer shall check all provided mock-ups and accessories, review all pre-construction submittals including certifications of lattice girder performance issued by the established manufacturer.

5.3.2.6 QUALITY CONTROL

a) If lattice girders are not supplied by the established manufacturer with established internal quality control for these products, Contractor shall perform ductility performance testing within the Internal Quality Control programme. One per 100 installed lattice girder of each type shall be tested, specimen to be selected by the Engineer.
b) If the required characteristics had not been met, Contractor shall perform at its own cost ductility performance testing of another three (3) specimens. Tests shall be supervised by the Engineer. If one of the specimens fails to adhere to the required characteristics, the respective type of lattice girder shall be considered unsuitable and Contractor shall be required to provide substitute product that shall undergo approval procedure as described herein. Furthermore, the Contractor assumes full responsibilty for safety of all individuals in case of failure of lattice girder until shotcrete had attained sufficient strength.
c) The Engineer has the authority to apply the following corrective measures if the requirements regarding steel arches as specified herein had not been fulfilled:
    a. require replacement of steel arches that are damaged, of inappropriate shape or size for the current excavation round or Tunnelling class, not conforming to the requirements listed herein or not being approved;
    b. require a geodetic check of arch position in case of doubts and re-positioning of arch if deviation from required position was confirmed;
    c. require installation of an arch according to the requirements of this Document and approved Work Plan;
    d. halt spraying operations if installation of an arch had not been executed according to the requirements of this Document and approved Installation Work Plan and
    e. order removal of already sprayed shotcrete to rectify observed deficiencies.
d) Contractor shall not be compensated for the loss of time or materials due to the Engineer's corrective actions.

5.3.3 WELDED WIRE MESH AND BAR REINFORCEMENT

5.3.3.1 SUMMARY AND DEFINITIONS

a) This Section sets forth material and installation requirements for welded wire mesh and additional bar reinforcement.
b) Welded wire mesh is used as a primary reinforcement for shotcrete lining unless use of fibre-reinforced shotcrete has been foreseen within the individual Support category.
c) Bar reinforcement will be additionally used exclusively in the areas with high utilization of primary lining e.g. portals, junctions of main tubes and cross-passages and longitudinal construction joints subject to compression loads.
d) Requirements for rebar which are not primarily used for the shotcrete reinforcement i.e. accessories for other support elements e.g. spacer bars for steel arches and shear reinforcement for the deformation elements are not covered within this Section.

5.3.3.2 GEOMETRY AND MATERIAL REQUIREMENTS

a) Welded wire mesh and bar reinforcement shall conform to EN 10080:2005 and its amendments, unless specified otherwise in this Document.
b) Welded wire mesh and bar reinforcement shall be produced of ribbed steel of strength class B 500 B or higher. Smooth reinforcement shall not be allowed.
c) Welded wire mesh shall have square sizes of 150 mm square or 100 mm square, minimum bar diameter of 6 mm. All subject to approval by the Engineer.

5.3.3.3 HANDLING AND EXECUTION

a) Prevent bending, scraping or overstressing of steel reinforcement at all times. Reinforcement that was plastically deformed more than once at the same spot shall not be used with exception of dowels in longitudinal joints where reinforcement can be plastically deformed twice.
b) Reinforcement shall be installed against previously applied shotcrete surface, not ground or previous layer of reinforcement. Minimum shotcrete cover on the extrados towards the ground shall be 50 mm.
c) Minimum clearance of any rebar either of welded wire mesh or of bar reinforcement to the applied shotcrete surface shall be twice the maximum grain size of aggregate used to allow for good encasement of the reinforcement in shotcrete and prevent inclusion of rebound. Additional reinforcement bars and construction dowels shall be separated with a clearance of at least three times the maximum grain size of aggregate.
d) If steel arches have been used for the Works, welded wire mesh shall be fixed to the steel arch with required clearance and shall follow exactly its shape. If the welded wire mesh shall be fixed directly to the flashcrete, it shall fit to the shotcrete contour as much as possible. Minimum required cover of shotcrete at the intrados of structural layer shall exceed 20 mm.
e) Longest possible sections of welded wire mesh and bar reinforcement shall be installed i.e. with least possible overlapping. Overlapping of welded wire mesh: minimum of three (3) squares in longitudinal and radial joints and minimum of two (2) squares in circumferential joints. Squares of both wire meshes at the overlap shall be aligned as much as possible to allow good penetration of shotcrete. Minimum overlap of additional reinforcement is shown on the Drawings.
f) Splice reinforcement: to prevent rupture of wire mesh in longitudinal joints i.e. joints between excavation stages, dowel reinforcement in construction joints can be installed (Kwikastrips or bent L-bars). Diameter and number of dowels installed shall as of minimum compensate the cross-section of welded wire mesh in the joint. Length of dowels shall be sufficient to provide minimum anchorage depth as per EN 1992-1-1:2005/AC:2011. During cleaning and joint preparation, dowels shall be straightened. Any broken or missing dowels shall be replaced by (1) percussion drilling of a new hole in the vicinity of the broken dowel up to the required anchorage depth and (2) full depth

resin grouting of a new dowel with a same length, diameter and characteristics as the broken/ missing one.

g) Clean and level muck in front of longitudinal construction joints between stages to remove obstacles for shotcrete application i.e. to ensure proper angle and distance of a nozzle to receiving surface.
h) Overlapping squares of wire mesh and overlapping rebar shall be free of rebound, laitance and overspray along the total required length of overlap.
i) Welded wire mesh and bar reinforcement shall be well secured to prevent vibration and movement during spraying. Welded wire mesh, first as well as the subsequent layers, shall be secured in spots not more than 750 mm apart.
j) Where two layers or more layers of reinforcement are to be incorporated in the lining, the preceding layer shall be encased prior to fixing the subsequent layer. Spraying through more than one layer of wire mesh or additional bar reinforcement is strictly forbidden (only allowed exception are dowels in the longitudinal joints)

5.3.3.4 PRE-CONSTRUCTION SUBMITTALS

a) As part of the Method statement for underground works, Contractor shall submit the following documents and Technical documentation for welded wire mesh and additional bar reinforcement to be used for Engineer's approval:
    a. Work Plan for the installation of welded wire mesh and bar reinforcement;
    b. within the Work Plan:
        i. details of securing the first and subsequent layers of welded wire mesh against vibration and movement for both cases, with and without steel arches;
        ii. details of fixing additional bar reinforcement where required;
        iii. methods of cleaning rebound, laitance and overspray from overlapping reinforcement;
        iv. details of dowel reinforcement in construction joints (if used) ;
        v. details of replacement of broken/ missing welded wire mesh/dowel reinforcement in joints together with certificates for proposed resins.
    c. Technical documentation from manufacturers proving that the proposed welded wire mesh and additional bar reinforcement fully comply with the requirements listed herein.
b) As part of the Method statement for underground works shall Contractor submit the Work Method Statement for installation of wire mesh and additional bar reinforcement for the Works for Engineer's approval.

5.3.3.5 QUALITY ASSURANCE

a) The Engineer has the authority to apply the following corrective measures if the requirements regarding welded wire mesh and bar reinforcement as specified herein had not been fulfilled:
    a. require replacement of the welded wire mesh or additional bar reinforcement with damaged section;
    b. require replacement of not approved welded wire mesh or additional bar reinforcement;
    c. require correction of placement of welded wire mesh or additional bar reinforcement not being installed according to the Drawings or requirements specified herein;
    d. require to clean overlapping welded wire mesh or any additional bar reinforcement including dowels at construction joints;
    e. require replacement of ruptured welded wire mesh and broken or missing dowels at construction joints;
    f. require installation of welded wire mesh and additional bar reinforcement as per the Drawings, requirements of this Document, and approved Work Plan;
    g. halt spraying operations if installation of welded wire mesh and additional bar reinforcement had not been executed according to the requirements of this Document and

approved Work Plan; special attention shall be paid to the cleanliness of joints and overlapping requirements;

h. halt spraying operations if vibration of wire mesh or additional bar reinforcement caused by spraying interrupts shotcrete flow and prevents good compaction of shotcrete at the receiving surface. Additional fixing of reinforcement is required before spraying may continue. Loose shotcrete shall be completely removed;

i. order removal of already sprayed shotcrete to rectify observed deficiencies.

b) Contractor shall not be compensated for the loss of time or materials due to the Engineer's corrective actions.

c.) .

5.3.4 RADIAL ROCK BOLTS AND FACE DOWELS

5.3.4.1 SUMMARY AND DEFINITIONS

a) This Section sets forth the requirements for materials, equipment and procedures for installation of different types of rock bolts: grouted rebar and self-drilling hollow core bolts, combination friction-grouted bolts and expandable friction bolts.

b) Rock bolts are used as a systematic ground reinforcement measure (systematic bolting) or to pin block/wedge of unstable rock in spots (spot bolting). Bolts are installed in radial direction along the perimeter of an underground opening (radial bolts) and into face (face dowels).

c) Rebar bolts (also referred to as SN) are rods with ribbed surface and thread at one end. Rebar bolts are inserted into pre-drilled borehole filled with grout. Rebar bolts are used in massive and also blocky and jointed rock where stand-up time of a borehole is sufficient to allow pre-drilling, filling with grout and insertion of bolt.

d) Self-drilling fully threaded hollow core bars bolts, spiles and face dowels are further in this document abbreviated with IBO. IBO if referring just to hollow core bar type of rod and shall be always followed by the type of support element e.g. IBO bolt.

e) IBOs feature "all-in-one" tool for drilling, flushing, post- or simultaneous grouting and finally the load-carrying member itself. Drilling is performed with sacrificial drill bits. IBOs are used in any ground type with short stand-up time of boreholes. IBOs can be grouted simultaneously with drilling or afterwards (subsequent grouting).

f) Rebar bolts and IBOs are generally made of steel, glass-fibre reinforced polymer (GRP) bolts may be used in aggressive ground conditions with high water flow for rock bolts or for face dowels if excavating with roadheaders.

g) Expandable friction bolts (EFB) are made of deformed steel tube which is at the end of installation expanded with high-pressure water to provide shear contact between borehole and bolt. They are predominantly used for spot bolting and in areas where high water flow prevents successful grouting.

5.3.4.2 GEOMETRY AND MATERIAL REQUIREMENTS

h) Each individual part of rock bolts shall be considered as the construction material as per provisions of ZGPro-1 , but not assembled rock bolt as a complete unit. Assembled rock bolt shall fully comply with the requirements of this Document.

i) Rock bolt diameter, length and pattern shall be used as per the applied Support categories as shown in the Drawings and confirmed by valid RESS Sheet.

j) Bolts shall be installed within 250 mm radius of their designed location as shown on the Drawings.

k) Bolts shall be always installed to the full required length. Rebar bolts are considered to be installed to the full required length when body of a bolt of a nominal length at least equal to the required length is fully embedded in grout within ground and lining, only thread is protruding outside the lining. IBO bolts are considered to be installed to the full required length when body of a bolt of a

nominal length at least equal to the required length is fully embedded in grout within ground and lining, and maximum of 100 mm is protruding beyond the intrados edge of a nut. Expandable friction bolts are considered to be installed to the full required length when body of a bolt of a nominal length at least equal to the required length is fully embedded within ground and lining, and plate is flush with the intrados of shotcrete lining i.e. in contact with lining and bushing.

l) End-bolt hardware shall be always in full contact with the final shotcrete surface. Blocking with wood or other materials beneath the bolt plate shall not be allowed.

m) For IBO bolts and face dowels, bolt tail shall be at least flush or protrude beyond the intrados edge of a nut. Having IBO bolt or face dowels tail inside the nut shall not be considered suitable for any installed IBO bolt or face dowel.

n) End-bolt hardware for grouted rebar bolts and IBO steel bolts consists of a plate and nut. If bolt had been installed perpendicular to the shotcrete lining in stable ground conditions with small convergence expected, flat plate and hex nut can be used. In case when bolt had not been installed perpendicular to the shotcrete lining or where considerable deformation is expected, domed plate and domed nut shall be used. Dimensions of plates and nuts shall be according to manufacturer's requirements for the type, diameter and bearing capacity of bolt used. Minimum steel grade of plates and nuts: S235.

o) Rebar bolts shall have a minimum nominal diameter of 28 mm, be of steel grade B 500 B or higher, have ultimate load higher than 250 kN and have ultimate elongation equal to or exceeding 5%.

p) Ribs of rebar bolts shall be in accordance with EN 10080:2005 and its amendments. Ribs in longitudinal direction shall not be allowed.

q) Rebar bolts shall be generally in one piece, coupling pieces together with butt welding shall not be permitted.

r) IBO bolts shall be of a fully threaded cold-rolled bar type with a minimum nominal diameter of 32 mm, a minimum yielding load of 190 kN, minimum ultimate strength of 500 N/mm2 and maximum elongation at failure exceeding 5%. Galvanized finish of the bar is required due to the permanent nature of bolt.

s) IBO bolts shall be drilled with sacrificial drill bits. Drill bits selected shall be able to efficiently drill with a minimum disruption to the surrounding ground for different ground conditions expected during the Works.

t) IBOs can be composed of several pieces, coupled together with central threadstop couplers of same or higher material properties as bolts. Couplers shall have smaller outer diameter than the drill bit to allow bypass of grout along the body of a bolt.

u) EFB shall have a minimum capacity as defined in the BOQ and confirmed by RESS Sheet. Minimum thickness of bolt body material shall be 2 mm for temporary applications and plastic coated 3 mm for permanent applications. Maximum elongation at failure for EFB used for the Works shall exceed 10%. Minimum steel grade for EFB: S355.

v) Dimensions of plates for EFB shall be as required by the manufacturer depending on the load capacity of bolts used. Only domed plates shall be allowed for EFB.

w) At no circumstances shall be rock bolts installed as ground support utilized also for hanging service lines, ventilation ducts, blasting mats or similar.

5.3.4.3 HANDLING AND EXECUTION

a) Bolts shall not be stored or placed directly on the ground and shall be free of dirt, mud and other foreign matter e.g. oils and greases at time of installation.

b) The length of borehole for grouted rebar bolts shall be drilled slightly longer than the bolt length to all allow potential debris falling off the borehole circumference to be pushed towards the end of a borehole, facilitate installation of a bolt and provide space for grout at the tip of a bolt. Requirement for longer borehole is valid also for IBO bolts to ensure encapsulation of bit with grout.

c) Boreholes for rebar and IBO bolts with diameter up to and including 32 mm may be drilled with

diameter of 50.8 mm (2''), while 76.2 mm (3'') boreholes are required for rock bolts with diameter above 32 mm. Borehole diameter for IBOs, friction stabilizers and combination friction-grouted rock bolts shall be in accordance with the requirements of manufacturer.

d) Rebar bolts: all required boreholes for the installation round may be pre-drilled before commencement of grouting operations i.e. drilling and immediate subsequent grouting is usually not required unless voids/ water had been encountered. Boreholes drilled shall be thoroughly cleaned, all spoil, cuttings and water shall be removed prior to grouting.
e) Borehole diameters for EFB shall be in accordance with manufacturer's requirements, borehole shall be prior to placement thoroughly cleaned and free from spoil and cuttings.
f) EFB shall be expanded with pumps approved by manufacturer for the type of bolt installed and water pressure according to manufacturer's requirement. Following the installation, water shall be drained from inside the bolt to prevent corrosion.

5.3.4.4 PRE-CONSTRUCTION SUBMITTALS

a) As part of the Method statement for underground works, Contractor shall submit the following documents and Technical documentation for drilling, installation and grouting of rock bolts used for the Works for Engineer's approval:
    a. Work Plan for drilling, installation and grouting for each type of rock bolts including technical details of equipment used for drilling and grouting/expanding.
    b. Within the Work Plan:
        i. proposed grout mix design with initial results and detailed grouting procedures shall be provided for cementitious grouts, and detailed installation procedures, specifications and certificates for resin grouts proving compliance with the requirements stated herein;
        ii. proposed blocking system to prevent sliding of installed rebar and IBO bolts from inclined boreholes;
        iii. materials and procedures shall be provided how to deal and temporarily seal off groundwater inflows through drilled boreholes.
    c. Internal Quality Control programme for testing bolts including description and certificates of pull-out testing equipment for each type and capacity of bolts used for the Works and description of testing procedure;
    d. if EFB will be used, written confirmation by manufacturer of EFB that the proposed pump for expanding EFB is appropriate for the proposed bolts;
    e. Technical documentation from manufacturers proving that the proposed bolting systems (bolts, end-bolt hardware) fully comply with the requirements listed herein.
b) As part of the Method statement for underground works shall Contractor submit the Work Method Statement for drilling, installation, grouting, plating and testing of rock bolts for Engineer's approval.

5.3.4.5 QUALITY CONTROL

a) Regular non-destructive testing of load capacity of installed bolts (pull tests) shall be performed during the Works. Tests shall be performed by the Contractor under direct supervision of the Engineer. All required stakeholders shall agree on the schedule of testing to fulfil the requirements liste in this Section.
b) Tests shall be performed by competent personnel who were trained to properly perform test accordint to the provisions of respective standards and this Document. The Engineer may require substitution of person executing pull tests if not performing to the required standard.
c) Non-destructive pull tests of rock bolts shall be performed in accordance with EN 14490:2010 for production bolts, EN ISO 22477-5:2018 Method 3 and provisions of this Document. In case of conflict, provisions of this Document take precedence.
d) Requirements for testing equipment are given in 1.1.1.1. The equipment used for bolt testing shall

be maintained in good working condition and shall not be used for any other purpose. Calibration of manometer shall be performed as required by the manufacturer or on request of the Engineer or External Quality Control if pull-out tests show volatility of testing results.

e) For non-destructive pull-out test of production bolts, the tested bolt shall be loaded to 80% of its nominal ultimate load. Force shall be applied gradually in minimum of 6 increments or maximum of 50 kN increments, whichever increment is smaller. Load of each increment shall be applied for 3 minutes; elongation shall be measured at the beginning and at the end of each increment to record slippage or creep of the grout. Elongation shall be measured as movement of the hydraulic jack provided there is no slippage on the connection between bolt and steel jaws of a jack. Results shall be presented with a load-displacement curve.

f) Recording: for every non-destructive pull-out test of production bolt, record the following information into the Shift Report:
   a. date and time of testing,
   b. heading, chainage and location of bolts tested,
   c. number and type of bolts tested and
   d. percentage of bolts tested including last testing campaign for all types and load capacities of bolts.

g) Reporting: Bolt Non-destructive Testing Report shall be attached within one (1) day of testing to the Daily Contractor's Report containing the following:
   a. heading, date and time of testing;
   b. testing equipment used;
   c. Engineer or External Quality Control representatives supervising pull-out tests and their signatures;
   d. for each tested bolt: chainage, location, type, length, diameter, load capacity, time lapse since grouting, table of measured jack offsets with applied load increment and load-displacement curve;
   e. comments and observations on testing and
   f. name and signature of person that performed testing.

h) Non-destructive pull-out of EFB can be performed at any time after installation, while tests of rebar bolts and IBO bolts shall be performed minimum of 3 days after grouting.

i) Bolt where excessive deformation had been exhibited (80% of ultimate elongation as per manufacturer's specifications) or where 80% of ultimate load could not have been reached shall be considered failed.

j) Initial frequency of testing: for each of different types and load capacities of bolts 10 out of first 100 installed bolts selected by the Engineer shall be tested. Locations of selected bolts shall be distributed evenly along the perimeter (overhead, sides, invert). The Contractor shall provide facilities to the Engineer to allow close inspection of pull testing.

k) Reduced frequency of testing: if none of the 10 bolts tested had failed during the initial frequency testing, testing frequency can be for the respective bolt type and load capacity reduced to three (3) bolts per every 100 subsequent bolts installed.

l) Bolts that were tested shall be clearly marked; on the surface of shotcrete lining circle using permanent spray paint bolt tested and mark with checkmark for compliant bolt or X mark for failed bolt.

m) Whenever bolt fails during testing, three (3) surrounding bolts of same type and load capacity shall be tested and initial testing frequency applied. Failed bolts shall be replaced with bolts of same diameter, length and load capacity. The cost associated with installing and testing of replacement rock bolts as a result of poor test bolt performance will be the responsibility of the Contractor unless otherwise determined by the Engineer to be due to causes beyond the Contractor's control.

n) If several bolts of same type and load capacity had failed over broader area, Contractor and Engineer shall immediately initiate investigation. Installation and grouting procedures shall be

thoroughly checked and reviewed with Workers to ensure compliance with the requirements of this Document and approved Work Plan.

o) If bolts of this type and load capacity continue to fail despite assurance of proper installation and grouting procedures, installation of these bolts shall be discontinued on the Project and other suitable type of bolts shall be proposed by the Contractor and approved by the Engineer.

p) Whenever EFB intended for permanent application had been pull-tested, replacement bolt shall be installed in the close vicinity due to potential damage of plastic coating caused by testing.

q) The Engineer may require the installation of a replacement bolt of same type, length and diameter as the one being replaced in the following cases:
   a. bolt had been installed outside the allowable area;
   b. bolt had not been installed to the full required length
   c. end-bolt hardware is not in contact with the final shotcrete surface for rebar, expandable friction and combination friction-grouted bolts;
   d. cut face of IBO bolts instead of recessed machined end of a bolt
   e. for rebar bolts and IBO bolts, boreholes have not been properly filled with grout or grout had leaked out from the mouth of a borehole due to inadequate blockage;
   f. bolt had been grouted using unapproved grout mix;
   g. IBO bolt tail is not long enough;
   h. EFB for permanent application had been forcefully driven into the borehole and
   i. bolt tail with end-bolt hardware had been broken by blasting/ excavation activities or moving equipment in the tunnel.

r) Contractor shall not be compensated for the loss of time or materials due to the Engineer's corrective actions.

5.3.5 SPILES

5.3.5.1 SUMMARY AND DEFINITIONS

a) This Section sets forth the requirements for materials, equipment and procedures for installation of different types of spiles.

b) Spiles are solid or hollow steel rods (IBO) installed from the current excavation face above the next excavation round to provide temporary support to the excavated span and to control overbreak.

c) Spiles can be installed either in a pre-drilled hole or self-drilling spiles are used, depending on the encountered ground conditions.

d) Spiles can be either grouted or un-grouted i.e. pushed into pre-drilled and cleaned borehole or driven into soft soil.

5.3.5.2 GEOMETRY AND MATERIAL REQUIREMENTS

a.) Spiles shall be driven through or above the lattice girder that is installed closest to the excavation face as shown in the drawings. Installation of spiles shall not be allowed without use of a steel arch to hold the tails of spiles.

b.) The nominal spacing of the spiles is shown on the Drawings. Actual spacing and lateral extent may be adjusted according to the encountered ground conditions and shall be confirmed by RESS Sheet.

c.) Ribbed steel reinforcement bars used as spiles (referred to as rebar spiles) shall have a minimum nominal diameter of 25 mm and be of steel grade B 500 B or higher. Rebar spiles shall be in one piece, coupling pieces together with butt welding shall not be permitted.

d.) Self-drilling hollow core steel bars (further referred to as IBO spiles) used for the Works shall be of a fully threaded cold-rolled bar type with a minimum nominal diameter of 32 mm, a minimum yielding load of 190 kN and minimum ultimate strength of 500 N/mm2.

Plain finish of the bar is allowed due to its temporary nature.

e.) IBO spiles shall be drilled with sacrificial drill bits. Drill bits selected shall be able to efficiently drill with a minimum disruption to the surrounding ground for different ground conditions expected during the Works. Spiles can be composed of several pieces, coupled together with central threadstop couplers of same or higher material properties as spiles. Coupling diameter shall have smaller outer diameter than the drill bit to allow bypass of grout along the body of a spile.

5.3.5.3 HANDLING AND EXECUTION

a) Maximum overcutting of boreholes for un-grouted rebar spiles shall not exceed 10 mm i.e. diameter of the drilled hole shall not exceed nominal diameter of an un-grouted rebar spile by more than 10 mm. When ramming rebar spiles with pointed tip, the ramming frequency shall be adjusted to minimize ground disturbance.
b) All spiles shall be installed to the full required depth, minimum tail length beyond the inner edge of a steel arch (edge that is farther from the face) shall exceed 150 mm to allow good anchorage in shotcrete.
c) The length of borehole for grouted rebar spiles shall be drilled slightly longer than the spile length to all allow potential debris falling off the borehole circumference to be pushed towards the end of a borehole and facilitate installation of a spile.
d) Requirements for grouting procedures for spiles are as per radial anchors.
e) Backfill of crotch underneath spiles i.e. above the Line 1a shall be performed during application of primary lining in the respective excavation step.

5.3.5.4 6.3.5.4 PRE-CONSTRUCTION SUBMITTALS

a) As part of the Method statement for underground works, Contractor shall submit the following documents and Technical documentation for each type of spiles to be used for the Works for Engineer's approval:
    a. Work Plan for drilling, installation and grouting (where required) of each type of spiles, including technical details of equipment if different as used for bolting;
    b. Within the Work Plan:
        i. proposed grout mix design with initial results and detailed grouting procedures shall be provided for cementitious grouts, and detailed installation procedures, specifications and certificates for resin grouts proving compliance with the requirements stated herein;
        ii. materials and procedures shall be provided how to deal and temporarily seal off groundwater inflows through drilled boreholes;
        iii. Technical documentation from manufacturers proving that the proposed spiles and roof bolts fully comply with the requirements listed herein.
b) The Engineer shall review all submittals. Grout mix design shall be only approved once the Final grout testing report had been submitted.
c) As part of the Method statement for underground works the contractor shall submit the Work Method Statement for drilling, installation and grouting of spiles for Engineer's approval.

5.3.5.5 QUALITY CONTROL

a) Based on the condition of installed spiles has the Engineer may require:
    a. installation of an additional spile if centre-to-centre distance between two neighbouring spiles is larger than shown in the Drawings;
    b. installation of an additional spile if one had not been installed to the full required length;
    c. extension of spile if its tail is too short;
    d. installation of additional spiles if spiles other than approved had been used for spiling;

e. cutting of tails beyond allowed length;
f. execution of spiling according to the requirements of this Document and approved Work Plan;
g. halt spraying operations if spiling had not been executed according to the requirements of this Document and approved Work Plan and
h. order removal of already sprayed shotcrete to rectify observed deficiencies.

b) Contractor shall not be compensated for the loss of time or materials due to the Engineer's corrective actions.

5.3.6 GROUTING OF ROCK BOLTS AND PRE-SUPPORT MEASURES

5.3.6.1 SUMMARY AND DEFINITIONS

a) This Section sets forth the requirements for materials, equipment and procedures for grouting of the following steel structural elements for the Works:
   a.) radial rock bolts,
   b.) face dowels,
   c.) rebar and self-drilling hollow core bar spiles.

5.3.6.2 MATERIAL AND MIXING REQUIREMENTS

a) Cementitious grouts can be used for grouting of rock bolts and pre-support measures.
b) Preparation of cementitious grouts: only ingredients that are compatible, non-corrosive to steel and free from calcium chloride shall be used.
c) Cement: same requirements as in Section (shotcrete). In areas with increased chemical reactivity of underground waters sulphate resistant cements shall be used for grouting rock bolts. Due to their temporary nature, spiles, face dowels can be grouted with regular cements.
d) Water-to-cement ratio shall be appropriate for the application (inclined/declined boreholes). In general, allowed range of water-to-cement ratio shall be from 0.30 to 0.40 (for inclined rebar bolts and spiles).
e) Cementitious additives and chemical admixtures may be used ofr the preparation of cementitous grouts if conforming to EN 934-4:2009 and approved by the Engineer. Allowable additives and admixtures:
f) microsilica or other pozzolanic materials,
g) accelerating agents,
h) retarding agents,
i) additives for impermeable grout,
j) water reducing agents and
k) additives for prevention of shrinkage.
l) Use of admixtures for prevention of shrinkage shall be required for grouting of rock bolts. Admixture used shall completely prevent plastic and hardened shrinkage, slight volumetric expansion is allowed. Effect of the admixture on shrinkage of grout specimens shall be tested as per ASTM C1090. Admixture shall be approved by the Engineer based on the results of aforementioned test.
m) In areas with possible water flows, chemical admixture for preparation of impermeable grout shall be used to increase the corrosion resistance of the bolt system. Admixture shall be approved by the Engineer.
n) Any admixture used shall be chloride free to allow for maximum durability of steel elements within the grout.
o) Cementitious grouts for grouting rock bolts, face dowels, spiles and roof bolts shall correspond to the following strength development criteria (test according to EN 445:2008):

4 hours 1 N/mm2
24 hours 8 N/mm2

28 days 20 N/mm2

p) Grouting equipment with controlled automatic dosing of cementitious materials, water and chemical admixtures allowing preparation of grout of consistent quality i.e. a uniformly mixed grout, free of lumpy and undispersed cement, and of proper consistency shall be required. Dosing and mixing grouts by hand shall not be permitted.
q) To ensure continuous flow and uniform pressure, only electrically driven grout pumps shall be used.
r) Grout pumps shall have automatic shut-off control to prevent grouting pressure from exceeding that specified. Grout pumps shall also include the release valve that allows instant relieve of pressure within the system in case of emergency.
s) Use of proprietary formulated grout mixes shall be allowed if they meet the specified criteria. Contractor shall provide certificates proving their chemical composition and performance tests results that confirm required strength development. Manufacturer shall specify suitable equipment for mixing, pumping and injection of these grouts and Contractor shall follow exactly manufacturer's requirements.
t) No chemical admixtures or resins shall be used which negatively affect the durability of the rock bolt. Contractor shall submit written confirmation by the manufacturers that chemical substance used to their best knowledge has no adverse effects on the durability of the rock bolt:

5.3.6.3 HANDLING AND EXECUTION

a) Cement or pre-prepared grout mixes used for grouting shall be stored on skids or platforms above the ground surface and protected from moisture with suitable plastic wrap. Cement or pre-prepared grout mixes shall be fresh at the time of grouting and shall not contain any lumps or other indication of hydration. Cement or pre-prepared grout mixes from damaged bags shall be discarded and not used for the Works.
b) Microfine and ultrafine cements are highly reactive cements and shall be stored in dry place with low ambient humidity i.e. outside of tunnel environment and shall be delivered to the tunnel just prior usage. Storage conditions shall be as recommended by the manufacturer.
c) Storage conditions and handling of chemical admixtures shall fully comply with the manufacturer's recommendations. Store admixtures at all times in clearly marked and labelled watertight containers to guard against dampness, evaporation, freezing, and contamination. If not stored in original containers, label on container shall including admixture name, type, storage requirements and use-before date. Any admixture failing to comply with these requirements shall not be used.
d) Grouting rebar bolts with cementitious grout: inclined boreholes shall be filled with grout of appropriate consistency that it does not leak from the borehole, declined boreholes shall be filled with grout in liquid state; filling shall start from the end of borehole towards its mouth, withdrawing grouting pipe with suitable speed that its end is constantly submerged within grout to prevent creation of voids. Rebar bolt shall be inserted immediately. Inclined bolts shall be properly secured with wooden wedge or similar not to slide out. Subsequent grouting of IBO: once IBO has been drilled and borehole flushed, IBO shall be immediately grouted through the central hole until (1) grout comes out at the mouth of borehole for inclined boreholes and (2) grout displaces all the water from borehole for declined boreholes. Inclined bolts shall be properly secured after installation with wooden wedge or similar approved blocking method not to slide out. To block leakage of the grout from borehole for inclined bolts, paper or textile fabric shall be stuffed around the bolt at the mouth of borehole immediately when grout flow from grouting pump stopped.
e) Grouting equipment shall be thoroughly cleaned after each usage and regularly inspected for lumps of hardened grout.

6.3.6.4 Pre-construction submittals

a) Pre-construction submission for grouting (grout mix design and grouting procedures) shall be included in the Work Plan for each of the structural elements where grouting is utilized: rock bolts

and spiles. Contractor shall additionaly submit the following documentation for Engineer's approval:

a. If proprietary certified grout mixes should be used for the Works, Technical documentation proving their chemical composition and mechanical properties fully comply with the requirements listed herein, and mixing, pumping and injection requirements by the manufacturer.
b. Technical documentation and MSDSs for all cementitious additives and chemical admixtures to be used for the on-site preparation of grout mixes, including dosage and storage requirements.
c. Written confirmation by the manufacturers that each chemical substance used to their best knowledge has no adverse effects on the durability of the rock bolt.

5.3.6.4 QUALITY ASSURANCE

a) Cementitious grouts shall be tested in accordance with EN 445:2008, EN 446:2008 and EN 447:2008. Tests shall be performed by the Contractor.
b) Compressive strength tests shall be performed on cubes with 50 mm edge. Specimens shall be cured in water.
c) Batch of five (5) specimens shall be prepared for testing compressive strength of grout at each specified time for different grout mixes used in the Works i.e. 3 times 5 specimens for grout used (separately for thick grout for inclined rebar bolts, face dowels and spiles, and liquid grout for declined rebar bolts and IBO rock bolts and face dowels).
d) Reported compressive strength is the mean value of obtained strengths when highest and lowest values within the batch had been discarded.
e) Any cementitious additives and chemical admixtures used in the cementitious grouts for the Works shall be tested for their performance; to present effectiveness of each admixture and its effect on the strength development of grout, results shall be always compared to the untreated grout.
f) Any part of laboratory testing of grouts shall be allowed to be witnessed by the representatives of the Engineer.
g) Reporting: Grout Compressive Strength Testing report issued by the Accredited Testing Agency shall include (for each grout mix design):
    - date and time of testing,
    - designation of mix design,
    - water-to-cement ratio used,
    - cementitious additives /chemical admixtures used and their dosage,
    - good quality photos of broken specimens and consistency of grout prior to placement into moulds and
    - table of all recorded compressive strengths and final compressive strength for grouts with and without cementitious additives/ chemical admixtures.
        i.) Contractor shall compile Final grout testing report that shall present final grout mixes to be used for the Works including water-to-cement ratio for inclined/ declined boreholes, additives/admixtures used with their dosage and Grout Compressive Strength Testing report.
h) Final grout testing report shall be submitted to the Engineer no later than 15 days prior to the pre-construction acceptance tests. Final report shall be reviewed by both stakeholders and approved or returned within 7 days after the submission.
i) Only approved final grout mixes shall be used for the pre-construction acceptance tests for rock bolts.

5.3.6.5 QUALITY CONTROL

a) Grouting of rock bolts and pre-support measures for the Works shall be only performed using approved cementitious grouts from the pre-construction acceptance tests for rock bolts and

approved grouting equipment. Approved grout: same water-to-cement ratio and dosage and type of cementitious additives and/or chemical admixtures shall be used as for the pre-construction acceptance tests. Any changes of the mix design shall be approved by the Engineer.

b) During the Works, cementitious grout samples shall be taken weekly for the type of support that had been used in last 7 days and compressive strength testing performed as described in previous Section.

c) The Engineer may halt grouting operations if:
    a. grouting equipment used is other than approved,
    b. grouting equipment is not performing as required and
    c. grout used is outside of specified criteria,
    d. until these deficiencies have been rectified.
    e. Contractor shall not be compensated for the loss of time due to the Engineer's corrective actions.

5.3.7 FACE SUPPORT MEASURES

5.3.7.1 SUMMARY AND DEFINITIONS

a) This Section sets forth the requirements for materials, equipment and procedures for installation of face support: face wedge, face dowels with end-dowel hardware and shotcrete used for face support.

5.3.7.2 GEOMETRY AND MATERIAL REQUIREMENTS

a) Number and arrangement of face dowels, and required overlap between two subsequent sets of face dowels are shown in the Drawings for different Support types and sizes of drifts and shall be considered the minimum required; number of face dowels and overlap shall not be reduced within the RESS process. However, dowel number, arrangement and overlap may change, if requested by the Engineer.

b) Face dowels shall be of fully threaded steel rod type with continuous thread, of minimum diameter as indicated in the Drawings, a minimum yielding load of 190 kN, minimum ultimate strength of 500 N/mm2 and maximum elongation at failure exceeding 5%. Due to its temporary nature, galvanized finish of the bar is not required.

c) Cement, and grouting procedures shall adhere to the same requirements as for the radial rock bolts. If different cementitious or resin grouts shall be used as those approved for the rock bolts, these grouts shall undergo same procedure as specified in this Document.

d) Flat plates shall be of minimum steel grade S235, of minimum size 200 mm square and 10 mm thickness. Regular bolt nuts: minimum steel grade S235. Steel profiles shall be of minimum steel grade S235, minimum of 600 mm long and have a centrally drilled hole of a suitable diameter to host a bolt and provide support to the bolt nut. End-dowel hardware shall be in full contact with the shotcrete surface.

e) Shotcrete thickness and required reinforcement are for different Support categories shown in the Drawings, any changes shall be confirmed by RESS Sheet. Shotcrete thickness specified is the minimum thickness to be applied. Shotcrete applied to the face shall be the same as for the primary lining regardless the provisions in the Drawings (plain shotcrete or fibre-reinforced shotcrete).

f) Shotcrete applied to the face shall comply with the same requirements as primary lining shotcrete.

g) g.)f.) Whenever face dowels are used for face support, reinforcement of shotcrete shall be mandatory. For ground conditions where small to medium face pressure may be expected and light end-dowel hardware may be used, area of one (1) metre square around the dowels shall be reinforced with welded wire mesh as shown in the Drawings and fully encased in shotcrete. For ground conditions where significant face pressure may be expected and heavy end-dowel hardware shall be used, continuous welded wire mesh reinforcement covering all dowels shall be placed and

fully encased in shotcrete. Type of welded wire mesh is specified in the Drawings.

5.3.7.3 HANDLING AND EXECUTION

a) Face dowels shall be always installed at designated locations and to the full required length. Face dowels are considered to be installed to the full required length when body of a dowel of a nominal length at least equal to the required length is fully embedded within ground and lining, and maximum of 150 mm is protruding beyond the intrados edge of a nut (for plates).
b) Dowels are installed as self-drilling type with sacrificial bit.
c) To effectively stabilize the face, full bondage between dowels and surrounding ground over the full length of bolt shall be established using cement grouts.
d) The end-dowel hardware shall be removed prior to excavation and re-used. Contractor shall not be paid for the end-dowel hardware material each round, but one end-dowel hardware for all excavation steps when respective face dowel shall be plated.
e) When pocket excavating, remove only end-dowel hardware of those dowels within the excavation area of the next pocket.
f) Wire mesh shall be encased in shotcrete as much as reasonably achievable due to uneven excavation surface.

5.3.7.4 PRE-CONSTRUCTION SUBMITTALS

a) As part of the Method statement for underground works, Contractor shall submit the following documents and Technical documentation for face support to be used for Engineer's approval:
    a. Work Plan for installation and removal of face support, including face wedge, face dowels with end hardware, shotcrete with reinforcement if required,
    b. Within the Work Plan:
        i. grout mix design and testing results if different grout mix shall be used as for the rock bolts,
        ii. materials and procedures shall be provided how to deal and temporarily seal off groundwater inflows if encountered during drilling,
        iii. Technical documentation from manufacturers proving that the proposed face dowels and their end-dowel hardware fully comply with the requirements listed herein (if different materials shall be used than for the rock bolts).
b) As part of the Method statement for underground works the Contractor shall submit the Work Method Statement for installation of face support for the Works for Engineer's approval. Document shall cover all aspects of face support works: drilling and installation of face dowels, cutting face dowel tails, installation of welded wire mesh, placement of shotcrete, placement of end-dowel hardware.

5.3.7.5 QUALITY CONTROL

a) The Engineer may to require from the Contractor execution of the following corrective measures:
b) •
    - installation of additional face dowel if one was installed more than 500 mm outside of its theoretical position;
    - installation of additional face dowel if one was overstressed by breaking it intentionally or pulling it out with excavation equipment;
    - installation of additional face dowel if dowel had not been installed to the full required depth;
    - installation of additional face dowel if dowel other than approved had been used;
    - plating of all dowels that shall be immediately after the total thickness of shotcrete had been applied to the face;
c) •

- placement of welded wire mesh even on top of shotcrete of sufficient thickness and require proper encasement if wire mesh had not been installed correctly and
- spraying of shotcrete sufficient thickness to the face and proper encasement of welded wire mesh.

d) Contractor shall not be compensated for the loss of time or materials due to the Engineer's corrective actions.

5.4 MEASUREMENT AND PAYMENT

5.4.1 GENERAL

a) The uinit prices for the various pay items shall include all materials, delivery, manipulations within the site, equipment and labour required for the complete execution of the work, including testing and quality control
b) Unit price for pay items for primary support elements is independent of the location where element is installed (top heading, bench with invert, top heading with bench, invert, main tubes, emergency exit tubes, cross-passages, niches) and from construction conditions (inclined or declined tunnel, increased groundwater inflow volumes, etc.).
c) Unit price for pay items for (fibre-reinforced) shotcrete, steel arches, radial bolts, face dowels, spiles, as well as deformation gaps shall include cost of testing prior to construction as well as regular construction testing according to the requirements of this Document.
d) Length of excavation round is measured along the axis of tunnels.
e) When drilling with water in ground sensitive to water, unit prices for pay items that include any kind of drilling shall include the execution of temporary retention basin and all required manipulation with water and drillings.
f) Unit prices for pay items for radial rock bolts, face dowels and spiles shall include variable costs of drilling in all materials that may be encountered during the Works.
g) Unit prices for support elements are valid for the whole length of tunnels regardless of the transportation length along the tunnel axis. Contractor shall not be entitled to the increase of unit prices if excavation from one portal should be extended comparing to Contractor's contractual timeline due to Owner's decisions or administrative limitations.

5.4.2 (FIBRE-REINFORCED) SHOTCRETE

5.4.2.1 DESCRIPTION

a) Work within this pay items includes mobilization, de-mobilization and cleaning of equipment, supply, placement, curing (if required), removal and disposal of (fibre-reinforced) shotcrete, including, but not limited to, all delays of work up to 2 hours during the execution of all aforementioned works.
b) Work within this pay item includes also required testing of constituents of (fibre-reinforced) shotcrete prior to construction.
c) Work within this pay item includes also incorporation of Line 1a for each Support category and drift into the selected Tunnel Guidance system.
d) Work within this pay item includes also surveying support and work for installation of guide wires, depth pins or other approved measures to control profile if not using steel arches.

5.4.2.2 MEASUREMENT

a) Primary lining made of (fibre-reinforced) shotcrete is measured for each nominal thickness in [m2] along Line 1a and is independent of the actual consumption of shotcrete.
b) Additional (fibre-reinforced) shotcrete required for backfilling of over-excavation attributed to

geological factors is measured in [m3] based on the measured volume of over-excavation with regards to Surface Boundary "Line O".

c) (Fibre-reinforced) shotcrete for face support is measured for each nominal thickness in [m2] along Line 2 (Equal to line D) for each drift and is independent of the actual consumption of shotcrete. Unit price shall include removal of (fibre) reinforced shotcrete during excavation of the next excavation round, including transport of demolished material to the temporary landfill, separation to construction waste and hand over to the processing facility.
d) Deformation gap (slot) is measured in [m1].

5.4.2.3 PAYMENT

a) (Fibre-reinforced) shotcrete for installation into the primary lining will be paid by the contractual unit prices the quantity measured as specified above only for work satisfactorily completed and approved by the Engineer.
b) (Fibre-reinforced) shotcrete for face support will be paid by the contractual unit prices for abovementioned measured quantity, nominal thickness and percentage of face covered as per the applied Support category.
c) Unit price for pay item plain shotcrete shall include increased rebound when spraying through steel arches, welded wire mesh and rebar.

5.4.3 LATTICE GIRDERS

5.4.3.1 6.4.3.1 DESCRIPTION

a) Work within this pay item includes mobilization and de-mobilization of equipment, supply and installation of steel arches, including all delays of work up to 2 hours during the execution of all aforementioned works.

5.4.3.2 6.4.3.2 MEASUREMENT

a) Steel arches for ground support are measured in mass units [t] along Line 1a.
b) For lattice girders, only mass of longitudinal bars and stiffeners along Line 1a is measured i.e. without potential overlapping length (for clamped connection), steel plates in joints and nuts for inserting spacer bars.
c) Auxiliary materials like steel plates in joints, clamps, bolts, nuts, washers, spacer bar and other material shall not be measured separately.

5.4.3.3 6.4.3.3 PAYMENT

a) Steel arches will be paid by the contractual unit prices for the quantity measured as specified above only for work satisfactorily completed and approved by the Engineer.
b) Auxiliary materials like steel plates in joints, clamps, bolts, nuts, washers, spacer bars and other material as well as overlapping length shall be included in the unit price.

5.4.4 WELDED WIRE MESH AND BAR REINFORCEMENT

5.4.4.1 DESCRIPTION

a) Work within this pay item includes mobilization and de-mobilization of equipment, supply, potential cutting and bending, and installation of welded wire mesh, including, but not limited to, removal and disposal, installation of joint reinforcement and all delays of work up to 2 hours during the execution of all aforementioned works.

5.4.4.2 MEASUREMENT

a) Welded wire mesh reinforcement is measured in [m2] along Line 1a, regardless of its position within

the primary lining.

b) Welded wire mesh reinforcement for face support is measured in [m2] along Line 2 for each drift.
c) Overlapping of wire mesh in the joints, auxiliary installation reinforcement and auxiliary materials (tying wire, spacers on steel arches) shall not be measured for payment.

5.4.4.3 PAYMENT

a) Welded wire mesh and bar reinforcement will be paid by the contractual unit price for the quantity measured as specified above and transletd into [kg] only for work satisfactorily completed and approved by the Engineer.
b) Overlapping length of wire mesh or placed rebar reinforcement for overlapping and fixing material (tying wire) shall be included in unit price.
c) Welded wire mesh for face support will be paid by the contractual unit price for abovementioned measured quantity and percentage of face covered as per the applied Support category.

5.4.5 RADIAL BOLTS

5.4.5.1 DESCRIPTION

a) Work within this pay item includes mobilization, cleaning and de-mobilization of equipment, supply, drilling, flushing of borehole, installation and grouting or expanding radial rock bolts, placement and tightening of end-bolt hardware, including, but not limited to, local removal and disposal or placement of additional shotcrete and all delays of work up to 2 hours during the execution of all aforementioned works.
b) Work within this pay item includes also surveying support for preparation of bolting schemes and guidance of drilling equipment for drilling and installation of radial rock bolts.

5.4.5.2 MEASUREMENT

a) Radial rock bolts are measured in [pieces] for different types, lengths and load capacities.
b) Auxiliary material like plates, washers, nuts and couplers shall not be measured separately.
c) Sacrificial drilling bit for self-drilling hollow core bar bolts (IBO) shall not be measured separately.

5.4.5.3 PAYMENT

a) Radial rock bolts of different types, lengths and load capacities as well as the type of required grout will be paid by the contractual unit price for the quantity measured as specified above only for work satisfactorily completed and approved by the Engineer. Unit prices for intermediate lengths of radial rock bolts shall be obtained by linear interpolation of adjacent lengths and their contractual unit prices.
b) Cement grouted rebar bolts: unit price shall include rod with appropriate tip and thread, cement grout, plate and nut.
c) Cement grouted self-drilling hollow core bar bolts: unit price shall include hollow core bar with endless thread, couplers (if required), sacrificial drilling bit, cement grout, plate and nut.
d) Expandable friction bolts: unit price shall include expandable friction bolt with bushin and plate.
e) Cement grouted combination friction-grouted bolts: unit price shall include rod with expandable shell and threaded body, protection sleeve, plate nad bushing or nut. Grouting of rock bolt with cement grout behind the face i.e. outside the critical path.

5.4.6 SPILES

5.4.6.1 DESCRIPTION

a) Work within this pay item includes mobilization, cleaning and de-mobilization of equipment, supply, drilling, flushing of borehole, installation and grouting of spiles, including, but not limited to, local

removal of ground and disposal or placement of additional shotcrete and all delays of work up to 2 hours during the execution of all aforementioned works.

5.4.6.2 MEASUREMENT

a) Spiles are measured in [pieces] for different types, length and diameter.
b) Execution of pointed tip for rebar spiles and spiles installed with resin grouts shall not be measured separately.
c) Sacrificial drilling bit for self-drilling hollow core bar spiles shall not be measured separately.

5.4.6.3 PAYMENT

a) Spiles of different types, lengths and diameters as well as required grout will be paid by the contractual unit price for the quantity measured as specified above only for work satisfactorily completed and approved by the Engineer.
b) Un-grouted rebar spiles: unit price shall include rod with pointed tip.
c) Cement grouted rebar spiles: unit price shall include rod with appropriate tip and cement grout.
d) Cement grouted self-drilling hollow core bar spiles: unit price shall include hollow core bar with endless thread, couplers (if required), sacrificial drilling bit and cement grout.

5.4.7 FACE DOWELS

5.4.7.1 DESCRIPTION

a) Work within this pay item includes mobilization, de-mobilization and cleaning of equipment, supply, installation and grouting of face dowels, continuous plating and removal of end-dowel hardware including, but not limited to, additional placement or removal of shotcrete, removal, separation and disposal of face dowels, and delays of work up to 2 hours during the execution of all aforementioned works.

5.4.7.2 MEASUREMENT

a) Face dowels are measured in [pieces] for different types, lengths and load capacities.
b) Auxiliary material like plates, washers, nuts and couplers shall not be measured separately.
c) Sacrificial drilling bit shall not be measured separately.

5.4.7.3 PAYMENT

d) Cement grouted self-drilling hollow core bar face dowels: unit price shall include hollow core bar with endless thread, couplers (if required), sacrificial drilling bit and cement grout.
e) Resin grouted self-drilling hollow core bar face dowels: unit price shall include hollow core bar with endless thread, couplers (if required), sacrificial drilling bit and resin grout.

5.4.8 EXCAVATION UNDER SPILES

5.4.8.1 DESCRIPTION

a) Due to inclination inclination of spiles a saw profile appears underneath. This volume shall be filled with (fiber reinforced) shotcrete, which is paied by separate pay item.

5.4.8.2 MEASUREMENT AND PAYMENT

a) Volume under the spiles is calculated accoding to the formula:
b) Where:
    a. n – number of spiles installed for one round length (pieces)
    b. e – starting distance between two neighbour spiles

c. la – round length -
d. If the angle of spiles installation is higher than 5°, this is not measured, but the Contractor should bigger volume consider in the unit price.

5.4.9 SMALLER NICHES

5.4.9.1 DESCRIPTION

a) Due to inclination inclination of spiles a saw profile appears underneath. This volume shall be filled with (fiber reinforced) shotcrete, which is paied by separate pay item.

5.4.9.2 MEASUREMENT AND PAYMENT

a) Volume under the spiles is calculated accoding to the formula:

6. WATERPROOFING AND PERMANENT GROUNDWATER DRAINAGE

6.1 GENERAL REQUREMENTS

a) There must be no intrusion of water, no seepage of water through the final (inner) lining of the main tunnel (with Lay-by niches and cross passage stubs) and its joints, and no wet spots must appear to ensure a dry environment.
b) Service life of the system: All components of the waterproofing system have a minimum service life of 100 years.
c) PVC waterproofing membrane layer: The contractor must provide a written warranty for a period of 10 years for the material issued by the membrane manufacturer upon completion of the works.
d) Contractor's guarantee: He must provide a written guarantee for the impermeability (water resistance) of water in watertight elements for a period of ten (10) years after the conclusion of the contract without additional costs for the Client. Construction work related to PVC waterproofing membrane layers that are incomplete or not in accordance with the tender documentation shall be removed and replaced without cost or special measures to repair the damage.
e) Warranty repairs shall be carried out within a reasonable time after the Contractor has been notified, but in no case later than 48 hours for emergency repairs or within 30 days for non-emergency repairs. Leaks and damp spots are eliminated during the warranty period.
f) The requirements for the leveling layer are set out in Document 3 of the Technical Specifications – Excavation and support of the tunnel .
g) The technical specifications set out general requirements for the materials and execution of the work. The selected materials and execution of the works must meet the requirements regarding operation, functionality and environmental requirements, which are prescribed by these specifications or are given by legislation, national or foreign standards and guidelines for such works.

6.2 WATERPROOFING MEMBRANE AND PROTECTIVE FELT

6.2.1 GENERAL

a) This section covers the waterproofing for allmain tunnel, Lay-by niches, cross passage stubs and all other niches in the main tunnel tube 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.
b) The waterproofing shall be such, that all underground structures are watertight. In case of leakage, provision shall be made for these to be repaired.

6.2.2 DESCRIPTION

a) The purpose of the waterproofing system is to prevent groundwater from entering the road tunnel and to protect the inner lining from harmful chemical effects. Waterproofing shall be applied to crown and sidewalls above footing or invert arch level. The waterproofing system shall always be installed between the layer of the primary lining (shotcrete layer) and the inner lining of the tunnel.
b) The waterproofing system consists of at least two main layers: the first layer is drainage and a protective layer (geotextile or geodrain membrane), which is placed on the surface of the primary lining, sprayed with a regulating layer. 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) Shall the the source of groundwater appear, the Contractor prepares or defines typical solutions. The solution must be approved by the Engineer.

6.2.3 MATERIALS AND EQUIPMENT

6.2.3.1 SUMMARY

a) This section includes requirements for the equipment and installation of a permanent PVC waterproofing tape system for a tunnel, as shown in the Design drawings. It should be noted that the waterproofing system is installed between the primary lining of shotcrete and the final (inner) lining. Equipment and installation of a permanent system of waterproofing tapes is carried out in the following steps:
b) surface preparation (regulating layer)
c) installation of a waterproofing system
d) protection of the waterproofing system
e) inspection of the waterproofing membrane for any damage
f) waterproofing membrane performance testing
g) remediation or repair of waterproofing membrane in case water resistance is not guaranteed or that the waterproofing membrane leaks water
h) repair/remediation of the visible surface of the tunnel.

6.2.3.2 GENERAL

a) The Contractor shall use products that have been specially designed and manufactured for use in the construction of tunnels under conditions similar to those in this project. The properties of the materials to be supplied and installed must exhibit properties that correspond to those specified in the design conditions.
b) Manufacturer's qualifications: The selected manufacturer must demonstrate his experience, performance and participation in the production of similar tunnel construction products. The product proves its effectiveness by being successfully used in at least five comparable facilities in the recent period and that it meets the EU standards.
c) Supervision and training: A representative of the manufacturer must be present at all times on the construction site during the construction of at least the first ten sections of the inner concrete lining and later, if necessary.
d) The installation of layers and quality assurance tests shall be performed under the direct supervision of the Engineer.
e) Prior to the commencement of works, the Contractor shall, at his own expense, provide appropriate training for those who will be involved in the implementation and testing of the waterproofing quality.
f) A report including information on progress in the implementation of the waterproofing system, including information on the verification of all joints, etc. the Contractor shall submit to the Engineer for approval. This information shall be an integral part of the documentation for the approval of the further construction of the inner concrete lining.

6.2.3.3 PROTECTIVE FELT (FOIL)

a) 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	PRESCRIBED VALUE	STANDARD
Uniform weight	min. 500 g/m^2 (+/- 50 g/m^2)	EN ISO 9864:2005
Thickness at 200 kPa	min. 1,7 mm	EN ISO 9863-1:2016
Tensile strength	min. 10 kN/m	EN ISO 10319:2015
Elongation at rupture	min. 60 %	EN ISO 10319:2015
Breakthrough resistance	2000 N	EN ISO 12236:2007
Permeability - perpendicular to the plane	min. 1 x 10^{-2}m/s	EN ISO 11058:2011
Permeability - in the plane at a pressure of 200 kPa and a hydraulic gradient i=1.0	min. 1 x 10^{-5}m2/s	EN 12958:2012

Table 3 Properties of protective and drainage layer

b) Where the inflow of groundwater is high, the geotextile is replaced by geodrain, which has a higher permeability.

6.2.3.4 GEODRAIN

a) Geodrain has similar properties to geotextiles. The main difference is its higher water permeability.
b) Drainage layer from »geodrain« can be made (replaced) with dimpled membrane.
c) The geodrain layer shall be made of at least two layers. The first or outer layers are made of continuous fibers of non-woven polypropylene (PP) geotextile with a uniform thickness and surface texture.
d) The second or middle layer is made of high density polyethylene (HDPE) with three dimensional structures.
e) The material for Geodrain shall meet the requirements given in table below:

PROPERTY	PRESCRIBED VALUE	STANDARD
Uniform weight	min. 700 g/m^2	EN ISO 9864:2005
Thickness at 200 kPa	min. 5 mm	EN ISO 9863-1:2016
Tensile strength	min. 3,5 kN/m	EN ISO 10319:2015
Elongation at rupture	min. 40 %	EN ISO 10319:2015
Permeability - perpendicular to the plane	min. 60 mm/s	EN ISO 11058:2011
Permeability - in the plane at a pressure of 200 kPa and a hydraulic gradient i=1.0	min. 0,25 l/m.s	EN 12958:2012

Table 4 Required properties of Geodrain layers

6.2.3.5 WATERPROOFING MEMBRANE

a) The waterproofing membrane shall be made of PVC (poly-vinyl-chloride) and shall must meet requirements specified in Table below.
b) The waterproofing membrane strip shall have a uniform thickness and surface texture and shall be supplied in dimensions that will allow the minimum number of welds to be performed during installation in an underground structure.
c) The waterproofing membrane shall be made as a single layer with a coating that acts as a protective/signal layer (max. 0.2 mm thick). The purpose of the signal layer is to mark damage to the waterproofing membrane that can be repaired before concreting the inner concrete lining.

Therefore, the membrane is thicker than 2 mm and has a signal layer of a maximum color of 0.2 mm. The signal layer must not adversely affect the welds.

d) Water barriers must be made of a material compatible with the waterproofing membrane so that they can be successfully welded to the membrane. All joints are made with cast or prefabricated cross sections that are properly joined according to the manufacturer's instructions.

e) Waterproofing tapes (membrane) shall comply with the requirements of Table 4.6 ÖBV 'Richtlinie Tunnelabdichtung Ausgabe Dezember 2012" and the following table:

Property	Specified Value	Standard
Thickness	min. 2.0 mm	DIN 16726:2017-1
Tensile strength	min, 12 N/mm^2	EN ISO 527-1 / 3/5 2009
Elongation at failure	min. 250%	EN ISO 527-1 / 3/5 2009
Elastic module	Min.20 N/mm^2	EN ISO 527-1 / 3/5 2009
Compressive strength at 20% strain	min. 2.5 N/mm^2 *	EN ISO 604:2003
Tear propagation strength	min. 80% at 0.4 m	EN 14151: 2010
Resistance under water pressure	waterproof at 10 bar for 10 hours	DIN 16726:2017-1
Flexibility at low temperature	No cracks at -20 ° C	EN 495-5: 2013
Tensile strength of welding seam Welding factor	min. 10.8 N/mm^2	DIN 16726:2017-1
Dimensional stability after accelerating ageing	max. +/- 2%	DIN 16726:2017-1
Material characteristics during and after storage at 80° C: - General appearance - Dimensional stability, long. and transverse - Variation of tensile strength, long. and transverse - Variation of elongation at failure, long. and transverse - Folding at a temperature of -20 degrees C	 no blisters ≤ 3% ±20% ±20% no fissures	DIN 16726:2017-1
Water absorption	max. 1% max	EN ISO 62:2009
Behavior after storage in acid and/or alkaline solutions: - Variation of tensile strength, long. and transverse - Variation of elongation at failure, long. and transverse - Folding at a temperature of -20 degrees C	 ±20% ±20% no fissures	DIN 16726:2017-1
Behavior during perforation test Behavior in fire	no perforation at 750 mm height of fall E	EN ISO 12236:200 EN 13501-1 EN ISO 11925-2

Table 5 Required properties of waterproofing membrane

6.2.3.6 ACCESSORIES

a) 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.

6.2.4 HANDLING AND EXECUTION

6.2.4.1 SURFACE PREPARATION

b) All surfaces to which waterproofing is to be applied shall be sufficiently clean, smooth and free from deleterious materials and projections.
c) The following treatment of surfaces shall be performed prior to the installation of waterproofing:
   a. For the fixing of the protective felt and the waterproofing membrane, a minimum shotcrete cover of 5 cm to rock is required.
   b. 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). Roundings at rock bolts, etc. shall have a min. radius of 0.3 m.
   c. Transitions and intersections of tunnel profiles shall be rounded off with a minimum radius of 50 cm.
   d. Protruding steel bars, wires, spacers, pipes etc. shall be cut off unless treated with additional shotcrete cover.
   e. Exposed steel parts such as rock bolts, if not intended to remain accessible, shall be covered with shotcrete.
   f. 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.

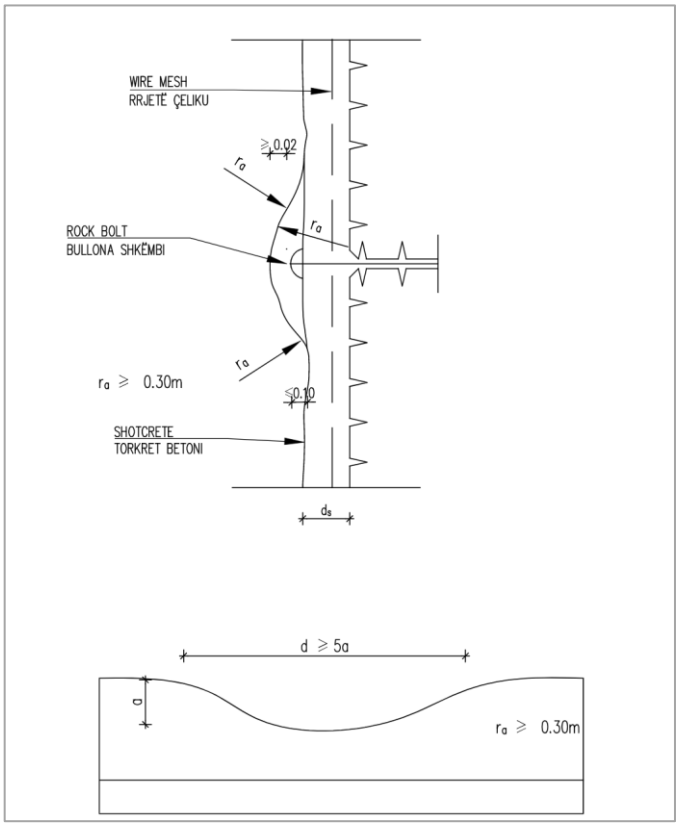

Figure 7 Requirements for substrate conditions before applying the waterproofing system

6.2.4.2 APPLICATION

a) Prior to the application of the waterproofing, all surfaces to which it shall be applied, shall be inspected and approved by the ENGINEER.
b) The application shall follow the written instructions of the manufacturer. Generally procedures are

the following preparations.

c) 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.

d) 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.

e) 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.

6.2.4.3 7.2.4.3 PROTECTIVE MEASURES

a) 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.

6.2.4.4 7.2.4.4 HANDLING AND STORAGE

b) All materials must be delivered in the original, sealed packaging with the name of the manufacturer, labels, product identification and batch numbers. Damaged material must be removed from the place of use immediately.

c) Store all materials in a cool, dry and preferably air-conditioned environment, raised from the ground and protected from rain or excessive heat until ready for use.

d) Equipment in contact with the product shall be stored in a cool place and away from direct sunlight.

6.2.5 PRE-CONSTRUCTION SUBMITTALS

a) In accordance with the contractual requirements, the Contractor shall submit the following documentation and implementation proposals for review and approval:
   - a.) Certificates of compliance attesting that the materials meet specification requirements,
   - b.) the manufacturer's instructions for the installation of the protective layer and the waterproofing membrane, including procedures for preparation, attachment, fixing, welding, etc.,
   - c.) certificates of competence of manufacturers and installers of waterproofing systems with evidence of experience gained in this field, including supervision of the installation of the regulating leveling layer,
   - d.) material samples of the following waterproofing elements:
     - i. waterproofing membrane: 1 m2 of each proposed type of protective felt,
     - ii. geotextile foil: 1 m2 of each type of protective membrane proposed,
     - iii. geodrain membrane: 1 m2 of each type of proposed protective membrane,
     - iv. double weld samples: 1 m' of weld for each proposed waterproofing strip and fitter,
     - v. fastening components: 10 examples of fastening rods and nails, 2 examples of sealing flanges for elements punching trough the waterproofing membrane.

b) The Contractor shall submit to the Engineer for approval his technical solutions and design changes, if any, which must contain the necessary data for the installation of the protective membrane and

waterproofing membrane, including installation phases, positions of working contacts of the waterproofing layer, leveling of perforations waterproofing membrane, production of water barriers, sketch of contacts with waterproofing elements in gallery construction, local reinforcements, etc.

c) The Contractor shall submit to the Engineer for approval the Competence of the Contractor's staff, including a curriculum vitae stating the relevant project experience, the position he holds, the duration and a description of the project which has been successfully carried out.
   - indication of the manufacturer of the waterproofing membrane
   - waterproofing installer
   - waterproofing membrane and grouting supervisor
   - proposed independent test laboratory (for geomembrane)

d) Solution of the temporary construction drainage system must be submitted to the Engineer for inspection and approval before the start of the relevant works.

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

6.2.6 QUALITY ASSURANCE

a) Before installing the waterproofing membrane, the Engineer shall inspect all surfaces on which the waterproofing system will be installed and approve the further execution of works. In the event that the Contractor does not meet the prescribed criteria, he must make all corrections at his own expense. Continuation of work is permitted when the prescribed criteria approved by the Engineer are met.

b) The installation must be carried out in accordance with the manufacturer's written instructions, design and approved technological process.

c) Production qualifications: The manufacturer of a given product must be ISO 9001:2008 and ISO 14000 certified and have a recognized quality assurance program in place, which is regularly checked.

d) The waterproofing installer must be qualified for the installation and proposed testing, must have at least five (5) years of experience in installing a flexible strip system in tunnel waterproofing installations.

e) The Contractor shall have at his disposal qualified personnel who have undergone product training organized by the manufacturer's representative at his own expense.

f) Materials must be installed in accordance with all safety and weather conditions required by the manufacturer or as amended by the applicable rules and regulations of the competent local, state and federal authorities. Material safety data sheets shall contain complete handling instructions.

g) All products shall be used in accordance with the latest technical data sheets and method description provided by the Contractor and approved by the Engineer.

h) All products in the waterproofing system shall be supplied by the same manufacturer to ensure a single source of liability and warranty.

i) The selected manufacturer shall demonstrate the durability and compatibility of all products, which are to be installed in direct contact with each other.

j) Prior to the installation of the waterproofing system, the Contractor shall prepare and attend a preliminary meeting to ensure that the drawings and specifications are clearly understood. Seven (7) days prior to the meeting, the Engineer must receive written notice of the time and place of the meeting. It must be ensured that the waterproofing installer, a representative of the membrane manufacturer and other experts who will carry out other works on or near the membrane after installation attend this meeting. All conversations and arrangements should be recorded, minuted and distributed to all parties in the project.

k) In-situ tests:

l) The test shall be performed for each type of membrane used on site during construction.
m) The site test shall be performed for the first section of the waterproofing membrane to be installed in the tunnel along the length of one section of the inner lining.
n) The test includes the installation of a geotextile with a fixing system, the installation of a waterproofing membrane or strips and fixing to the base, double welding of radial and longitudinal joints, including monitoring the velocity and temperature of joints welding. The goal is quality execution of welds that are sufficiently resistant to water, including manual welding of patches. The test includes pressure testing of single and double welds, membrane strip repair techniques, attachment of water barriers and weld testing, and installation of injection pipes

6.2.7 QUALITY CONTROL

a) The installation inspection for geotextile foil and Geodrain performed by the Engineer shall confirm or otherwise document the following:
    a. Use of intended materials
    b. Proper storage and handling of material
    c. Air temperature in the tunnel
    d. Number of fastenings/fixing elements
    e. Breakthroughs shall be performed as shown in the Design drawings or in the manufacturer's instructions.
b) An installation review for PVC membrane, whether or not approved by the Engineer, shall include the following content sets:
    a. Use of intended materials
    b. Proper storage and handling of material
    c. Atmospheric temperature
    d. Number of fastenings/fixing elements
    e. Appropriate supervision by the Waterproofing Supervisor
    f. An approved waterproofing installer has passed a welding test
    g. Weld direction and layout
    h. Number and arrangement of connections
    i. Proper orientation of the top layer of geodrain
    j. Membrane overlap at welded joints
    k. Breakthroughs shall be performed as shown in the Manufacturer's Plans or Instructions.
    l. Descriptions of the location, type and height of water barriers in accordance with the provisions and requirements in the relevant construction documentation should be given.
    m. Descriptions of the location and height of inspection and grouting pipes and re-grouting pipes, in accordance with the provisions and requirements of the relevant construction documentation should be given.
    n. The construction documentation in question must be of good quality in accordance with the requirements given in these specifications.
    o. Descriptions of the location and height of existing contact injection pipes in accordance with the provisions and requirements in the relevant construction documentation.
c) Before the start of the next construction phase, testing of the installed waterproofing membrane shall be performed. The test is performed by a weld test. All welds should be checked. An Engineer must be present during the inspection. The findings and results of welding suitability testing must be recorded in writing, and the Contractor is obliged to submit the documentation to the Engineer.
d) The test is performed by two methods. The first method is mandatory unless local constraints prevent the test from being performed.
e) Control of compressed air welds: The impermeability of the insulating membrane welds shall be checked with compressed air by supplying compressed air to the test space during double welding. The initial test pressure must be 200 kPa (2 bar) for 5 minutes or 150 kPa (1.5 bar) for 10 minutes.

The contact is considered to be watertight if the drop in air pressure in both cases does not exceed 20% at the stated intervals.

f) Inspection of welds with vacuum equipment: Vacuum checking may be used to check welds in restricted areas, such as special forms of joints or local damage repairs. When performing the control, a suction bell is used, which is sucked through the control area and from which air is then sucked out and the seal of the weld is determined

6.3 PERMANENT GROUND WATER DRAINAGE

a) 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.

6.3.1 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.

6.3.2 MATERIALS

a) The longitudinal ground water drainage shall be made of PP materialpipes that are resistant to the chemical composition of groundwater and provide the stiffness of the SN8 pipe according to the design. Selected pipes shall not be ribbed construction. The perforation of the pipe shall be only in the upper part, the openings are around the circumference of the pipe arranged at an angle of 220 °, the width of each slot shall be at least 10 mm. The length of each slot must not exceed 1/8 of the pipe circumference (45 °). The total perforation area for the water inflow must be at least 150 cm2 per meter of pipe length depending on the hydrological conditions in the rock. All drainage pipes must be marked with a signal line at the top of the perforated side that allows control of the correct execution of the assembly pipes..

b) The main tunnel drainage (collector tube) shall consist of PP material pipes that are resistant to the chemical composition of groundwater and provide the stiffness of the SN8 pipe according to the design. Selected pipes shall not be ribbed construction. The perforation of the pipe shall be only in the upper part, the openings are around the circumference of the pipe arranged at an angle of 120 °, the width of each slot shall be at least 10 mm. The length of each slot must not exceed 1/8 of the pipe circumference (45 °). The total perforation area for the water inflow must be at least 150 cm2 per meter of pipe length depending on the hydrological conditions in the rock. All drainage pipes must be marked with a signal line at the top of the perforated side that allows control of the correct execution of the assembly pipes.

6.3.3 HANDLING AND EXECUTION

c) Materials shall not be stored directly on the ground. There shall be no dirt or debris inside the pipes and fittings. The protection of the seals must be carried out in accordance with the manufacturer's instructions.
d) Before, during and after installation, plastic pipes shall be protected against external adverse effects in order to maintain the quality of the material and to prevent any damage or deterioration of the material.
e) The Contractor shall perform work on the construction site in accordance with the written instructions of the Manufacturer, unless otherwise specified by the Engineer.
f) 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.
g) Prior to the installation of drainage pipes, they shall be inspected and, if they are damaged or damaged between them, they must be removed from the construction site.
h) The pipe connection must be carried out according to the manufacturer's instructions.
i) The pipes are installed on a lean concrete layer with the strength specified in the Design. The lean concrete must ensure the prescribed longitudinal slope of the drainage pipes in order to permanently ensure the outflow of rockmass water from the tunnel.
j) All groundwater inflows that were installed through the primary lining at the time of excavation must be connected to the ground water system. In the event that the constant inflows are extremely large, the Contractor, together with the Engineer, shall find a solution on how to collect water completely and ensure permanent drainage of ground water through the drainage systemls.
k) The longitudinal ground water drainage pipes shall be covered and protected by granular material 16-32 mm.
l) Inspection niches shall be installed in the inner concrete lining for permanent maintenance (flushing) of the drainage system as shown on the drawings.
m) The CONTRACTOR shall 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.
n) All drainage pipes for control of the ground water shall be installed to line and grade as shown on the drawings.

6.3.4 7.3.4 PRE-CONSTRUCTION SUBMITTALS

a) Product information: The manufacturer's product information for standard prefabricated concrete shafts, niche floor elements, pipes, fittings, fittings and covers, and other related items must be provided prior to use. Product information includes construction components, mechanical characteristics, configurations, and dimensions as required in the Plan.
b) The construction plan shall be submitted to the Engineer for approval at least 30 days before the start of work.
c) The quality control plan must be drawn up in accordance with the applicable quality control requirements. The contractor must provide a quality control plan to ensure uniformity of materials, conformity to models, and compliance with the Specifications.

6.3.5 QUALITY CONTROL

a) Before backfilling the drainage pipies, the Engineer shall inspect and take over the installed pipes of the ground water system.
b) Prior to the installation of filling concrete, the Engineer shall inspect and approve the installation of shafts, formwork, covers and pipe joints in order for the Contractor to proceed with the works.
c) The Contractor shall clean and test the installed piping within 15 working days of their installation. Tests can be performed on individual sections in accordance with standards.

d) Before starting the drainage system, the Contractor shall clean the system with high-pressure water (>100 bar). After cleaning, a TV inspection of the entire system is to be performed.

6.4 MEASUREMENT

6.4.1 WATERPROOFING MEMBRANE

a) The waterproofing membrane applied in traffic tunnels and lay-by nicheswill be measured by square meter along "Line 1" (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 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.

6.4.2 LONGITUDINAL GROUNDWATER DRAINAGE

a) The executed works for the longitudinal drainage pipes will be measured by linear meter of each drainage pipes. Lean concrete and protection of the longitudinal drainage pipes by granular material 16-32 will not be measured separately.
b) Construction of inspection shafts will be measured separately.
c) Main dewatering system (collector tube) for ground water water will be measured in linear meters (m1). Lean concrete is not measured separately.

6.5 PAYMENT

6.5.1 WATERPROOFING MEMBRANE

a) 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.

6.5.2 LONGITUDINAL GROUNDWATER DRAINAGE

a) The Unit Price for the longitudinal groundwater drainage system shall include all labour, equipment and materials required for execution of the works, including lean concrete and granular material 16-32 according to drawings, quality control and testing

7. CONCRETE WORKS AND REINFORCEMENT

7.1 GENERAL

a) This section contains specifications for the construction of the final tunnel lining, the foundation beams, the concrete invert arch and precasted 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..

7.1.1 DESCRIPTION

a) The final (inner) 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.
b) The foundation beams form the abutments for the final tunnel lining. Cable ducts and side walks are generally placed on these longitudinal concrete beams.
c) The invert arch forms the ring closure of the tunnel lining (tunnel tube) where poor geological conditions prevail.
d) 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.
e) Precasted concrete elements form the lateral boundaries of the road surface (kerbs) and are also used for cable duct slabs.
f) Contact grouting is the injection of grout material under pressure (up to 2.0 bar) 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.
g) Coating of the concrete surface of the inner lining will be necessary for protection of concrete and to facilitate cleaning.

7.1.2 SUBMISSIONS

a) Working drawings shall be submitted showing the camber of formwork as required for compensation of deflection by concrete placing operation.
b) The CONTRACTOR shall 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 shall be submitted by the CONTRACTOR for approval by the ENGINEER.
d) Prior to fabrication of precasted concrete components the CONTRACTOR shall submit references of the manufacturer to the ENGINEER.
e) Method statement, plant and material description for contact grouting shall be submitted to the ENGINEER for approval before commencement of inner lining concreting works.
f) Test reports and examples of material used for coating shall be submitted by the CONTRACTOR for approval by the ENGINEER.

7.1.3 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 precasted 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.

7.2 MATERIAL AND EQUIPMENT

7.2.1 FORMWORK

a) Steel formwork shall be used for the construction of the inner lining. Formwork must be designed in such a way that it can be used repeatedly. The use of wooden formwork locally is allowed only with the prior approval of the Engineer.
b) The formwork must be sufficiently rigid to maintain its shape and position durin concreeting to such an extent that the concrete structure is constructed within the permissible tolerance limits.
c) Openings along the formwork walls shall be provided every 3.0 m and at a maximum height of 2.0 m. The openings must also be in the dome of the tunnel. The openings must allow access to the equipment for mechanical vibration of the concrete and control of the concrete during the installation and inspection of the hardened concrete surface before moving or removing the formwork. The size of each opening in the plate must be at least 600 mm2. Concrete installation openings should be placed at such heights to prevent segregation of the concrete mass. The joints in the formwork must be so tight as to prevent leaching and leakage of cement laitance from the concrete.
d) The formwork must be regularly maintained to ensure the accuracy of the required shape, strength, stiffness, watertightness and smoothness of the substrate surface. Prior to use, the surface of the formwork lining must be cleaned, oiled and free of dust. In the event of down times, the formwork must be protected against corrosion.
e) The formwork and formwork oil must not leave any stains on the inner lining, cause chemical reactions and/or affect the color tone of the concrete. Before using formwork oil, concrete residues on the formwork surface must always be cleaned regularly and thoroughly.
f) The shape of the inner wall of the tunnel must be able to mount external vibrators at appropriate intervals in the area of the shaft, so that the prescribed compactness or density of the lining can be achieved.
g) Steel formwork shall be fitted with appropriate adjusting elements to allow the edge of the formwork to be adjusted so that an end edge can be made along the perimeter of the tunnel at the beginning/end of each concrete section. In this way, a smooth transition of the lining surface can be carried out even in the curves.

7.2.2 CONCRETE

a) Standards and other requirements for the preparation of the concrete mix shall be considered and fulfilled.
b) The size of the maximum aggregate of the aggregate concrete mix must be in accordance with the

standards or a specific concrete mix.

c) The concrete mix is prepared using methods to mitigate the hydration heat.
d) An aggressive environment (freezing and/or salt, for example) may occur near the entrance to the tunnel, so the instructions for concrete resistance to frost and thawing must be observed. The requirements must be met in accordance with the Tunnel Interior Lining Design.
e) For the specific structural elements of the tunnel, the Concrete classes and related exposure requirements are defined in the Design drawings. For specific requirements, the requirements given in the Design drawings shall be taken into account.
f) The consistency of the mix shall be chosen to allow placing of concrete by pumping.
g) 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.

7.2.3 PRECAST CONCRETE COMPONENTS

a) Standards and other requirements for precast concrete elements shall be fullfielrd fulfilled. Concrete of class at least C35/45 or in accordance with the Design shall be used for the production of precast concrete elements
b) Concrete strength classes and their exposure requirements are defined for the specific structural elements in the Design.
c) Precasted concrete elements shall be produced with a dimension tolerance of 2 mm.

7.2.4 OTHER CONCRETE WORKS

a) Concrete must be installed in such a way that the prescribed dimensions and prescribed quality are fulfilled, as specified in the Design and in accordance with the prescribed technical conditions.
b) Concrete works include the supply of basic materials for the production of concrete mixtures (rock aggregate, cement, water, chemical and mineral additives) and the production, transport and installation of fresh concrete mixtures on the construction site, as specified in the Design. These works also include the protection of fresh concrete surfaces after installation.
c) These works must be carried out in dry weather, when there is no precipitation during the installation of the concrete and the air temperature (for no wind condition) is between 5° C and 30° C. If work is to be carried out under different conditions, the required concrete temperatures in production must be ensured in such a way that appropriate procedures (heating, cooling) are used. Also, after the installation of concrete is completed, protective measures must be taken to ensure that the concrete hardens in accordance with the prescribed procedure.
d) The concrete mix must meet the requirements of EN 206, concrete specifications, national standards and other special requirements specified in the Design. Natural and recycled normally heavy aggregate (grain density>2.000 kg/m3) must be prepared in accordance with the requirements of the EN 12620 standard, and EN 13055-1 applies to the light aggregate.
e) Cement is basically a hydraulic binder, i.e. finely ground inorganic material mixed with water to form a paste that binds and solidifies aggregate grains based on chemical reactions and hydration processes and maintains strength and stability after drying.
f) Cement consists of different materials. Their composition determines the properties of cement as an integral part of fresh and hardened concrete.
g) Cement compliant with EN 197-1 is generally considered to be suitable for concrete. In special cases, other cements that do not comply with the EN 206 standard can also be used for concrete preparation, e.g. sulphate resistant cement, three calcium aluminate cement or low-hydrate cement.
h) The quality of water for concrete preparation can affect the setting time or solidification, rate of strength increase, ensuring durability and corrosion protection of resistant steel.
i) Water for the preparation of concrete mix may be used in accordance with EN 206, and in accordance with the conditions specified in EN 1008.

j) The use of chemical and other additives must comply with the requirements of EN 206.
k) The effects of chemical additives, their compatibility with cement, must be checked in initial tests.
l) The manufacturer's instructions must be followed when using chemical additives.
m) Concrete may be treated as visible (washed or otherwise treated concrete) on the surface (with formwork or otherwise) or it may be treated as protective concrete. The types of structures that require visible concrete are listed in the Design drawings

7.2.5 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 CONTRACTOR shall provide satisfactory water from other main sources.
b) Cement shall be compliant with EN 197-1. 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.
d) The grouting mass for contact grouting shall be stable to pressure and have the prescribed strength C30/37 after 28 days. The mass must be sufficiently fluid to be able to flow under pressure (200 kPa) into all spaces, which are filled through the injection pipe

7.2.6 STEEL REINFORCEMENT

a) For the inner concrete lining steel reinforcement is necessary in heavily stressed areas such as shallow cover, 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.
b) Steel reinforcement is required for the Concrete Arch as well and the precasted concrete elements as well.
c) Reinforcement means wire mesh, reinforcement of bars or fibers, which may be made of steel.
d) Welded reinforcement meshes shall be installed in the maximum possible practical lengths. The dimensions of reinforcing mesh must be in accordance with the standard EN ISO 15630-1:2011 - Steel for reinforcement and prestressing of concrete and EN 10080:2005 - Weldable reinforcing steel.
e) Ribbed reinforcement bars shall meet the requirements of EN ISO 15630-1:2011 - Steel for reinforcement and prestressing of concrete.
Ribbed reinforcement bars shall be made of type B 500 B steel or must comply with the standard SIST EN 10080:2005 - Weldable reinforcing steel.
f) Spacers for reinforcement are an important element in ensuring the durability of the structure, as they provide the necessary layer of concrete over the reinforcement. They shall meet the following requirements:
    a.) Shall provide the necessary protective layer of concrete to the reinforcement (possible deviation upwards by 5 mm and downwards by 0 mm),
    b.) The use of micro-reinforced cement spacers is required. This also applies to prefabricated elements.
    c.) Spacers shall have a sufficiently high compressive strength (min. 50 N/mm2) to be able to withstand the thrust loads of the hydraulic formwork when reinforcing the inner arch or the load of own weight of the installed reinforcement, concrete mix and workers during installation when reinforcing the ceiling slab.

d.) The use of prismatic spacers is required for the inner arch in the tunnel on the inside. The orientation of the spacers should be done in such a way that the thinnest part is on the formwork side. Spacers for the inner vault must be attached to the reinforcement in at least 2 places.

e.) Spacers on the outside - against the waterproofing membrane - shall be firmly attached to the reinforcement in such a way to prevent damage to the waterproofing layer. The area of the spacers touching the waterproofing membrane must be rounded (usually this is stated in the reinforcement Design drawings).

f.) After removing the formwork, the spacer must not be visible on the inner surface of the lining from a distance of 5 meters.

g.) In critical areas of lining overload, spacers should be placed more frequently to meet design requirements and to avoid excessive stress

7.2.7 COATING

a) The quality of materials for the protective coating of concrete surfaces shall be in accordance with the provisions of the Austrian Construction Association - ÖBV Merklatt "Tunnelbeschichtungen" edition 2014
b) Material quality tests shall be carried out by an authorized institute carrying out such tests
c) At least three (3) test fields shall be performed to pre-determine the suitability of the materials for each paint system. Each test field shall include separate phases for each activity individual system.
d) The adhesion value tested by cutting a grid of 5 mm x 5mm shall be at least 85 %.

7.3 HANDLING AND EXECUTION

7.3.1 PREPARATION OF FORMWORK BEFORE CONCRETING

a) The inside surface of forms shall be coated with an approved nonstaining mould oil to prevent adhesion of the concrete.
b) Release agents shall be applied strictly in accordance with the manufacturer's instructions and shall not come into contact with reinforcement.
c) The composition of the release agent shall be such that it will not interfere with future surface treatments.
d) 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.
e) 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.
f) Formwork shall be erected to such levels as to make allowance for anticipated deflection of the formwork under load.

7.3.2 PREPARATION FOR CONCRETE WORKS

a) Before the concrete tunnel lining is cast the CONTRACTOR shall 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.
b) Mixing trucs shall be used for transportation of concrete from concrete plant to the site of installation.
c) The requirements for Portland cement concrete are:
    i. Cement must be stored in dry rooms in containers or silos that do not contain contaminants
    ii. Coarse and fine aggregate must be stored and handled in such a way as to prevent segregation and contamination with other materials or other sizes and types of rock aggregates. Coarse and fine aggregate must be stored so that the water is free or

gravitationally drains away from the warehouse. Aggregates containing frozen lumps must not be used

iii. Additives must be stored and used in accordance with the manufacturer's written instructions

iv. The water to be used for the concrete mix must be protected from contamination

d) The transport of concrete to the construction site must be carried out in such a way to ensure and enable efficient delivery of concrete to the installation site, without negatively changing prescribed properties of concrete, especially water-cement ratio, fall of concrete, air entry into the concrete mix and concrete homogeneity.

e) Feeding or storage of the products concerned in accordance with the manufacturer's written instructions.

f) All materials must be delivered in the original, sealed packaging with the manufacturer's name, labels, product identification and batch numbers. Damaged material must be removed from the site immediately to prevent its use.

7.3.3 INSTALLATION OF CONCRETE

a) The CONTRACTOR shall submit full details of his proposed tunnel concrete placing methods, including a description of the equipment to be used.

b) 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.

c) Concrete shall not be placed in any part of the structure until the ENGINEER´S approval has been given.

d) Concrete shall be placed by a concrete pump or by another method approved by the ENGINEER. Installation must be carried out in such way that the technology of pumping concrete is suitable for concrete mixtures and that there is no segregation of the concrete mixture. The concrete pump must operate in a way that the flow of the concrete mix is constant and that no air pockets are formed. When installing the concrete mix in the inner lining of the tunnel, it is necessary to prevent the concrete mix from being installed in such a way that an internal cavity is formed through openings from a height of more than 150 cm. The concrete mix must not be transported more than 2 m from the opening for the concrete mix in the horizontal direction. The installation of the concrete mixture in the upper third (at the top) of the formwork must be carried out by means of a distribution trolley that moves in the longitudinal direction and allows connection to the installation openings in several locations. .

e) 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.

f) 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.

g) Concrete shall be pumped into the formwork through suitable temporary openings.

h) 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.

i) Maximum level differences shall not exceed the values as specified by the manufacturer of the formwork.

j) 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.

k) Particular care shall be taken to ensure the complete filling of the crown of the tunnel arch. The CONTRACTOR shall 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.
l) 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 compact the concrete at such joints to a reasonably uniform and stable slope while the concrete is plastic and any concrete which remains uncompacted shall be removed.
m) Final lining for tunnels shall be cast in blocks of maximum 12.5 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 blocks shall be perpendicular to the tunnel axis.
n) Concreting at high or low temperature must be carried out in accordance with EN 13670:2010 - Execution of concrete structures COMPACTION OF CONCRETE FOR FINAL LINING
o) All concrete shall be compacted to produce a dense homogeneous mass.
p) The concrete shall be compacted by vibrators anchored to the formwork and immersion vibrators operated through the inspection openings in the formwork.
q) 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.
r) The operating time of the vibrator mounted on the formwork must be short (max. 30 seconds of vibration for each vibrator) in order to avoid segregation of the concrete mass.
s) No later than 2 hours after completion of installation, the concrete must not be further vibrated.

7.3.4 REMOVAL OF FORMWORK

a) During the setting phase of concrete, the requirements of standard EN 13670:2010 - Execution of concrete structures shall be observed, unless otherwise specified in the Design.
b) The Contractor shall notify the Engineer if he intends to remove the formwork.
c) The removal of formwork is permitted when the inner lining reaches the minimum required compressive strength as stated below. The Contractor is responsible for the quality of the procedure.
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 damage to the concrete lining caused by the removal of the formwork must be repaired by the Contractor at his own expense.
f) The formwork shall not be removed until the concrete has reached sufficient strength to prevent damage to the structure in the event of the most unfavorable load case. The strength of the installed concrete must be measured after removing the front formwork at the top of the tunnel lining. The minimum strength that the concrete has before removing the formwork must be high enough to meet the static requirements in the case of self-weight loading, as well as the requirements for inner lining given in the Tunnel Inner Lining Design.
g) The achieved compressive strength shall be checked by a uniaxial compressive test of concrete. Samples shall be taken from the mixture beforehand and stored under the same conditions as the lining in the tunnel or according to established methods approved in advance by the Engineer.

Removal of formwork:

Regular Cross Section, Main tunnel

- The minimum time for removal of the formwork is 8 hours
- The minimum strength of the concrete at removal of the formwork shall be 2.0N/mm² and preferably not more than 3.0N/mm²
- The strength shall be tested at the front of the concrete block by Schmidt hammer model PT.

Layby Niche Cross Section

- The minimum time for removal of the formwork is 8 hours
- The minimum strength of the concrete at removal of the formwork shall be 3.5N/mm² and preferably not more than 5.0N/mm²
- The strength shall be tested at the front of the concrete block by Schmidt hammer model PT.

Intermediate Ceiling

- The minimum time for removal of the formwork is 36 hours
- The minimum strength of the concrete at removal of the formwork shall be 16.0N/mm²
- The strength shall be tested by Schmidt hammer model PT.

7.3.5 CURING OF CONCRETE

a) During the concrete care phase, the requirements of standard EN 13670:2010 - Execution of concrete structures shall be observed, unless otherwise specified in the Design.
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) The Contractor shall prevent or reduce the development of cracks in the concrete due to shrinkage through careful work and proper organization. The minimum allowable crack widths resulting from shrinkage in reinforced concrete linings can be up to 0.3 mm. In case of wider cracks, they should be repaired by filling with resin or mortar. Cracks caused by shrinkage in unreinforced linings that are larger than 1.0 mm must be filled with cement mortar or epoxy or polyurethane resin or repaired in a manner approved by the Engineer.
g) Immediately after installation, the concrete must be protected against excessive drying, heat or low temperatures, mechanical damage or discoloration.
h) During the setting phase, concrete must be protected against mechanical and physical loads that may be caused by the movement of heavy equipment and exposure to shocks or excessive vibrations.

7.3.6 REMEDIAL TREATMENT OF SURFACES

a) Any repair of the concrete surface must be approved by the Engineer. Repairs must be carried out immediately after the removal of the formwork, in accordance with EN 13670:2010 - Execution of concrete structures.
b) If the concrete surface in a certain area has been treated prior to the Engineer's inspection, this may be a reason for rejecting the concrete work carried out in that area. Further procedures shall be determined by the Engineer. .

7.3.7 PRECASTED CONCRETE COMPONENTS

a) Precasted concrete components shall be placed with a tolerance of ± 5 mm, related to the theoretical position.
b) Precasted elements shall be placed on lean concrete with a minimum thickness of 30 mm.
c) The standard length of the precasted concrete elements shall be 100 cm (e.g. cable duct slab, concrete kerbs)
d) Reinforcement for prefabricated concrete elements used for cable duct covers shall be calculated in accordance with the standards for the design of reinforced concrete structures.
e) The joints between precasted concrete elements shall be sealed (using permanetly elastic material).

7.3.8 CONTACT GROUTING

a) Prior to the commencement of inner lining works, the CONTRACTOR shall submit to the ENGINEER for his approval full details of the working method and equipment to be used.
b) The Contractor shall ensure that all contact grouting work at the top of the tunnel lining is carried out by suitably qualified and experienced workers. The values of the maximum grouting pressures are limited to 2 bar (200 kPa). .
c) Grouting and ventilating pipes shall be positioned prior to concreting.
d) Upon completion of grouting, the CONTRACTOR shall cut off all surplus lengths of pipes.
e) The CONTRACTOR shall 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 CONTRACTOR shall 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.

7.3.9 REINFORCEMENT WORKS

a) Welded wire fabrics shall be installed in the longest practical length. The overlap for welded wire fabrics shall be at least three distance in circumferential and two square distance in longitudinal direction.
b) A minimum concrete cover or a protective layer which shall not be thinner than 6.0 cm for the inner lining of the tunnel and/or a minimum of 4.0 cm for other concrete structures. The thinnest nominal concrete cover is specified in the individual Design drawings.
c) The CONTRACTOR shall pay utmost attention not to damage the waterproofing membrane during the construction of the reinforcement.
d) Reinforcing steel bars shall be attached securely to the previously wire mesh. Overlaps shall be arranged as shown on relevant drawings.

7.3.10 COATING

a) Execution of coating works shall shall be in accordance with the provisions of the Austrian Construction Association - ÖBV Merklatt "Tunnelbeschichtungen" edition 2014unless 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.

7.4 PRE-CONSTRUCTION SUBMITTALS

a) In accordance with the contractual requirements, the Contractor shall submit to the Engineer for review and approval the following documentation and implementation proposals:
   i. Product information and the manufacturer's written instructions for storage, handling and assembly must be provided for each product.
   ii. Certificate of accreditation for an independent testing laboratory as regards the technical competence to perform the required tests.
   iii. The technological study prepared by the Contractor which shall contain the methods of work, the plan for safety and health at work, the methods for the installation of formwork, removal and billing, and information on the Contractor's equipment for carrying out works with all work procedures.
   iv. The Contractor shall carry out testing of the proposed mixture of aggregate contents to demonstrate the suitability of the mixture and its compatibility with the intended construction method presented in the description of the method, which must be in accordance with the Design drawings. The mixture must contain the materials that will be used in the planned construction.
   v. Templates for records of installations or Reports on the location of the completed work for each grade of concrete and the start and end times of the installation of each batch of concrete.
   vi. Templates for Quality Control Review, test reports and documents (concrete spread, air content, temperature, compressive strength, concrete truck batch map)
   vii. Permit templates for each concreting phase or installation of concrete in the tunnel.
b) The required enlargement shall be shown in the formwork projects or in Design drawings to compensate for deformation of the lining during concrete installation.
c) Test reports shall be submitted for the strength of the concrete mix used in construction. The design of the concrete mix shall be submitted to the Engineer at least 30 days before the start of the planned works.
d) At least 30 days before the start of production of precast concrete elements, the Contractor must provide the Engineer with a reference list of the element manufacturer.
e) At least 30 days before the start of the installation of the inner lining of the tunnel, the Contractor shal provide the Engineer with all information on the method, equipment and materials for the implementation of contact grouting:

7.5 QUALITY CONTROL AND ASSURANCE

a) The quality and control of concrete structures must be carried out in accordance with EN 13670:2010 - Execution of concrete structures. Standards EN ISO 15630-1:2.011 - Steel for the reinforcement and prestressing of concrete.
b) The quality and control of the formwork must be carried out in accordance with EN 13670:2010 - Execution of concrete structures.
c) Quality and control for reinforcement must be carried out in accordance with EN 13670:2010 - Execution of concrete structures and EN ISO 15630-1:2011 - Steel for reinforcement and prestressing of concrete.
d) Quality and control for the manufacture and installation of precast concrete elements must be carried out in accordance with the standards EN 13225:2013 - Precast concrete products - Linear structural elements and EN 13369:2013 - Common rules for precast concrete products.
e) The contractor shall carefully and systematically check the profiles of the tunnel inner lining. When performing the control, the same measurement technology is used as for the primary lining, or the results must be comparable (e.g. comparison between the primary lining and the measurement of

the final lining).

f) By comparison, the thickness of the individual layers (primary lining, inner lining) and/or the amount of material installed can be checked.

g) The concrete installation inspection performed by the Engineer shall include the following:
   i. Installation records - Location reports or the place of installation of concrete for each class of concrete and the time of start and end of installation of each batch of concrete.
   ii. Review of the concrete quality control and test reports together with the accompanying documents (concrete spread, air content, temperature, compressive strength, batch map of the concrete truck)
   iii. Signed permit for each concreting phase by the Engineer.
   iv. Sampling of concrete for the purpose of carrying out laboratory tests must contain at least:
      - 1 group (3 samples) for concretes of compressive strength C8/10 and C12/15 for every 100 m3 or per mixing batch,
      - 1 group (3 samples) for concretes with compressive strengths above C12/15 to C20/25 every 50 m3 or per mixing batch, and
      - 2 groups (6 samples) for concretes with compressive strengths above C20/25 for every 200 m3 or mixing batch.

7.6 MEASUREMENT

a) The inner concrete lining in the tunnel will be measured in cubic meter, comprising the theoretical thickness of the inner lining (di) inside the "Line 3", as shown on Figure 8. Quantities for the inner concrete lining outside of "Line 4" will not be measured.

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 per runining tunel meter (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) 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.

g) 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.

h) Curing of concrete (e.g. refilling of cracks) will not be measured for payment and has to be included in the relevant Unit Price.

i) Precasted concrete components will be measured by linear meters.

j) 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.

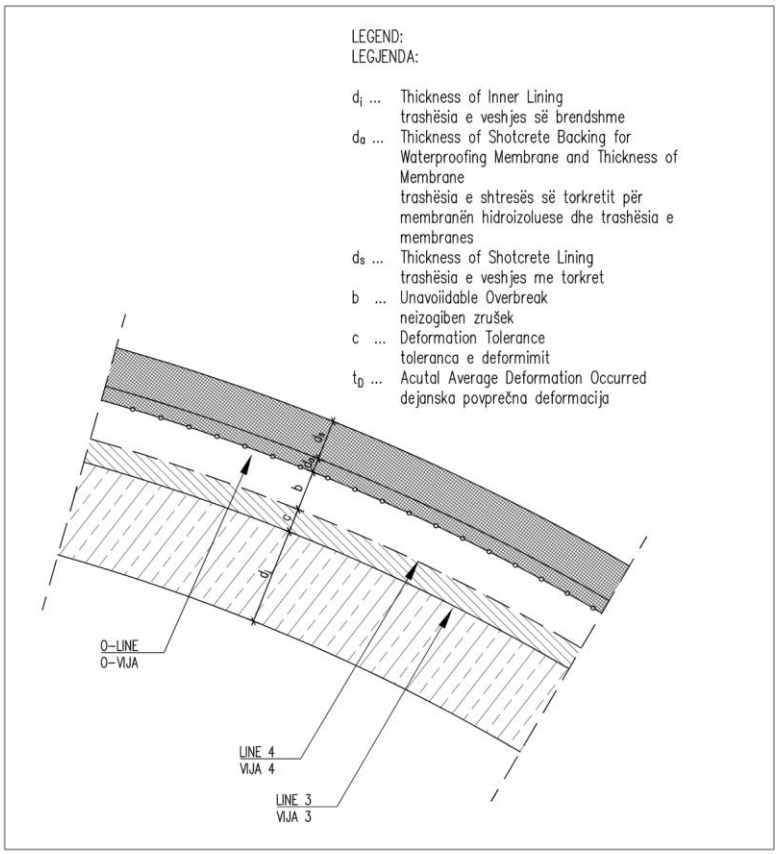

Figure 8 Definition of lines for measurement and payment of inner concrete lining

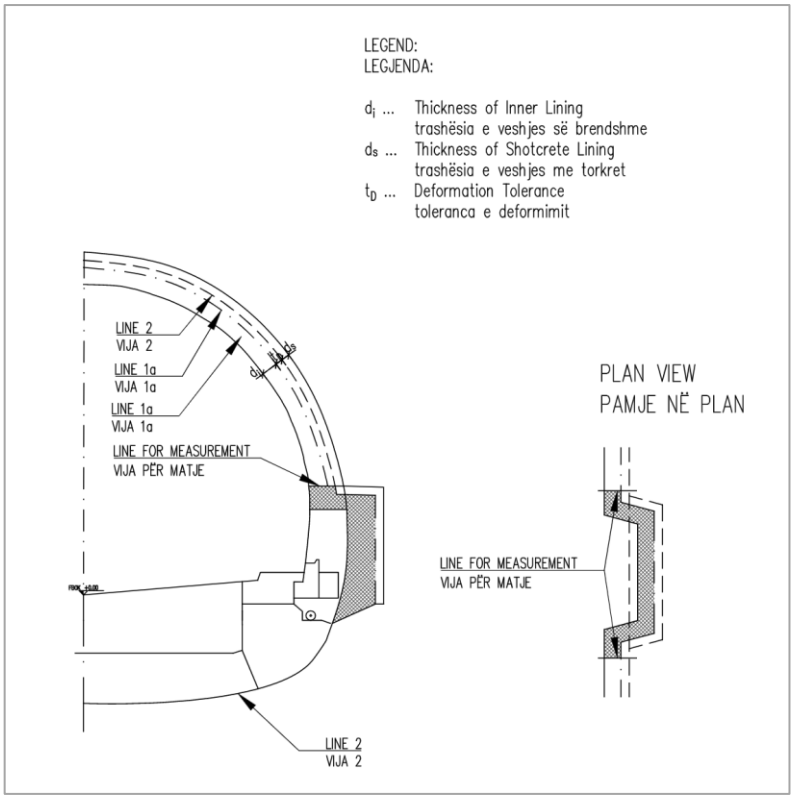

Figure 9 Defintion of lines for measurement for concrete at niches

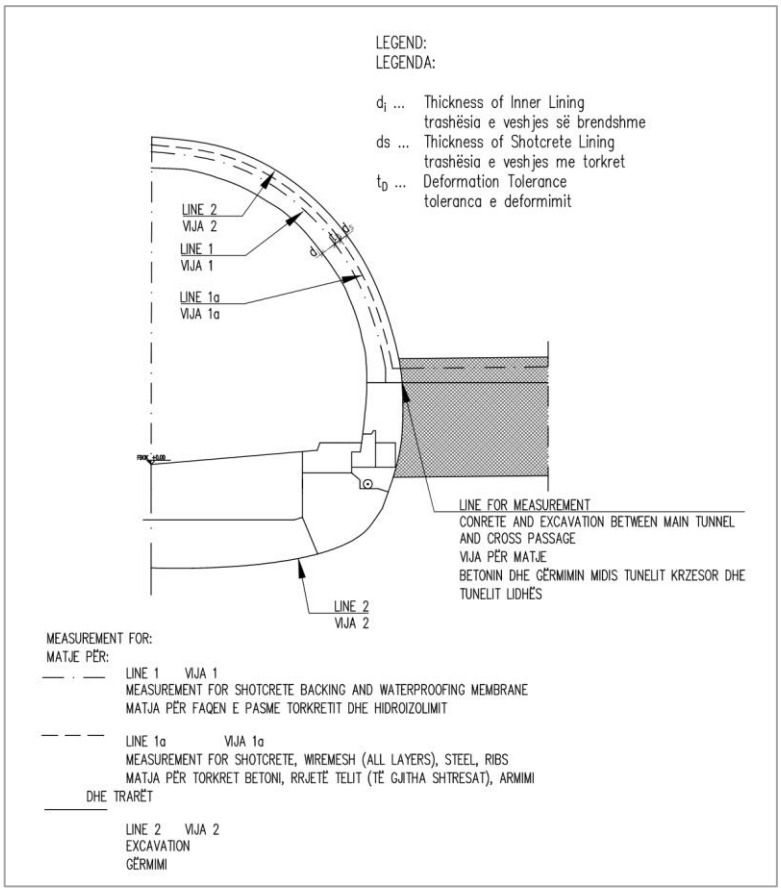

Figure 10 Definition of lines for measurement at cross passage intersection

7.7 PAYMENT

k) 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.

l) 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.

m) The Unit Prices for precasted 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.

n) The Unit Prices for coating shall include all labour, equipment and materials required for the complete execution of the work.

8. GEOTECHNICAL MEASUREMENTS AND GEOLOGICAL MAPPING

8.1 GENERAL

8.1.1 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, reading of instruments and plotting of measurement results.
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 ENGINEER.
g) Interpretation and evaluation of monitoring results as well as geological mapping during excavation will be carried out by the CONTRACTOR.
h) Geological mapping during execution of portal cuts and tunnel excavation will be carried out by the engineering geologist nominated by the CONTRACTOR. Inspections will be carried out by the engineering geologist nominated by the EMPLOYER or ENGINEER. The CONTRACTOR shall provide access and the necessary support for geological mapping to his engineering geologist and to the engineering geologist nominated by the EMPLOYER or ENGINEER.

8.1.2 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) Convergency pins are pins or bolts installed in the tunnel lining. The bolts must have a length in respect to the lining thickness and a minimum diameter of 20 mm. Measurements are made by opto-electronical method to determine absolute displacements of the tunnel lining or tunnel opening in general.

d) Targets or reflectors suitable for opto-electronical high precision measurements are fixed on the pins described above.

8.1.3 SUBMISSIONS

a) Samples of convergency pins.
b) Specifications and catalogues for the instrumentation and readout devices intended to be used.
c) All submissions are subject to the approval of the ENGINEER.

8.2 MATERIALS

8.2.1 LEVEL POINTS

a) For the determination of elevation of tunnel crown or at other points only approved pins or bolts shall be used.
b) Levelling 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 convergency readings.
c) The method of performing the level measurements shall be such as to ensure an accuracy of ± 1 mm.

8.2.2 CONVERGENCY BOLTS

a) Convergency bolts or pins shall consist of ribbed bars protected against corrosion The pins shall be securely attached to the exposed rock, reinforcement mesh or shotcrete surface. After installation the convergency pins shall be protected by a protective cap. The pins should be protected by a pipe with a diameter of approx. 120 mm as shown on the drawings. The pin has to be fixed in the centre of the pipe using 2 crossing welded steel bars. The protection system has to be mounted on the 1st layer of wire mesh before spraying the 1st layer of shotcrete lining. The inner end of the steel pipe has to be even with the shotcrete surface. The tapped end of the pin has to have a certain distance to the final shotcrete surface so that after placing the plastic cap on the pin the cap will not exceed the even level with the shotcrete surface.

8.2.3 TRAGETS OR REFLECTORS

a) For the opto-electronical 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.
b) The plastic reflector can be replaced by a positive centred prism (target) providing the same standard as the reflector above.

8.2.4 THEODOLITE

a) An opto-electronical theodolite (DISTOMAT) with integrated coaxial electronic distance meter (EDM) shall be used. The equipment shall be such as to ensure an accuracy of 3cc for directions as well as an accuracy of ± 0,5 mm for distances.
b) The measuring arrangement shall include further equipment as follows:
    a. Illuminated 4-line matrix display
    b. Numeric and alphanumeric input options
    c. Plug-in data recording module with 2000 data blocks

8.3 EXECUTION

8.3.1 GENERAL REQUIREMENTS

a) The instruments shall be installed at locations and in accordance with a schedule as agreed by the 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 CONTRACTOR shall 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 ENGINEER throughout the construction period as requested.

8.3.2 READING, PLOTTING AND INTERPRETATION

a) Reading, plotting and interpretation of the instruments and measuring results shall be carried out by qualified personnel of the CONTRACTOR and/or qualified subContractor subject to approval of the ENGINEER.
b) The CONTRACTOR shall 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 also to the ENGINEER'S personnel as deemed necessary by the ENGINEER.
c) The first measurements (zero-readings) shall, for each measuring instrument, be made immediately after installation or as soon as the particular instrument may allow.
d) The frequency of the further measurements or readings for normal behaviour of surrounding rock can be envisaged for each measuring section as follows:
   i. • Up to 50 m behind excavation face: daily
   ii. • 50 to 100 m behind excavation face: twice a week
   iii. • 100 to 200 m behind excavation face: once per week
   iv. • 200 m and more behind excavation face: monthly and bimonthly
e) 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.
f) 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.
g) 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.

h) Measurements shall continue until construction work at the inner lining stops the taking of measurements.
i) The electronically version of the ASCII-file has to be handed over to the ENGINEER at 13h00min at the latest or to a person determined by the engineer.

8.4 MEASUREMENT

a) The works specified in this Section will be measured as follows:
    a. Installation of monitoring devices and instrumentation will be measured by actual quantities within the framework of the Bill of Quantities.

8.5 PAYMENT

a) Execution of measurements, reading and filing of data will be paid for at Unit Prices per measuring section. The Unit Price per measuring section shall include all labour, equipment (e.g. theodolite and tape extensometer), materials (e.g. reflectors for optical measurements) and software required for the execution of the services for the whole period of construction.
b) 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.
c) The measurement unit price has also includes all equipment like lifting platforms to maintain accesbility to all measurement points during construction time according to measurement frequency.
d) The Unit Prices for the instrumentation shall also include all necessary drilling and grouting work.
e) Geological mapping of the tunnel face after each step shall not be assessed separately. The price for geological mapping shall be included in the Unit Price for excavation.

9. PRE-DRILLING AND GROUTING

9.1 PRE-DRILLING

a) Drilling ahead of the tunnel face for dewatering and ground investigation purposes is termed „pre-drilling„.

9.1.1 GENERAL

a) In tunnel sections as indicated in the "Geological and Geotechnical Report" the CONTRACTOR shall always probe ahead of the face with 12 to 15 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.

9.1.2 SUBMISSIONS

d) All probing details shall be approved or instructed by the ENGINEER.
e) 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.

9.1.3 EXECUTION

a) The CONTRACTOR is 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.

9.2 GROUTING

9.2.1 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.

9.2.2 SUBMISSIONS

a) The CONTRACTOR shall 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 CONTRACTOR shall 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.

9.2.3 NECESSITY OF GROUND TREATMENT DRILLINGS

a) 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.

9.2.4 GROUT HOLES AND GROUND TREATMENT DRILLINGS

a) 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.

9.3 MATERIAL

a) The grout may consist of
   i. • chemical grout
   ii. • cement mortar grout (cement/sand)
   iii. • cement grout with clay or bentonite
b) Ordinary Portland Cement shall be used.
c) Sand for grouting purpose shall be a clean, mineral sand, uniform in quality and from an approved source.
d) Water shall be clean, free from oil, acid, alkaline, organic and other deleterious substances.
e) Additives for the improvement of grouting performance may be used.

9.4 EXECUTION

9.4.1 TESTING

a) The CONTRACTOR may 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.

9.4.2 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.

9.4.3 MIXING OF GROUT

a) All grout mixes shall be prepared using high speed, high shearing action mixers to produce a grout of uniform homogenousconsistency.
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.

9.4.4 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.

9.5 MEASUREMENT

9.5.1 PRE-DRILLING

a) Drilling works shall be measured by linear meter considering the actual length of drill holes.

9.5.2 GROUTING

a) The executed work shall be measured according to items defined in the BOQ.

9.6 PAYMENT

9.6.1 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.

9.6.2 GROUTING

a) Payment for the executed work shall be calculated according to the items defined in the BOQ.

10. EARTHING IN TUNNELS

10.1 GENERAL

a) This chapter specifies materials for the construction and installation of the main earthing strips in the tunnel. These must be laid in the foundations of the tunnel and interconnected in the invert. In addition, the earthing strips must be connected to the cables in the cable ducts. Reinforcement (reinforcement mesh and steel arches) installed in the primary lining and the innner (secondary) lining reinforcement shall be connected to the main earthing as well.
b) 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.
c) For details of the installation of the earthing lines refer to the relevant drawings.
d) This section will not deal with the earthing system in the portal areas and other structures outside of the tunnel, which is covered by the Electrical design.
e) 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.

10.2 MATERIALS

a) The main earthing strips in the tunnel tubes, both the longitudinal and transversal bars , shall consist of 25x4 mm FE-Zn.
b) All necessary connections between earthing strips have to be executed by means of 2 connection bolts M8 with their correspondent nuts and washers, all made of brass.

10.3 HANDLING AND EXECUTION

a) Materials delivered to the construction site shall be inspected by the Engineer. If damage is found and storage on the construction site is not carried out in accordance with the Manufacturer's instructions, the Contractor shall remove the damaged material from the site and arrange storage as required by the Manufacturer's instructions
b) The main longitudinal earthing strips must be installed in the tunnel abutments on each side and casted in together with this structural element.
c) Transversal strips have to be installed between both longitudinal earthing bars. These transversal bars will have to be layed in the invert concrete or sub-base course of each carriageway. The interconnections of the main earthing lines must also be connected to the shotcrete reinforcement as well as to the lining reinforcement. The distance between the individual transverse earthing lines shall not exceed 25 meters. Longitudinal earthing lines in electrical installation ducts must be connected to the main earthing line at a distance, as specified in the Design.
d) 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 layed in the precasted walkway duct with the main earthing bars. Length of this vertical bars must be minimum 80 cm.
e) In accordance with the available length of flat Fe-Zn strips, the Contractor shall supply the required quantity of connecting elements so that intermediate connections can be made between the transverse and longitudinal earthing lines. The installation procedure must take into account the phases of excavation and installation of the support system and other phases of construction that

affect the implementation of grounding in the tunnel.

f) 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 point vertical lances, must be connected, which will guarantee the further connection of the tunnel earthing system with other structures through the portal area earthing cables.

10.4 PRE-CONSTRUCTION SUBMITTALS

a) All material must be approved by the Engineer prior to installation.

b) The Contractor shall submit the work plan to the Engineer for approval at least 30 days before the start of installation or implementation of the works in question. The minimum content of the submission is:

   a. specification of materials and certificates
   b. staff information
   c. the methods and technologies to be used and
   d. a list of the manufacturer's requirements.

10.5 MEASUREMENT

a) Measurement of the longitudinal and transversal flat bars and the vertical lances will be done by linear meter. Connecting elements, vertical lance, etc., will not be masured.

10.6 PAYMENT

a) Payment for the installation of earthing lines made of flat Fe-Zn strips is charged at the price per running meter (m1). All works, equipment and materials required for the installation of earthing lines (connecting elements, vertical lance, etc.) shall be included in the unit price.