ЈАВНО ПРЕДУЗЕЋЕ
ПУТЕВИ СРБИЈЕ

REPUBLIC OF SERBIA

TRANSPORT REHABILITATION PROJECT

SERBIAN ROAD CONSTRUCTION SPECIFICATIONS

2. SPECIAL TECHNICAL CONDITIONS

2.8 UNDERGROUND WORKS

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2.8.1 INTRODUCTION

2.8.1.1 Subject matter of specification

These specifications deal with the subject of underground works performed in tunnels and are divided into eight chapters:
- classification of rock masses,
- underground excavations,
- control of the profile and permitted deviations,
- support measures,
- geotechnical measurements,
- drainage and waterproofing,
- internal lining,
- earthing of the tunnel.

For each group of works, a list of provisions has been provided referring to:
- the description of the procedures and technical requirements of works,
- type of measurement of works,
- mode of payment.

2.8.1.2 Technical regulations

Relevant standard	Standard title in English language	Standard title in Serbian language
SRPS EN 196- (grupa standarda)	Methods of testing	Metode ispitivanja cementa
SRPS EN 197-1	Cement - Part 1: Composition, specifications and conformity criteria for common cements	Cement – Deo 1: Sastav, specifikacije i kriterijumi usaglašenosti za obične cemente
SRPS EN 206-1	Concrete - Part 1: Specification, performance, production and conformity	Beton - 1.dio: Specifikacija, karakteristike i kriterijumi usaglašenosti
SRPS EN 450- (grupa standarda)	Fly ash for concrete	Leteći pepeo za beton
SRPS EN 932- (grupa standarda)	Tests for general properties of aggregates	Ispitivanja opštih svojstava agregata
SRPS EN 933- (grupa standarda)	Tests for geometrical properties of aggregates	Ispitivanje geometrijskih svojstava agregata
SRPS EN 934- (grupa standarda)	Admixtures for concrete, mortar and	Dodaci betonu, malteru i injekcionoj masi
SRPS EN 1008	Mixing water for concrete - Specification for sampling, testing and assessing the suitability of water, including water recovered from processes in the concrete industry, as mixing water for concrete	Voda za pripremu betona - Specifikacije za uzimanje uzoraka, ispitivanje i ocenu pogodnosti vode za pripremu betona, uključujući vodu dobijenu iz procesa u industriji betona
SRPS EN 1097- (grupa standarda)	Tests for mechanical and physical properties of aggregates	Ispitivanje mehaničkih i fizičkih svojstava agregata
SRPS EN 1367- (grupa standarda)	Tests for thermal and weathering properties of aggregates	Ispitivanja toplotnih svojstava agregata i otpornosti prema raspadanju
SRPS EN 1401- (grupa standarda)	Plastics piping systems for non-pressure underground drainage and sewerage - Unplasticized poly(vinyl chloride) (PVC-U) -	Sistemi cevovoda od plastičnih masa za podzemno odvodnjavanje bez pritiska i kanalizaciju - Neomekšani polivinilhlorid (PVC-U)
SRPS EN 1537	Execution of special geotechnical work - Ground anchors	Izvođenje specijalnih geotehničkih radova – Ankeri

SRPS EN 1744-(grupa standarda)	Tests for chemical properties of aggregates	Ispitivanja hemijskih svojstava agregata
SRPS EN 1926	Natural stone test methods - Determination of compressive strength	Metode ispitivanja prirodnog kamena - Određivanje čvrstoće pri pritisku
SRPS EN 10025-(grupa standarda)	Hot-rolled products of non-alloy structural steels and their technical delivery conditions	Toplovaljani proizvodi od nelegiranih konstrukcionih čelika - Tehnički zahtevi za isporuku
SRPS EN 10080	Steel for the reinforcement of concrete - Weldable reinforcing steel - General	Betonski čelik - Zavarivi betonski čelik - Opšti deo
SRPS EN 12350-(grupa standarda)	Testing fresh concrete	Ispitivanje svežeg betona
SRPS EN 12390-3	Testing hardened concrete - Part 3: Compressive strength of test specimens	Ispitivanje očvrslog betona - Deo 3: Čvrstoća pri pritisku uzoraka za ispitivanje
SRPS EN 12620	Aggregates for concrete	Agregati za beton
SRPS EN 12390-(grupa standarda)	Testing hardened concrete	Ispitivanje očvrslog betona
SRPS EN 13055-(grupa standarda)	Lightweight aggregates	Laki agregati
SRPS EN 13108-(grupa standarda)	Bituminous mixtures - Material specifications	Asfaltne mešavine - Specifikacije
SRPS EN 13179-(grupa standarda)	Tests for filler aggregate used in bituminous mixtures	Ispitivanja kamenog brašna koje se koristi u bitumenskim mešavinama
SRPS EN 13242	Aggregates for unbound and hydraulically bound materials for use in civil engineering work and road construction	Agregati za nevezane i hidraulički vezane materijale za upotrebu u građevinskim radovima i izgradnji puteva
SRPS EN 13263-(grupa standarda)	Silica fume for concrete	Silikatna prašina za beton
SRPS EN 13990	Wood flooring - Solid softwood floor boards	Drveni podovi - Podne daske od masivnog četinarskog drveta
SRPS EN ISO 2431	Paints and varnishes - Determination of flow time by use of flow cups	Boje i lakovi - Određivanje vremena isticanja pomoću posuda za isticanje
SRPS EN ISO 13736	Determination of flash point - Abel closed-cup method	Određivanje tačke paljenja - Metoda u zatvorenom sudu po Abelu
SRPS ISO 10319	Geotextiles - Wide-width tensile test	Geotekstil - Ispitivanje zatezanjem metodom širokog laboratorijskog uzorka
SRPS ISO 11058	Geotextiles and geotextile-related products - Determination of water permeability characteristics normal to the plane, without load	Geotekstil i geotekstilu srodni proizvodi - Određivanje svojstva permeabilnosti vode upravno na ravan epruvete, bez opterećenja
SRPS ISO 12236	Geotextiles and geotextile-related products - Static puncture test (CBR-Test)	Geotekstil i geotekstilu srodni proizvodi - Statičko ispitivanje proboja (CBR ispitivanje)

SRPS ISO 12956	Geotextiles and geotextile-related products - Determination of the characteristic opening size	Geotekstil i geotekstilu srodni proizvodi - Određivanje karakteristične veličine otvora
SRPS ISO 12958	Geotextiles and geotextile-related products - Determination of water flow capacity in their plane	Geotekstil i geotekstilu srodni proizvodi - Određivanje kapaciteta protoka vode u ravni

2.8.1.3 Terminology

Admixture (hemijski dodatak) is a chemical substance added to the concrete mixture, in small quantities as compared to the mass of cement, to modify the properties of wet or hardened concrete.

Hemijski dodatak (admixture) je hemijska materija koja se tokom procesa spravljanja betona dodaje u malim količinama u odnosu na masu cementa radi modifikovanja svojstava svežeg ili očvrslog betona

Aggregate (agregat) particulate, graded mineral material suitable for use as a component of concrete. Aggregates can be natural or artificial, or recycled from used construction material.

Agregat (aggregate) zrnasti, granulisani mineralni materijal pogodan za upotrebu pri izradi betona. Agregati mogu biti prirodni ili veštački, a takođe i reciklirani od materijala prethodno korišćenih za građenje

Bearing course/layer (noseći sloj) is the (bound or unbound) pavement structure course between the wearing course and the substructure or substrate formation, constructed, in particular to ensure proper distribution of traffic loading.

Noseći sloj (bearing course/layer) je (nevezani ili vezani) sloj u kolovoznoj konstrukciji između habajućeg sloja i posteljice ili planuma podloge, ugrađen, pre svega, da omogući odgovarajuće raspodele saobraćajnog opterećenja.

Behavior of the system rock – support –SB (ponašanje sistema stenska masa – podupirači – SB) is the behavior of the entire system that stems from rock-excavation-support interaction.

Ponašanje sistema stenska masa – podupirači – SB (behavior of the system rock – support – SB) je ponašanje celokupnog sistema koje potiče od uzajamnog delovanja stenska masa-iskop-podupirači.

Behaviour type of rock – BT (način ponšanja stenske mase – BT) is rock category describing similar behaviour of rock in terms of demolition manner, deformation development or related to any other criteria.

Način ponašanja stenske mase – BT (behaviour type of rock – BT) je kategorija stenske mase koja opisuje sličan način ponašanja stenske mase u odnosu na način rušenja, razvoj deformacija, ili u odnosu na bilo koji drugi kriterijum.

Bench (stepenica) s the section of an excavation between the top heading and invert arch.

Stepenica (bench) je deo iskopa izmedju kalote i podnožnog svoda.

Calculation line (linija obračuna) is the line along which the cost of individual works is calculated during construction and is defined in the tender documentation. The cost for support elements is calculated according to the line defined by the sum of the following: clearance radius, inner lining thickness, thickness of leveling for waterproofing and waterproofing, and thickness of the deformation superelevation that the commissioning party or its agent (supervisor, designer) defines during construction).

Linija obračuna (calculation line) je linija duž koje se tokom gradnje vrši obračun pojedinih stavki rada i definisana je tenderskom dokumentacijom. Za obračun elemenata oslanjanja se koristi linija koja je određena zbirom: poluprečnika svetlog profila, debljine unutrašnje obloge, debljine poravnavanja za hidroizolaciju i hidroizolacije, debljine nadvišenja deformacije koje tokom gradnje određuje naručilac odn. njegov punomoćnik (nadzor, projektant).

Category of rock (kategorija stenske mase) is marking of rock with equal characteristics related to excavation of entire cross section, as well as to time and space deformation during excavation, regardless of supporting measures and other additional measures.

Kategorija stenske mase (category of rock) je označavanje stenske mase sa podjednakim svojstvima u odnosu na iskopavanje celokupnog poprečnog preseka, kao i na vremensku prostornu deformaciju tokom iskopavanja bez obzira na mere podupiranja i ostale dodatne mere.

Cement (cement) is a pulverized inorganic material that forms a paste when mixed with water, which, due to reactions and hydration processes, sets and hardens, and upon hardening retains its firmness and volume stability, even under water.

Cement (cement) je fino samleven neorganski materijal, koji pomešan sa vodom pravi pastu; zbog reakcija i procesa hidratacije vezuje se i stvrdnjava, i nakon stvrdnjavanja zadržava čvrstoću i zapreminsku postojanost, čak i pod vodom.

Cement concrete, Beton (cementni beton) is a material obtained by mixing stone grain (course and fine aggregate), hidraulic cement binder, and water, with chemical and/or mineral admixtures as needed; it develops its properties by cement hydration.

Cementni beton (cement concrete, Beton) je materijal, koji nastaje mešanjem mešavine kamenih zrna (krupnog i sitnog agregata), hidrauličnog veziva cementa i vode, po potrebi sa dodatkom hemijskih i/ili mineralnih dodataka (aditiva); hidratacijom cementa razvija svoja svojstva.

Contractor (izvođač) is a legal entity or natural person that has concluded a contract with the commissioning party with the obligation to complete a specific job according to the provisions of the contract, the approved project and other terms, constituting an integral part of the contract; it can also signify the legal entity responsible for the product, procedure and job, which fulfills the quality assurance requirements.

Izvođač (contractor) je pravno ili fizičko lice koje je sa naručiocem sklopilo ugovor sa obavezom da izvrši određeni posao po odredbama ugovora, odobrenim nacrtima i drugim uslovima, koji su sastavni deo ugovora; takođe, to može da bude i pravno lice odgovorno za proizvod, postupak i posao, koje realizuje uslove za garanciju kvaliteta.

Convergence (konvergencija) is the radial movement of the base support (primary support) contours. It is determined by measuring the change of distance between two or more points on the tunnel contour (on primary support).

Konvergencija (convergence) je radijalno pomeranje konture osnovne podgrade (primarne podgrade). Do nje se dolazi merenjem promene rastojanja dve ili više tačaka na konturi tunela (na primarnoj podgradi).

Cross passage (poprečni tunel) is a tunnel which connects two tubes of a two- or multiple lane tunnel. It facilitates necessary redirecting of traffic and evacuation of people in emergency situations and is used as an auxiliary structure for tunnel maintenance. The dimensions of the cross section depend on the intended purpose of the tunnel.

Poprečni tunel (cross passage) je tunel koji povezuje dve cevi dvo ili višetračnog tunela. Omogućava nužno preusmeravanje saobraćaja odnosno evakuisanje ljudi u hitnim slučajevima i koristi se kao pomoćni objekat kod održavanja tunela. Dimenzije preseka zavise od namene za koju se upotrebljava.

Cut and cover (pokriveni iskop) is an underground structure with a curved or rectangular form over the route of the road which is constructed in an open trench and subsequently filled in.

Pokriveni iskop (cut and cover) je podzemni građevinski objekat zakrivljenog ili pravougaonog oblika na trasi puta, koji je izveden u iskopu i naknadno nasut.

Cutting rock (sečenje stenske mase) is mechanical rock crushing by using cutting machines for full or separated excavation profile.

Sečenje stenske mase (cutting rock) je mehaničko drobljenje stenske mase mašinama za sečenje punog ili podeljenog profila iskopa.

Deformation tolerance (deformaciona tolerancija) is part of planned excavation profile whose purpose is to take over the unexpected deformity in rock i.e. deformity between excavation and primary support.

Deformaciona tolerancija (deformation tolerance) je deo planiranog iskopnog profila čiji je cilj da preuzme očekivanu stensku deformaciju odn. deformaciju koja nastupa između iskopa i primarnog podupiranja.

Discontinuity (diskontinuitet) is surface inside the rocky mass i.e. rock where some characteristics of the rock had been interrupted or significantly deviate from characteristics of surrounding rock.

Diskontinuitet (discontinuity) je površina unutar stenske mase odn. stene duž koje su neka svojstva stena prekinuta ili suštinski odstupaju od svojstava okolne stene.

Ditch (rov) is long underground horizontal area or area without slope with excavated diameter not larger than 20 m^2.

Rov (ditch) je dugačak podzemni horizontalan prostor ili prostor bez nagiba čiji je iskopni presek do 20 m^2.

Drain (drainage) is used for efficient drainage of water from the surroundings of the structure to prevent the onset of hydrostatic pressure.

Drenaža (drainage, drain) je namenjena efikasnom odvodnjavanju vode iz zaleđa objekta u cilju sprečavanja pojava hidrostatičkih pritisaka.

Excavation line (linija iskopa) is the line along which the cost of excavation is calculated during construction and is defined in the tender documentation. The cost for excavation is calculated according to the line defined by the sum of the following: clearance radius, inner lining thickness, thickness of leveling for waterproofing and waterproofing, thickness of the deformation superelevation that the commissioning party or its agent (supervisor, designer) defines during construction, and the thickness of the shotcrete as support element.

Linija iskopa (excavation line) je linija duž koje se tokom gradnje vrši obračun iskopavanja i definisana je tenderskom dokumentacijom. Za obračun iskopavanja se koristi linija koja je određena zbirom: poluprečnika svetlog profila, debljine unutrašnje obloge, debljine poravnavanja za hidroizolaciju i hidroizolacije, debljine nadvišenja deformacije koje tokom gradnje određuje naručilac odn. njegov punomoćnik (nadzor, projektant), i debljine mlaznog betona kao elementa oslanjanja.

Excavation of profile step by step (iskopavanje profila deo po deo) is excavation where during each excavation step the excavation head is divided to single component profiles which have to be supported by supporting elements immediately after excavation.

Iskopavanje profila deo po deo (excavation of profile step by step) je iskopavanje u kome se na svakom iskopnom koraku čelo iskopa deli na pojedinačne sastavne profile koji odmah po iskopavanju – napredovanju moraju da se poduprу potpornim elementima.

Excavation step (iskopni korak) is part of excavation executed entirely in one cycle or step by step (calotte, bench, invert arch made of sprayed concrete).

Iskopni korak (excavation step) je deo iskopa izveden u potpunosti u jednom ciklusu ili deo po deo (kalota, stepenica, podnožni svod od mlaznog betona).

Extended profile (nadprofil) is increased excavation profile compared to basic theoretical profile.

Nadprofil (extended profile) je povećan iskopni profil u odnosu na osnovni teoretski profil.

Gallery (galerija) is a structure which as a rule is of a rectangular or arched form, constructed according to the system of open tunnel construction in locations where the road is threatened by avalanches or landslides. A gallery may be covered, partially covered or uncovered. Openings are typically constructed in the external wall in the shape of a semicircle or rectangle. The conditions for constructing the walls with openings are the same as those for constructing middle pillars from columns.

Galerija (gallery) je građevinski objekat po pravilu pravougaonog ili lučnog oblika, koji je izgrađen po sistemu otvorene izgradnje na mestima puta koji su ugroženi lavinom (sneg, kamenje). Galerija može da bude nasuta, delimično nasuta ili nenasuta. U spoljnom zidu se obično izrađuju otvori u obliku polukruga ili pravougaonika. Uslovi za izvođenje zida sa otvorima su isti kao i za izvođenje središnjeg zida od stubova.

Geotechnical model (geotehnički deo projekta tunela) are computer models and plans for excavation and bracing which ensure that the tunnel fulfils the key requirements in the given geological-geotechnical situation.

Geotehnički deo projekta tunela (geotechnical model) su računski modeli i planovi iskopa i podupiranja, kojima se obezbeđuje da tunel ispunjava ključne zahtevi u datoj geološko-geotehničkoj situaciji.

Holders (koplja) are steel tubes or steel bars built in front of excavation head and that play role in providing arch and sides of excavated step during the excavation progress.

Koplja (holders) su čelične cevi ili čelične šipke koje su ugrađene ispred čela iskopa i imaju ulogu u obezbeđivanju svoda i strana iskopnog koraka tokom napredovanja iskopa prostora.

Inner linning (unutrašnja obloga) is a structural element made of cement concrete or reinforced cement concrete which provides additional protection from underground space collapse and which improves the appearance of underground space.

Unutrašnja obloga (inner linning) je konstruktivni element napravljen od cementnog betona ili armiranog cementnog betona koji obezbeđuje dodatnu zaštitu od obrušavanja podzemnog prostora i kojim se postiže estetski izgled podzemnog prostora.

Invert arch (podnožni svod) is a phase of excavation below the bench; structure in the form of an arch which spans and encloses an underground opening below the pavement structure.

Podnožni svod (invert arch) je faza iskopa ispod stepenice; konstrukcija u obliku luka koja premošćuje i zatvara podzemni otvor ispod kolovozne konstrukcije.

Injection or fixing (injektovanje ili utvrđivanje) is technological procedure where by means of injection mass or by means of other material for fixing natural soil pores in rocks, cracks and other gaps are filled under pressure, leaving the inside rocks characteristics essentially unchanged.

Injektovanje i učvršćivanje (injection or fixing) je tehnološki postupak u kome se masom za ubrizgavanje ili drugim materijalom za učvršćivanje pod pritiskom popunjavaju prirodne pore u stenskoj masi, pukotine, kao i druge praznine, tako da se stenska masa u unutrašnjosti suštinski ne menja.

Jet-grouting (jet-grouting) is procedure made in drill where soil or partially solid rock is mixed with cement binder (mortar) to increase firmness after hardening.

Jet-grouting (jet-grouting) je postupak izveden u bušotini tokom kojeg se tla ili delimično čvrsta stena izmeša sa cementnim vezivom (malterom), tako da se nakon stvrdnjavanja povećava njena čvrstoća.

Layby (zaustavna niša) is a space within an underground structure for stopping vehicles in emergencies and when a stopping lane has not been envisaged. It is constructed on the right side of the carriageway in the direction of travel and outfitted with additional equipment depending on the type of traffic travelling through the structure.

Zaustavna niša (layby) je prostor u podzemnom građevinskom objektu za zaustavljanje vozila u nuždi, onda kada zaustavna traka nije predviđena. Izgrađena je na desnoj strani kolovoza u smeru vožnje i opremljena je dodatnom opremom u zavisnosti od vrste saobraćaja kroz objekat.

Length of excavation step (dužina iskopanog koraka) is average value of horizontal length of one excavation step.

Dužina iskopnog koraka (length of excavation step) je srednja vrednost horizontalne dužine jednog koraka iskopa.

Main construction plan (osnovni plan (konstrukcioni) izgradnje) is a summary of the geotechnical project, including clearly defined reasons that provide ground for subsequent changes to the project or „in situ“ decisions within the construction project.

Osnovni plan (konstrukcioni) izgradnje (main construction plan) je sažetak geotehničkog projekta, uključujući jasno definisane razloge koji omogućuju naknadne izmene projekta ili odluke „in situ“ u projektu gradnje.

Mastic asphalt (liveni asfalt) is a voidless asphalt mixture, in a dense liquid state when hot; compaction at implementation is not required.

Liveni asfalt (mastic asphalt) je asfaltna mešavina bez šupljina, u vrućem stanju gusto tekuća; pri ugrađivanju nije potrebno zbijanje.

Micro reinforced shotcrete (mikroarmirani mlazni beton) is cement concrete with reinforcing fibres, which enable improvement of certain properties of cement concrete, e.g. cohesiveness of wet cement concrete and mechanical properties of hardened cement concrete (compressive and bending/flexural strength, toughness), as well as limitation of shrinkage, and increase of rigidity of a structural element after the first crack has appeared.

Mikroarmirani mlazni beton (micro reinforced shotcrete) je cementni beton sa vlaknima za armiranje koja omogućavaju poboljšanje određenih svojstava cementnoga betona, npr. kohezivnosti svežeg cementnog betona, mehaničkih svojstava očvrslog cementnog betona (čvrstoća na pritisak i savijanje, žilavost), kao i ograničenje skupljanja i povećanje krutosti konstruktivnog elementa nakon pojave prve pukotine.

Middle pillar (središnji zid) is the central load bearing structure in a two- or multiple-tube covered excavation, gallery or underpass, rectangular in shape, constructed as a wall or with columns. If it is constructed with columns, the lower section between the columns, up to a height of 1,20 m, must be covered with filler or a perforated wall (parapet) with a thickness equal to the columns, so that the external surface along the entire length of the wall is even. In structures intended for travel speeds of up to 80 km/h, the surface between the columns can be constructed by placing panelled safety barriers instead of an inserted wall.

Središnji zid (middle pillar) je središnja potporna konstrukcija kod dvo- ili višecevnih pokrivenih iskopa, galerija i podvožnjaka u pravougaonom obliku, izvedena kao zid ili sa stubovima. Ako je izveden sa stubovima, donji deo između stubova mora do visine 1,20 m da bude ispunjen međuispunom ili šupljim zidom (parapetom) jednake debljine kao i stubovi, tako da spoljna površina po celoj dužini zida bude ravna. U objektima koji su namenjeni za brzinu vožnje do 80 km/h, ravnina između stubova se umesto umetnutog zida može postići postavljanjem višečlane sigurnosne ograde.

Monitoring (monitoring) is the set of factors used to monitor the behavior of the structure during construction and exploitation.

Monitoring (monitoring) je skup činilaca sa kojima se prati ponašanje konstrukcije u toku izgradnje i eksploatacije.

Open construction of the tunnel (otvorena izgradnja) is a method of construction in which underground structures are partially or entirely built in an open trench and subsequently filled in.

Otvorena izgradnja (open construction of the tunnel) je način izvođenja u kojem se podzemni građevinski objekti delimično ili u celosti grade u otvorenom iskopu i naknadno zatrpavaju.

Open road rout (otvorena trasa) is part of the road outside the scope of underground structures traffic lane, each of both lanes of the bidirectional road, on which the lanes for the individual directions of travel are divided physically or by horizontal signalization only and with normal functioning of the road they are intended exclusively for travel in one direction or another.

Otvorena trasa (open road rout) je deo puta van područja podzemnih građevinskih objekata kolovozna traka svaka od obe trake dvosmernog puta, na kojoj su trake za pojedini smer vožnje fizički ili samo horizontalnom signalizacijom odvojene međusobno i kod normalnog funkcionisanja puta namenjene isključivo za vožnju u jednom ili u drugom smeru.

Overbreak (backbreak) (prekoprofilski iskop) the area of rock excavation in excess of the designed profile, including deformation and structure tolerance.

Prekoprofilski iskop (overbreak) je prostor nastao lomljenjem stenske mase preko projektovanog profila koji uključuje toleranciju deformacije i konstrukcije.

Porous concrete (drenažni beton) is made of single-fraction pervious aggregate with grain size of Ø16 mm.

Drenažni beton (porous concrete) je sastavljen iz jednofrakcijskog agregata veličine zrna Ø16 mm koji propušta vodu.

Porous geotextile (drenažni geotekstil) is primarily made of pervious synthetic fibers or strips.

Drenažni geotekstil (porous geotextile) je pretežno izrađen iz sintetičkih vlakana ili traka koji propušta vodu.

Portal (portal) is the beginning or end of the tunnel at the transition into an open route. In the broad sense the portal area is the section of open route in front of the tunnel where structures, equipment and devices are placed which are necessary for the unobstructed and safe use of the tunnel.

Portal (portal) je početak odnosno kraj tunela na prelazu u otvorenu trasu. U širem smislu je portalno područje onaj deo otvorene trase ispred tunela, gde su postavljeni objekti, oprema i uređaji, potrebni za neometano i sigurno korišćenje tunela.

Primary support (primarna podgrada) is a structure which provides stability for an underground opening during excavation and for the entire duration of exploitation of the tunnel.

Primarna podgrada (primary support) je konstrukcija koja osigurava stabilnost podzemnog otvora kod iskopa i za celokupno vreme eksploatacije tunela.

Revision nishe (niša za čišćenje) je manji pomoćni prostor u zidu tunela, namenjen održavanju drenažnog sistema i sistema za odvodnjavanje tunela.

Niša za čišćenje (revision nishe) je manji pomoćni prostor u zidu tunela, namenjen održavanju drenažnog sistema i sistema za odvodnjavanje tunela.

Ring (kampada) is the segment of the structure between two construction or expansion joints.

Kampada (ring) je deo konstrukcije objekta između dva radna ili dilataciona spoja.

Road tunnel (putni tunel) is an underground structure along the route of the road which enables: maintaining the order of the road within the prescribed limitations of the geometric and technical elements of the road through relief obstacles; providing protection around the road from the extremely harmful effects of road traffic. Underground roads are constructed in areas where it is not possible to construct them on the surface due to landscape or urban features.

Putni tunel (road tunnel) je podzemni građevinski objekat na trasi puta, kojim se omogućava: očuvanje poretka puta u propisanim granicama geometrijskih i tehničkih elemenata puta kroz reljefne prepreke, obezbeđivanje zaštite okoline puta od preterano štetnog uticaja putnog saobraćaja. Izvođenje podzemnog toka puta u područjima, na kojim nije moguće graditi na površini zbog pejzažnih ili urbanih odlika.

Rock (stena) is aggregate made of mineral grains (parts) created naturally, characteristic for the type and group of existing mineral, with characteristic structure, texture etc.

Stena (rock) je agregat od mineralnih zrna (delova) koji je nastao prirodnim putem, koji je karakterističan za vrstu i grupu postojećeg minerala, karakteristične strukture, teksture i sl.

Rock behaviour (ponašanje stenske mase) is a rock reaction ability during excavation of a structure's entire profile, where effects of further excavation and primary supporting are not taken into account.

Ponašanje stenske mase (rock behaviour) je reakcijska sposobnost stenske mase tokom iskopavanja celokupnog profila objekta, pri čemu se ne uzimaju u obzir uticaji daljeg iskopavanja i primarnog podupiranja.

Rock bolt (sidro) is a supporting element used to support excavated open space and to improve rock characteristics. Commonly, these are steel rods, steel tubes or ropes built into drills filled with binding agents or empty drills (e.g. Swellex).

Sidro (rock bolt) je potporni element koji služi da obezbedi otvoren iskopani prostor i da poboljša svojstva stenske mase. Često su to čelične šipke, čelične cevi ili užad koja se ugrađuju u bušotine koje su ispunjene vezivom ili su prazne (npr. Swellex).

Rock mass (stenska masa) is the part of crust made of solid rock and/or earth, including anisotropic compounds, separation surfaces and empty space filled with liquid or gasses.

Stenska masa (rock mass) je deo zemljine kore koju sačinjavaju čvrste stene i/ili zemljište, uključujući anizotropske sastojke, razdelne površine i prazni prostori ispunjeni tečnošću ili gasovima.

Shotcrete (mlazni cementni beton) is a mixture of cement, stone grain, and water, sprayed by means of compressed air through a nozzle onto the specified surface to form a compact homogeneous mixture; shotcrete can also contain various combinations of chemical and mineral admixtures, as well as fibres.

Mlazni cementni beton (shotcrete) je mešavina cementa, kamenih zrna i vode, koja se pomoću komprimiranog vazduha prska kroz mlaznicu na određenu površinu tako da nastane zbijena homogena mešavina; mlazni cementni beton može da sadrži i različite kombinacije hemijskih i mineralnih dodataka, kao i vlakna.

Soil (tla) is accumulation of inorganic solid particles of various sizes which can contain parts of organic substances. Characteristics of soil are generally determined by granulometric composition, consistency, compression, and water content.

Tla (soil) je akumulacija anorganskih čvrstih čestica različitih veličina koja može da sadrži i primese organskih materija. Svojstva zemljišta uglavnom određuju granulometrijski sastav, konzistencija, stišljivost i sadržaj vode.

Stabilization (stabilizacija) is a procedure where binder and water are mixed with existing material, and the prepared mix is then suitably compacted, to permanently increase resistance of the placed mix to traffic loading impacts and to adverse climatic and hydrological actions.

Stabilizacija (stabilization) je postupak pri kojem se mešanjem veziva i vode sa postojećim materijalom uz odgovarajuće zbijanje pripremljene mešavine trajno povećava otpornost ugrađene mešavine na uticaj saobraćajnog opterećenja, kao i uticaj štetnih klimatskih i hidroloških uticaja.

Steel lagging (talpe) are formwork steel elements such as corrugated steel plates which during the next excavation step rest on steel distribution support and suppress or compact rock of low bearing capacity in front of excavation head to protect excavation area from collapsing during excavation.

Talpe (steel lagging) su čelični elementi oplate, kao što su talasaste čelične ploče koje se uoči narednog iskopnog koraka oslanjaju na čeličnu lučnu potporu i potiskuju ili sabijaju stensku masu slabe nosivosti ispred čela iskopa da bi se prostor iskopa zaštitio od urušavanja tokom iskopavanja.

Step (korak) is execution of entire excavation cycle, load, transport and installation of supporting elements.

Korak (step) je izvođenje celokupnog ciklusa iskopavanja, utovara, prevoza i ugradnje potpornih elemenata.

Supervision (nadzor) is the assessment of compliance after certification, by which the certification (monitoring) authority verifies the ongoing compliance of the product with the given requirements.

Nadzor (supervision) označava ocenjivanje usklađenosti nakon dobijanja sertifikata kojim sertifikacioni (kontrolni) organ proverava trajnu usklađenost proizvoda sa propisanim zahtevima.

Supporting elements (potporni elementi) are structural elements such as steel plates, holders, steel arches, pumped cement concrete, reinforced meshes, anchors, reinforcement etc.

Potporni elementi (supporting elements) su konstrukcioni elementi kao što su čelične talpe, kopja, čelični lukovi, cementni mlazni beton, armaturne mreže, sidra, armatura itd.

Supporting number (potporni broj) is a coefficient of sum of evaluated supporting elements at a given meter (m') of a tunnel, and corresponding evaluation surfaces in a specific case.

Potporni broj (supporting number) je koeficijent zbira vrednovanih potpornih elemenata na datom metru (m') tunela i odgovarajućih površina procene u datom slučaju.

Temporary portal (privremeni portal) is the chainage at which the underground excavation of a tunnel is opened. The section of the tunnel in between the temporary and final portal is constructed as a gallery or covered excavation.

Privremeni portal (temporary portal) je predstavlja stacionažu početka podzemnog iskopa tunela. Deo tunela između privremenog i konačnog portala je izgrađen kao galerija ili pokriveni iskop.

Top heading, calotte (kalota) is the upper part (curved) of the excavation of the cross section of the tunnel.

Kalota (top heading, calotte) je gornji deo (zakrivljen) iskopa poprečnog profila tunela.

Tunnel (tunel) is horizontal i.e. slightly inclined further underground space with excavation diameter larger than 20 m^2, used for road or railway traffic.Tunnel has entrance and exit from the rock.

Tunel (tunnel) je vodoravan odnosno blago nagnut dalji podzemni prostor čiji je iskopni presek veći od 20 m^2, namenjen drumskom ili železničkom saobraćaju. Tunel ima ulaz i izlaz iz stenske mase.

Tunnel equipment (tunelska oprema) means devices which facilitate the unobstructed and safe flow of traffic in partially limited conditions and also enable the implementation of special measures in special situations. This equipment includes the elements placed on the carriageway at the necessary distance in front of the entryway to the tunnel.

Tunelska oprema (tunnel equipment) su uređaji koji obezbeđuju neometan i saobraćajno bezbedan protok saobraćaja u delimično ograničenim uslovima, ujedno omogućavaju izvođenje posebnih mera u posebnim slučajevima. U tu opremu spadaju i elementi, koji su postavljeni na kolovozu na potrebnoj udaljenosti ispred ulaza u tunel.

Tunnel lenght (dužina tunela) is the specified length of the longest completely covered driving lane.

Dužina tunela (tunnel lenght) je određena dužinom najduže potpuno pokrivene vozne trake.

Tunnel lining (obloga tunela) is a smaller auxiliary space in the wall of the tunnel intended for maintenance of the tunnel drainage system and water removal system.

Obloga tunela (tunnel lining) je betonska ili armirano betonska konstrukcija koja služi kao zaštita prometa u tunelu.

Type of rock mass – GT (vrsta stenske mase – GT) is a rock mass with similar geological, geomechanical and chemical properties.

Vrsta stenske mase – GT (type of rock mass – GT) je stenska masa sličnih geoloških, geomehaničkih i hemijskih svojstava.

Water–cement ratio (vodocementni faktor) is the ratio of the effective share of water to the effective share of cement in wet cement concrete.

Vodocementni faktor (water–cement ratio) označava odnos efektivnog udela vode i cementa u svežem cementnom betonu.

2.8.1.4 Abbreviations used

NATM (**N**ew **A**ustrian **T**unneling **M**ethod) is a new Austrian tunneling method indicating a method of excavation and tunnel construction.

C&C abbreviated from **Cut and cover,** refers to a method of tunnel construction from the surface of the terrain by using surface excavation, tunnel construction as well as filling of the tunnel from the surface of the terrain - covered cut.

ÖNORM (**Ö**sterreichische **Norm**en) abbreviation that stands for Austrian standards.

ÖGG (Die **Ö**stereichische **G**esellschaft für **G**eomechanik) abbreviation that stands for Austrian Society for Geomechanics.

ÖVB (Österreichische **V**ereinigung für **B**eton- und **B**autechnik) abbreviation that stands for Austrian Institute for Concrete and Construction Technology.

DIN (**D**eutsches **I**nstitut für **N**ormung) abbreviation that stands for German Institute for Standardisation.

SIA (**S**chweizerischer **I**ngenieur- und **A**rchitektenverein) abbreviation that stands for Swiss Society of Engineers and Architects.

RVS (**R**ichtlinien und **V**orschriften für das **S**traßenwesen) abbreviation that stands for Guidelines and Specifications for Roads.

ISRM abbreviated from **I**nternational **S**ociety for **R**ock **M**echanics.

2.8.2 CLASSIFICATION OF ROCK MASSES

2.8.2.1 Genral

This chapter includes a classification of rock masses and various types of behaviours of rock masses in terms of underground construction, with a special accent on the geotechnical characteristics of rock masses in the area of influence of the tunnel construction. Generally speaking, the classification of rock masses has been taken from the Austrian standard ÖNORM B 2203 (October 2001 edition).

Such classification of rock masses does not only take into consideration the characteristics of the rock masses in terms of underground spaces, but also allows an estimate of the expected deformations, it requires for the excavation profile to be divided into individual sections, enables an estimate of the rate of progress, provides a schedule of working phases during excavations, assesses the impact of underground waters and provides an estimate of the intensity of the incorporation of the support elements.

The plans depict the types of support elements and potential rate of progress of the excavations for each type of rock mass behaviour. Variable geotechnical conditions and non-homogeneous characteristics of rock masses frequently require adjustments of the support measures in accordance with the realistic conditions at the construction site. Support measures as described in the plans for a particular type refer to the type of rock mass behaviour. The number of anchors is subject to change, as well as the direction of anchoring, which needs to be adjusted to the prevailing position of the discontinuity and the stratification. The increase and decrease of the thickness of the lining made of shotcrete and reinforcement mesh depends on the geotechnical conditions at the construction site. The distance between the steel support segments (TH arches, I-profiles, braced girders) is determined in a similar manner, whereas the distance has to correspond to the rate of progress of the excavations. All changes of the standard support system resulting from the variable geotechnical conditions of construction need to be confirmed by an ENGINEER.

2.8.2.2 Application and procedures

The type of rock mass is determined based on the list of rock mass at the head of the tunnel prior to works commencing.

Results obtained from geotechnical measuring of similar conditions of rock mass are used for the evaluation of deformities (strain) and for determining the type of support.

Depending on the size of the overall excavation profile and the geotechnical conditions of construction, the excavation profile may be divided in subsections, which as a consequence, affects the choice of support types.

In the situation where excavation profiles are divided into calotte, bench and invert arch, the same category determined and set for the calotte does not have to be followed for the overall profile.

The same support type determined for the tunnel pipe in these sections has to be applied to the excavations and the support of niches and laybys.

The characteristics of rock masses conditioned by weather in the area surrounding the head of excavations influence the strength properties of the rocks, which mean that the strength of the rocks is reduced if the support is not constructed in a timely manner. Based on aforesaid, it may be concluded that the longest excavation round, which includes the excavation and construction of support within a set time frame, depends on the quality of rock which needs to be taken into consideration while determining an appropriate support type. While estimating the support type, the following have to be taken into consideration: the conditions of primary stress state, quality and the structure of the rock mass, discontinuities, existing tectonic characteristics, water in the rocks, as well as the impact of water and air on the freshly excavated areas at the head of the tunnel.

The support type for each individual excavation round has to be agreed upon amongst the authorised representatives of the ENGINEER, CONTRACTOR and DESIGNER.

If agreement is not reached, the adequate type of support shall be determined by a GEOTECHNICAL COUNCIL – a commission consisting of an authorised representative of the DESIGNER-CONSULTANT and one or more independent EXPERTS in that field of expertise. The members of the GEOTECHNICAL COUNCIL are appointed by the EMPLOYER before the excavation works in the tunnel commence. Until agreement is achieved, the works have to be carried out in accordance with the decisions of the ENGINEER.

Each change of the support type has to be recorded in the construction journal. The report on support types represents a collection of all pages in the record, i.e. documents which refer to the decisions reached in this respect. This report has to be available to all authorised individuals (ENGINEER, CONTRACTOR, DESIGNER, geotechnical commission) so that they can give comments and consult, during the execution of excavation works.

Before the beginning of each technological cycle, the SHIFT SUPERVISOR is obligated to guarantee to the CONTRACTOR that the works will be executed in accordance with the support type agreed upon. The CONTRACTOR shall be obligated to ensure that the construction site is safe during the construction phase.

2.8.2.3 General classification system - according to standards

The table below represents a survey of all the basic types of rock behaviour used for determining the type of support for tunnel excavation (excavation of underground structures). Generally speaking, the categorisation of rock masses has been taken from the Austrian guidelines ÖGG: Richtlinie für die Geomechanische Planung von Untertagebauarbeiten mit zyklischem Vortrieb, (October 2001 edition), which, primarily, analyses the geological aspects of the project.

Behaviour types describe the way in which unsupported rock mass behaves in specific geotechnical conditions. These conditions depend on the type of rock, their properties, but also on more indirect factors such as water, primary in-situ stress, orientation of the discontinuity and dimensions and the shape of the excavation.

Table 2.8.1: Categories of rock mass behaviour types

Rock mass behaviour type – BT (behaviour type of rock – BT)	**Description of rock behaviour (unsupported rock mass)**
1. Stable rock mass	Stable rock mass with the potential of small local gravity induced falling or sliding of blocks
2. Stable with the potential discontinuity controlled block fall	Deep reaching, discontinuity controlled, gravity induced falling and sliding of blocks, occasional local shear failure
3. Shallow shear failure	Shallow stress induced shear failures in combination with discontinuity and gravity controlled failure of the rock mass.
4. Deep seated shear failure	Deep seated stress induced shear failures and large deformation
5. Rock burst	Sudden and violent failure of the rock mass, caused by highly stressed brittle rocks and the rapid release of accumulated strain energy
6. Buckling failure	Buckling of rocks with a narrowly spaced discontinuity set, frequently associated with shear failure
7. Shear failure under low confining pressure	Potential for excessive overbreak and progressive shear failure caused mainly by a deficiency of side pressure
8. Ravelling ground	Flow of cohesionless dry or moist, intensively fractured rocks

Rock mass behaviour type – BT (behaviour type of rock – BT)	**Description of rock behaviour (unsupported rock mass)**
9. Flowing ground	Flow of intensely fractured rocks with high water content
10. Swelling	Time dependent volume increase of the rock mass caused by physical-chemical reaction of rock and water in combination with stress relief
11. Heterogeneous rock mass characterised by frequently changing behaviour	Rapid variations of stresses and deformations, caused by block-in-matrix rock situation (e.g. brittle fault zone, tectonic melange)

2.8.2.4 Tunnelling class matrix

Excavation and support works based on the matrix system rely on the Austrian standard ÖNORM B 2203-1: Untertagebauarbeiten-Werksvertragsnorm, Teil 1: Zyklischer Vortrieb. – December 2001, which defines the manner in which support types are defined, as well as measurement and monitoring of the works?

The essence of the system is that rock behaviour types are determined based on the definitions of rock mass type, taking into consideration the water content, orientation of the structures, primary stresses and values, shapes and position of the opening. Based on the behaviour of rock types, support types are determined which represent the sum of the support elements which have to be used as measures to ensure the stability of the underground construction.

Individual support type is represented as a rectangular matrix, where the coordinates represent the length of the excavation round within that type and the abscissa represents the support number.

Supporting number is determined based on the table which specifies the weighting factors for the individual support elements. Supporting number is calculated as a sum of the partial products of the quantity of support elements per linear meter of the tunnel multiplied by the weighting factors and the rating area of the excavation. Weighting factors are taken from the standard ÖNORM B 2203-1 12/2001 – table 2.8.4.

Organising number / supporting type includes the support elements and the supporting measures (in accordance with table 2.8.4.) used the head of the excavation, i.e. at most 20 m behind the excavation face.

Table 2.8.2: Example of the support types matrix for calotte or calotte and bench (ÖNORM B 2203-1)

FIRST CLASIFICATION NUMBER	excavation step to top head. or top head. + bench	BENCH	SECOND CLASIFICATION NUMBER / SUPPORT NUMBER 1	2	3	4	5	6	7	8	9
1	no limit	defined by the design									
2	4,0 m										
3	3,0 m										
4	2,2 m				v 4/2,4	v 4/3,6					
5	1,7 m						v 5/4,5	v 5/6,1			
6	1,3 m							v 6/5,5	v 6/7,5		
7	1,0 m										
8	0,8 m										
9	0,6 m										

Table 2.8.3: Example of the support types matrix for invert arch (ÖNORM B 2203-1)

FIRST ORGANISING NUMBER	Excavation round	SECOND ORGANISING NUMBER / SUPPORT NUMBER Open bottom	Foot plate	Invert arch with longitudinal separation	Invert arch without longitudinal separation
		1	2	3	4
1	No limit	1 / 1			
2	36,0 m		2 / 2		
3	24,0 m		3 / 2		
4	12,0 m		4 / 2	4 / 3	4 / 4
5	6,6 m				5 / 4
6	4,4 m				
7	2,2 m				

Table 2.8.4: Evaluation of support elements and auxiliary measures (ÖNORM B 2203-1)

Support element (for 1 m of tunnel)		Unit	Quantity	Factor	Partial no.	Notes
Rock bolts	Swellex or alike	m		**0,8**		
	SN bolt in mortar	m		**1,1**		
	Self-threading injection bore bolt	m		**1,7**		
	Injection bore bolt	m		**2,0**		
	Pre-stressed rock bolts	m		**2,5**		
Rock bolts in head	Number of anchors per round	pc		**8,0**		1
	Anchor plate without pre-stressing	pc		**1,7**		2
	Anchor plate with pre-stressing	pc		**5,0**		2
Holders	Impressed ribbed bars	m		**0,5**		
	Ribbed bars in the borehole	m		**0,6**		
	Ribbed bars in mortar	m		**0,9**		
	Self-drilling injection piles	m		**1,3**		
	Injection piles / holders	m		**1,6**		
Injection	Injection >10 kg per m of anchor, pile, pilot	kg		**0,1**		
Reinforcement mesh	External side with an arch	m²		**1,0**		3
	Internal side with an arch	m²		**1,5**		3
	External side without the arch	m²		**2,0**		3
	Temporary invert arch	m²		**0,8**		3
	Additional reinforcement, excavation face	m²		**2,0**		3,4
Steel rib	Steel rib	m		**2,0**		
Shotcrete	Calotte and bench	m³		**20,0**		5

Support element (for 1 m of tunnel)		Unit	Quantity	Factor	Partial no.	Notes
	Invert arch, temporary invert arch	m^3		**12,0**		5
	Face	m^3		**14,0**		5
	Filling of the wedge and overbreak	m^3		**14,0**		5,6
Deformation elements	Without deformation elements	m		**3,5**		7
	With deformation elements	m		**5,0**		7
Steel laggings	Steel laggings	m^2		**5,5**		
Pilot at the toe of the calotte	Pilot ≤ 38 mm	m		**4,5**		
	Pilot > 38 mm	m		**5,0**		
Phase excavation	Phase excavation	pc		**22,0**		8
Excavation of the calotte toe - widening	Excavation of the calotte toe - widening	m		**50,0**		9
Excavation of the temporary invert arch	Excavation of the temporary invert arch during bench progress	m		**50,0**		10
Sum						

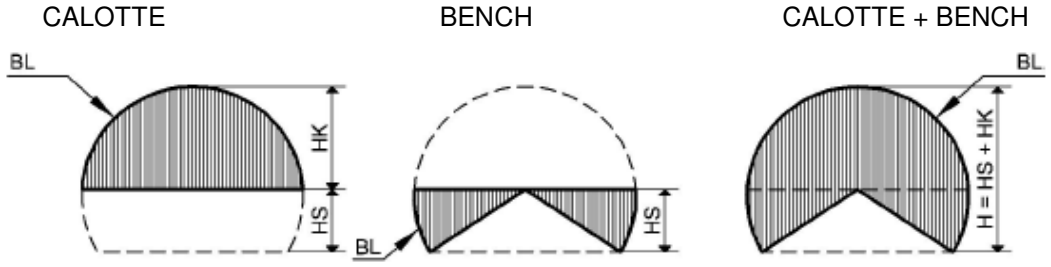
NOTE:

1. Number of existing anchors in each excavation round. Weighting factors have been taken into consideration for installation, shortening and loading during the excavation phase.
2. Number of anchor plates, installed at the face in question.
3. Theoretical quantities, not taking into consideration the exceeding in the longitudinal and transversal direction.
4. Layout surface, covered with reinforcement - reinforcement at the joints calotte / bench and bench / invert arch is not estimated.
5. Theoretical quantities, not taking into consideration the super section and the fender.
6. Filling of planned wedges (adjacent to driven steel laggings, etc.) or filling of accepted wedges over the excavation in the rock side of the boundary plane A.
7. Linear metre of the deformation slot.
8. Phase excavation area refers only to the area where the excavation phase is immediately and adequately supported after the excavation.
9. For both calotte toes, per linear metre of the tunnel
10. The length of the temporary invert arch of the calotte, during the bench excavation round in question, regardless of the potential phase excavations.

Table 2.8.5: Area where the second organising number applies (support number)

Calotte	
Round of excavation	**Maximum validity for the second organising number**
No limit	± 0,35
4,0 m	± 0,35
3,0 m	± 0,45
2,2 m	± 0,60
1,7 m	± 0,80
1,3 m	± 1,00
1,0 m	± 1,30
0,8 m	± 1,60
0,6 m	± 2,10

Bench	
Bench excavation round up to	**Maximum validity for the second organising number**
No limit	0,45
3,0 m	0,70
2,0 m	1,20
1,0 m	2,10



HK	Height of calotte
HS	Height of bench
BL	Boundary line, outer lining surface
HK, HS i BL	Stipulated by contract

Figure 2.8.1 Schematic drawing showing rating areas

2.8.2.5 Understanding the matrix

The matrix system used in this contract represents a theoretical payment model for the construction of a tunnel based on the lump-sum price.

The mode of payment is determined based on the following factors:

- Lump-sum payment for excavation and chosen support type, determined by the first or the second characteristic value (length of the excavation round, supporting number).
- Lump-sum payment for the work on supporting elements transferred to the excavation item.
- The time for completion is subject to change, dependent upon the conditions found on site.
- Construction which results in the actual distribution of support types, which is in general different from that provided in the tender documents. In this way, payments conditioned by deadlines are adjusted to the actual conditions of the rock mass.
- Additional payments for water complications due to the inrush of underground water from the rock mass.
- Payment for actually installed support elements with respect to the support item.

2.8.2.5.1 Application of the support type

Pursuant to the standard ÖNORM B2203-1, support type is defined by calculating the supporting number (second organising value) and taking into consideration the first organising value (length of the excavation round/ round length).

As part of the lump sum, the CONTRACTOR has to include the risk of deviation from the lower limit of the excavation round, as well as the position of the support number in the matrix box.

While computing the support number, support elements as defined by the support type itself are taken into consideration, as well as the support elements for the additional support measures.

The CONTRACTOR has to cover the risk of changing the support type, the length of excavation, composition of the support elements, methods of excavation and closing of the invert arch, as well as the time required for learning.

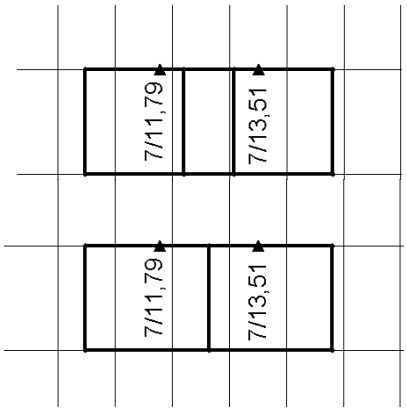
In the situation where two cells (support types) overlap in the matrix, the upper value of the lower support type, i.e. lower value of the upper support type is taken as an average value of the overlapping of these two cells (see the example below).

Calculation of the excavation price and of the rate of progress applies to the entire area of the individual support type.

The CONTRACTOR is responsible for choosing the excavation method, calculating the proposed time for completion and calculating a unique excavation price for each individual support type, in a manner that ensures the minimum of excavation and fulfilment of the geotechnical requirements.

For example:

Support type:	7/11,79	7/13,51
Lower limit:	10,49	12,21
Upper limit:	13,09	14,81
Overlapping:	12,21 – 13,09	
Overlapping midrange: 12,65		
Valid lower limit:	10,49	12,65
Valid upper limit:	12,65	14,81



2.8.2.5.2 Determining the design parameters which refer to the payment for the support elements

Unless this chapter specifies otherwise, the valuation of the support elements for conventional tunnel construction has to be performed in accordance with the Austrian standard ÖNORM B2203-1.

The perimeter length taken into consideration during the valuation is interrupted in the following cases: the distance between two adjacent ribbed bars (two adjacent injection piles) exceeds the designed distance or the distance between two adjacent steel laggings is greater than the steel laggings width.

The support core is not valued or paid for separately. The CONTRACTOR is obligated to execute the works in accordance with the design.

2.8.2.5.3 Setting of progress rate parameters during excavation

Determining the excavation rounds serves as a lay-out for payment and has to be incorporated in an adequate form (form for choosing the support - table 2.8.4.). Representatives of both the CONTRACTOR and the ENGINEER have to sign the form. The support number is valid if it is calculated at the excavation face during the determination of the support types and elements, or subsequently in an office.

The quantities in the rating area and payment Line 1a (depending on the deformation

tolerance set by the ENGINEER) are fixed quantities.

For potential changes of the thickness of the inner lining, the rating area remains the same.

The valuation of the bench is performed regardless of whether the bench is excavated in sections or as a whole. The excavation round and the support type for the invert arch have to be determined before they are constructed.

In a special section of the technical report, the contractor is obligated to determine (the offer) the progress speed, i.e. the advance rate. These specific values represent an integral part of the contract.

Niches and cross passages have to be constructed subsequently.

Temporary backfills for the invert arch must serve as an adequate protection of the shotcrete lining. The cost of the time taken for the backfilling and cleaning of the residual backfilling material is no extra charge. These works, the time consumed and the expenses are taken into consideration while calculating the rate of progress.

2.8.2.5.4 Calculating prices for non-tendered types of support

n simple cases where the support system deviates from the support types specified during the tender procedure, together with the respective tolerance in the matrix box, the standard ÖNORM 2203/1 prescribes the systematic determination of new unique prices for excavation and the contracted progress speed, i.e. the advance rate.

Pursuant to standard ÖNORM B2203-1, not more than one tender support type may be extrapolated, to the left or to the right respectively.

Extrapolation when there is only one support type in the horizontal matrix row:

If the tender documentation foresees only one support type in the horizontal row of the matrix, the following procedure has to be followed:

Extrapolation of the offered unique price has to be calculated in the following manner:

$$F = 1 + \left[\left(\frac{B}{A}\right) - 1\right] * 0{,}6$$

$$UP_{new} = UP_{old} * F$$

$$V_{new} = \frac{V_{old}}{F}$$

A - 2. characteristic value of the offered matrix box

B - 2. characteristic value of the newly set matrix box

UP_{new} - extrapolated unique price

UP_{old} - unique price for the tendered support type

V_{new} - extrapolated contracted excavation speed

V_{old} - contracted excavation speed for the tendered support type

Extrapolation when two or three support types are located next to each other in the horizontal row of the matrix:

Extrapolation has to be performed as shown in example B2 in the standard ÖNORM B2203-1.

The example of extrapolation for two support types in the horizontal row of the matrix:

Example:

Support types:

5/4,5 5/6,1

Offered unique prices:

41,-- 52,-- [€/m^3]

Offered unique speed:

2,0 1,7 [m/day]

Second organising number (support number) for the construction of several support elements amounts to 8.1.

The next greater second organising number (support unit) amounts to:

6,1 + 2 * 0,8 = 7,7.

For the support type 5 / 7.7 the price is:

52,-- + (52 – 41) = 63,-- [€/m^3]

For the support type 5 / 7.7 the speed is:

1,7 - (2,0 – 1,7) = 1,40 [m/dan].

The example of extrapolation for three support types in the horizontal row of the matrix:

Support types:

5/4,5 5/6,1 5/7,7

Offered unique prices:

41,-- 52,-- 69,-- [€/m^3]

Offered unique speed:

2,0 1,7 1,1 [m/day]

Second organising number (support number) for the construction of several support elements amounts to 9.1.

The next greater second organising number (support number) amounts to:

7,7 + 2 * 0,8 = 9,3.

Quadratic polynomial is used as an approximation function.

Extrapolation curvature for the unique price of the new support type is as follows for the given example:

$$UP_{new} = 1{,}1719 * B^2 - 5{,}5469 * B + 42{,}23$$

Extrapolation curvature for the unique speed of the new support type is as follows for the given example:

$$V_{new} = -0{,}0195 * B^2 + 0{,}0195 * B + 2{,}3076$$

B – support number of the new support type
For the support type 5 / 9.3 the price is: 92.00 [€/m^3].

For the support type 5 / 9.3 the speed is: 0.80 [m/day].

If the tender documentation foresees more than three support types in one horizontal row of the matrix, three tendered adjacent support types have to be taken into consideration while determining the new support type.

2.8.3 UNDERGROUND EXCAVATION

2.8.3.1 General

This chapter refers to the execution of all underground excavation works in any rock behaviour type. Excavation may be carried out by drilling and blasting (pre-split blasting technique, smooth blasting) or by using mechanical equipment (road header, tunnel excavator). The CONTRACTOR is responsible for choosing the excavation method and the necessary equipment.

The CONTRACTOR is obligated to adhere to all the procedures as described in the drawings, described in the Specifications and submitted documents, in accordance with the requirements set forth in chapter 2.8.3.1.1 of the Specifications, as well as to adhere to other procedures agreed to with the DESIGNER and approved by the ENGINEER.

The CONTRACTOR is obligated to execute the excavation and support in the manner that ensures fulfilment of all the requirements referring to the determined and approved support type. Excavation has to be carried out in such a manner that prevents damage and caving-in of the surrounding rock mass, as well as the caving-in and damage of the primary lining.

Excavation sequencing and the subdivision of excavation headings has to be in accordance with the tender drawings, specifications and detailed plans drafted by the CONTRACTOR.

2.8.3.1.1 Documentation

Prior to commencement of any underground excavations, the CONTRACTOR is obligated to provide the ENGINEER with the detailed plans and/or descriptions of the proposed methods and sequences, including the required drainage of the construction site, safety measures and the results of the tests required by valid legislation.

The CONTRACTOR shall be obligated to provide the ENGINEER with the sequence of excavations for different underground works within the general schedule for all the works on the construction of a tunnel.

The CONTRACTOR is obliged to provide the ENGINEER with a detailed plan of the working cycle for excavation and support, separately for each support type and separately for each excavation profile, based on the classification of rock masses presented in chapter 2.8.2.

The ENGINEER has to be provided with an excavation method for each type of rock mass, including the description, specification and adequate literature provided by the manufacturer, referring to drilling, removing and transporting of waste materials.

All blasting works have to be carried out in accordance with the local regulations referring to the safety measures applicable while handling explosives.

The ENGINEER has to be provided with all the details referring to the proposed blasting design for each cross profile or subdividedcross profile , containing the following information:

- drilling pattern, diameter of the holes, spacing between holes, depth and inclination.
- the type, strength, mass of the explosive and the number of cartridges used for one hole, number of cartridges used in every hole, individually and collectively, disposal and activation of the explosive,
- distribution of explosives in individual holes and the location where the detonator is placed,
- type, 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 mechanism,
- sealing of holes and protecting, i.e. covering of the blast area,
- written evidence of the qualifications of the persons directly responsible for the supervision of the charging and blasting.

Material excavated in the tunnel which is suitable for the construction of embankments on the motorway shall be used for this purpose, unless otherwise instructed by the ENGINEER. The CONTRACTOR shall be obligated to deliver the plans of stockpile and spoil areas for the approval of the ENGINEER, prior to the dumping or stockpiling of any material. The plans must show all the data regarding the working methods, stability conditions, safety measures, temporary and final drainage arrangement including the final landscaping.

All suggestions have to be delivered to the ENGINEER in a timely manner, before the beginning of the construction phase or at a previously agreed time.

2.8.3.2 Execution

2.8.3.2.1 Equipment

All mechanical equipment used for underground excavations and transport have to be adequate for the works included in the tender documents and have to correspond to the safety regulations valid in the Republic of Serbia. It also has to correspond to the requirements set forth in the construction time programme and has to be approved by the ENGINEER.

The underground mechanical plant and the equipment have to be powered by electricity, compressed air or diesel engines. Diesel engines have to be equipped with filters for the treatment of exhaust gases. Petrol or paraffin mixtures must not be used as fuel during the construction of the tunnel.

Rock-drilling with water flushing is not allowed in rock formations sensitive to water, unless otherwise instructed by the ENGINEER.

2.8.3.2.2 Lighting and power during the construction phase

The CONTRACTOR is obligated to provide the adequate protection and maintenance of electric power lines so as to ensure safe working conditions. In cases when safe working conditions are not ensured, the ENGINEER may require that the electrical devices be disconnected or replaced.

The CONTRACTOR is obligated to provide a back-up diesel generator for each heading. The capacity of the generator has to be sufficient to provide uninterrupted power to the lighting devices and the pumps used for water supply.

The CONTRACTOR is obligated to install and maintain the minimum illumination of 100 W per 10 m of tunnel, or higher if required.

2.8.3.2.3 Ventilation during construction

The CONTRACTOR is in charge of the ventilation during the construction phase. The ventilation system has to be planned and has to work in accordance with local legislation.

The ventilation system has to be planned to take into account the length of the tunnel, the applied excavation method and the number of workers working in the tunnel. Concentrations of poisonous gases, smoke and dust particles, as measured at the construction site, must not exceed the allowable concentrations (MPC).

For tunnels with the potential for the occurrence of dangerous gases (for example, methane), ventilation has to be designed and installed in a manner that will ensure the adequate reduction of the concentration of dangerous gases (CO_2, CO, NO, NO_2, etc.). The concentration of gases is measured by portable or stationary measuring instruments.

Generally speaking, the ventilation system has to be designed in such a way to provide a flow of fresh air to the furthest excavation heading. The distance between the end of the ventilation duct or hose pipe and the excavation face must not exceed 30 m. The thrust of the ventilation fans has to be sufficient to dilute the concentration of explosive gases to below 0.5 % and simultaneously ensure a velocity of air stream greater than or equal to 0.5 m/sec.

2.8.3.2.4 Definition of the excavation profile

The excavation profile as indicated in the drawings (characteristic tunnelcross profile) refers to the theoretical excavation profile defined as Line 2 – U_m.

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

The excavation Line 1a - line (see figure 2.8.2) is designed for compensation of radial deformation U_m for various support types. Deformations which correspond to the deformation tolerances U_m (t_d) have been given for each support type. Values given on the corresponding drawings or in the tender documents for expected deformations U_m may be adjusted so as to take into consideration the actual deformations in accordance with the experience gained during the excavations. Adjustments have to be made by the DESIGNER, whereas the ENGINEER has to approve them.

Line A represents the minimum excavation profile. Generally speaking, rock mass must not protrude inside this line during excavations. It is allowed only locally, for

protruding edges and corners of sound rock, within the tolerance of two thirds of the nominal shotcrete thickness.

The CONTRACTOR is obligated to construct the profile as defined by Line A. It is achieved through careful control of the drilling and through the application of various elements of smooth blasting or other special blasting techniques.

In order to maintain the excavation profile as defined by Line A, the CONTRACTOR must adhere to the construction tolerance U_p (t_c) for excavation and support installation. Construction tolerance U_p (t_c) also has to include survey inaccuracies, as shown in figure2.8.2.

2.8.3.2.5 Overbreak

The overbreak is the space created when the rock mass breaks beyond the profile which includes the deformation and construction tolerances. Overbreak may be caused by inconsistent work and inadequate excavation methods (avoidable overbreak) and/or due to reasons beyond the control of the CONTRACTOR (unavoidable overbreak)

Unavoidable overbreak may occur as a consequence of:
- the caving-in of the rock mass in the form of overbreak which cannot be prevented by working carefully and the application of adequate working methods,
- overbreak which may occur as a consequence of prevailing unfavourable geological conditions.

The average order of magnitude of the so-called "unavoidable overbreak" is estimated for all rock types and indicated in the drawings and/or in the tender documents (see figure 2.8.2.).

Excessive overbreak (see figure 2.8.2) may occur as a consequence of extremely unfavourable and/or unpredictable geological conditions. In short, this means that the CONTRACTOR has been careful and has applied the most suitable work techniques, but the unavoidable overbreak still could not have been prevented due to the prevailing unfavourable geological conditions.

In the case of excessive overbreak, adequate support has to be installed immediately so as to stabilise the area. The DESIGNER and the ENGINEER have to be informed immediately. The CONTRACTOR and the DESIGNER or ENGINEER have to consult and agree on the means of a solution. A detailed solution plan has to be drafted by the CONTRACTOR and approved by the ENGINEER. Remedial works have to be performed before the excavation continues, unless otherwise ordered by the ENGINEER.

After it has been determined that an overbreak has occurred as a consequence of physical conditions beyond the control of the CONTRACTOR, and that the overbreak was not caused by inadequate working methods or carelessness, the volume of the void formed by the overbreak has to be measured. The ENGINEER has to approve and cover all the costs of materials required for the repair of the overbreak.

2.8.3.2.6 Excavation requirements

Drilling and blasting have to be performed in such a manner as to ensure that the rock mass breaks along the desired profile.

The diameter and the spacing between the blast holes have to be adapted to the actual conditions of the rock mass on site. As the works progress, the CONTRACTOR is obligated to develop and continually improve the blasting technique so as to achieve a better level of suitability for the excavation profile.

Rock excavation has to be performed by using modern blasting methods. Modern blasting methods, which include smooth blasting or pre-splitting, have to be applied so as to reduce the overbreak as much as possible and to prevent shattering of the excavation surface.

The excavation of all types of niches, except of the laybys in the lateral sides of the tunnel and cross passages, have to be performed after the installation of the primary support in the main tunnel. Shotcrete and steel ribs in the tunnel side wall have to be carefully cut along the profile of the niches or the cross passage. Excavation has to be performed in such a manner that the tunnel and the tunnel support are not damaged.

Excavation of the tunnel widening beyond the normal cross profile of the tunnel intended for the construction of the laybys has to be executed under a 40-degree angle to the main axis of the tunnel. After the width required for the planned laybys is ensured, the works may continue in accordance with the requirements set forth in this chapter.

Construction works in an area with the type of rock sensitive to water (swelling) have to be performed under increased supervision so as to prevent potential damage caused by the swelling of the rock mass. In order to prevent the contact of the rock mass with the water, such areas require a special construction method and the appropriate organisation of staff.

2.8.3.2.7 Safety measures

After each blasting, the excavated surface has to be carefully inspected and cleaned. The support elements have to provide efficient measures for ensuring the overall stability of the tunnel. Depending on the current conditions on the construction site, or if required, the CONTRACTOR has to prevent the loosening of rock blocks, i.e. has to ensure adequate local stability conditions by installing local rock bolts.

The CONTRACTOR has to carry out systematic inspections of the tunnel side walls and the roof so as to detect any potential cracks or other signs of instability in the tunnel. The evaluation of the number of cracks and the size of the cracks has to be performed based on the results of geotechnical measuring and in cooperation with the DESIGNER.

Blasting may commence only after all safety measures have been implemented and personnel and machinery have been protected.

Drilling, blasting, excavating and shotcreting have to be performed using methods and equipment which prevent the creation of dust, smoke, gases, fog and mist to a large extent.

2.8.3.2.8 Continuous working

In order to provide safety and protection of the works, excavation of the tunnel has to be performed without interruption, unless the ENGINEER approves otherwise. Should the nature of the works allow it, interruption of work is allowed over weekends and holidays, on the condition that the works are secured and that safe conditions are ensured.

Interruptions are allowed only after all support elements have been installed as required for the support type at a given location.

Moreover, the heading and the surrounding area have to be covered with a 3-5 cm thick layer of shotcrete. This does not apply in the situation where stable rock mass conditions are ensured.

2.8.3.2.9 Drainage during construction

Scope

The CONTRACTOR is obligated to deliver and install all the equipment necessary for pumping water out of the tunnel. Uninterrupted work and maintenance of the pumps and pipelines has to be ensured since standing water is not allowed in the tunnel.

The capacity of the pumps installed at each excavation face has to be at least one and a half (1.5 x) bigger than the inflow of water and the quantity of water used for drilling.

The CONTRACTOR has to have spare pumps available in a functional condition, with a capacity that is at least equal to the capacity of the pumps installed in the tunnel.

The CONTRACTOR has to provide a sedimentation tank or other equipment for decontamination, in accordance with the requirements of the ENGINEER, which has to be used before the water is released into the environment.

The CONTRACTOR is obligated to remove the silt, sediment or gravel that is a result of the excavation works, in accordance with the requirements of the ENGINEER.

At the portals, the CONTRACTOR is obliged to make, maintain and manage the structures and devices required for the treatment of the contaminated waste water that is being drained from the tunnel during construction. These structures and devices have to consist of two sedimentation tanks, an oil separator, a neutralisation device and the required control station. The neutralisation device has to be designed and managed in such a way that the pH value of the treated water is constantly kept in the range between 6.5 and 8.5 before it can be released into the environment.

Materials and execution

Longitudinal drainage: Draining of the tunnel during the construction phase has to be achieved by means of the drainage channel dug at the bottom of the calotte i.e. benching. The walls of the drainage channel have to be covered with shotcrete. The areas with a greater inflow of water have to be drained by means of perforated or threaded unplasticised PVC pipes, 150 to 250 mm in

diameter, depending on the quantity of water that has to be drained.

When works are performed in rocks that are sensitive to water, the CONTRACTOR has to pay special attention to seepage, collecting and draining of the water from the rock mass and of the technological water that was used for construction of the tunnel.

In the situation where the tunnel is constructed downwards, the CONTRACTOR must construct chambers for pumping of water at an appropriate distance from each other. Water has to be pumped out of the tunnel by means of suitable steel or PVC pipes.

Radial drainage: For concentrated inflow of water, draining holes have to be drilled in the soil or in the shotcrete. These holes have to be equipped with perforated steel or unplasticised PVC pipes, 1.5 to 2“ in diameter. The space between the pipe and the mouth of the hole has to be filled with quick-setting mortar. Quick-setting mortar is a material that enables setting and hardening within minutes and is used for temporary consolidation and filling. One end of the pipe is connected to a rubber hose for draining the water to a temporary longitudinal drainage point, to the chamber for pumping water or to a longitudinal channel at the bottom of the calotte or bench in the tunnel.

Circulatory drainage: In wet areas, water from the tunnel walls is collected by means of corrugated, plasticised PVC pipes attached to the rock by means of quick-setting cement mortar or cement shotcrete, and which are subsequently connected to the chamber for pumping or the longitudinal channel at the bottom of the calotte or the bench in the tunnel.

Wet areas that subsequently appear on the shotcrete lining have to be drilled and treated as previously described.

In tunnels which are constructed on water permeable soil or heavily cracked rocks, the systematic installation of circulatory drainage has to be conducted with the approval of the ENGINEER, with the minimal diameter of 4 cm, so as to prevent the occurrence of water pressure behind the shotcrete lining.
The CONTRACTOR has to ensure that the chambers for pumping are cleaned regularly and that the drainage system is maintained in a manner which enables the controlled drainage of all waters during the construction phase.

2.8.3.2.10 Traffic at the construction site on the finished excavation grade level

Površina iskopavanja koja odgovara niveleti
The excavation surface which corresponds to the grade level of the final subgrade formation and which is ready for the construction of the carriageway, has to be protected from wearing or deterioration that may occur due to the transportation of rocks or other types of transport, by creating a backfilling layer consisting of the materials excavated in the tunnel or other materials with adequate properties, with a minimum thickness of 0.5 m.

The CONTRACTOR has to prevent the detention of water in the tunnel. Traffic movement over the residual water at the construction site is not permitted.

All materials of poorer quality than permitted have to be removed prior to the installation of the carriageway and have to be replaced by adequate material in accordance with the instructions and requests of the ENGINEER.

Material used for the protection of the carriageway must not be removed before the works on the construction of the carriageway commence.

2.8.3.2.11 Traffic at the construction site over the invert arch

Traffic over the unprotected construction of the invert arch is forbidden, both if it is made of cement or shotcrete and if it is temporary or permanent in character.

These construction units or assembly have to be protected against damage or destruction by means of a backfill layer made of adequate excavated or other material, with a thickness of 0.5 m. Backfill must not consist of rock pieces larger than 150 mm.

2.8.3.3 Dimensions of the excavation

The works specified in detail in this chapter are measured in the following manner:

- Excavation of tunnels and laybys in all rock behaviour types have to be measured in cubic metres (m^3) along "Line 2", as shown in the figure 2.8.2. The length of each round is calculated along

the tunnel axis. Dimensions are given for partial excavations of cross profiles as shown in the plans. In cases when there is a need to construct a temporary arch in the calotte, the dimensions of the bench have to be reduced proportionally.

- Excavation of the cross passages in all support types is measured in cubic metres (m^3) along "Line 2", in the manner shown in the previous line.

- Excavation of the niches is measured in cubic metres (m^3) along "Line 2"".

- The increase of the excavation profile due to the permitted construction tolerances (t_c) and unavoidable overbreak inside Line A are not measured for payment (see figure 2.8.2).

- Excessive overbreaks outside Line A, occurring due to unfavourable geological conditions, are measured at the locations where they occurred, in actual quantities, under the condition that the overbreak exceeds 2 m^3 per linear metre of the tunnel. Overbreak up to 2 m^3 per linear metre is not measured and not paid for.

- Additional excavation works due to the widening of the profile in areas where the crown is reinforced with pipe roof is paid as a separate item. A special matrix is used for the excavation and support of the calotte underneath the pipe roof. These payment conditions also apply for the support, i.e. support type below the pipe roof. This means that rating areas shall apply, such as "payment lines" 1a and 1b, which remain unaltered.

- It has to be pointed out that the increased consumption of support elements, due to the variable geometry of the primary tunnel lining (pipe inclination approx. 5.2°, used length of the pipe roof 10.0 m , which represents the length of the saw tooth profile) is not taken into consideration for determining the support unit. Larger quantities are compensated by unique prices. The contractor has to design and calculate the variable geometry of the shotcrete in respect of the execution method he uses.

- The increased quantities required for the filling of the wedge below the pipe roof are not included in the matrix, since the filling of the wedge is not performed in the immediate progress area. This also applies in the situation where the contractor fills the wedge 20 m behind the excavation face due to working reasons.

- Increased quantities, as well as the shotcrete required for the filling of the wedge below the pipe roof, are paid for separately, under the following conditions, regardless of the quantities more or less required:
  - for the item "excavation of the saw tooth profile below the pipe roof" / installed pipe roof pipe (e = 40 cm),
  - for the item "shotcrete filler" / installed pipe roof pipe (e = 40 cm),
  - furthermore, a timeframe has to be submitted for the construction of the pipe roof (together with the grouting and other works).
  - Additional excavation works necessary for the construction of temporary foundations in the calotte are measured by linear metres of the foundation (m').

- Additional work and the materials necessary for the careful execution of work in rock types that are sensitive to water (swelling of the rock mass) are not measured additionally and are not paid for.

- In the case of excavation in a downward direction, the control of water of up to 5 l/sec, which involves adequate drainage, redirection flow and removal of the water, is the obligation of the CONTRACTOR and thus is not calculated. The occasional control of water quantities that exceed 5 l/sec is calculated separately, based on the time spent pumping out the water. The water being used for drilling, washing, setting and other works is not measured and not paid for.

- In the case of excavation in an upward direction, occasional control of overall water that occurs at the tunnel face, which involves adequate drainage, redirection and removal of the water, is the obligation of the CONTRACTOR and thus is not measured and not paid for.

- Distractions and interruptions of downward excavations, i.e. upward excavations, resulting from the inflow of water, are calculated as additional items if the water quantity exceeds 10 l/sec. This measurement does not include the quantity of water used for drilling, washing, setting and other works. The

amount of inflow is determined (measured) 20 meters behind the excavation face.

- The CONTRACTOR is responsible for the ventilation of the tunnel during the construction phase. This ventilation is calculated separately, i.e. it may be included in the time-dependent costs.

- The CONTRACTOR is in charge of the lighting of the tunnel and the supply of electric energy during the construction phase. These costs are calculated separately, i.e. they may be included in the time-dependent costs.

- Primary support of the rock mass, which includes the cement shotcrete, reinforcement mesh, steel segments, anchors, protection of the excavation face by means of cement shotcrete and holders, is calculated separately (see chapter 7 of this specification).

- Transportation of the excavated material from the tunnel portal or the temporary dump site next to the tunnel portal to the permanent dump site or embankment is measured by cubic metre of the initial rock mass (fragmentation factor is not taken into consideration).

- The CONTRACTOR has to include in the price all potential interruptions that may occur due to the coordination of works with other construction sites (e.g. due to traffic) and must not calculate them separately.

- Interruptions shorter than 2 hours caused by the inflow of water, overbreak or other unforeseen events are not calculated.

- Interruptions shorter than 2 hours caused by high concentrations of explosive gases (e.g. methane) are not calculated.

2.8.3.4 Payment

- The unit price for the excavation works has to include the costs for all works, equipment and materials required for excavation within the determined boundaries, the removal of the primary support (e.g. temporary invert arch, arch made of shotcrete, rock bolts), required adjustment to the excavation equipment, loading, transport and dumping of the material excavated from the face to the portal or embankment in front of the portal, i.e. to a temporary dump site located up to 300 m from the portal, temporary control of water in upward excavations, difficulties caused by inflow of water up to 10 l/s, difficulties caused by geotechnical measuring and geological mapping, interruptions due to the installation of the support elements and development and adjustment of the drilling programme used for blasting purposes, as well as all potential additional measured, interruptions and problems listed in the previous chapter 2.8.3.3.:
  - Excavation of the tunnel for different support types is paid as per unit price per cubic meter (m^3).
  - Difficulties due to water inflow that exceeds 10 l/s are paid per unit price per cubic metre of excavated material for the entire duration of the excessive inflow.
  - Temporary control of the inflow of water that exceeds 5 l/s in downward excavations is paid per unit price for one hour of pumping. The unit price for the temporary control of water inflow has to include all the works, costs of equipment and materials (e.g. pipes, chambers for pumping of water, etc.) required for the execution of works. Pumping equipment is calculated separately and may be included in time-dependent costs.
  - Interruptions of works lasting for more than 6 hours, which occurred due to heavy inflow of water, overbreak or other unforeseen circumstances, are paid per unit price for one hour of interruption. Payment is made only in cases when the workers and the equipment in the tunnel cannot be redistributed to other locations or works.
  - Interruptions of works lasting for more than 2 hours, which occurred due to high concentrations of gas which exceed the allowable concentrations, are paid per unit price for one hour of interruption. Payment is made only in those cases when the workers and the equipment in the tunnel cannot be redistributed to other locations or works.

- The unit price for the excavation also includes the excavations above the Line 2 (figure 2.8.2). Increase of the excavation profile (super section) due to permitted construction tolerances U_p (t_c).

- The unit price for excavation has to include all the works, costs of equipment and materials required for the control and reduction of the concentration of gases during the excavation phase, as well as the pre-drilling required for early detection of explosive gases (methane). The equipment is calculated separately and may be included in the time-dependent costs.

- The offered unit price for the excavation has to be independent of the method actually used for excavation (drilling and blasting methods or by means of mechanical devices).

- The unit price for the transportation of excavated material to the embankment or the dump located 300 m from the tunnel portal has to include all the works and equipment required for the loading, transportation and unloading of material. The dump site has to be designed in such a way to allow for the uninterrupted runoff of water. Loading and unloading of the material at the temporary storage has to be included in the transport unit price.

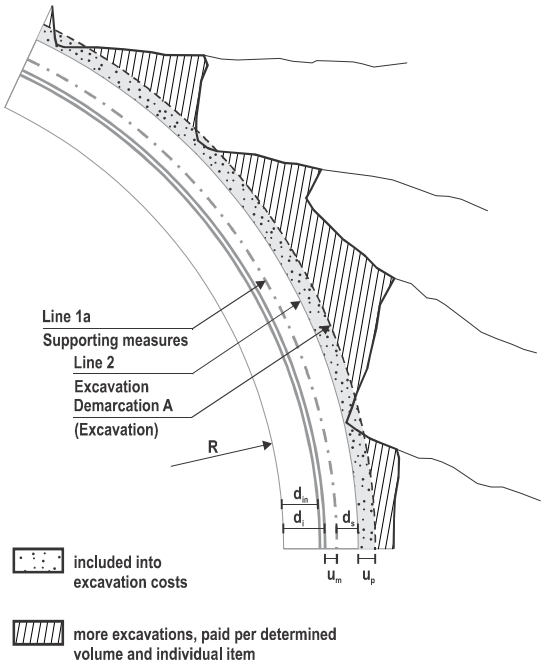
- The unit price for excavation also has to apply to the local widening of the profile for temporary portals that need to be constructed in order to increase the thickness of the concrete lining in the cut & cover constructions).

- Jedinična cena za iskopavanje mora da The unit price for excavation has to include all the works, costs of equipment and materials required for treatment and recharge of all contaminated waters in the tunnel before they are released, which is not paid for separately. Equipment is separately calculated and may be included in the one-off costs.

- Final excavation for construction of the body of the road has to be included in the unit price for excavation and is not measured and paid for separately.

- The unit price for excavation has to include the interruptions caused by parallel drafting of the geological-technical documentation.

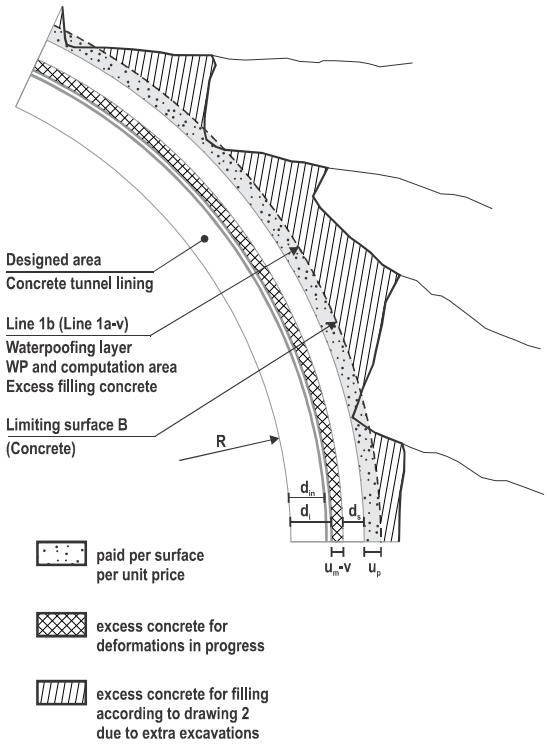
- The unit price for excavation has to include all the work on filling and backfilling (protection of the support in the invert arch area, with minimal thickness of. 0,5 m).



R	radii of the transversal clear profile
d_i	thickness of the inner lining with levelling for waterproofing and the waterproofing itself
d_{in}	thickness of the inner lining
d_s	set thickness of shotcrete as a support element
U_p	set by the Employer during tender procedure (limits it to up to 5 cm for the invert arch and to up to 5 cm for calotte and bench)
U_m	camber set by the Employer during excavation works
V	deformations of the rock mass

Figure 2.8.2: Calculation lines: excavation and support elements - layout prior to deformation

After deformation



R	radii of the transversal clear profile
d_i	thickness of the inner lining with levelling for waterproofing and the waterproofing itself
d_{in}	thickness of the inner lining
d_s	set thickness of shotcrete as a support element
U_p	determined by the Employer during the tender procedure
U_m	camber set by the Employer during excavation works
V	deformations of the rock mass

Figure 2.8.3: Calculation lines: concrete and excess concrete - layout per deformations

2.8.4 CONTROL OF THE PROFILE AND PERMITTED DEVIATIONS

2.8.4.1 Profile control

The CONTRACTOR is obligated to carefully and systematically check the final free profile of the primary tunnel lining, aiming to determine the space for the designed nominal thickness of the inner concrete lining.

2.8.4.1.1 Control of the profile for the final concrete lining

- In accordance with the provisions, the installation of the final concrete lining is performed by installation of the steel formwork placed on a rail which moves the beam footings.

- The CONTRACTOR shall be fully responsible for the marking out and construction of the footing, onto which the rails are being mounted on each side of the tunnel and onto which the tunnel lining is placed.

- The CONTRACTOR shall be responsible for providing the minimum free profile for the final lining, as shown in the drawings. In order to prevent deviations from the theoretical profile, the CONTRACTOR has to provide a profile measuring vehicle equipped with a marking pattern which is used for determining the minimal profile required for the nominal thickness of the final concrete lining. The profile measuring vehicle has to be designed in such a way to be able to move over the rail or to use the tunnel lining for moving. Furthermore, this profile measuring vehicle has to enable access for the marking of the areas of the initial lining which penetrate into the minimal free profile area. The profile measuring vehicle has to be designed as a working platform for replacing the initial lining (primary lining), if necessary, as well as for the

execution of works on the preparation of the surface, as specified in this specification.

- The CONTRACTOR is obligated to obtain the approval of the SUPERVISOR for all the details which refer to the design of the profile measuring vehicle with the pattern. Upon obtaining the approval, the SUPERVISOR shall issue instructions referring to the systematic verification of the geometry of the pattern during the profiling process.

- The CONTRACTOR, having obtained the consent of the SUPERVISOR, may use modern geodetic techniques and processes for data processing with the aim to determine the final free profile.

2.8.4.1.2 Execution

- The final free profile must not be tested until geotechnical measuring confirms that the degree of radial movement at any peripheral point of the tunnel is less than 4 mm a month.

- After the installation of the supports is finished and after the surface has been prepared as specified in this specification, as well as after a deformation, in accordance with the previous line in this article, the final free profile for the inner lining has to be adjusted to the minimum thickness of the inner lining, as shown in the drawings.

- Control of the profile has to be conducted by constant utilisation of the profile vehicle equipped with a pattern, or otherwise by applying modern geodetic techniques on at least every 2.0 m.

- Any deviation from the theoretical free profile for the inner lining has to be adjusted by the application of an additional layer of shotcrete or with the installation of thicker inner concrete lining, if the free profile is too big, or by reshaping of the tunnel support sections which penetrate into the free profile. The CONTRACTOR is responsible for the execution of these works without the right to additional payment.

- The CONTRACTOR has to present the SUPERVISION with suggestions for the execution of remedial works.

- No reshaping of the tunnel support is allowed unless approved by the SUPERVISOR.

- Geotechnical measuring prior to, during and after the implementation of adequate measures has to be performed in accordance with relevant design specifications. Measuring points, such as convergent wedges and/or extensometers have to remain installed or have to be replaced by new ones at the excavation face so as to get a zero reading, which is not paid separately.

- The station for geotechnical measuring and testing may not be relocated or abandoned without prior consent of the SUPERVISOR.

2.8.4.1.3 Records

- A record has to be kept for each phase of the remedial measures.

- The final free profile has to be periodically surveyed in a longitudinal direction and at the points along the periphery of the tunnel, in accordance with the proposal of the CONSTRUCTOR, as recommended by the DESIGNER and with the consent of the SUPERVISOR.

- The final examination of the free profile upon the completion of the re-profiling and surface preparations, has to be performed in the presence of the SUPERVISOR.

2.8.4.2 Permitted construction deviations

2.8.4.2.1 Permitted deviations for the initial lining

- The reduction of the theoretical thickness of the inner concrete lining is not allowed, unless approved by the SUPERVISOR. In order to meet this requirement, the support elements, such as shotcrete, anchor heads, steel ribs, etc. must not penetrate the theoretical inner concrete lining, as shown in the drawings.

- In the invert arch and foundation beam area, parts of rocks must not penetrate the theoretical excavation line.

2.8.4.2.2 Permitted deviations from the excavation level of the invert arch

- If the tunnel is constructed without the concrete invert arch, the CONTRACTOR

has to excavate the lower invert arch level with the accuracy of +0 to -100 mm, relative to the theoretical excavation line of the invert arch.

- If after the cleaning of the silt, loose material, etc. the lower excavation level is more than 100 mm below the designed theoretical excavation line, the CONTRACTOR is obligated to backfill these surfaces up to the designed, theoretical level using the material from the lower bearing layer or in accordance with the instructions and approvals obtained from the SUPERVISOR.

- If the tunnel is being constructed with a concrete invert arch or with the invert arch made of shotcrete, the reduction of the designed, theoretical thickness of the concrete construction is not allowed. Overbreak has to be compensated through the application of concrete or shotcrete on the construction of the invert arch. The inside surface of the concrete invert arch may deviate up to +/- 50 mm in inclination of the theoretical cross profile.

2.8.4.2.3 Permitted deviations of the inner concrete lining

Permitted geodetic deviations

The tunnel axis of the completed cross profile may deviate from the calculated road centre line (alignment) not more than ± 30 mm in the base. Permitted deviation for the inclination is limited to ± 10 mm.

Permitted formwork deviations

Permitted formwork deviations, including the deviations referring to the construction of the formwork, irregularities during the installation and deformation of the formwork during concrete works, must not exceed 60 mm in the radial direction.

Curvatures impact

Having in mind that the tunnel formwork is straight, a curved tunnel is actually polygonal in shape. Therefore, deviation of the theoretical shape has to occur with the maximum at the centre of the concrete block. This permitted deviation depends on the length of the block L, width of the free profile envelope B and the radius R of the tunnel alignment. The necessary "permitted deviation of curvature C" may be calculated by means of the following formula:

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

Overall permitted deviation of the inner lining.

- The overall permitted deviation of the inner concrete lining may be calculated by adding the "permitted geodetic deviation", "permitted lining deviation" and the "permitted curvatures deviation ".

- Deviation of the inner surface of the concrete lining from the theoretical cross profile must not exceed 100 mm (in the radial direction) towards the inner side. The inclination of the walkway has a permitted deviation of the inner surface which is limited to 50 mm towards the inner side, so as to maintain the minimal dimensions of the cable duct.

- Moreover, as is the same with any other permitted deviation, the designed theoretical thickness of the inner concrete lining has to be maintained, as well as the appropriate free road cross-profile and walkway.

Other permitted deviations

- Niches and similar constructions have to be constructed with a permitted deviation of ± 50 mm compared to the designed location. Permitted deviations for the sizes of the niches are limited to ± 10 mm.

- Prefabricated elements and cable ducts have to be constructed with a permitted deviation of ± 10 mm compared to the theoretical position.

2.8.5 SECURING OF THE TUNNEL

2.8.5.1 General requirements

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

2.8.5.1.1 Construction method

The CONTRACTOR is obligated to understand and recognise the technical and design concepts of the new Austrian tunnel method (NATM) for mined tunnels as well as to understand the function and significance of each component of tunnel support.

2.8.5.1.2 Documentation that needs to be delivered

- Before the commencement of works covered by this Specification, the CONTRACTOR is obligated to submit to the SUPERVISOR for approval a comprehensive programme for material testing and quality control, which includes all the elements of the tunnel support.

- Furthermore, manufacturer's certificates of compliance also have to be submitted to confirm that the materials to be used meet the requirements set forth in the specification.

- The SUPERVISOR also has to be provided with the following: the method of installation of each type of support element, including the description, specification and manufacturer's instructions for drilling, anchoring, etc.

- The above mentioned documentation has to be delivered to the SUPERVISOR in a timely manner, i.e. within a set time period prior to the commencement of works or by the date agree upon among the parties.

2.8.5.1.3 Implementation of tunnel supporting works

- Vrs The type and the amount of tunnel support that needs to be installed immediately upon the completion of excavation are directly related to the determined rock category. Standard initial support associated with the determined rock classification system is shown in the drawings. However, as a consequence of variations from the anticipated characteristics of the rock, the standard support systems as shown in the drawings for each rock mass type may require modifications and adjustments during the construction phase, in accordance with the agreement between the authorised representatives of the SUPERVISOR and the CONTRACTOR, or in accordance with the instructions of the GEOTECHNICAL COUNCIL (pursuant to section 2.8.2.2).

- The CONTRACTOR is obligated to install or apply the support elements in the manner and in the sequence which will prevent the disintegration and loosening of the rock mass, in front of and around the excavated tunnel.

2.8.5.1.4 Records

- The CONTRACTOR is obligated to prepare and keep comprehensive records on a daily basis, containing all the details on the tunnel support installed and its performance during the execution of the works. These records have to be available to the SUPERVISOR at all times. The records have to include the type, quantity and location of the installed support elements, the clearance profile after the installation of support, deviations from the standard support system, observations of excessive deformations, shotcrete cracking, etc. The SUPERVISOR has to be informed immediately if excessive deformations and shotcrete cracking is observed.

- The CONTRACTOR is obligated to keep a record of the chainage of each face position and to update the record as the works progress. This record has to be available at all times and has to be kept at a suitable location near to the relevant face. The forms of all the records mentioned have to be agreed on in advance with the SUPERVISOR.

- All the mentioned records have to be delivered to the SUPERVISOR on a daily basis and the supervisor has to approve them. The form of the record has to be agreed on in advance with the SUPERVISOR.

2.8.5.1.5 Equipment and the supply of material

- Mechanical plants and the equipment for the installation of underground support have to be suitable for the works specified, taking into consideration the mode of operations and valid safety regulations. Furthermore, the capacity of the equipment has to be sufficient to meet the production requirements in terms of the construction programme.

- The equipment has to be properly maintained and spare parts have to be available so as to ensure that the equipment required for support installation is available at all times, regardless of the location of the underground excavations.

- The uninterrupted supply of materials to all working areas that require support installation has to be ensured at all times. It should be recognised that for excavations in poor quality rock this pre-requisite is mainly related to the safety of the tunnel construction.

- For each tunnel heading, the CONTRACTOR is obligated to provide the material and equipment necessary for a quick and efficient response in emergency situations, such as unexpected instability of the rock mass, heavy water inflow, etc., which cannot be handled with the regular procedures of tunnel support installation.

- The CONTRACTOR is obligated to keep onsite or have immediately available at least a two-week supply of any of the support elements required according to the rock mass classifications, as indicated in the drawings and foreseen by the work programme.

2.8.5.2 Shotcrete

2.8.5.2.1 General

- All works referring to the application of shotcrete have to be performed in accordance with the latest edition of the Austrian "Sprayed concrete guideline", issued by the Austrian Concrete Society, unless otherwise prescribed in this Section.

- For the acceleration of setting and development of early strength (see also the requirements for "young" shotcrete) the following is used: non-alkaline additives for acceleration of setting or special "cement-binder" (without additives for acceleration of setting). The use of alkaline setting accelerators is not allowed.

- If a non-alkaline additive for the acceleration of setting is being used, the quantity of alkali (Na_2O-equivalent) must not exceed 1 vol. %. The decrease in compressive strength of shotcrete with alkali-free setting accelerator compared with the base shotcrete (without accelerating admixtures) at the age of 7 and 28 days must not exceed 10%, regardless of the actual strength.

- Only wet mix shotcrete is allowed. Regardless, however, a dry mix plant has to be kept on site in the situation of the eventual failure of the wet plant, provided that it is approved by the SUPERVISOR.

2.8.5.2.2 Materials

Cement

- Cement used for the preparation of shotcrete has to correspond to SRPS B.C1.011, 013, 014 Standards.

- Cement used together with the additive for non-alkali acceleration of setting has to be Portland cement PC 450 and has to correspond to the following requirements which refer to compressive strength, all in accordance with the Austrian standard ÖNORM B3327-1:

Age at the day of testing:	Min. compressive strength:
Day	9 N/mm^2 (5 % facture)
28 days	40 N/mm^2 (5 % facture)

- Special cement binder has to meet the following requirements:

Specific surface:	4500 cm^2 /g $\pm$ 300 cm^2 /g
Na_2O equivalent:	< 10%

Aggregates

- Aggregates have to be clean, tough, durable, with adequate gradation, and they must not contain dangerous quantities of dust, silt, clay or other inorganic impurities.

- Coarse aggregates must not contain large quantities of long rocks.

- A quantity of fine aggregate with particle size under 0.1 mm must not exceed 2% of the overall mixture.

- Maximal aggregate size must not exceed 11 mm.

- Granulometric composition has to be between lines A11 and C11, preferably near line B11, as shown in the drawing 2.8.4.

- The use of frozen aggregate is not allowed. Minimum temperature of the aggregate is plus 5°C.

- During rainy and cold periods, aggregate has to be stored in a covered warehouse for at least 48 hours before usage, so as to reduce the water content.

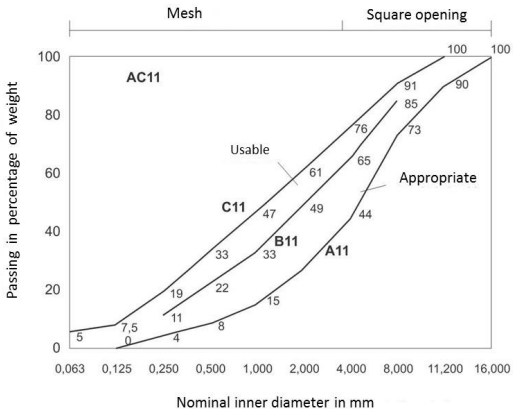


Figure 2.8.4: Granulometric composition of aggregate

Numbers given in the table refer to passing of a percentage weight.

Binding accelerators

- Non-alkaline setting accelerators have to be compatible with the cement being used. It is permitted to use either liquid or powdered mixtures. Compatibility is to be verified both in the laboratory and at the site, so as to achieve the required setting properties and strengthening over time, in accordance with chapter 2.8.5.2.6 of this specification.

- The dosage rate to be used is determined based on the suitability tests carried out in accordance with the requirements set forth in chapter 2.8.5.2.6. of this Specification. Any addition to this dosage rate must not exceed 1% of the cement content in the weight of the designed mix. The dosage rate may be reduced in cases of downhand and horizontal spraying positions. An automatic device has to be used for the adding of the setting accelerator mixture. The appropriate dosage has to be determined through laboratory testing.

Additives

- With the consent of the SUPERVISOR, additives for the improvement of characteristics, workability, etc. may be added.

- Additives which are to be used need to be included in the testing described in chapter 2.8.5.2.6 of these specifications.

2.8.5.2.3 Mixture design

The mixture of shotcrete has to be designed based on laboratory tests and on site trials, as described, so as to meet the requirements for strength development and final strength. The following factors should be considered:

- type and content of cement
- mixtures used for acceleration of setting
- water to cement ratio
- setting and strength development
- temperature of the mixture.

Cement content

For the dry procedure for the preparation of shotcrete, cement content must not be less than 350 kg/m³ of the dry mixture.

The content of cement has to be designed so as to meet the requirements for shotcrete strength applied on site.

For the wet procedure for the preparation of shotcrete, minimal cement content has to comply with the standard mix of C 20/25 concrete.

Cement to water ratio

Dry procedure:

Water content has to be controlled by an individual handling the hose nozzle, so that water content is adjusted depending on the condition of the surface to which it is applied as well as depending on the location where the application takes place. A slightly shiny appearance of the shotcrete immediately after application will indicate that the cement to water ratio is adequate.

Wet procedure::
Onsite testing has to be carried out so as to determine and establish a suitable water to cement ratio.

Binding and strength development

- Accelerating admixtures or special "cement-binders" have to be used so as to meet the requirements for the setting and strength development of shotcrete applied onsite.

- In order to determine an adequate dosage rate of acceleration admixtures, suitability tests have to be carried out.

- The compressive strength of shotcrete onsite (taken from the tunnel lining or panels sprayed in the tunnel) has to develop progressively to the final strength, in accordance with the minimal requirements set forth in the text below. Uniaxial comprehensive tests have to be carried out in accordance with the provisions set forth in chapter2.8.5.2.6.

- Strength development, due to suitability testing, has to exceed the specified onsite strength by a factor of 1/0,85 (=1,18).

- The strength of 28 day old shotcrete has to be at least 25 N/mm². Shotcrete strength development has to meet the following requirements:
  - 0,1 – 0,2 MPa after 2 minutes (not more than 0,2 MPa)
  - 0,2 – 0,5 MPa after 6 minutes
  - approx1,0 MPa after 1 hour
  - approx2,0 MPa after 2 hour
  - 2,0 – 5,0 MPa after 6 hours.

- When it comes to tunnelling under buildings or shallow cover, the strength development of young shotcrete has to reach 12 N/mm² after 24 hours.

2.8.5.2.4 Batching, mixing and transportation

Truck mixers which are to be used for the transportation of shotcrete into the tunnel have to be equipped with approved exhaust filters.

Dry procedure for the preparation of shotcrete

- Cement and aggregates have to be batched in the specified and designed proportions. Measuring has to be done by weight. During batching, all aggregates have to be dry or sufficiently drained to have a stable moisture content which must not exceed 7 %.

- Mixing of cement and aggregate has to be performed mechanically with a mixer. The use of shotcrete is not recommended if it cannot be placed within 90 minutes from the time of mixing. The time span has to be as short as possible, especially during seasons characterised by high temperatures and high humidity.

- Mixing time must not be shorter than 3 minutes.

- A system of delivery notes has to be introduced to be able to record the date and time of mixing, number of the design mix, quantity, delivery point, time of delivery and the completion of application. Delivery notes have to be available to the SUPERVISOR who has to approve them.

- For the dry procedure, liquid or powdered setting accelerator is added to the dry mixture. The powdered accelerator shall be proportioned and added through a mechanical device (dispenser) just before the dry mix enters the shotcrete machine. Liquid accelerator is introduced by means of a special dosing pump and is added to the dry mixture at or near the nozzle. The dosing pump and the hoses of the nozzle have to be in functional condition at all times.

- During period of cold weather, the setting properties of shotcrete have to be maintained by heating of the water or aggregate or both, depending on the temperature. Relevant standards have to be applied.

- During periods of hot weather, the water content of the aggregates used in the dry procedure has to be above 4% so as to avoid cement loss at the rotor of the shotcrete machine.

Wet procedure for the preparation of shotcrete

- See also Section - Work with cement concrete - SPECIAL TECHNICAL CONDITIONS.

- Only liquid types of setting accelerators are used for the wet procedure for the preparation of shotcrete; these mixtures are added at or near the nozzle. The output of the accelerator pump must be controlled and has to be proportional to the output of the concrete pump. The nozzle has to enable the preparation of a homogeneous mixture of wet mix with the additives for the acceleration of setting.

Special cement binder

Basically, there are two ways to apply shotcrete with a special cement binder:
- using dry aggregates with water content less than 0.8%; aggregates may be mixed with cement binder immediately prior to application.

- Using wet aggregates with water content less than 4 %; aggregates and cement binder have to be mixed immediately prior to application.

2.8.5.2.5 Applying shotcrete

- Rock surfaces or surfaces to which shotcrete has previously been applied and to which shotcrete will be applied again have to be carefully cleaned of all loose materials, rocks and other impurities. It has to be cleaned by compressed air or water jet, if the rock is not sensitive to water.

- The optimal distance between the nozzle and the surface of application is from 1.0 to 1.3 meters. The nozzle has to be positioned at a right angle to the surface to which the shotcrete is being applied. For normal progress through the tunnel, at least two nozzles have to be used.

- The maximum thickness of shotcrete applied at once must not exceed 15 cm. If it is necessary to increase the thickness, additional layer/layers must not be applied until the previous layer develops sufficient strength to support the additional layers. The application of additional layers has to be completed over the course of three days.

- Steel ribs, roof ties, reinforcement mesh and other types of reinforcement have to be embedded into shotcrete as shown in the drawings. On the inner side of the tunnel lining, reinforcement mesh and reinforcing bars have to be covered with at least 2 cm of shotcrete or as shown in the drawings.

- If more than one layer of reinforcement is being used, the second layer must not be placed before the first layer is placed and covered with shotcrete.

- If shotcrete is applied to a sound rock, shotcrete has to follow the rock surface with the proper rounding of notches and corners. At projections of sound rock, the actual shotcrete thickness may be locally reduced to two thirds of the specified thickness. This applies only to behaviour type BT 1 (See Serbian Road Design Manual 11.2 Earth Works, Table 11.2.4: Categories of Rock Mass Behaviour Types).

- Waste shotcrete has to be removed immediately after finishing the application of the shotcrete. Waste shotcrete has to be removed in particular at the horizontal shotcrete connections due to separate excavation sequences and at all cold joints, if necessary, using pneumatic hammers, prior to the application of shotcrete.

- Under no circumstances can waste shotcrete be reused. Waste shotcrete has to be regularly removed from the construction.

- Curing: required, where necessary.

- Measures for establishing the total thickness of shotcrete shall be determined by the CONTRACTOR and approved by the SUPERVISOR. These measures may include visual guides installed prior to the application of the shotcrete or holes drilled after the application of the shotcrete.

- Surface preparation for the waterproofing membrane: shotcrete of finer granulation has to be applied as preparation of the surface and for protection of the waterproofing membrane, in accordance with section 2.8.7.

- In order to avoid excess shotcrete load on the lining, especially in heavy squeezing rock, deformation slots have to be placed

in the shotcrete lining. Generally, the slots have to have an opening width of 20 to 40 cm and have to be boarded radially. The actual position of the slot depends on the geotechnical conditions.

2.8.5.2.6 Shotcrete testing

- Suitability tests and the quality control of shotcrete have to be performed in accordance with Austrian "Sprayed Concrete Guideline", unless otherwise prescribed in this section.

- The type and number of suitability tests for mix design are listed in table 2.8.6.

- The type, number and frequency of tests necessary for quality control during construction are listed in table 2.8.7.

Suitability tests

- The compatibility of the cement and the mixtures for the acceleration of setting have to be tested in the laboratory with the checking of setting times and whether the addition of the accelerator leads to excessive reduction in the long term compressive strength of the shotcrete.

- On site tests have to be performed so as to determine setting and strength development, as well as to determine the required dosage of additives used for accelerating the of setting of shotcrete.

- For each type of setting accelerator that has previously been determined as being suitable through laboratory testing, a trial mixture has to be applied on the test panels (3 pieces 500x500x200 mm per trail mixture). These mixtures have to be cured under site conditions and have to be subjected to tests. At least three different dosages of each type of setting accelerators have to be tested as described. The range of accelerator dosages has to vary between 2% and 7% of the cement weight.

- The ambient temperature during the test has to correspond to actual conditions in the tunnel.

Testing of fresh shotcrete (early strength class)

Proctor's test (measuring range 0 to 1,2 MPa)

Strength development up to 1.2 N/mm² may be determined by means of a penetrometer using a plunger of 3 mm diameter, where the penetration depth has to be approximately 15 mm. Testing has to be carried out in accordance with the "Sprayed Concrete Guideline".

Measuring range 1 to 8 MPa

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

Measuring range 3 to 16 MPa

Bolt screws are shot into the concrete and the depth of penetration is determined. Then the bolt screws are removed and the pull-out force is measured. The ratio of the pull-out force to the penetration depth is the parameter used for determining the compressive strength. A HILTI DX 450 L bolt-setting unit with green cartridges is used to drive the bolt screws into the concrete. The pull-out force is determined by means of a pull-out device (for example, HILTI Tester 4). Testing has to be carried out in accordance with the Austrian "Sprayed Concrete Guideline".

Measuring range 16 to 56 MPa

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

Shotcrete testing

The development of the compressive strength is tested by the crushing of cylindrical shotcrete samples at the age of 7 and 28 days. Samples are taken by drilling of

the core from the test panels which need to be cured under conditions similar to the ones in the tunnel. The sample diameter has to be 100 mm and has to be cut to a height of 100 mm. The drilling of the cores has to be performed no earlier than 48 hours after spraying. The minimum distance to the edge of the test panel has to be kept at 100 mm.

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

The permeability of shotcrete is tested in accordance with the Austrian standard ÖNORM B 3303. Water penetration depth must not exceed 35 mm. Three core samples have to be tested, with the diameter of 200 mm and height of 120 mm, at the age of 28 days.

2.8.5.2.7 Quality control

To ensure the required quality of shotcrete during construction, it is necessary to test the aggregate gradation, cement, additives (for example, fly ash), additives for acceleration of setting, strength development of "young" shotcrete and shotcrete strength at 7 and 28 days, as shown in table 2.8.7.

Compressive strength failures

This chapter presents a list of all the actions which need to be undertaken in situations where the strength requirements specified in chapter 2.8.5. of this specification are not met.

- Failure of pull-out test at 24 hours, or cores on 3 day tests:
  - notify the supervisor,
  - immediate examination of the tunnel lining in the area in question,
  - immediate examination of the elements used for the making, transport and application of shotcrete,
  - constant supervision,
  - prepare for further tests that have to last for three days,
  - take new test panels as soon as possible and conduct a penetrometer test, pull-out test and compression test in core samples as specified above.

- Failure of cores on 7 day tests:
  - notify the supervisor and the designer,
  - install a measurement section,
  - monitor in accordance with the specification (section 10 of this specification),
  - should the results of the monitoring indicate instability of a certain section, additional rock support has to be installed,
  - if the interpretation of deformation measurements is such that additional support is not required, further tests shall be carried out at 28 days.

- Failure of cores on 28 day tests:
  - notify the supervisor and the designer,
  - take the cores from the tunnel lining,
  - determine the area in question
  - test the cores and if failure occurs:
    - prepare a proposal for the strengthening of a certain area, in cooperation with the designer,
    - submit proposals for the approval of the supervisor before the remedial works commence.

If the required 28-day-strength of the shotcrete is not achieved, the SUPERVISOR may require that the theoretical thickness of the shotcrete d_s is increased by the value d_1, calculated using the following formula:

$$d_1 = \left[\frac{F}{M} - 1\right] d_s$$

F – required 28-day-strength in N/mm²
M – actual measured strength of the shotcrete lining in N/mm²
d_1 – additional thickness of shotcrete to be sprayed, in cm
d_s – theoretical thickness of shotcrete lining in cm

In some cases, the SUPERVISOR may require for the failed shotcrete to be removed and the rock support to be re-installed in accordance with the specified type of rock mass.

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

Failure of the compressive strength as described above is the responsibility of the CONTRACTOR. The required strengthening or reinforcement of the installed rock support due to failed quality control tests will not be measured for payment.

2.8.5.3 Micro-reinforced shotcrete reinforced with steel or polymer fibres

General

Steel or polymer fibres may be used for the production of fibre reinforced shotcrete. The resistance and the flexural strength of shotcrete are increased after fibres are added into the shotcrete, compared to the properties of the shotcrete that has not been reinforced with fibres.

Material

The shape, length and diameter of the fibres vary from one manufacturer to another. Fibre reinforced shotcrete has to contain at least 30 kg of steel fibres per cubic meter of concrete. When polypropylene fibres are being used, fibre reinforced shotcrete has to contain more than 0.8 kg of fibres per cubic meter of concrete.

In order to achieve the desired adhesion of the fibres and the concrete, the required strength of 28-day old concrete has to be at least 25 N/mm^2.

Application

Fibres may be added to the shotcrete either into the mixer or in situ, prior to application. If an adequate dosing device is available, the injection device may be filled with fibres in a controlled manner, or fibres may be added directly into the nozzle.

If fibres are joined together, they should be separated by water.

Testing

Flexural strength being tested after 7 days must not be less than 5MPa. In accordance with SRPS EN 14488-3 three bending tests have to be carried out on the shotcrete samples (beams) with the dimensions of 100 mm x 100 mm x 400 mm, with the span of 300 mm or 150 mm x 150 mm x 600 mm with the span of 450 mm, with the load positioned on three locations. The load points have to be 100 i.e. 150 mm apart. Testing by means of artificially caused deformations has to be carried out by the bending of the samples (bending rate 0.1 mm/min), where the ratio load/bending has to be simultaneously recorded. For this purpose, it is more appropriate to use lateral fixing at the sample axis. Test samples are subjected to a load until the bending of the beam reaches 1/150 of the span (2mm or 3 mm). The first crack on the beam with 300 mm span may occur only after deflection of 0.03 mm to 0.05 mm.

Based on the test results, equivalent flexural strength and flexural resistance are calculated in accordance with SRPS EN 14488-3.

2.8.5.4 Reinforcement

2.8.5.4.1 Reinforcement mesh (welded steel fibres)

Material

- Reinforcement mesh has to correspond to the requirements set forth in SPECIAL TECHNICAL CONDITIONS, unless otherwise prescribed in this section.

- Reinforcement mesh has to be made of MA 500/560 quality steel; SRPS EN 10080.

- Depending on the approval of the SUPERVISOR, the reinforcement mesh to be used is either 150 x 150 mm or 100 x 100 mm, with a diameter of 5 - 6 mm.

Installation

- Reinforcement mesh has to be installed so that it follows as closely as possible the irregularities of the excavation surface or the previous layers of shotcrete. It has to be firmly fixed to prevent vibration and change of position during the spraying of the shotcrete. Reinforcement mesh has to be installed in the longest practical length. The overlap of reinforcement mesh installed into the shotcrete lining has to be at least twice the pitch distance in circumferential and one pitch distance in longitudinal direction.

- The installation of the reinforcement mesh has to be such to ensure concrete coverage with the minimal thickness of 3.0 cm.

2.8.5.4.2 Reinforcing steel bars, re-bars

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

Material

- Reinforcing steel bars have to correspond to the provisions set forth in SPECIAL TECHNICAL CONDITIONS, unless otherwise prescribed in this section.

- Re-bars have to be made of RA 400/500 quality steel.

Installation

- Reinforcing steel bars have to be securely attached to the previously applied shotcrete layer or the reinforcement mesh.

- Overlapping has to be performed in accordance with the relevant drawings.

2.8.5.5 Steel arches

2.8.5.5.1 General

- This part of Section 2.8.4. applies to the supply and installation of the steel ribs required and used as support in underground excavations. Steel ribs have to be effective as primary support elements immediately after excavation and have to subsequently act as reinforcement of the concrete lining.

- The steel ribs have to be manufactured to meet the geometrical requirements referring to the excavation geometries for each type of rock mass, including the relevant deviations.

Documentation that needs to be delivered

- Pursuant to chapter 2.8.5.1.2. of this specification.

- Workshop drawings.

- Before the commencement of works, the following needs to be delivered:
  - complete fabrication details of the steel ribs,
  - installation procedures andplan ,
  - details on joints, rib connections, rib spacers, geometry etc.
  - certificates of compliance of the materials.

Types of steel arches

H - profile arches

H - profile arches have to consist either of HEB or GI hot rolled profiles with the dimensions shown on the tunnel support drawings.

TH - profile and E - profile arches

TH - profiles and E - profiles originating from mining are hot rolled and have a bell shapedcross profile . Rib sections are connected with clamps, so that there is an overlapping of the profiles that fit into one another. This type of connection allows for larger deformations due to friction in the clamp connections.

In ground conditions where larger deformations may be expected, TH - profiles and E - profiles have to be used.

Lattice girders

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

In the situation of fabrication onsite, the CONTRACTOR shall submit a detailed method statement to be approved by the SUPERVISOR.

Materials

- Hot rolled profiles (H, TH and E profiles) have to be made of structural steel with the minimum tensile strength of 240 N/mm^2.

- Lattice girders have to be manufactured of reinforcing steel bars with the minimum tensile strength of 400 N/mm^2.

Manufacturing steel arches

Geometry

Steel ribs have to be manufactured to meet the geometrical requirements of each of the support classes requiring their use as shown in the design drawings.

Welding

- A manual electric-arc welding process has to be employed. The manufacturer is obligated to ensure that the capacity of the welding plant and of the auxiliary equipment is adequate for the welding process, as well as to ensure that the

welding plant and the auxiliary equipment is maintained in good working order.

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

- Welding surfaces have to be dry. Welding seams and the surrounding surfaces have to be clean, free from moisture, oil, paint or any other substance which might affect the quality of the weld. Slag has to be removed after every welding session. The most favourable welding position has to be chosen for each individual case.

- Manual flame cutting is used for the cutting of steel profiles. Sawing is also permitted.

- Further preparation of joints and welds has to be done by grinding.

- Parts to be welded have to be placed so that the joints are easily accessible and visible to the operator.

- Slag has to be removed from all welds in order to allow visual inspection.

- Welding operations have to be supervised by a suitably trained supervisor with sufficient experience in production. The welding supervisor is responsible for the following duties listed hereunder:
  - engagement of welders or skilled operators and supervision over their work,
  - selection, use and storage of suitable welding filler metals and auxiliary materials,
  - selection and use of suitable welding apparatus, the welding plant and welding fixtures.
  - visual and dimensional inspection of the welding seams, as described in the 12th line.

- Welders have to pass the acceptance test.

- Prior to the commencement of welding, each welder has to perform three trial welding sequences, under the conditions that exist during regular production. These joints have to be inspected by the SUPERVISOR.

- The routine inspection of welded joints has to be performed by the SUPERVISOR on site, whereas at least 10% of the welded joints have to be inspected in accordance with the 12th line.

- The acceptance test and routine inspection have to be conducted in accordance with the criteria described in the table below. Visible defects exceeding the limits shown in the table have to be removed and replaced in an adequate manner.

welds of inadequate size	0.1 "a" permitted (10 %)
notch	permitted to a limited extent
visible pores	10% by area
visible slag remains	permitted to a limited extent, but not continuous
craters	minor depressions permitted
lack of fusion	permitted, but not on large areas and not continuously
cracks	individual minor local cracks permitted
excessive asymmetry of welds	side ratio < 1:0.6.

Installation

- Steel ribs have to be placed in accordance with the levels indicated in the drawings. The exact excavation levels have to be determined by the CONTRACTOR in accordance with the equipment and construction method used, with the approval of the SUPERVISOR.

- Hardwood foot blocks and wedges have to be used for placing the steel ribs at the required level. Tie bars have to be provided to connect the rib to the adjacent steel rib and fix it securely in place.

- Steel ribs have to be embedded in shotcrete, in order to achieve contact between the rock and the steel rib by

means of solid shotcrete packing with a minimal thickness of 20 mm.

- The steel ribs have to be erected perpendicular to the tunnel axis.

- The joints of the ribs have to be such to maintain the static efficiency of the cross profile.

- In the case of TH - profiles, the hole has to be oriented towards the tunnel in order to enable load transfer and to avoid cavities behind the steel profile. Contact between ground and steel has to be obtained in accordance with item 3.

2.8.5.6 Steel holders

Holders are a pre-excavation support element required for the tunnel excavation. Holders have to be applied in rock and soil conditions which tend to produce overbreak, collapsing or falling rock immediately following excavation. Holders may be applied locally or systematically, depending on the circumstances, if required for the safety of the works and for the prevention of overbreak, which is always connected to the erection of steel ribs. The length of steel pipes or rods has to be at least 1 m longer than the anticipated length of the excavation round.

2.8.5.6.1 Injected holder pipes

Material

Holders are a pre-excavation support element required for tunnel excavation works. Holders have to be applied in rock and soil conditions which tend to produce overbreak, collapsing or falling rock immediately following excavation. Holders may be applied locally or systematically, depending on the circumstances, if required for the safety of the works and for the prevention of overbreak, which is always connected to the erection of steel ribs. The length of steel pipes or rods has to be at least 1 m longer than the anticipated length of the excavation round.

Installation
Grout mortar has to comply with chapter 2.8.4.6. of this specification.

Instalacija

- Supporting holders has to be done as shown in the drawings or as instructed by the SUPERVISOR.

- The pipes have to be grouted through a nozzle, immediately after drilling.

- Holder has to be properly supported by steel ribs and shotcrete above the steel ribs. Therefore, filling the gap between the ribs and rocks in the portions of the holder support has to be completed after the installation of the holder.

- The distance between consecutive holder pipes or bars around the crown of the excavation profile must comply with the distance specified in the drawings, and must be adjusted to the prevailing geological conditions of the tunnel face.

2.8.5.6.2 Dowels

Material

Dowels are steel bars with a minimum steel grade of St 37-3U (SRPS EN 10080) and a minimum diameter of 26 mm. Dowels are embedded into the mortar in accordance with chapter 2.8.5.6.

Installation

- Supporting holders have to be done as shown in the drawings or as instructed by the SUPERVISOR.

- Mortar has to be filled into the predrilled holes from the bottom to the top.

- Dowels have to be inserted into the predrilled holes from the face of the drive towards the unexcavated ground.

- Forepiling has to be properly supported by the steel ribs and the shotcrete above the steel ribs. Therefore, filling the gap between the ribs and rocks in the portions of the supporting holder has to be completed after the installation of the holders.

- The distance between consecutive holder pipes or bars around the crown of the excavation profile must comply with the distance specified in the drawings, and must be adjusted to the prevailing geological conditions of the tunnel face.

2.8.5.6.3 Steel laggings

Steel laggings should be placed mainly on bad, non-cohesive terrain, so as to prevent the collapse of material during and immediately after excavation. In order to use steel laggings, steel arches have to be installed.

Materials

- Steel laggings from 4 to 6 mm of thickness are to be used.
- Lengths are to be determined based on the length of the excavation and the support requirements beyond the face.
- The length of steel laggings has to be from 1.5 to 2.0 m.
- The sheet has to be 180 mm to 225 mm thick.

Installation

- Steel laggings have to be placed in accordance with the lengths shown in the drawings. The steel laggings have to be driven into the ground in front of the excavation of the respective round, to a depth that exceeds the minimum length of 0.8 metres beyond the face into the ground.

- The cavities and openings behind the steel laggings have to be filled with shotcrete or injection mass made of cement mortar.

2.8.5.7 Rock bolts

2.8.5.7.1 General

- The provisions contained hereunder apply to all rock bolts installed either locally or in a systematic pattern in the roof, side walls and the invert arch of the tunnel. Rock bolts are part of the primary support, with the purpose of activating the composite action between the surrounding rock and the shotcrete, contributing to the load bearing capacity of the primary tunnel lining. These provisions also cover the rock bolts occasionally required for the support of the tunnel face.

- The rock bolts have to be installed according to the lengths and rock bolt patterns shown in the drawings for each relevant standard support system, unless otherwise determined by the representatives of the CONTRACTOR and the SUPERVISOR based on the classification of the existing rock mass.

Definitions

- SN-bolts are made of ribbed steel bar. They are bonded to the surrounding rock by means of mortar. The hole is filled with cement mortar before the insertion of the bolt. The abbreviation SN derives from the mine "Store Norfors" where these bolts were first applied.

- PG - bolts (bolts subsequently grouted with cement mortar or injection bolts) are made of ribbed steel bars with an attached injecting hose. After the bolt is in position, it is grouted with cement mortar through a hose.

- IBO-bolts (self-drilling bolts) represent a combined system consisting of a rock bolt and a drill rod. During drilling, the bolt is used as the drill rod, fixed with a drill bit. The rod and bit remain in the hole as a rock bolt, which is injected through a hole. If the borehole collapses, this system enables the positioning of the rock bolts.

- Swellex rock bolts (friction anchored rock bolts) are mechanically folded steel pipes. High water pressure inflates the pipe and adapts its shape to the irregularities of the borehole.

Material

SN- bolts and PG-bolts

- Bolts shall have a minimum diameter of 28 mm for steel grade RA 400/500; B 500 A.

- The specified breaking load also applies to the nut, rock bolt plate and joint, if any.

- Rock bolts have to be made of ribbed reinforcing steel (ribbed rod). Steel ribs on the steel rod have to have a corrugated, ribbed surface (f_R) in accordance with DIN 488, section 3, between 0.02 and 0.03. A diameter of 24 mm is most frequently used, while the above mentioned conditions refer to a distance between ribs of approximately 25 mm to 50 mm, depending on the height and the inclination of the rib. Longitudinal ribs should be avoided. Bolts have to be approved by the SUPERVISOR.

- One end of the rod has to be fitted with a suitable nut which is to receive an anchor rock bolt plate and a fixing nut.

- As a safety measure, all types of rock bolts have to be used with rock bolt plates, size 150 x 150 mm and thickness of 8 mm, unless otherwise instructed by the DESIGNER and approved by the SUPERVISOR. The shape of the rock bolt has to allow a uniform seat, even if the bolt is not installed exactly perpendicular to the surface below.

- Washers and nuts have to enable a secure transfer of the anchor force to the anchor plate.

IBO- bolts (self-drilling bolts)

- IBO- bolts must have a minimum breaking load of 2250 kN.

- The breaking load also applies to nuts, anchor plates and joints.

- The steel rods must have a corrugated surface.

Swellex and Super Swellex rock bolts

- Super Swellex rock bolts for systematic rock bolt patterns must have a minimum breaking load of 200 kN.

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

- Anchor plates are used for the transfer of anchor force over the head of the rock bolt to the shotcrete, steel rib or rock surface.

- The equipment recommended by the manufacturer of the rock bolts has to be used for injecting water into the rock bolts.

Joints for bolts

Joints have to be made of the same material as the rock bolts or of even higher quality material. The joint diameter has to enable grouting of the whole bolt length from the deepest point of the drill hole.

Cement mortar grout

- The cement mortar grout has to consist of sand, cement and water or pure cement and water.

- Regular Portland cement is used.

- The sand being used for grouting has to be pure, mineral sand, of uniform quality and has to originate from an approved source. This material has to be approved by the SUPERVISOR.

- Water has to be clean, without traces of oil, acid, base, organic or any other harmful substances.

- The use of additives for improving the level of workability is permitted.

- The cement mortar grout has to be mechanically mixed so as to result in a uniform consistency.

- Expanding additives must be added.

Execution

SN-bolts

- Boreholes for all rock bolts have to be drilled to the depths required by the lengths of the rock bolts specified for the support of the respective rock mass types. The diameter of the boreholes has to ensure the best workability during grouting, joining and installation. The minimum diameter of the boreholes has to be larger by 10 mm than the diameter of the rock bolts/joints installed.

- The boreholes have to be cleaned of all drill cuttings, silt and debris. Rock bolts have to be installed within 3 hours after the drilling and the preparation of the borehole.

- Prior to the installation of the rock bolt, the entire borehole has to be filled with cement mortar. Filling is performed by inserting a grout hose to the full depth of the hole and withdrawing the hose while the grout is pumped in.

- The nozzle has to be kept buried in the grout while the hose is being drawn out so that air is displaced as the hole fills with grout. The bolt is then pushed into the hole.

- The nut of the grouted rock bolts has to be tightened no later than 2 rounds behind the face or 12 hours after installation so as to achieve a force of approx. 20 kN at the rock bolt plate. This force has to be applied by a calibrated torque wrench.

- In the situation of confined working space and/or great length of rock bolts, joining is permitted. The number of joined parts has to be as low as possible. However, the load capacity of these joined rock bolts must not be less than that of a standard integral rock bolt. Special attention has to be paid to the cement mortar grouting procedure in order to ensure full bedding in of the bolt with the grout.

PG – bolts

- In the situation of joined rock bolts or partially collapsed boreholes, cement mortar grouting may be performed after the installation of the bolt. The hole is then grouted by a special attachment which allows the mouth of the borehole to be sealed whilst the grout is pumped in. Air is displaced from the hole by means of a pipe, which is attached to the full length of the installed rock bolt. Cement mortar grout is then pumped in and the filling of the hole is visible. The hole is full when the grout starts escaping from the end of the pipe.

- The same applies as for SN bolts, with the exception of item 3.

IBO- bolts

- IBO-bolts have to be used when ground conditions are such that it is not possible to install other types of rock bolts in an efficient manner.

- IBO-bolts are placed by drilling the rod into the ground without withdrawing the rod.

- IBO-bolts have to be grouted by means of a grouting hose, immediately after completion of the drilling operation.

- Depending on the ground conditions encountered and the approval of the SUPERVISOR, the CONTRACTOR determines the mixture of the cement mortar, as well as the pressure and the quantity required.

Swellex rock bolts

- Boreholes for the rock bolts have to be drilled to the required depth. The boreholes must be cleaned of all drill cuttings, silt and other impurities.

- Rock bolts have to be installed within no more than 2 hours after the drilling of the borehole.

- The installation of rock bolts and the injection of water have to be performed in accordance with the manufacturer's recommendations. The injection of water has to be done by means of a special injection pump. The rock bolt has to be dried after the injection is finished.

Testing

Cement mortar

- Prior to the acceptance tests for rock bolts, tests with the available cements and sands have to be carried out so as to determine the appropriate mix design required to achieve the needed strength and proper workability for the particular grouting equipment being used.

- Additives may be used to improve workability. The influence of the additive to the development of strength has to be determined based on tests described herein.

- Cement mortar has to be tested on cubes 5x5x5 cm. The cubes have to be cured in water.

- Five cubes have to be prepared for each compressive strength test. The resultant strength represents an average obtained from the three remaining values, after the highest and the lowest value are eliminated.

- During the construction phase, cube samples have to be taken on a weekly basis. Samples are taken at the nozzle of the grouting hose and at every fifth installed rock bolt.

- Zahtevana čvrstoća na pritisak cementnog maltera:
  - after 24 hours 8 N/mm^2
  - after 28 days 20 N/mm^2
  - w/c = 0.25 – 0.30 pure cement
  - w/c = 0.50 – 0.60 mixture of cement and sand (0-5 mm)

Pull out tests on rock bolts

Pull-out tests have to be performed based on ISRM Doc.2, Part 1 "Suggested Methods for rock bolt testing ".

- Usability tests
  Prior to testing, the SUPERVISOR has to approve a detailed test programme drafted based on the above mentioned document.

  Deviations from the ISRM suggested method have to be approved by the SUPERVISOR.

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

  Information referring to each type of rock bolt has to include:
  - type of bolts, testing equipment, location and installation records,
  - applied testing loads and records of deformation,
  - the evaluation of test results as specified in ISRM's document,
  - interpretation and suggested actions for failed pull-out tests.

  Usability tests have to be carried out for all types of bolts that will be used for this project, prior to the commencement of construction of the tunnel, so as to demonstrate the impact and the service capacity of the bolts in situ.

  The tests have to be performed under geological ground conditions similar to the ones the CONTRACTOR will encounter during tunnel driving. The location of the bolts to be tested has to be selected by the SUPERVISOR.

  The tests have to be carried out on at least five bolts of each type. Depending on the testing procedure and the test results obtained, the SUPERVISOR may require further testing of the bolts.

  Adequate testing equipment, as specified in the above mentioned ISRM document, has to be provided. This equipment has to include the equipment for registering bolt elongation, movement of the bolts and tension forces.

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

- Testing during tunnel excavation
  The SUPERVISOR will select the rock bolts whose production will be tested. For each type of rock bolt, the SUPERVISOR will choose five bolts from the first 100 bolts installed in the tunnel. From the remaining bolts, five per every 200 bolts have to be selected for testing purposes. The testing force to be applied has to be at least 80% of the bolt breaking load.

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

  For each failure, the SUPERVISOR will require that further bolts be tested in the vicinity of the ones that failed the test.

  The rest is the same as for the usability tests.

Installation records

The CONTRACTOR is obligated to keep records on the details of bolt installation during driving, including that of cement mortar consistency, drilling depth, length and type of rock bolts, deviations from the theoretical position, type and time of grouting, time of tightening, special observations, etc. The CONTRACTOR is obligated to keep records for each series of bolt installation, and representatives of the SUPERVISOR are obligated to sign them. Copies of these records have to be delivered to the SUPERVISOR.

2.8.5.8 LSC - Lining stress controller

General

In order to withstand larger the deformations that occur during the excavation of the tunnel in rocks with unfavourable characteristics, the tunnel lining is divided into segments by means of longitudinal gaps. To make better use of the lining carrying capacity, yielding elements (LSC) made of soft steel are installed into the deformation gaps in a circumferential direction.

The LSC elements are used to achieve the controlled ductility of the tunnel lining. Over-stressing of the concrete lining is prevented by the limitation of normal forces developing in the lining, thus ensuring the load bearing capacity of the support.

System

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

In order to limit inward and outward buckling, the load pipe is coaxially arranged between two supporting pipes shorter than the load pipe. To allow for initial load development, special provisions have to be anticipated (weakening at the ends of the load pipe). Minimal shortening dlp to reach the design load Fp is 60 mm.

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

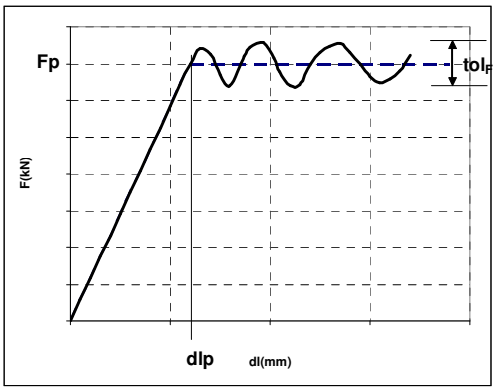


Figure 2.8.5: Cell load line for control of the stress in the lining. The dashed line represents the line of the designed load, while the full line represents the line of the actual load; Fp designed load; dlp abatement to the designed load; tolF permitted deviation of the actual load from the designed load

In order to optimise the bearing capacity of the lining, especially that of a shotcrete lining, a multi-stage system has to be used. A multi-stage system is a unit consisting of at least two LSCs with the same height (L1) and one or more shorter units (L2) which are activated due to certain deformations. In this case, the bearing capacity of the element is gradually increased.

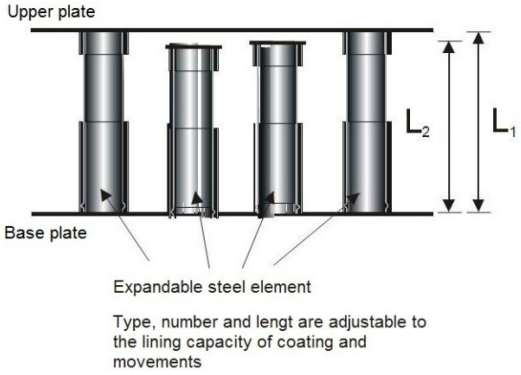


Figure 2.8.6: Group of 4 yielding elements; two elements in this group are shorter for later activation

Single elements are grouped. Different combinations of LSC types and lengths of elements are possible, to allow for optimal adjustment to the displacements and to the development of shotcrete properties.

Depending on the project requirements, the following types or combinations of LSC may be used:

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

The length of yielding elements has to be designed to meet the requirements of the project. Common lengths amount to 400 – 450 mm.

Installation

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

Special attention must be paid to the proper placement of the elements on the lining. The functionality of the lining must not be affected by the assembly, transport and installation.

Before shotcreting, the elements have to be covered by timber boards, or similar, at the

tunnel side so as to avoid the penetration of shotcrete into the LSC action zone.

The timber cover may be removed when shotcreting is finished, after making sure that the functionality of the adjacent elements will not be affected by the continuation of works.

2.8.5.9 Pipe roof (umbrella, cevni štit)

A pipe roof consisting of steel pipes is installed in the situation of low rock cover (from 2 to 3 tunnel diameters) in order to reduce subsidence and to increase excavation speed and face stability. Normally, pipe roofs are used in soil and very weak rock (decomposed or completely weathered rock).

In loose ground or soil, steel pipes may be used as “manchette" pipes for injecting of the ground between and around the pressurised pipes.

Material

- Perforated steel pipes are used with a minimum steel grade St 37-3U (acc. to DIN 2448) (ENV 1993 – S 235 J0) with a minimum outer diameter of 114 mm.
- The thickness of the rock must not be less than 6 mm.
- The steel pipes are generally installed in lengths of 15 m. The overlap has to be 4 – 5 m.
- The cement mortar has to comply with chapter 2.8.5.6. of this specification. The water to cement ratio has to be adjusted to the requirements of the surrounding rocks. The ring zone and the volume in the pipe have to be grouted from the deepest borehole area by means of a low pressure grout (max. 10 bara).
- Pipes have to be coupled with injection holes located opposite each other, placed at a minimal distance of 1m. Injection holes have to be displaced by 90 degrees.

Execution

- The pipe roof has to be installed as shown in the drawings or as instructed by the SUPERVISOR. The drilling has to be executed with an accuracy of 1%.
- Steel pipes have to be inserted into holes, starting from the face of the excavation towards the unexcavated ground. In the situation of unstable boreholes, protected steel pipes may be used while drilling.
- Spacing between the steel pipes in the crown of the excavation profile must comply with the distance specified in the drawings, but must be adjusted to the prevailing geological conditions of the tunnel face.
- After drilling, steel pipes have to be cleaned by means of compressed air, prior to low pressure grouting.

2.8.5.10 Geotechnical bar anchor

General

- This part of the specification applies to the supply and installation of prestressed bar anchors required for, and used as additional support.
- All works have to be carried out in accordance with SIA 191 (1996) standard.

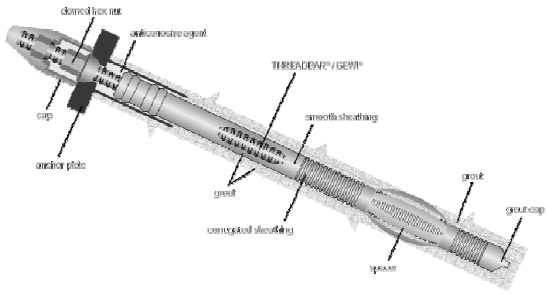


Figure 2.8.7: Bar anchors

Materials

Anchors must not contain materials that are mutually incompatible or incompatible with the surrounding environment.

Prestressed bars

- Prestressed anchors consist of prestressed steel bars in accordance with ÖNORM B 4258. The distance between the bars and plastic pipes has to be sufficient to enable faultless embedding in the cement or mortar or in the permanently plastic corrosion protection material. The bars have to be made of steel with a high tensile strength.

- The mechanical properties and technical characteristics have to comply with the following requirements:
  - steel bars St 835/1030 MPa
  - double corrosion protection

Injection mass

- The injection mass has to consist of Portland cement, water and admixtures, if required. The cement must not contain (by weight) more than 0.02% of chlorides or 0.10 % of sulphides. The admixtures must not damage the properties of the bars or the injection mass. The water to cement ratio must be kept as low as possible. It must not exceed 0.45. After 3 hours after mixing, the permitted bleeding of the injection mass must not exceed 0.5 % of the volume or not more than 1 % when measured at 20° C in a covered glass or metal cylinder 100 mm in diameter and with a injection mass t depth of approximately 100 mm.

- At prestressing, the compressive strength of the injection mass must be at least 20 N/mm².

Protective pipes

- The free length of the bars has to be encased in a smooth HDPE pipe. The HDPE pipe has to be homogeneous and free of voids. The use of recycled material is not allowed. The pipe wall has to be at least 3 mm thick.

- The bond length of the bars has to be encased in a corrugated pipe with a minimum wall thickness of 1 mm.

Anchor head

The strength of the anchor head has to be at least equal to the strength of the bars.

System requirements

Protection against corrosion

- The anchor system has to be protected against corrosion in accordance with SIA 191 (1996).

- Protection against corrosion includes all the necessary parts, such as: the anchor head, packer, free anchor length and bond length of the bar and the distant end of the anchor.

- In principle, the bond length is protected by cement suspension and one corrugated HDPE pipe. The injecting of the cement suspension is performed before or after installation of the anchor, depending on the application.

- The bond length has to be determined based on suitability tests.

System components

- The system has to be designed to provide the ultimate load carrying capacity of not less than s x P_w (P_w ..... working load). The safety factor according to SIA 191 (1996) is specified as follows:
  - failure of prestressing tendons
  - yielding of prestressing tendons
  - limited creep load
  - failure of injection mass .

- The anchor has to be designed so as to allow monitoring of the load (e. g. with hydraulic load cells or equivalent).

- The stressing of the anchors has to be designed to enable the release of the load in the situation where the work load has considerably increased due to ground movement.

Anchoring

Drilling

- The anchor length has to be such to allow for the boreholes to be drilled with standard face drilling rigs. The diameter of the boreholes for anchors has to be 80 mm, depending on the rock quality and as shown in the drawings.

- If there is the likelihood that the borehole will collapse, the sides of the borehole have to be supported by suitable casing pipe.

- Before the insertion of the anchor, the borehole has to be thoroughly washed.

- The CONTRACTOR's geologist has to keep a drilling record for each borehole, containing all the relevant data, such as: drilling method, depth of the borehole, washing device, drilling speed, type of rock being drilled, etc. Records have to be available to the SUPERVISOR at all times.

Pressure test

- Pressure tests have to be carried out in defined boreholes, only in rocks that are not sensitive to water. The first three boreholes in each typical geological cross profile have to be tested at 4 bars. Based on the data obtained from the tests, the SUPERVISOR decides whether it is necessary to continue with the water pressure tests or these tests may be omitted for the subsequent anchors at each location. Every 15th borehole has to be routinely tested.

- If the loss of water over the bond length of the anchor exceeds 5 litres per minute over a period of 5 minutes, at water pressure of 3 to 4 bars in the test section, the borehole has to be injected. Then, the borehole has to be re-drilled and re-tested under pressure.

- A full record of water pressure tests has to be kept by the CONTRACTOR and submitted to the SUPERVISOR.

Installation of the anchors

- The anchor has to be inserted as soon as possible, but no later than 12 hours from the completion of the drilling.

- Anchors have to be manipulated very carefully during installation. The anchor has to be installed by use of an injection ventilation pipe.

- The anchor has to be positioned in the centre of the borehole by use of spacers, while the bearing plate has to be positioned vertically to the borehole axis. In order to achieve vertical positioning of the bearing plate, it may be necessary to cut out pockets in the rock.

Injecting

- The injection procedure has to ensure that there are no air or water pockets left in the injected area.

- Injecting has to be performed at a slow, steady rate. Injecting has to continue until injection mass of the same composition and consistency as was mixed can be seen emerging from the outlet of the vent pipe for at least one minute.

- A record containing all the details of the injection operation for each anchor has to be submitted by the CONTRACTOR to the SUPERVISOR.

- Injecting of the free anchor length has to be done after the prestressing of the anchor.

Procedures for the testing of anchors

Anchor testing procedures have to be performed in accordance with SIA 191 (1996) standards.

Suitability tests

Suitability tests are carried out on anchors constructed under the same conditions applied to the working anchors. These tests indicate the results which may be obtained by the subsequent testing of working anchors, i.e. by conducting a routine acceptance test. Considerable and significant changes to the conditions of the working anchors e.g. geological conditions, require the suitability tests to be conducted.

Anchor acceptance test

In the course of the anchor acceptance test, each anchor has to be stressed up to the relevant test load. In cohesive soils, the creep values also have to be determined.

Testing programme:

A cyclic loading and unloading procedure has to be carried out so that the initial load is increased in each successive round for each load step, until a specified maximum load is reached. At each increase of the load, the displacement of the bars at the anchor head relative to a fixed point in the environment has to be observed, under a constant load corresponding to the set schedule.

2.8.5.11 Cable anchors

General

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

- All works have to be carried out in accordance with SIA 191 (1996) standard.

Materials

General

Anchors must not contain materials that are mutually incompatible or incompatible with the surrounding environment.

Prestressing tendons

- Prestressing tendons have to consist of prestressing steel strands (bars) in accordance with prEN 10138-3. The distance between individual wires has to be sufficient to enable faultless embedding in cement or mortar or in the permanent plastic corrosion protection material. The wires have to be made of steel with high tensile strength.

- The mechanical properties and technical characteristics have to comply with the standard prEN 10138-3, as follows:
  - seven-wire strand, tensile strength 1570/1770,
  - nominal wire diameter 15.2 and 16,0 mm.

Injecting

- Injection mass has to consist of Portland cement, water and admixtures, if required. The cement must not contain (by weight) more than 0.02% of chlorides or 0.10 % of sulphides. The admixtures must not damage the properties of the bars or the injection mass . The water to cement ratio must be kept as low as possible. It must not exceed 0.45. After 3 hours after mixing, the permitted bleeding of the injection mass must not exceed 0.5 % of the volume or not more than 1 % when measured at 20° C in a covered glass or metal cylinder 100 mm in diameter and with a injection mass depth of approximately 100 mm.

- At prestressing, the compressive strength of the injection mass must be at least 20 N/mm².

Protective pipes

- The free length of the bars has to be encased in a smooth HDPE pipe. The HDPE pipe has to be homogeneous and free of voids. The use of recycled material is not allowed. The pipe wall has to be at least 3 mm thick.

- The bond length of the bars has to be encased in a corrugated pipe with a minimum wall thickness of 1 mm

Anchor head

The strength of the anchor head has to be at least equal to the strength of the bars.

System requirements

Protection against corrosion

- The anchor system has to be protected against corrosion in accordance with SIA 191 (1996).

- Protection against corrosion includes all the necessary parts, such as: anchor, head, packer, free anchor length, bond length of the anchor and the distant end of the anchor.

- In principle, the bond length is protected by cement suspension and one corrugated HDPE pipe. The injection of the cement suspension is performed before or after the anchor installation, depending on the application.

- The bond length has to be determined based on suitability tests.

System components

- The system has to be designed to provide the ultimate load carrying capacity of not less than s x P_w (P_w ..... actual load). The safety factor according to SIA 191 (1996) is determined depending on the following:
  - failure of prestressing tendons
  - yielding of prestressing tendons
  - limited creep load
  - failure of injection mass
  - the anchor has to be designed so as to allow monitoring of the load (e. g. with hydraulic load cells or equivalent).

- Stressing of the anchor has to be designed so as to enable the release of the load in cases when the work load has significantly increased due to displacement of the terrain.

Anchoring

Drilling

- The anchor length has to be such as to allow for the boreholes to be drilled with standard face drilling rigs. The diameter of

the boreholes for anchors has to be 130 mm, depending on the rock quality and as shown in the drawings.

- If there is likelihood that the borehole will collapse, the sides of the borehole have to be supported by suitable casing pipes.

- Before the insertion of the anchor, the borehole has to be thoroughly washed.

- The contractor's geologist has to keep a drilling record for each borehole, containing all the relevant data, such as: drilling method, depth of the borehole, washing device, return of water while washing, drilling speed, type of rock being drilled, etc. Records have to be available to the SUPERVISOR at all times.

Testing under pressure

- Water pressure tests have to be carried out in defined boreholes, only in rocks that are not sensitive to water. The first three boreholes in each typical geological cross profile have to be tested at 4 bars. Based on the data obtained from the tests, the SUPERVISOR decides whether it is necessary to continue with the water pressure tests or these tests may be omitted for the subsequent anchors at each location. Every 15th borehole has to be routinely tested.

- If the loss of water over the bond length of the anchor exceeds 5 litres per minute over a period of 5 minutes, at the water pressure of 3 to 4 bars in the test section, the borehole has to be injected. Then, the borehole has to be re-drilled and re-tested under pressure.

- A full record of water pressure tests has to be kept by the CONTRACTOR and submitted to the SUPERVISOR.

Installation of the anchors

- The anchor has to be inserted as soon as possible, but not later than 12 hours from the completion of the drilling.

- The anchors have to be manipulated very carefully during installation. The anchor has to be installed by use of an injection and a ventilation pipe.

- The anchor has to be positioned in the centre of the borehole by use of spacers, while the bearing plate has to be positioned vertically to the borehole axis. In order to achieve vertical positioning of the bearing plate, it may be necessary to cut out pockets in the rock.

Injecting

- The injection procedure has to ensure that there are no air or water pockets left in the injected area.

- Injecting has to be performed at a slow, steady rate. Injecting has to continue until grout of the same composition and consistency as was mixed can be seen emerging from the outlet of the vent pipe for at least one minute.

- A record containing all the details of the injecting operation for each anchor has to be submitted by the CONTRACTOR to the SUPERVISOR.

- Injection of the free anchor length has to be done after the prestressing of the anchor.

Procedures for testing of anchors

Anchor testing procedures have to be performed in accordance with SIA 191 (1996) standards.

Suitability tests

Suitability tests are carried out on the constructed anchors under the same conditions applied to the working anchors. These tests indicate the results which may be obtained from the subsequent testing of working anchors, i.e. by conducting a routine acceptance test. Considerable and significant changes to the conditions of the working anchors e.g. geological conditions, require the suitability tests to be conducted.

Anchor acceptance test

- In the course of the anchor acceptance test, each anchor has to be stressed up to the relevant test load. In cohesive soils, the creep values also have to be determined.

- Testing programme:
  A cyclic loading and unloading procedure has to be carried out so that the initial load is increased in each successive round for each load step, until a specified maximum load is reached. At each

increase of the load, the displacement of the bars at the anchor head relative to a fixed point in the environment has to be observed, under a constant load corresponding to the set schedule.

2.8.5.12 Anchor beams

General

For the specification of concrete works and steel reinforcement see Section 2.8.8 - CONCRETE WORKS AND REINFORCEMENT.

2.8.5.13 Measuring

2.8.5.13.1 Shotcrete

- Shotcrete lining applied in tunnels, parking niches, cross passages and other niches is measured for each nominal thickness by square meter along "Line 2" (as shown on figure 2.8.2.). The length of the tunnel is measured along the central line.

- Additional shotcrete required for refilling of cavities between roof pipes is not measured for payment.

- Additional excavation works due to the widening of the profile in areas where the crown is reinforced with pipe roof is paid as a separate item. A special matrix is used for excavation and support of the calotte underneath the pipe roof. These payment conditions also apply to the support, i.e. support type, below the pipe roof. This means that calculation zones shall apply, such as "payment lines" 1a and 1b, which remain unaltered.

  It should be noted the increased quantities of support elements (shotcrete, reinforcement mesh, steel ribs, etc.) due to the changed geometry of the primary tunnel lining (with pipe roof, the inclination of the pipe is approx. 5.20, while the used length of the pipe roof is 11.0, which is actually the length of the saw tooth profile), are not taken into consideration while determining the support unit. When the pipe roof is installed, the supporting numbers are valued for a "normal" cross profile and do not include the widening of thecross profile. The quantity of support elements and excavation elements is valued and paid for as per the middle cross profile of the widening.

  The increased quantities required for the filling of the wedge below the pipe roof are not included in the matrix, since the filling of the wedge is not performed in the immediate progress area. This also applies in the situation where the CONTRACTOR fills the wedge 20 m behind the excavation face due to work reasons.

  Increased quantities, as well as the shotcrete required for the filling of the saw tooth profile below the pipe roof, are paid for separately, under the following conditions, regardless of the quantities more or less required::
  - together with the item "concrete" for the "concrete for the inner lining",
  - together with the item "shotcrete filler",
  - furthermore, a time frame has to be provided for the construction of the pipe roof (together with the injection and other works).

- The additional quantities of shotcrete required for the temporary footing are measured by meter length of the footing.

- Deformation gaps are measured by length in meters.

2.8.5.13.2 Reinforcement mesh

- The shotcrete lining applied in tunnels, parking niches, cross passages and other niches is measured by weight along "Line 2" (as shown on figure 2.8.2.). The length of the tunnel is measured along the central line. Overlap, waste material and the additional material required for temporary footings and auxiliary materials for fixing are not measured.

- The additional reinforcement required for to the widening of the cross profile under the pipe roof is not measured for payment and has to be included in the relevant unit prices.

2.8.5.13.3 Reinforcing steel bars, re-bars

Re-bars used for tunnel support are measured by weight.

2.8.5.13.4 Steel ribs

Steel ribs for tunnel support are measured by weight along "Line 2" (as shown on figure 2.8.2.). Auxiliary materials such as spacer bars between the ribs, steel plates at

connections, connecting bolts etc. are not measured for payment.

2.8.5.13.5 Supporting holders

Holder pipes or bars (dowels) are measured by piece for different lengths. Drilling is not measured separately.

Injected pipes

The unit price has to include the drilling, injeced up to a solid cement usage of 10 kg per m.

Dowels

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

Steel laggings

teel laggings are measured by weight.

2.8.5.13.6 Rock bolts

Rock bolts are measured by “piece“ for different types and lengths. Drilling, injection and the pumping in of water (Swellex) are not measured separately. Additional materials, such as anchor plates, nuts, shims and joints are not measured for the purpose of calculation.

2.8.5.13.7 LSC (Lining stress controller)

LSC (Lining Stress Controller) is measured by “piece” for the various types. Transmission plates are not measured for payment. The deformation gaps are included as a separate item in the bill of quantities and thus are measured by length.

2.8.5.13.8 Pipe roof

- Steel pipes are measured by piece. Drilling and low-pressure injection are not measured separately.

- The additional consumption of materials such as reinforcement mesh, shotcrete and waterproofing membrane, required due to the widening of the pipe roof section, is not measured and therefore these materials are calculated as a separate item.

2.8.5.13.9 Bar anchors

Bar anchors are measured by piece for various lengths, types and designed working loads. The supply and installation of materials, such as anchor plates, joints and nuts, has to be included in the unit price.

2.8.5.13.10 Cable anchors

Cable anchors are measured by piece for various lengths, types and designed working loads. The supply and installation of materials, such as anchor plates, joints and nuts, has to be included in the unit price.

2.8.5.13.11 Anchor beam

- Concrete is measured in cubic metres, in accordance with Section 2.8.8.6. Form work for the construction of concrete beams is not included in the unit price for concrete.

- Reinforcement for concrete beams is measured by weight for actual quantities (t), in accordance with the drawings.

2.8.5.14 Payment

2.8.5.14.1 General

Unit prices for different calculation items have to include the labour, equipment and materials required for the completion of works, including the securing of the working face, testing and quality control.

Payment for the installation of additional support elements at a distance of more than 50 m behind the respective excavation face is made as a separate calculation item, but not including cross passages and niches.

2.8.5.14.2 Supporting holders

Supporting holder’s pipes or bars (dowels) are measured by piece for different lengths. Drilling is not measured separately.

Injected support pipes

The unit price has to include the drilling, mass injecting up to a solid cement usage of 10 kg per m.

Dowels

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

2.8.5.14.3 Anchors

Unit prices for different calculation items have to include the labour, equipment and materials required for the completion of works, including the joining, grouting of the

free anchor length, prestressing, quality control and testing. Drilling and grouting of bond length is paid separately.

The unit price for anchors of different lengths than specified is calculated by linear interpolation or extrapolation.

The drilling for anchors is paid for as per unit price, per metre length, considering the respective total length of the borehole.

The unit price also has to cover the installation of the anchors in an inclined direction.

2.8.5.14.4 Anchor beams

The unit prices for different calculation items have to include the labour, equipment and materials required for execution of the works.

In accordance with section 2.8.8. - Shuttering and scaffolding required for the installation of anchor beams have to be included in the unit price for concrete.

2.8.5.14.5 Pipe roof

Steel pipes are measured by piece. Drilling and low-pressure injection are not measured separately.

The additional consumption of materials such as reinforcement mesh, shotcrete and waterproofing membrane, required due to the widening of the pipe roof section, is not measured and therefore these materials are calculated as a separate item.

Table 2.8.6: Suitability - usability tests for shotcrete

Test items	Properties	Testing Method	Samples	Age at Test
Young shotcrete	Early strength	Penetration needle Kaindl-Meyco	Test panels	5', 15', 30', 1h, 3h, 6h, 9h, 24h
Shotcrete	Compressive strength	Core samples	Diameter 100 mm, Height 100 mm, from each panel 5 core samples	7 d, 28 d
	Permeability	ÖNORM 23303: 2010 09 01 max. water penetration 35 mm	3 Core samples Diameter 200 mm, Height 120 mm	28 d
Cement	Specific surface, initial setting, final setting, water requirement, compressive strength 1d, 28d	Specific surface (Blaine), Vicat needle, ÖNORM 23303: 2010 09 01	2 kg	
Aggregates	Grain size distribution	ÖNORM B131: 2010 08 01 (EN 12620)	10 kg	
	Moisture content	ÖNORM B131: 2010 08 01 (EN 12620)	10 kg	
Accelerating additives	Content of alkali	Authorised laboratory	2l	

Test items	Properties	Testing Method	Samples	Age at Test
(powder or liquid)	Initial setting	Guideline on Shotcrete, chapter 2; item 1.2	800 cm^3	>45 sec <180 sec
	Early strength	Guideline on Shotcrete, chapter 2; item 1.2	Prism sample 4x4x416 cm made from cement mortal	7 d

Notes:
1) The requirements and specifications for suitability tests for shotcrete refer to the application in the tunnels and on the slopes
2) Suitability tests have to be carried out by an authorised laboratory

Table 2.8.7: Suitability - usability tests for shotcrete

Test items	Properties	Testing method	sample testing location	Age at Test	Frequency of sampling and testing	Test type
Young shotcrete	Early strength	Penetration needle Kaindl-Meyco	Shotcrete lining	5', 15', 30', 1h, 3h, 6h, 9h, 24h	1x /500m^2	A
Shotcrete cement	Compressive strength	Core samples	Diameter 100 mm, height 100 mm, shotcrete lining	7d, 28d	1x /50m^2 ili 1x /250m^2 ili min. 3 samples	B
	Permeability	ÖNORM 23303: 2010 09 01	3 Core samples Diameter 200 mm, Height 120 mm	min. 28d	1 X monthly	B
	Deformation modulus	ÖNORM 23303: 2010 09 01	Diameter 100 mm, height 200 mm	3d, 7d, 28d, 56d	1 x for each mix	B
Shotcrete without accelerator	Compressive strength, Reduction of Compressive strength	Austrian Guideline on Shotcrete, chapter 2; item 2.2		28d	1 x 2 a month	B
Cement	Specific surface, initial setting, final setting, water	Specific surface (Blaine), Vicat needle, ÖNORM B3310	5kg	Immediately after taking samples onsite	1 x 250 t	B

Test items	Properties	Testing method	sample testing location	Age at Test	Frequency of sampling and testing	Test type
	requirement, compressive strength 1 d, 28 d					
Fly ash	Specific surface	ÖNORM 23303: 2010 09 01	1kg	Immediately after taking samples onsite	1 x 2 a month	B

2.8.6 PRE-DRILLING AND GROUTING

2.8.6.1 Pre-drilling

Drilling at the tunnel face for drainage and ground investigation purposes is called "pre-drilling".

For drainage purposes, SPECIAL TECHNICAL CONDITIONS apply, unless otherwise prescribed by this section.

2.8.6.1.1 General

- In accordance with the "Geological and geotechnical report", in tunnel sections the CONTRACTOR is obligated to probe ahead of the face with a length of 20 to 30 m pre-drilling so as to prove or investigate the ground ahead, as well as to check whether gas and water sources are present. Probe testing has to be repeated and overlapped so that probe testing is always at least 10 m ahead of the tunnel face.

- The number of probe tests, their position and angles are determined based on the type of ground and the testing data available. Radial probe testing may also be necessary.

- At locations where excessive ground water flow is expected or present, pre-drilling ahead of the tunnel face is proposed so as to reduce the hydrostatic pressure at the tunnel face.

2.8.6.1.2 Documentation

- All details related to probe testing have to be determined and confirmed by the SUPERVISOR.

- If unexpected conditions appear during the excavation of the tunnel, such as underground water, the suspicious colour or smell of water, floor heave, voids or gas, careful observation and recording of the condition ahead of the tunnel face is obligatory. The SUPERVISOR has to be fully informed.

2.8.6.1.3 Execution

The CONTRACTOR shall be held responsible for the validity of the data obtained by pre-drilling, especially from the perspective of additional costs which may occur due to incorrect and inadequate data obtained by pre-drilling.

2.8.6.2 Grouting

This section should be read and applied in accordance with the applicable sections of the SPECIAL TECHNICAL CONDITIONS, unless otherwise prescribed by this section.

2.8.6.2.1 General

- “Grouting of layers“: This term refers to the pressurised injection of material into the layers of rock so as to consolidate cracked rocks or to fill the openings and cavities in the rocks surrounding the tunnel. Grouting of layers does not include injections for loose soil.

- "Consolidation grouting": This term refers to the grouting of loose material by means of bentonite, cementitious or chemical grouting.

2.8.6.2.2 Documentation

- The CONTRACTOR is obligated to prepare a detailed grouting specification, since the grouting work is diverse and there is a wide range of methods and techniques that may be used for improving the ground to match the actual conditions. The grouting specifications have to be submitted to the SUPERVISOR for approval, unless otherwise agreed with or instructed by the Supervisor.

- The CONTRACTOR is obliged to provide the SUPERVISOR with the details of the proposed grouting procedures, including the details of grouting equipment, location, depth and orientation of the grout holes, grout methods, grout composition, grouting pressures and time scaled programme for each sequence of the grouting operation. The depth and means of grouting have to be such to allow for the holes to be positioned exactly along the zones that need to be grouted.

2.8.6.2.3 Necessity of ground treatment drilling

After the consultations of the SUPERVISOR and the CONTRACTOR, the necessity for ground treatment, in addition to the ground treatment indicated in the drawings, shall be

based on soil investigations, probe testing, the amount of water at the face, or any other indications that the ground which is to be excavated is soft, fissured or heavily water laden, as well as on the data contained in the contract.

2.8.6.2.4 Grout bore holes and ground treatment drilling

Grout holes for primary and secondary grouting have to be drilled at a certain distance and according to the sequence in the area that needs to be grouted and which requires injection mass to be injected under pressure, all in accordance with the approval of the SUPERVISOR. Gauges have to be installed adjacent to the point of injection and have to be used for measuring the pressure of the grout. The design pressure of the grouting proposed by the CONTRACTOR and approved by the SUPERVISOR must not be exceeded without the previous consent of the SUPERVISOR.

2.8.6.3 Material

The grout may consist of the following:
- chemical grout,
- cement mortar grout (cement/sand),
- cement grout made of clay or bentonite.

- Ordinary Portland cement is used.

- The sand being used for grouting has to be pure, mineral sand, of uniform quality and has to originate from an approved source.

- Water has to be clean, without traces of oil, acid, base, organic or any other harmful substances.

- The use of additives for improving the performance of the grouting is permitted.

2.8.6.4 Execution

2.8.6.4.1 Testing

- Upon the request of the SUPERVISOR, the CONTRACTOR has to carry out grouting tests so as to determine whether treatment proposals are acceptable. Such testing has to be designed so as to enable the visual inspection of the treated mass, as well as to prove that the required improvements have been achieved.

- In accordance with the SUPERVISOR'S requests, water acceptance tests of grout holes have to be carried out prior to grouting, in a manner that enables the measurement of water volume under different pressures.

- After the grouting is finished, the grouted area has to be tested by a procedure agreed upon with the SUPERVISOR.

2.8.6.4.2 Drilling

- Grout holes have to be drilled either with percussion type or rotary type drilling equipment.

- The diameter of the bottom of the grouting hole must not be less than 35 mm. If drilling is performed with percussion type drilling equipment, the diameter of the drilling bit must be at least 8 mm larger than the diameter of the joints used for the drill rods.

- Unless otherwise ordered by the SUPERVISOR, only dry drilling may be performed. All drill holes have to be thoroughly cleaned immediately after drilling, by means of compressed air. After cleaning, downward holes have to be kept closed until the commencement of the grouting operation.

2.8.6.4.3 Mixing of grout

- All grout mixes have to be prepared in high speed, high shearing action mixers so as to produce a grout of uniform homogeneous consistency.

- If the mixed grout is stored prior to pumping for a short period of time, it has to be stored in an agitation tank made for that purpose.

- If clay or bentonite additives are used, special agitation tanks need to be provided for the preparation and mixing procedure.

- Water meters have to be used to accurately measure the water used for mixing. If necessary, pressure gauges, safety valves, by-pass valves, etc. have to be installed on the mixers, agitators, pumps and injection hoses.

2.8.6.5 Grouting operation

- Hoses and pipes must have small diameters so as to ensure high velocity flow without segregation.

- The grouting operation has to be performed without major interruptions.

- In the situation of an interruption before the grouting operation is finished (plant malfunction), the hole has to be washed with clean water.

- Until the condition of the ground is satisfactory, the grouting operation has to be performed with extreme caution. Safety valves have to be examined prior to each use.

- Grouting in the tunnel has to be performed in such a way that the pressure is distributed evenly and that the initial tunnel lining is not overstressed.

- In the situation where the pressure does not increase when the sand/cement mix is being used, grouting has to be stopped and the hole has to be washed out. After several hours, the grouting operation has to recommence using a sand/cement mix, until the desired pressure increase is achieved.

- If grout holes are connected, the grouting operation has to be performed simultaneously or the holes that the grout is spreading into have to be closed.

- The grouting operation is completed if the required pressure is kept constant for 10 minutes.

- The CONTRACTOR is obligated to keep records on all grouting details, such as location, inclination, diameter of holes, drilling time, equipment used, water pressure tests, quantity, grouting pressure, special events during the grouting operation, etc. This record has to be signed by the representatives of the Supervisor on site, and the record has to be submitted to the SUPERVISOR.

2.8.6.6 Quality assurance

The quality and quality control of grouting have to comply with the requirements set forth in SPECIAL TECHNICAL CONDITIONS.

2.8.6.7 Measuring

2.8.6.7.1 Pre-drilling

Drilling works are measured in metres, relative to the actual length of the drill hole.

2.8.6.7.2 Grouting

Performed works are measured in accordance with the provisions of the SPECIAL TECHNICAL CONDITIONS.

2.8.6.8 Payment

2.8.6.8.1 Pre-drilling

- Pre-drilling is paid for in accordance with the corresponding unit prices set forth in the Priced bill of quantities.

- The required equipment, materials and auxiliary works have to be included in the unit price, as well as the interference of the execution of other works.

2.8.6.8.2 Grouting

The performed works are calculated and paid for in accordance with the provisions of the SPECIAL TECHNICAL CONDITIONS.

2.8.7 WATERPROOFING AND PERMANENT DRAINAGE OF GROUND WATERS

2.8.7.1 Waterproofing and protective felt

2.8.7.1.1 General

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

Waterproofing has to enable the water tightness of all underground structures. In the situation of water penetration, remedial measures have to be prepared.

Waterproofing for executing in the open is explained in Serbian Road Construction Specifications (Technical Conditions for Road Construction in the Republic of Serbia), Chapter 2.6 Trade Works, Chapter 2.6.5 Waterproofings.

Description

- The purpose of the waterproofing membrane in underground structures is to prevent the penetration of underground water or mountain water into the tunnel, as well as to protect the final concrete lining against harmful chemical influences. Waterproofing is applied on the crown and on the side walls above the footing or on the invert arch level. The waterproofing membrane is always applied between the shotcrete support and the final concrete lining. Having in mind that the above mentioned structures are not immersed in water below a distinct underground water level, the use of a waterproofing membrane for the invert arch is not necessary.

- The waterproofing system consists of two layers: the first layer consists of a protective felt placed onto the shotcrete surface; the other layer is a waterproofing membrane fixed in a special manner as per the recommendation of the manufacturer.

- As the membrane has a sealing function, a layer of felt has to be placed so as to protect the waterproofing membrane against damage during contact with the shotcrete surface, and to prevent interlocking between the concrete and shotcrete in the case of the differential movements of shotcrete support and the final lining, as well as to provide a drainage layer which drains off underground water into the longitudinal lateral drainage pipes, thus preventing a build-up of hydrostatic pressure on the tunnel lining.

- If underground water emerges, design solutions have to be applied as foreseen by the SUPERVISOR.

Documentation that needs to be delivered

Pursuant to the terms of the contract, the following documents need to be provided:

- Compliance certificates confirming that the materials fulfil the requirements set forth in the specification.

- Manufacturer's instructions for the installation of the felt and waterproofing membrane, including the description of the preparation, fixing, welding and connecting procedures, etc.

- The manufacturer's and installer's qualifications must include evidence of the experience of the manufacturers and installers engaged in the fixing, as well as the resumes of personnel supervising the installation of the lining.

- Samples, as listed hereafter:
  - membrane: one square metre of each membrane type,
  - protective felt: one square metre of each felt type,
  - welding seam: 1 m of welded seam on the membrane for each membrane type.
  - fixings and fittings: 10 samples from different lots of rondels and nails,
  - 2 samples of sealing flanges for projections passing through the membrane.

- Workshop drawings have to be submitted for approval, showing all the necessary details for the installation of the felt and waterproofing, including the sequence of installation, position of joints, connection to waterstops, connection to waterproofing of the structures in the open cut, local reinforcements, etc.

Quality assurance

General

- The supply and installation of appropriate products specially designed and produced for application in the tunnels, under the conditions similar to the ones expected for this project, have proved to be acceptable.

Manufacturer's qualifications

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

Supervision and training

- The representative of the manufacturer has to be present onsite at least during the first 10 days of installation, and afterwards as required.

- Installation and testing has to be performed under the direct supervision of an individual who has proven (continuous work and in line with modern technologies) experience in the installation of membranes onto the tunnel lining.

- Staff engaged on the installation and testing of the lining has to undergo appropriate training before the commencement of work on the lining.

- Reports on the installation have to be approved by the SUPERVISOR, together with all relevant data referring to all inspections of seams. The above mentioned records represent a part of the documentation which needs to be delivered in order to obtain approval for the continuation of works on the inner concrete lining, also refer to section 2.8.7 in these specifications.

2.8.7.1.2 Materials

Protective felt

Protective felt is a geotextile made of continuous, non-woven poly-propylene fibres of uniform thickness and with a uniform surface structure, which fulfils the requirements set forth in the text below.

Waterproofing membrane

- Waterproofing membrane has to be made of one of the following materials, or similar materials, and has to fulfil the below mentioned requirements.

- A signal layer is placed over the membrane, i.e. a thin layer of a different colour attached on one side, intended for the detection of damage.

Property	Specified value	Standard
unit of weight	min. 500 g/m^2	DIN 53854
thickness at 0.02 bar	min. 3,9 mm	DIN 53855/3
thickness at 2.0 bar	min. 1,7 mm	DIN 53855/3
tensile strength	1000 N/50 mm	DIN 53857/2
elongation at failure	min. 70 %	DIN 53857/2
elongation at 30% of tensile strength	min. 20 %	DIN 53857/2
permeability in plane:		
at 0.02 bar	min. 5 x 10 - 1 cm/s	*
at 2.00 bar	min. 5 x 10 - 2 cm/s	*
resistance to acid and alkaline solutions, pH 2-13	strength loss max. 10 %	SN 640 550 DIN 53857/2
puncture resistance	2000 N	DIN 54307

* Test according to Franzius Institute, Hannover, BRD

ECB Waterproofing membrane (ethylene-copolymer bitumen)

Property	Specified value	Standard
thickness	min. 2,0 mm	DIN 53370
tensile strength	min. 10 N/mm^2	DIN 53455
elongation at rupture	min. 500 %	DIN 53455
tensile strength at 20% deformation	min. 2,5 N/mm^2 *	DIN 53454
Rupture strength	min. 150 N/mm	DIN 53363
resistance to hydrostatic pressure	watertight at 10 bar for 10 hours	DIN 16726
strength of welded seam	min. 7,2 N/mm^2	DIN 16726
dimensional stability during accelerated ageing	maks. +/- 2 %	DIN 16726
characteristics of materials during and after storage at 80º C:		DIN 16726
– general appearance	no bulges	
– dimensional stability, longitudinal and transversal	< - 3 %	
– change of tensile strength, longitudinal and transversal	< ± 10 %	
– change of elongation at rupture, longitudinal and transversal	< ± 10 %	
– bending at temperature of 20º C	no cracks	
– water absorption	max. 1 %	DIN 53495
– behaviour after being stored in acid and/or alkaline solutions:		DIN 16726
– change of tensile strength, longitudinal and transversal	< ± 20 %	
– change of elongation at rupture, longitudinal and transversal	< ± 20 %	
– bending at temperature of - 20º C	no cracks	
bitumen joint shearing strength	100 N / 50 mm	DIN 16726
perforation testing	no perforations after fall from height of 750 mm	DIN 50014

* cube shaped sample, side length 10 mm.

PVC Waterproofing membrane (polyvinyl chloride)

Property	Determined value	Standard
thickness	min. 2,0 mm	DIN 16726
tensile strength	min. 12 N/mm^2	DIN 16726
elongation at rupture	min. 250 %	DIN 16726
compressive strength at 20% of deformation	min. 2,5 N/mm^2 *	DIN 53454
rupture strength	min. 100 N/mm	DIN 53363
resistance to hydrostatic pressure	watertight at 10 bar for 10 hours	DIN 16726
tensile strength of the welded seam welding factor (90% of tensile strength)	min. 10,8 N/mm^2	DIN 16726
dimensional stability after accelerated ageing	max. +/- 2 %	DIN 16726
characteristics of materials during and after storage at 80º C:		DIN 16726
– general appearance	no bulges	
– dimensional stability, longitudinal and transversal	< - 3 %	
– change of tensile strength, longitudinal and transversal	< ± 20 %	
– change of elongation at rupture, longitudinal and transversal	< ± 20 %	
– bending at temperature of 20º C	nema pukotina	
– water absorption	1 % max	DIN 53495
– behaviour after being stored in acid and/or alkaline solutions:		DIN 16726
– change of tensile strength, longitudinal and transversal	< ± 20 %	
– change of elongation at rupture, longitudinal and transversal	< ± 20 %	
– bending at temperature of - 20º C	no bulges	
bituminous joint shearing strength	100 N / 50 mm	DIN 16726
perforation testing	no perforations after fall from height of 750 mm	DIN 50014
behaviour in case of fire	B 1	ÖNORM B 3800/1

* cube shaped sample, edge length 10 mm.

Auxiliary materials

Fixing materials, reinforcement for expansion joints, sealing flanges are produced and corners and intersections are prepared in accordance with the instructions obtained from the manufacturer of the membrane.

2.8.7.1.3 Execution

Preparation of the surface

- Surfaces to be fitted with waterproofing have to be cleaned, smooth and free of all waste materials.

- Prior to waterproofing, the following treatment of surfaces has to be performed:
  - For the fixing of the protective felt and the waterproofing membrane, a minimum layer of 3 - 5 cm of shotcrete has to be applied onto the rock.
  - Irregularities of the shotcrete lining surface have to be eliminated by means of an additional shotcrete layer. The ratio of the diameter to the depth of the irregularity must not be less than 5:1 (see figure 2.8.8.). The minimum radius of rounding at rock bolts has to be 0.3 m.
  - Transitions and intersections of tunnel profiles have to be rounded with a minimum radius of 50 cm.
  - Protruding steel bars, wires, spacers, pipes, etc. have to be cut off, unless covered by an additional layer of shotcrete.
  - Exposed steel parts, such as rock bolts have to be covered with shotcrete unless it is required that they remain available.
  - All shotcrete surfaces have to finally be smoothed with fine-grade shotcrete backing (rounded aggregates, grain size 0 - 8 mm), applied in a 3 to 5 cm thick layer.

Installation

Prior to the application of waterproofing, all surfaces that need to be waterproofed have to be inspected and approved by the SUPERVISOR.

The application has to be performed in accordance with the written instructions of the manufacturer. Essentially, the procedure is as follows:

- Preparation
  Special preparations are required for the application of waterproofing at the transitions and intersections of the tunnel face, as well as for projections passing through the membrane. These preparations have to be carried out in accordance with the manufacturer's recommendations.

- Fixing of felt
  ZProtective felt has to be attached to the shotcrete surface using suitable fixings specified by the manufacturer. Depending on the location, from 2 to 4 fixing elements have to be used per square metre. Felt has to be loosely fixed so as to avoid overstressing during casting. Adjacent sections of felt need to overlap by approximately 10 cm and be joined by point welding or a similarly adequate procedure. Along the bottom of the tunnel side walls, the felt has to be long enough to cover the lateral drainage channels, as shown in the drawings.

- Placing of the waterproofing membrane
  The waterproofing membrane has to be placed so that it covers the felt. The waterproofing membrane has to be attached to the membrane fixings by means of thermal welding. For installation purposes, punctures of the membrane are not permitted. The waterproofing membrane must by covered with a signal layer towards the inside, loosely enough to avoid overstressing during casting. The adjacent waterproofing sheets have to be joined by double weld. Along the bottom of the tunnel side walls, the felt has to be long enough to cover the lateral drainage channels, as shown in the drawings. Connection of the waterproofing membranes in a tunnel with open cuts has to be performed by means of a water barrage, in accordance with the drawings provided by the supplier.

Protective measures

Special attention needs to be paid to ensure that the waterproofing membrane is not damaged during and after installation. All damage that occurs need to be repaired and examined before the final concrete lining is applied.

2.8.7.1.4 Quality control of execution

Testing of seams

All seams have to be tested, while the CONTRACTOR is obligated to keep a record on the testing performed and to deliver the records to the SUPERVISOR.

Testing of seams using compressed air

The tightness of the seams between the adjacent sheets of waterproofing membrane must be tested. This test has to be performed by pumping compressed air into the test channel created from a double welded joint. The initial pressure test has to be 2 bars during a trial period of 5 minutes or 1.5 bars during a trial period of 10 minutes. Seams are deemed waterproof if the loss of air pressure does not exceed 20 % in both cases.

Testing of seams using vacuum equipment

Vacuum equipment may be used for the testing of a membrane area of a limited size, such as special configurations of joints or local repairs with patches. Such equipment consists of a vacuum bell which is emptied by pumping after being firmly placed above the testing area so as to detect cavities in the membrane.

2.8.7.2 Permanent drainage of underground water

This section refers to installation and maintenance of the system for the permanent drainage of underground water from the tunnels. If underground water appears during the construction phase below the designed level of the longitudinal underwater drainage system, a permanent underground drainage system has to be designed.

2.8.7.2.1 General

- This section covers the requirements that refer to the permanent underground water drainage system in the tunnel, which consists of perforated pipes in the shape of a tunnel or circle, placed on both sides above the abutments, revision niches, inspection shaft underneath the carriageway, connection pipes between revision niches and inspection shafts and the main drainage pipe in the tunnel.

- Revision niches and inspection shafts have to be placed at the designed spacing along the main drainage pipe of the tunnel.

- Two separate drainage systems have to be constructed in the tunnel, one for the drainage of underground water and the other for waste water (coming from the carriageway).

- This section does not cover the provisions referring to the system for the drainage of the road surface and the system for water treatment outside the tunnel. The road drainage system inside the tunnel consists of slotted prefabricated kerb stones. Reinforced-concrete kerbs are placed into the cement mortar and are sealed with elastic silicon mastic.

2.8.7.2.2 Materials

- The longitudinal drainage of underground water consists of PE-HD double-layered ribbed pipes, as shown in the drawings. The overall area of the slots for water intake has to be bigger than 200 cm^2 per metre length of the pipe, depending on the hydrological conditions of the rock mass.

- The porous concrete has to consist of ordinary Portland cement and natural aggregate with a grain size of 32 mm. The ratio of aggregate to cement has to be 8:1 by volume or 10:1 by mass.

- Cross connections have to consist of PE-HD double-layered, ribbed, non-perforated pipes with a minimum inner diameter of 200 mm.

- The main drainage channel in the tunnel has to be made of concrete pipes (C 30/35), in accordance with the drawings.

- The kerbs for drainage of the road have to be made of prefabricated concrete (C 35/45), made in steel formwork, reinforced and water tight. The joints between the kerbs are sealed with elastic silicon mastic.

2.8.7.2.3 Execution

- The water that appears and/or is collected behind the waterproofing membrane has to be permanently diverted by means of longitudinal drainage pipes placed on both side walls of the tunnel.

- The longitudinal drainage pipes for the drainage of underground water have to be covered and protected by porous concrete placed between the revision shafts inside the tunnel.

- Revision niches are made on the inner concrete lining to enable permanent maintenance (washing) of the drainage system, as shown in the drawings.

- The CONTRACTOR shall be obligated to ensure that the system for the permanent drainage of underground water is used only for the purpose of controlling of the underground water. During the construction and maintenance period, regular inspections and maintenance of this system is required.

- Drainage pipes used for the control of underground water have to be placed in accordance with the levels and inclinations shown in the drawing.

- Porous concrete has to be mixed using a machine or manually until a uniform colour and consistency is achieved prior to application. The quantity of water used must not exceed the quantity required for the coating of all aggregate particles, without forming an excessive mass.

- Porous concrete may only be compacted manually.

2.8.7.3 Measuring

2.8.7.3.1 Waterproofing membrane

- The waterproofing membrane being used in the traffic tunnels, for parking niches and pedestrian lanes is measured by square metres along "line 2" (as shown on the Figure 2.8.2.). The length of the tunnel is measured along the central line.

- Necessary enlargements of tunnel cross-sections for smaller niches (emergency call niches, niches for electrical facilities, fire fighting niches, revision niches, space under the pipe roof, etc.) are not measured for the waterproofing membrane.

- U Application of a waterproofing membrane inside the water distribution niche is not measured for the calculation, so it needs to be included in the relevant unit price.

2.8.7.3.2 The longitudinal drainage of underground waters

- Work on the laying of longitudinal drainage pipes and cross-connection pipes leading to revision shafts are measured per linear meter of each drainage pipe laid. The protection of the longitudinal drainage pipes with porous concrete is not measured separately.

- The construction of revision shafts for the collective drainage is measured separately.

- The main system for the drainage of mountain water and water from the carriageway is measured in metres (m^1).

2.8.7.4 Payment

2.8.7.4.1 Waterproofing membrane

The unit price of the waterproofing membrane has to include the labour, equipment and materials required for the execution of works, quality control and testing.

2.8.7.4.2 The longitudinal drainage of underground waters

The unit price of the longitudinal underground water drainage system has to include the labour, equipment and materials required for the completion of works.

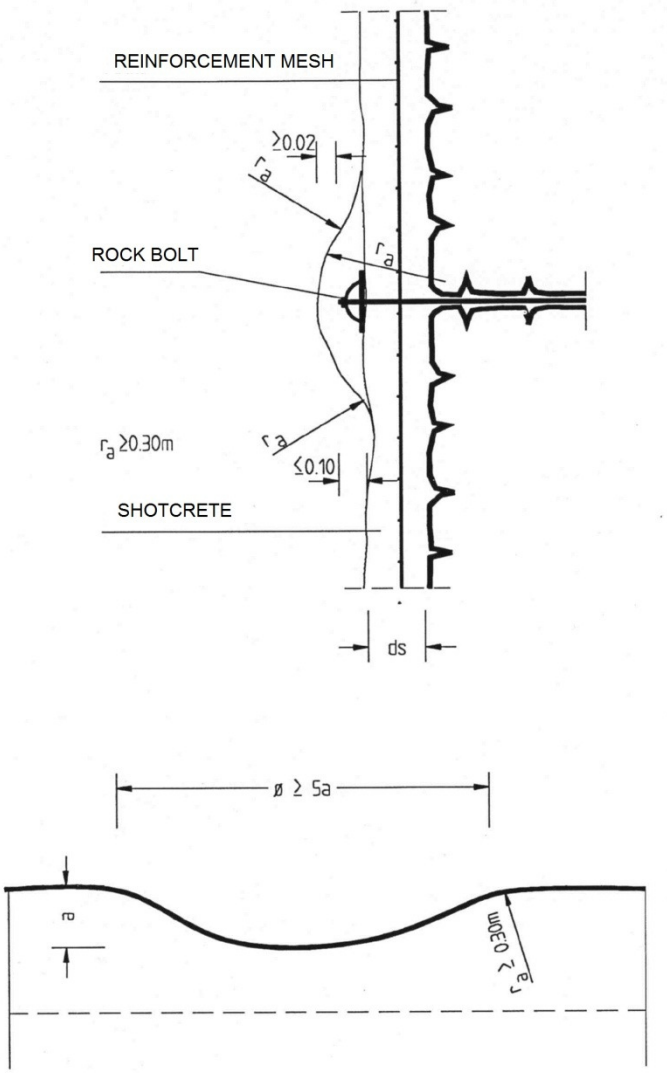


Figure 2.8.8: Requirements for elimination of shotcrete surface irregularities

2.8.8 CASTING AND REINFORCEMENT

2.8.8.1 General

This section contains specifications for the construction of the final tunnel lining, the foundation beams, the concrete invert arch and prefabricated concrete components, as well as for the concrete work on the cut-and-cover tunnel sections, for the concrete arch and support structures. The constructions of the excavated tunnel are predominantly not reinforced, but they may also be reinforced locally, as designed and approved by the SUPERVISOR, while cut-and-cover sections, the concrete arch and supporting structures are generally reinforced.

2.8.8.1.1 Description

- Section SPECIAL TECHNICAL CONDITIONS, unless otherwise prescribed in this section.

- The final tunnel lining, a concrete lining installed onsite, increases the overall safety factor of the tunnel lining system, provides a uniform interior surface and improves the water tightness of the tunnel lining. A smooth internal surface is required to facilitate airflow, for aesthetic reasons and for maintenance and lighting reasons.

- The foundation beams form the abutments for the final tunnel lining. Cable ducts are mainly placed on longitudinal concrete beams.

- The invert arch forms the rounded end of the tunnel lining (tunnel pipe) where poor geological conditions prevail.

- The formwork for the foundation beams, invert arch and roof arch are necessary tools for the construction of the final tunnel lining. The formwork has to be designed and made of steel in such a manner that the shape, dimensions and surface finish of the concrete are achieved, as specified.

- Prefabricated concrete elements form the lateral boundaries of the road surface (kerbs) and are also used in the construction of cable duct slabs.

- Contact injecting represents the injection of material under pressure so as to fill the voids between the in-situ concrete lining and the shotcrete or the membrane lining (waterproofing membrane). The contact injecting has to be carried out systematically in the roof section of the tunnel after the concrete lining hardens. Provisions for the fixing of the pipes for contact grouting have to be anticipated in the roof arch formwork. The position of the injection holes has to be approved by the SUPERVISOR.

- The coating of the concrete surface of the inner lining is required so as to protect the concrete and allow for easier cleaning.

- A reinforced concrete arch built in-situ forms the roof of the mixed tunnel/cut-and-cover method. The concrete arch transfers the forces created by the backfill, into the lateral load bearing rock mass. After the concrete arch is protected, the tunnel may be constructed using the conventional methods.

2.8.8.1.2 Documentation that needs to be delivered

- Working drawings have to be submitted which depict the camber of formwork required as compensation for the deflection caused by the application of concrete.

- The CONTRACTOR is obliged to provide the SUPERVISOR with detailed workshop drawings of the formwork.

- The CONTRACTOR shall be obligated to submit for the approval of the SUPERVISOR the following: separate workshop drawings for the formwork of the tunnel cross profile, pedestrian cross passage, niches, concrete arch and cut-and-cover.

- Reports on the testing of concrete which is to be used have to be delivered in accordance with the section of the SPECIAL TECHNICAL CONDITIONS.

- The CONTRACTOR shall be obligated to provide the SUPERVISOR with a list of references of the manufacturers prior to the production of the prefabricated concrete elements.

- The CONTRACTOR is obliged to provide the SUPERVISOR with the methodology,

as well as the description of facilities and materials for contact injecting, prior to the commencement of works on the inner concrete lining.

- The CONTRACTOR is obliged to provide the SUPERVISOR with the test results and the samples of the material for the coating of the concrete surfaces.

2.8.8.1.3 Conditions for the execution of works

- The inner concrete lining in the tunnel must not be applied 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 ordered by the SUPERVISOR.

- The inner concrete lining must not be placed before the SUPERVISOR accepts and consents to the re-profiling results.

- The inner concrete lining in the tunnel must not be placed until the installed waterproofing system has been accepted by the SUPERVISOR.

- The installation of the prefabricated concrete components cannot commence prior to obtaining consent from the SUPERVISOR.

- The concrete surface cannot be coated until the SUPERVISOR approves the surface of the inner concrete lining.

2.8.8.2 Material

Materials have to comply with the requirements set forth in SPECIAL TECHNICAL CONDITIONS, unless otherwise prescribed in this section.

2.8.8.2.1 Formwork

- Refer to - section SPECIAL TECHNICAL CONDITIONS.

- The shape of the concrete arch has to be modelled with a steel formwork or the excavated material has to be used to create an earth form for the concrete arch.

- The formwork has to be rigid enough to maintain the forms in the correct positions, shape and profile, so that the final concrete construction is within the limit of tolerances.

- The formwork for the tunnel lining has to be made of steel and has to be adequate for subsequent re-use.

- The formwork for the tunnel lining has to have openings along each side wall and at the crown. The openings have to be designed in such a way to permit the use of vibrators for the compacting of concrete, to permit the inspection of concrete during placement and the inspection of the hardened concrete surface, prior to discharge or removal of the formwork. The size of the opening has to be at least 600 square mm. Openings intended for the pouring of concrete have to be provisioned at such heights that prevent the segregation of the concrete. Joints in the forms have to be sufficiently tight to prevent the leakage of grout and water from the concrete.

- The forms have to be kept in good condition so that the accuracy of shape, strength, rigidity, water tightness and smoothness of the surface are guaranteed at all times. The forms have to be clean, corrosion-free and in good condition.

- The upper sector of the lining formwork has to be provisioned with elements for the mounting of external vibrators at regular intervals, so as to provide uniform compaction of the arched soffit.

- The steel form must be equipped with suitable elements which allow for the construction of the groove on the outside rim of the secondary lining segment. This results in a uniform appearance of the secondary lining and of the area where the tunnel is on a curve.

2.8.8.2.2 Concrete

- Section SPECIAL TECHNICAL CONDITIONS, unless otherwise prescribed in this section.

- The concrete grade for the tunnel lining, foundation, invert arch, concrete arch and cut-and-cover works has to be C 25/30.

- The maximum aggregate size has to comply with those set forth in SPECIAL TECHNICAL CONDITIONS.

- The strength of the mixture has to be such to allow the placement of the concrete by pumping.

- Plasticizers may be used in the concrete mix to improve flow and compaction. Detailed data regarding such additives have to be delivered to the SUPERVISOR for approval prior to their application.

2.8.8.2.3 Prefabricated concrete components

- Section SPECIAL TECHNICAL CONDITIONS, unless otherwise prescribed in this section.

- The concrete grade for prefabricated concrete components has to be C 35/45 (C 30/37).

- Prefabricated concrete elements have to be produced with a dimension tolerance of ± 2 mm.

2.8.8.2.4 Injection mass for contact injecting

- Grout has to be based on a mixture of cementitious materials and water, but may also contain additives to improve the performance, subject to the approval of the SUPERVISOR. All water sources to be used for the production of cement have to be approved by the SUPERVISOR. If at any time during construction, the water from an approved source becomes unsatisfactory, the CONTRACTOR is obliged to provide water of satisfactory quality from other sources.

- Cement has to comply with current standards. The grout has to be a uniform mixture of adequate fluid consistency to ensure that the pressurised grout can flow into all sections of cavities.

- The grout mix has to have low or no bleedability and low shrinkage properties. The grout mix has to have the lowest possible permeability after it sets.

2.8.8.2.5 Reinforcement

For the inner concrete lining, steel reinforcement is necessary in heavily stressed areas, such as cut-and-cover tunnel sections, sections under houses and shallow cover, portal areas, niches, junctions of tunnels and pedestrian cross passages, depending on the local ground conditions and as shown in the design drawings. Furthermore, the inner concrete lining may be reinforced in areas of heavy installations inside the tunnel, for example where ventilation fans are fixed.

Reinforcement is required for the concrete arch, as well as for the prefabricated concrete elements.

Materials for reinforcement mesh

- Reinforcement mesh has to comply with the provisions set forth in SPECIAL TECHNICAL CONDITIONS, unless otherwise prescribed in this section.

- Reinforcement mesh has to be made of MA 500/560 quality steel.

Materials for re-bars

- Re-bars have to comply with the provisions set forth in SPECIAL TECHNICAL CONDITIONS, unless otherwise prescribed in this section.

- Re-bars have to be made of RA 400/500 quality steel; B 500 A.

2.8.8.2.6 Coating

- The quality of the coating material has to comply with the valid provisions of the Austrian provision RVS 8.29.4.

- Testing has to be performed by an authorised institute.

- Material consists of a mixture of two components based on epoxy resin.

- The adhesion value being tested by cutting a grid of 5 mm x 5 mm (in accordance with RSV 8.29.4) has to be at least 85 %.

2.8.8.3 Casting

Castinghas to be performed in accordance with the provisions set forth in SPECIAL TECHNICAL CONDITIONS, unless otherwise prescribed in this section.

2.8.8.3.1 Preparation of formwork prior to concrete works

- SPECIAL TECHNICAL CONDITIONS, unless otherwise prescribed in this section.

- The internal surface of the formwork has to be coated with approved oil that does

not leave stains, in order to prevent the adhesion of concrete.

- Release agents have to be applied strictly in accordance with the manufacturer's instructions and must not come in contact with the reinforcement.

- The composition of the release agent has to be such that it does not interfere with future surface treatments.

- All surfaces have to be thoroughly cleaned prior to casting. The formwork surfaces that come in contact with the concrete have to be clean, free of foreign particles, nails and the like, and free of cracks and other defects.

- The formwork has to be erected and anchored in such a way that it retains its shape and position during casting, thus avoiding the occurrence of surface irregularities in the concrete.

- The formwork has to be erected to such levels as to make allowances for the anticipated deflection of the formwork under load.

- In cases when an earth form is being used for the concrete arch, the earth form has to be covered with a separation membrane prior to placement of the reinforcement, in order to avoid bonding between the earth and concrete.

2.8.8.3.2 Preparation for concrete placement

Before the concrete lining is installed in the tunnel, the CONTRACTOR has to thoroughly clean the invert arch, the sides and the roof of the excavation made of loose material or unsound fragments of rock, mud, debris, standing water, oil or any other foreign matter.

2.8.8.3.3 Placement of concrete

- Section SPECIAL TECHNICAL CONDITIONS, unless otherwise prescribed in this section.

- The CONTRACTOR is obligated to provide the details regarding the proposed method of concrete placement in the tunnel, including the description of the equipment to be used.

- The mode of transport and mode of concrete placement have to be approved by the SUPERVISOR. The concrete is to be transported and placed in a manner that prevents the occurrence of contamination, segregation or loss of constituent materials.

- Unless approved by the SUPERVISOR, the concrete cannot be placed into a single segment of the construction.

- The concrete is placed by means of a displacement pump or a similar procedure, in accordance with the approval of the SUPERVISOR. The method of concrete placement has to be such that the concrete is not introduced into the formwork at a high velocity and it has to prevent the occurrence of the segregation of the concrete. The concrete pump has to produce a continuous stream of concrete without air pockets.

- Casting of the foundation beams and the invert arch construction has to be performed in separate phases, prior to the placing of the inner lining arch of the tunnel. The method used for the placement of concrete onto the invert arch has to be approved by the SUPERVISOR.

- The concrete foundations on each side have to be used as abutments for the rails necessary for moving the tunnel formwork. The concrete foundations have to be placed at least 7 days before the formwork for the inner lining arch is placed.

- The concrete has to be pumped into the formwork through suitable openings.

- The concrete in the walls and the crown of the tunnel has to be applied in horizontal layers not exceeding 50 cm, evenly distributed over the casted section.

- The differences in maximum level must not exceed the values specified by the manufacturer of the formwork.

- Pumping in of concrete through the crown of the arch is not allowed, nor is its flow down into the walls and invert arches. Therefore, pumping concrete into the crown before the concrete level has reached the height of the opening in the formwork is not permitted. The concrete has to be forced into all irregularities in the rock or initial support surface by means of submersive vibrators, so as to

fill the void between that surface and the formwork.

- Particular care has to be taken to ensure the complete filling of the crown of the tunnel arch. Besides the details which refer to the method of concrete placement, the CONTRACTOR is obligated to include his proposals for fulfilling this requirement. Where necessary, air pockets in the tunnel roof have to be relieved by means of ventilation hoses placed behind the relevant temporary formwork.

- Cold joints in final lining have to be avoided where practicable. A standby concrete pump has to be available during casting placement. In the event of continuous placement being interrupted by equipment malfunction occurring for any reason, the CONTRACTOR has to consolidate the concrete at joints to a reasonably uniform and stable slope while the concrete is still plastic. Any concrete which remains unconsolidated has to be removed.

- The final lining for tunnels has to be cast in sections of a maximum of 12 metres in length, measured along the tunnel axis. Each section has to be cast in one continuous operation without interruptions and without cold joints. All cold joints at the ends of the sections have to be perpendicular to the gradient.

- For concrete works during warm and cold weather, refer to SPECIAL TECHNICAL CONDITIONS.

2.8.8.3.4 Compaction of concrete for final lining

- All concrete has to be compacted to produce a dense homogeneous mass.

- Concrete may be compacted by vibrators anchored to the formwork and by immersion vibrators operated through an inspection opening in the formwork.

- Concrete may be compacted by vibrators anchored to the formwork and by immersion vibrators operated through an inspection opening in the formwork.

- External vibrators must operate only for short periods of time so as to prevent segregation.

- The concrete must not be subjected to vibrations for 4 hours after casting.

2.8.8.3.5 Removal of formwork

- Section SPECIAL TECHNICAL CONDITIONS, unless otherwise prescribed in this section.

- The SUPERVISOR has to be informed in advance regarding the date the CONTRACTOR intends to remove the formwork.

- The CONTRACTOR shall be responsible for the time in which the formwork is removed.

- The formwork has to be designed in such a way to enable its easy removal, without resorting to hammering or levelling against the surface of the concrete, and without damaging the concrete.

- The CONTRACTOR is obligated to remedy any damage that has occurred during the removal of the formwork.

- The removal of the formwork must not commence until the concrete attains sufficient strength to withstand the most unfavourable load conditions which could cause damage to the construction. The strength of the concrete has to be measured after the removal of the stop-end shutter in the tunnel roof. The minimum strength required for the removal of formwork must satisfy the structural requirements for "dead load" of the lining. This strength has to be checked by a Schmidt pendulum-type hammer, or similar, while for low strength concrete, a piston of 40 mm diameter has to be used.

  The following equipment or similar has to be used:
  Manufacturer: Wykeham Farrance, Slough, England Model no.: WF 53932.

2.8.8.3.6 Curing of concrete

- Sections of the SPECIAL TECHNICAL CONDITIONS, unless otherwise prescribed in this section.

- Immediately after placement, the concrete has to be protected from the harmful impacts of the weather, including rain, rapid temperature changes, frost and drying out over the duration of at least 7 days. The methods applied have to be confirmed by the SUPERVISOR.

- The method which is applied for the curing of the concrete has to reduce the loss of moisture from the concrete.

- The sealing agent must not interfere with the bonding of any subsequent surface treatment.

- Curing may be omitted if measurements show that the curing process is no longer affecting the moisture and shrinkage of the concrete.

- The CONTRACTOR is responsible for avoiding or minimising the occurrence of cracks due to shrinking and thus has to execute the works very carefully and to apply the methods and techniques as prescribed. In reinforced concrete linings, the of shrinkage cavities is limited to 0.3 mm. Wide cracks have to be filled with resin or mortar. Shrinkage cracks in non-reinforced lining, whose width exceeds 1.0 mm have to be filled with mortar or resin, or processed in accordance with the instructions obtained from the SUPERVISOR.

2.8.8.3.7 Remedial treatment of surfaces

- Any remedial treatments of surfaces have to be agreed upon with the SUPERVISOR, and executed without any delay after the inspection of the surfaces, subsequent to the removal of the formwork.

- Any concrete whose surface has been treated prior to the inspection performed by the SUPERVISOR is subject to rejection.

2.8.8.3.8 Prefabricated concrete elements

- Prefabricated concrete elements have to be placed with the permissible deviation of ± 10mm relative to the theoretical position.

- Prefabricated concrete elements are placed in at least 30 mm thick mortar.

- The standard length of prefabricated concrete elements has to be 100 cm (for example, cable duct slabs, kerb stones)

- The reinforcement for the prefabricated concrete elements used for the cable duct slabs has to amount to at least 5 kg/m.

- The joints between the prefabricated concrete elements have to be sealed (by means of a permanently elastic material).

2.8.8.3.9 Contact injecting

- Prior to the commencement of the inner lining works, the CONTRACTOR has to provide the SUPERVISOR with the details concerning the work methodology and the equipment to be used.

- The CONTRACTOR has to make sure that the injection procedure is performed under the direct supervision of qualified and experienced individuals. The maximum pressure being applied has to be approved by the SUPERVISOR.

- Injecting and ventilation pipes have to be placed before the commencement of casting.

- After injecting is finished, the CONTRACTOR has to cut off the surplus lengths of the pipes.

- The CONTRACTOR is obligated to provide the SUPERVISOR with the records referring to the areas being injected, injection pressures, consumption of grout and details about the mix, as potentially required by the SUPERVISOR.

- The SUPERVISOR may require tests to be carried out to confirm that the injection mix and its constituent materials are in accordance with the specifications. The CONTRACTOR is obligated to carry out these tests and to deliver them to the SUPERVISOR for approval, when requested.

- If pre-prepared dry injection mass produced by an accepted manufacturer is being used, this mix has to be made with water/solids ratios recommended by the manufacturer. All injection mixes have to be prepared using high speed mixers.

- The CONTRACTOR may propose a casting method which excludes the contact inecting of the tunnel lining.

2.8.8.3.10 Application of the protective coating

- Coating works have to be performed in accordance with the provisions set forth in Austrian directive RVS 8.29.4, unless otherwise prescribed in this section.

- Before the commencement of works on the coating, the concrete surface has to be smoothed and cleaned.

- Cracks occurring due to shrinking have to be filled with synthetically modified mortar.

- The concrete surface has to be coated with two layers. The first layer may be sprayed, while the other has to be roll-coated.

- Contamination caused by coating works has to be dealt with.

2.8.8.4 Reinforcing

2.8.8.4.1 Reinforcement mesh

- Reinforcement mesh has to be installed in the longest practical length. Reinforcement meshes have to overlap by at least twice the pitch distance in circumferential, and one pitch distance in longitudinal direction.

- The installation of the reinforcement has to be such to ensure a concrete cover of a minimum 4.0 cm.

- The CONTRACTOR has to take particular care not to damage the waterproofing membrane during the installation of the reinforcement.

2.8.8.4.2 Reinforcing steel bars

Reinforcing steel bars have to be attached to the previously installed reinforcement mesh. Overlapping has to be performed in accordance with the relevant drawings.

2.8.8.5 Quality assurance

- The quality and quality control of the casting have to comply with the requirements set forth in SPECIAL TECHNICAL CONDITIONS.

- The quality and quality control of the lining have to comply with the requirements set forth in SPECIAL TECHNICAL CONDITIONS.

- The quality and quality control of the reinforcement have to comply with the requirements set forth in SPECIAL TECHNICAL CONDITIONS.

- The quality and quality control of the prefabricated concrete components have to comply with the requirements set forth in SPECIAL TECHNICAL CONDITIONS.

- The quality and quality control of the coating material and works have to comply with the provisions of the Austrian directive RVS 8.29.4.

2.8.8.6 Measuring

Works listed in this section are measured as follows:

- The inner concrete lining in the tunnel is measured in cubic metres, including the theoretical thickness of the inner lining (d_i) inside "Line 3", as shown on figure 2.8.9. The quantities for the inner concrete lining outside of "Line 4" are not measured, except for the filling of the excessive overbreak due to unfavourable geological conditions.

- In cases when the average value of the actual deformation in a specific section is smaller than the agreed deformation tolerance, the measurement for the additional inner concrete is done in cubic metres, provided that the difference "c" is bigger than 10 cm. The quantity of additional concrete has to be calculated between "Line 3" and "Line 4". The actual average deformations have to be derived from geological measurements.

- Filling of an excessive overbreak with inner concrete has to be measured in-situ as per the actual quantities, provided that the requested quantity of concrete does not exceed 2 cubic metres (in accordance with figure2.8.9).

- The inner concrete lining in a niche is measured in cubic metres, as shown in figure 2.811.

- The inner concrete lining for the invert arch and the foundation beams is measured in cubic metres inside "Line 2", according to figure 2.8.11.

- Additional quantities of concrete for the concrete lining, if used for widening of the cross-section under the pipe roof, are not measured for payment.

- Reinforcement mesh and re-bars installed in the concrete lining of tunnels, pedestrian cross passages, niches, cut&cover tunnels and in supporting structures are measured by weight, in accordance with the actual quantities.

Auxiliary fixing materials are not measured for payment purposes.

- Interruptions due to the installation of the protection of the waterproofing membrane during the installation of the reinforcement are not measured separately and thus have to be included in the relevant unit prices.

- The curing of concrete (for example, refilling of cracks) is not measured for payment purposes, and thus has to be included in the relevant unit price.

- Prefabricated concrete components are measured in metres of length.

- The preparation and coating of the concrete surface is measured in square metres along the inner surface of the lining. Cleaning of the surface has to be included in the unit price.

2.8.8.7 Payment

- Unit prices for different calculation items have to include the labour, equipment and materials required for completion of works, including sampling, testing and quality control. Formwork and scaffolding have to be included in the unit prices of the relevant calculation items.

- Should aggressive components appear in the leachate during the excavation of the tunnel, the inner concrete lining at these sections has to be made of concrete which is resistant to sulphates. Labour, equipment and materials have to be included in an additional payment for sulphate-resistant concrete.

- The unit price for prefabricated elements has to include the labour, equipment and materials required for the completion of works, including the reinforcement, sealing of joints and the transport to the construction site.

- The unit price of coating has to include the labour, equipment and materials required for the completion of works.

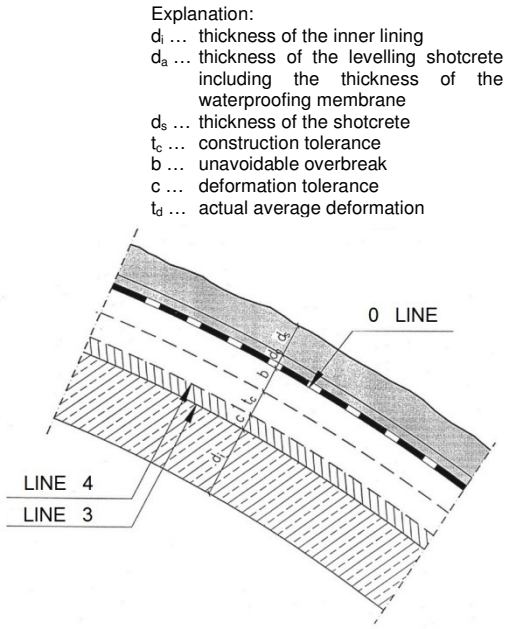


Figure 2.8.9: Lines for measuring and calculating the inner concrete lining

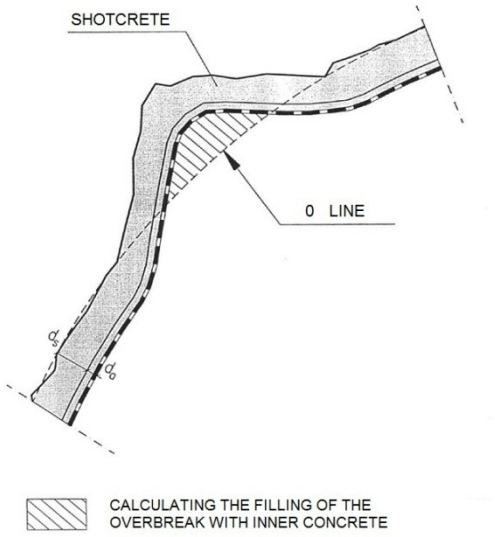


Figure 2.8.10: Lines for measuring and calculating the filling of the overbreak with inner concrete lining

Explanation:
d_i … thickness of the inner lining
d_a … thickness of the levelling shotcrete including the thickness of the waterproofing membrane
d_s … thickness of the shotcrete
t_d … deformation tolerance

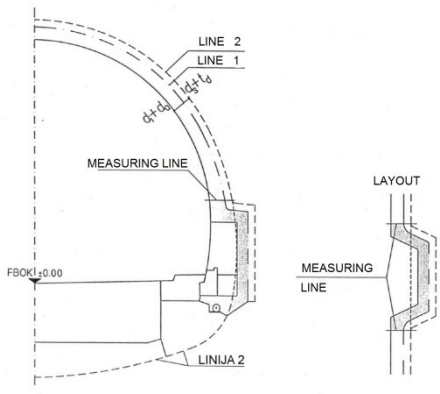


Figure 2.8.11: Lines for the measuring of concrete in the niches

2.8.9 EARTHING IN THE TUNNEL

2.8.9.1 General

- This section specifies the materials and fittings of main earthing steel flat bars which are to be installed 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.

- For details on the laying and connection of the earthing bars, refer to the relevant drawings.

- This section does not refer to the earthing systems in the portal area or the distribution facilities which are covered in the Electrical specification.

- The CONTRACTOR is responsible for the connecting of the earthing system in the tunnel, as well as for the testing and functioning of the earthing facilities. The CONTRACTOR is obligated to deliver a comprehensive testing programme to the SUPERVISOR, together with the record of the results obtained.

2.8.9.2 Materials

- The main earthing bars in the tunnel pipes, both longitudinal and transversal bars, have to consist of 25 x 4 mm FE-Zn bars.

- All necessary connections between the earthing bars have to be made by means of 2 connection bolts M8 with their corresponding nuts and washers, all made of brass.

2.8.9.3 Execution

- The main longitudinal earthing flat bars have to be installed in the tunnel abutments on both sides and cast in together with this structural element.

- The transversal bars have to be installed between both longitudinal earthing bars. These transversal bars have to be laid in the invert concrete or the sub-base course of each carriageway. The earthing bars have to be connected to the reinforcement mesh in the shotcrete at the transversal connections. The distance between transverse bars has to be around 50 m.

- At each connection point between the longitudinal and transversal earthing bars in the tunnel abutment, a vertical lance has to be installed, made of the same material, which has to protrude from the abutment so as to enable the connection of the cable duct earthing conductor laid in the prefabricated duct with the main earthing bars. The length of vertical bars must be at least 80 cm.

- In accordance with the available length of flat Fe-Zn conductors, the CONTRACTOR is obligated to provide a sufficient quantity of connecting elements, as listed in Line 2. in 2.8.9.2., so that the longitudinal and transversal conductors can be connected.

- The main longitudinal earthing bars located in the tunnel abutments, as specified above, have to end at each final portal chainage of both tunnel pipes. In accordance with this item, the vertical lances have to be connected, as specified in item 3, which will guarantee further connection of the tunnel earthing system to the distribution facilities through the portal area earthing cables.

2.8.9.4 Measuring

Measurement of the longitudinal and transversal flat bars and the vertical lances is done by linear metre.

2.8.9.5 Payment

Payment for the flat bars shall be made as a per unit price by linear metre. The labour, equipment and materials required for the placement of the flat bars has to be included in the unit price.