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*Updated, consolidated and supplemented edition of the Set of Instructions*

**SET OF INSTRUCTIONS FOR THE DESIGN, SUPPLY,  
INSTALLATION AND MAINTENANCE OF MOTORWAY ELEMENTS,  
STRUCTURES OR PARTS THEREOF**

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Based on Article 27 of the Statute of JP Autoceste FBiH d.o.o. Mostar No. 1.1-2866-1/12 dated 29 June 2012 and Article 10, item 3, Article 11 of the Rules of Procedure of the Management Board 1.01-2131-8/14 dated 10 April 2014, the Management Board, at its session held on 11 June 2014, hereby adopts:

## **Set of Instructions for Design, Supply, Installation And Maintenance of Motorway Elements, Structures or Parts Thereof**

### **Introduction**

During the preparation of design drawings, construction and subsequent maintenance, it was found that certain structures, parts of structures and some elements (signalling, guardrails, guardrails, lane separators, transitional devices on structures, etc.), on different sections (subsections) are designed differently. This fact is most visible during subsequent maintenance, where the Management and Maintenance Sector faces the problems of maintaining many different systems with the same function.

For these reasons, a team of experts was set up from the Section for Design and Construction and the Section for Management and Maintenance with a task to address this problem i.e. to standardize as much as possible the systems that serve the same function on all sections of the motorway and to draft these instructions for designers, supervisory teams and contractors. When analysing the aforementioned problem, the team of experts ensured that the most up-to-date standards, recognized throughout the world, which cover the respective fields be applied. Experiences from previous projects, good engineering practices, as well as design solutions from all completed projects and those under construction, were also utilized.

Based on the above, a set of instructions was drafted, comprising the following:

1. Instructions for placing road markings
2. Instructions for installing vertical traffic signalization
3. Instructions for the supply, installation and maintenance of garage doors on COKP (Traffic Control and Maintenance Center) facilities
4. Instructions for the design and construction of canopy structures on CP buildings
5. Instructions for the design and construction of flexible guardrails on the motorway
6. Instructions for the design and construction of noise protection panels (noise shields)
7. Instructions for the design and construction of protective wire fencing
8. Instructions for the construction of concrete pavement at the CP
9. Instructions for energy certification of structures belonging to the JP Autoceste FBiH
10. Instructions for the design and installation of LED lighting
11. Instructions for the design and installation of low voltage systems
12. Instructions for the design and construction of roads in tunnels
13. Instructions for the design and construction of road structures on the motorway
14. Instructions for planning and carrying out asphalt work
15. Instructions for approving the material –aggregate fractions
16. Instructions for the application of micro-reinforced shotcrete
17. Instructions on optical convergence measurements in tunnels
18. Instructions for the design of safety systems in tunnels on Corridor Vc
19. Instructions for the design and construction of sustainable drainage systems on the motorway in FBiH
20. Instructions for the design and execution of blasting works on motorway projects

**In the event of any inconsistencies or conflicts between individual instructions, Instruction No. 18 shall prevail.**

The instructions are described in detail in the following text.

## **1. INSTRUCTION FOR PLACING ROAD MARKINGS**

## **Introduction**

Instructions for Placing Road Markings include the placement of road markings for traffic regulation on the roadway according to the projects of traffic technical equipment of the road, the Rulebook on traffic signs and road markings, the method of marking works and barriers on the road and signals given to traffic participants by an authorized person ("Official Gazette of BiH", No. 16/07) and other legal regulations governing this area.

The following is described in these instructions:

- Types, shape, dimensions and use of road markings;
- Quality of road markings;
- Traffic control during the execution of road work;
- Conditions for placing road markings;
- Evaluation of the quality of road markings, and
- Calculation of work costs.

### **1.1. Types, shape, dimensions and use of road markings**

Road markings are:

- 1) longitudinal markings,
- 2) transverse markings and
- 3) other road markings and objects along the edge of the roadway.

Road markings are drawn, glued, embedded or pressed into the pavement surface and must not reduce the friction coefficient of the roadway surface. Road markings must not be raised more than 0.6cm above the roadway level.

Exceptionally, road markings (delineators) used to mark center or edge lines on structures or deviations may be raised than 0.6 cm above the roadway level. Their height must not exceed 2.0 cm above the roadway level.

The technology of works on the execution of renewal or creation of new road markings can include paint, cold plastic or cold plastic in vibro tape technology.

The colour of road markings shall be white.

Exceptionally, the following are marked in yellow:

- markings of places on the roadway and sidewalk where parking is prohibited,
- markings of parking spaces for persons with disabilities,
- traffic calming devices (artificial bumps and raised surfaces) and
- markings that temporarily redirect traffic (temporary traffic regulation) and mark temporary hazards on the roadway resulting from roadworks.

### 1.1.1. Longitudinal road markings

Longitudinal road markings include centre lines, edge lines, and warning lines.

The centre line serves to separate two-way traffic areas according to the direction of movement or to separate traffic lanes in the same direction of movement.

The edge line marks the edge of the driving surface of the roadway and separates roadway areas with a special purpose – lanes for the movement of public passenger transport vehicles.

The centre and edge lines can also be implemented as an acoustic or rumble strip.

The shape and dimensions of longitudinal road markings must comply with the requirements of BAS U.S4.221, BAS U.S4.222, BAS U.S4.223, BAS U.S4.224;

The width of the central centre line according to the width of the traffic lane:

- 1) over 3.50 m - 20 cm;
- 2) 3 – 3.50 m - 15 cm;
- 3) 2.75 – 3.00 m - 12 cm,
- 4) 2.5 – 2.75 m - 10 cm.

The width of the edge and centre lines is identical. For motorway standards, it amounts to 20 cm.

Longitudinal lines on the roadway are executed as solid, broken, and double lines, and the edge line.

A solid longitudinal line (central and edge) indicates a prohibition for vehicles to cross that line or a prohibition for vehicles to move along that line (Figure 1).

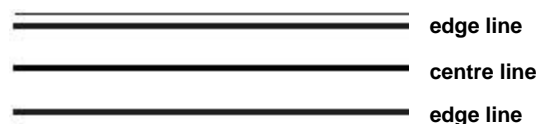


Figure 1.

A broken longitudinal line can be a broken centre line, a dotted line, a wide broken line, and a warning line. A broken centre line divides the roadway into traffic lanes (Figure 2.).

The length of the broken centre line gap shall be twice as long as the solid line segment on an open road and permissible speed > 60 km/h.

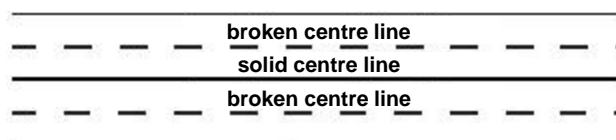


Figure 2.

The wide broken line serves as an edge line for separating traffic flows at intersections on roads outside urban areas and as an edge line for separating turning and exit niches, that is merging on motorways and roads reserved for motor vehicle traffic, i.e., expressways, and is at least 30 cm wide (Figure 3.). For motorway standards, it amounts to 50 cm. The length of the empty space of a wide broken line is equal to the length of the solid space. The length amounts to 3.0 m.

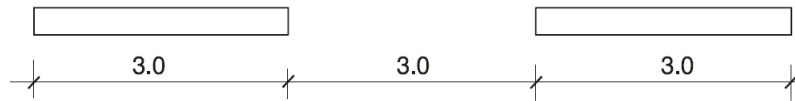


Figure 3.

The warning line serves to announce the proximity of a solid centre line (Figure 4.).

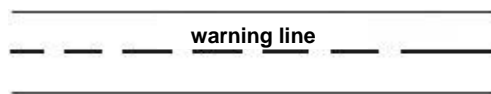


Figure 4.

A double centre line can be a double solid, double broken, and double combined line.

The marking of the warning line can be supplemented with one or more arrows, which show drivers which traffic lane they must use.

### 1.1.2. Transverse road markings

Transverse markings are:

- 1) stop line,
- 2) diagonal lines,
- 3) boundary lines,
- 4) pedestrian crossings, and
- 5) bicycle path crossings.

Transverse road markings are marked with solid or broken lines and can be drawn on the roadway so that they cover one or more traffic lanes.

Transverse markings are, considering the angle at which the driver sees them, wider than longitudinal markings.

The shape and dimensions of transverse road markings should meet the requirements of BAS U.S4.225, BAS U.S4.226, BAS U.S4.227, BAS U.S4.228;

The stop line can be solid or broken. A solid stop line marks the place where the driver must stop the vehicle. In front of the stop line, the word STOP can be written on the roadway (Figure 5). For a traffic lane width of 3.00-3.50 m, the width of the marking is 0.50 m;

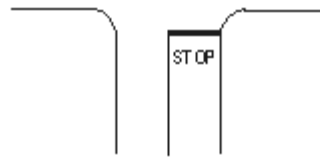


Figure 5.

Diagonal lines indicate the point of opening of the exit lane (Figure 6) and closing of the entry lane (Figure 7) on a motorway, expressway, and road reserved for motor vehicle traffic:

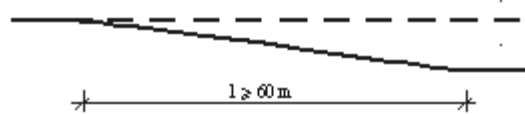


Figure 6.

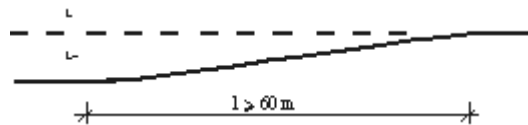


Figure 7.

### 1.1.3. Other road markings and objects along the edge of the roadway

Other road markings and objects along the edges of the roadway are arrows, traffic routing fields, routing lines, inscriptions, markings for special purpose traffic surfaces, markings for designating parking spaces, and longitudinal markings (markings on objects along the edge of the roadway).

For other road markings, material or paint that does not increase the slipperiness of the roadway must be used. These markings must not be higher than 0.6cm above the level of the roadway.

The shape and dimensions of other road markings should comply with the requirements of BAS U.S4.229, BAS U.S4.230, BAS U.S4.231, BAS U.S4.232, BAS U.S4.233, BAS U.S4.234;

Arrows on the roadway mark the mandatory direction of vehicle movement if they are drawn in a traffic lane bordered by a solid centre line. Also, they inform drivers about the purpose of traffic lanes if they are drawn in a lane bordered by a broken centre line.

Arrows can indicate:

- one direction (Figure 8);
- two directions (combined) (Figure 9 and Figure 10);
- three directions (combined);
- lane changing at two closer intersections, i.e., connectors where the lane change must be done before the first intersection, i.e., connector where turning in the marked directions is prohibited;
- direction of movement in garages;
- turning of traffic;
- announcement of the end of overtaking.



Figure 8.



Figure 9.



Figure 10.

Traffic routing fields indicate an area where traffic is prohibited and where stopping and parking of vehicles is not allowed:

- between two lanes with opposite directions (Figure 11.);
- between two lanes in the same direction (Figure 12);
- at the place of opening a special turning lane;
- in front of the traffic flow separation island;
- on the entrance ramp to the motorway (Figure 13);
- on the exit ramp from the motorway (Figure 14).



Figure 11.



Figure 12.

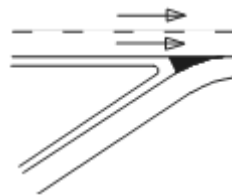


Figure 13.

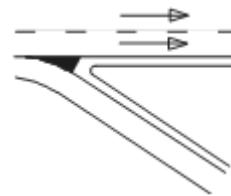


Figure 14.

The guiding line indicates the place of change of the free road surface before solid obstacles located on the road or on the edges of the road.

Guiding lines can be placed in front of the island for the realignment of public passenger transport vehicles, for shaping an obstacle on the edge of the road, and for marking a change in the useful surface of the roadway (Figure 14).



Figure 14.

Road markings provide road users with necessary information, such as, for example, the word »STOP«, but also place names »SARAJEVO«, »ENC«, speed limits, etc.

Place names are written in the Latin script in the Federation of Bosnia and Herzegovina and in the Cyrillic script in Republika Srpska.

International markings are written only in the Latin script.

Road markings can also be executed as inserted traffic signs.

Marking of vehicle parking spaces serves to designate parking areas. Parking in relation to the edge of the roadway can be longitudinal (Figure 15), angled (Figure 16), and perpendicular (Figure 17).



Figure 15.



Figure 16.



Figure 17.

Elements of the construction and equipment of public roads and other objects that indicate permanent obstacles within the dimensions of the traffic profile are marked with a red-and-white marking, and of the free profile with a black-and-white marking (Figure 18).

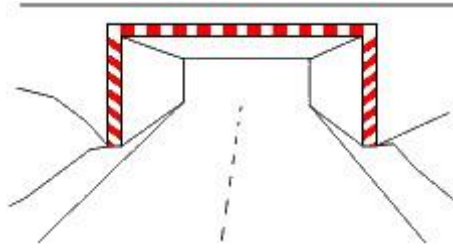


Figure 18.

The evacuation line on the tunnel lining is marked along the entire length of the tunnel on the side where the entrances to pedestrian passages and vehicle passages are located, with a 50 cm wide line in red colour (RAL 2002) (Figure 19).

The evacuation line on the tunnel lining is executed so that the lower edge of the line is at a height of 90 cm from the level of the pedestrian walkway.

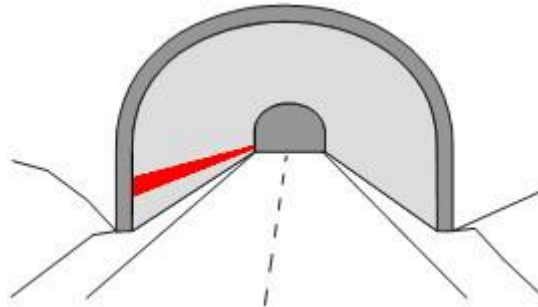


Figure 19.

## 1.2. Colours permitted for use

Materials for the execution of works on the creation of road markings on public roads must meet the following standards:

- EN 1436:2007+A1:2008 – Road marking performance for road users
- EN 13197:2001 – Wear simulator
- EN 1871:2000 – Physical properties

According to the aforementioned standards, two systems (types) of road markings are defined, namely:

- **Type I** for sections south of the Mostar North interchange with the following characteristics:
  - Paint in film thickness of 400 mic
  - Reflective beads 100 to 850 mic
  - Good daytime visibility
  - Good night-time visibility in dry conditions
  - Poorer night-time visibility in wet conditions and rain
- **Type II** for sections north of the Mostar North interchange with the following characteristics:
  - Paint in film thickness of 600 mic
  - Reflective beads 200 to 1400 mic

- Good daytime visibility
- Good night-time visibility in dry conditions
- Good night-time visibility in wet conditions and rain

### 1.2.1. Minimum requirements

The minimum requirements for the white paint used for road signalling are shown in the table as follows:

Type I, Type II
Q2
B2
R2
RW 1
RR 1
S1

### 1.3. Explanation of the marking system

#### 1.3.1. Road marking performance for road users - EN1436:2007+A1:2008

The road marking performance for road users include:

- **Daytime visibility**

Reference parameters (classes) for daytime visibility for dry conditions are given in the following table

Table 1. – Reference parameters (classes) of daytime visibility for dry conditions

Road marking colour	Road surface type	Class	Minimum luminance coefficient under diffuse illumination $Q_d$ in mcd/m <sup>2</sup> lx
White	Asphalt pavement	Q0	-
		Q2	$Q_d \geq 100$
		Q3	$Q_d \geq 130$
		Q4	$Q_d \geq 160$
	Cement concrete pavement	Q0	-
		Q3	$Q_d \geq 130$
		Q4	$Q_d \geq 160$
		Q5	$Q_d \geq 200$
Yellow		Q0	-
		Q1	$Q_d \geq 80$
		Q2	$Q_d \geq 100$
		Q3	$Q_d \geq 130$

- **Night-time visibility**

Reference parameters (classes) for night-time visibility for dry conditions are given in the following table

Table 2 – Reference parameters (classes) of night-time visibility for dry conditions

Type of road marking	Road marking colour	Class	Minimum coefficient of retroreflected luminance RL in mcd/m <sup>2</sup> lx
Permanent	White	R0	-
		R2	RL ≥ 100
		R3	RL ≥ 150
		R4	RL ≥ 200
		R5	RL ≥ 300
	Yellow	R0	-
		R1	RL ≥ 80
		R3	RL ≥ 150
R4		RL ≥ 200	
Temporary		R0	-
		R3	RL ≥ 150
		R5	RL ≥ 300

- **Visibility in wet conditions**

Reference parameters (classes) of visibility for wet conditions are given in the following table.

Table 3 – Reference parameters (classes) of visibility for wet conditions

Wet Conditions	Class	Minimum coefficient of retroreflected luminance RL in mcd/m <sup>2</sup> lx
Values obtained 1 minute after flooding the surface	RW0	-
	RW1	RL ≥ 25
	RW2	RL ≥ 35
	RW3	RL ≥ 50
	RW4	RL ≥ 75
	RW5	RL ≥ 100
	RW6	RL ≥ 150

- **Visibility under rainy conditions**

Reference parameters (classes) of visibility under rainy conditions are given in the following table.

Table 4. – Reference parameters (classes) of visibility under rainy conditions

Rainy conditions	Class	Minimum coefficient of retroreflected luminance RL in mcd/m <sup>2</sup> lx
Values obtained after at least 5 minutes of exposure in accordance with B.7 during constant rain at a rainfall rate of 20 mm/hh	RR0	-
	RR1	RL ≥ 25
	RR2	RL ≥ 35
	RR3	RL ≥ 50
	RR4	RL ≥ 75
	RR5	RL ≥ 100
	RR6	RL ≥ 150

### - Slip resistance

Reference parameters (classes) of slip resistance are given in the following table

Table 5 – Reference parameters (classes) of slip resistance

Class	Minimum slip resistance value
S0	-
S1	SRT ≥ 45
S2	SRT ≥ 50
S3	SRT ≥ 55
S4	SRT ≥ 60
S5	SRT ≥ 65

### 1.3.2. Wear simulators - EN 13197:2001

Wear simulators represent the value (amount) of the number of passes (P) for the values: Q, B, R, RW, RR, SRT. The number of passes for individual traffic classes is given in the following table.

Table 6 – Traffic classes

Traffic class	Number of passes
P0	-
P1	$0.5 \times 10^5$
P2	$1.0 \times 10^5$
P3	$2.0 \times 10^5$
P4	$5.0 \times 10^5$
P5	$1.0 \times 10^6$
P6	$2.0 \times 10^6$
P7	$> 2.0 \times 10^6$

### **1.3.3. Physical properties - EN 1871:200**

The following values of the physical properties of the material are tested:

- Daytime visibility – luminance factor;
- x,y chromaticity coordinates
- Coverage (in accordance with ISO 2814) - min 95% for white colour
- UV aging resistance
- Bleeding resistance
- Alkali resistance
- Storage stability - min 4

In addition to the mentioned properties, the following must also be analysed by laboratory tests:

- Density (according to EN 12802)
- Viscosity or consistency (according to EN 12802)
- Drying time (according to EN 13197)
- Durability (according to EN 13197)

### **1.4. Traffic control during the execution of road works**

Before starting the road marking works, the contractor must prepare a traffic regulation project during the execution of road markings and obtain approval for this project from the Employer. The procedure for placing markings must be such that it can be carried out under traffic, without compromising the safety of traffic participants and the team working on the road markings. For this purpose, the engagement of a traffic police patrol shall not be avoided, and sufficient use of traffic cones must be ensured; cones shall only be removed once the marking material is completely dry.

The contractor is responsible for fulfilling all the aforementioned conditions, as well as for all harmful consequences resulting from the execution of the subject works. The contractor is also responsible for any potential damages caused by spraying marking paint on vehicles in traffic as a result of the execution of the subject works.

The Employer will under no circumstances be held responsible for such damages.

### **1.5. Conditions for placing road markings**

#### **1.5.1. Weather conditions**

Road marking works are carried out at an air temperature of at least +10 degrees C and a maximum of +30 C, and at a relative air humidity of up to a maximum of 85%. The optimal value of air temperature is 20-25 degrees C, and relative air humidity less than 75%. The substrate must be completely dry. The temperature of the substrate ranges from 5-45 degrees C (BAS Z.S2.240).

### **1.5.2. Road surface preparation**

Before applying the paint, the road surface must be completely dry, clean, free of dust and salt residues. Oil and other grease stains must be removed.

The contractor will perform a general cleaning of the pavement on public roads after the end of the winter service, which is usually done in the first half of April (for valley routes), or in the second half of April (for mountainous areas), and this is not included in the unit price of making road markings. The unit price for placing road markings includes the removal of all pavement impurities immediately before placing the markings.

### **1.5.3. Machines and equipment for placing road markings**

Machines for placing road markings must be automated. The required amount of paint and glass beads (pearls) is regulated by automatic equipment. The machines must be adjusted to ensure the prescribed geometry of the markings and the uniform application of paint and reflective glass beads. If problems in the quality of the markings are noticed during work, the supervising engineer may require the contractor to provide detailed manufacturer's instructions for operating the equipment. The contractor will then be required to use the equipment according to the specified instructions of the equipment manufacturer, with an emphasis on the operating speed of the equipment during the execution of the markings, or make other adjustments until a satisfactory quality of the markings is achieved in the opinion of the supervising engineer (the opinion of the supervising body must be supported by measurements and testing in accordance with the Quality standard).

## **1.6. Assessing the quality of road markings**

### **1.6.1. Quality control for placing road markings**

In order to determine the quality of road markings, the following data on road marking works must be recorded:

- road category and section,
- date and time of execution of works,
- type of equipment,
- type of paint and other materials used,
- thickness of the dry and wet layer of the marking,
- material consumption per unit of marking,
- calculation of the dry film thickness of the marking/paint manufacturer's specifications,
- weather conditions at the time of execution of works;

Control of the thickness of the dry and wet films (without glass beads) of the marking is carried out with control plates at least every 2000-5000 m of marked roadway, i.e., a maximum of 4 samples per day, especially for center, edge, and other types of markings.

The contractor is responsible for quality control, and will create and implement an effective quality control plan.

As part of quality control, the contractor will measure daytime and night-time visibility with a portable device in a period not earlier than 30 days, and not later than 60 days, from the date of placement of the markings. Measurements are performed in one zone with a length of 500 m, on each section, where a section is a part of the marking executed by one team during one day. The beginning of the measurement zone is in the first third of the section length. In each zone, 10 measurements of daytime and night-time visibility should be performed at a mutual distance of 50 m. The beginning and end of the zone should be marked with spray paint on the edge of the roadway.

If the dry paint film thickness of the marking is equal to or greater than the minimum required on three out of four samples related to the daily application of the marking, the marking on that section will be accepted. If more than one sample related to the daily application of the marking does not have the minimum required dry paint film thickness, the marking on that section will not be accepted, and the contractor must renew it at their own expense.

In the event that the daily sample for any reason requires testing on fewer than four samples, all samples must meet the prescribed minimum dry film thickness.

If 80% (8 or more) of the visibility readings in one zone meet or exceed the required minimum daytime and night-time visibility, the marking on that section will be accepted. And if less than 80% (less than 8) of the visibility readings in one zone meet the required minimum daytime and night-time visibility, the marking on that section will not be accepted, and the contractor must renew it at their own expense.

#### **1.6.2. Quality assurance for works carried out by the Employer**

As part of quality assurance, the Employer will conduct measurements on a part of the executed works, the purpose of which is the verification and checking of the data submitted by the contractor as part of quality control. These measurements will be performed where the appearance of the markings indicates possible errors in the measurement results conducted by the contractor, and visual observations of possible errors by the Employer.

The measurement results submitted by the contractor will be accepted if the corresponding average values within the control tests conducted by the contractor do not differ by more than 10% from the average measurement results conducted by the Employer for the section in question.

During the guarantee period of 6 months, the Employer shall visually check the condition of the markings for any damage to them (cracking, bleeding, peeling off, colour loss, etc). Should the above-mentioned damages affect more than 90% of a marking's surface, the contractor shall – weather permitting - re-apply the marking at their own cost, starting not later than within 7 days following the receipt of a notice in writing to that effect from the Employer. Should such a deficiency come up during the guarantee period, but later than 15 October of the current year, the contractor shall not re-do the damaged part of the marking without a specific approval from the Employer; however, such a deficiency shall be charged against the guarantee in the amount of 30% of the contracted value of the marking on the damaged part.

Damage to the marking resulting from damage to the roadway will not be taken into account when determining the damage to the markings.

**1.7. Calculation of work costs**

Work shall be measured per one meter of applied longitudinal and transverse markings and per one square meter of other road markings. It shall be charged applying the contracted unit price including all written work, material, transportation, marking, the quality control described, as well as anything else necessary to carry out this type of work.

## **2. INSTRUCTIONS FOR PLACING VERTICAL TRAFFIC SIGNALIZATION**

## **2.1. Description of work**

This work includes the production, supply, and installation of all types of traffic signs according to the road traffic equipment project. The work must be carried out in accordance with the project, the Rulebook on Traffic Signs and Traffic Signalization, Method of Marking Works or Obstacles on the Road and Signs Given to the Participants in Traffic by Authorized Person („Official Gazette of BiH“ number 16/07), as well as with all applicable standards and requirements of the supervising engineer.

## **2.2. Manufacture**

Traffic signs, by their type, meaning, shape, colour, size, and method of placing, must comply with the "Rulebook on Traffic Signs and Traffic Signalization, Method of Marking Works or Obstacles on the Road and Signs Given to the Participants in Traffic by Authorized Person", and the applicable standards in Bosnia and Herzegovina.

### **2.2.1. Colour – conditions**

The colour of the back of the sign base must be grey and not shiny so that it would not draw the drivers' attention. The surface of traffic signs is made of materials with retroreflective properties for motorways and roads intended exclusively for motor vehicle traffic - expressways, at least class II.

### **2.2.2. Dimensional requirements**

The dimensions of the signs are determined by the "Rulebook on Traffic Signs and Traffic Signalization, Method of Marking Works or Obstacles on the Road and Signs Given to the Participants in Traffic by Authorized Person", and applicable standards.

When placing the vertical traffic signalization, retroreflective sheeting of at least retroreflection class 2 - "High Intensity Grade" should be applied, stable to ultraviolet radiation and applied to an aluminium sheet with a thickness of 2 to 3 mm, with a reinforced frame and road reinforcements, which guarantees the quality and durability of traffic signs.

Traffic signs of larger dimensions, whose surface area is more than 2 m<sup>2</sup>, are made of profiled segments 20 cm high with connection grooves, which shall be combined into a single sign unit at the site of installation.

### **2.2.3. Placement and mounting**

The traffic signs shall be mounted in a way that the place of connection is not visible from the front of the sign. Special attention should be paid not to use screws and plates made of other types of materials (iron, etc.) due to the occurrence of electrolysis. Connective elements must be designed to prevent the traffic sign from rotating around the axis of the pole.

Traffic signs are attached to support posts with a diameter of  $\phi$  63.5 mm, which are made of Al or Fe steel welded pipes and protected against corrosion by the hot-dip galvanizing process.

On the motorway route, traffic signs (panels) that have large surface areas are mounted on the right side of the roadway on I-profiles or cantilever support posts for reasons of static stability; if the panels are mounted above the roadway on portals, additional securing (cables) is required.

Large rectangular signs are placed on two or more posts, and exceptionally large ones on a load-bearing structure that requires a special static calculation. The calculation should take into account local meteorological conditions (frequency, strength, and direction of winds, snow) and the weight and surface area of the traffic sign.

When installing, the traffic sign should be rotated by  $3^\circ$  relative to the axis of the roadway to avoid intense reflection and reduce the contrast of the markings, the sign, and the illuminated background. No more than two traffic signs may be placed on the same post.

The traffic sign is placed at a height of 1.20 to 1.40 m from the roadway surface to the lower edge of the sign or the supplementary panel placed below the sign, on the right side of the roadway. Exceptions are traffic signs for mandatory detour and roundabout traffic, signs for road structures (tunnel, viaduct, etc.), and signs showing the road number, highways, main roads, mileage on the motorway or highway, and indications of the section of the main road that are mounted at the height of 80-120 cm.

Traffic signs located above the roadway are placed at a minimum height of 4.8 m from the lower edge of the sign to the roadway level; as a rule, traffic signs are placed at a height of 5.0 m above the roadway.

The minimum road distance of the traffic sign from the right edge of the roadway must be 0.5 m (for standard dimensions), and for larger signs min. 1.5 m (1.0 m). In the central median, the road distance of the traffic sign from the left edge of the roadway must be min 0.75 m. The traffic sign post is generally placed a maximum of 2.0 m from the edge of the roadway.

The foundations of the traffic sign support posts are made based on the guidelines and standards valid in Bosnia and Herzegovina.

### **2.3. Quality control**

Materials used for the manufacture of the signs and poles are defined by standards, and the contractor shall provide at their own expense evidence that the materials satisfy the prescribed quality requirements before placing them. The original evidence shall be delivered to the supervising engineer.

### **2.4. Calculation of work costs**

The work includes the production and delivery of traffic signage, supply, transport, and installation of a traffic sign with a pole and foundation. It is calculated according to the number of installed signs of specific dimensions, including poles and foundations, distinguishing locations based on the number of signs on a single pole (pole with one sign - pole with two signs), and locations with a load-bearing structure (gantry or cantilever pole).

### **3. INSTRUCTIONS FOR SUPPLY AND INSTALLATION OF GARAGE DOORS ON COKP FACILITIES**

## **Introduction**

Considering that there is a need for the supply of garage doors for the COKP, and that they are not covered by domestic standards, as well as the fact that there is a great variation in quality, price, and requirements that the doors must meet on the market, for the purpose of unifying the requirements that the doors must meet, we have conducted a technical analysis and defined the minimum necessary requirements that the doors must meet.

In the analysis, available standards, i.e., European standards, which regulate certain areas in terms of technical requirements for garage doors, were used, along with local market research to assess the availability of the required items, as well as an assessment of the actual operating conditions of the doors and the architectural and construction requirements of the building itself in which they are installed.

When defining the minimum conditions, we made a regional division, according to the geographical location of the door installation site and the specific climatic and temperature conditions to which the garage doors must respond. Possible architectural and construction conditions of individual projects were also considered, where it was established that there may be a variation in the minimum requirements, in terms of fulfilling the intended function, so that the doors can better respond to the project requirements.

After considering the real operating conditions of the garage doors, we consulted European standards in order to accurately define the required classes of individual requirements.

During the analysis, the following standards were used:

- 1) EN 12424 – Wind Load Resistance
- 2) EN 12425 –Water Penetration Resistance
- 3) EN 12426 – Air Permeability
- 4) EN 13241 Annex B EN 12428 – Thermal Insulation

Having taken into consideration all the facts and the above listed documents, we propose the minimum technical requirements that the garage doors for the COPK buildings should comply with.

### 3.1. Minimum technical requirements

Table 1. - Minimum technical requirements

	Wash		Garage for freight vehicles		Auto mechanic shop	
	Region 1*	Region 2**	Region 1*	Region 2**	Region 1*	Region 2**
Dimensions						
- Height	up to 7.0 meters		up to 7.0 meters		up to 7.0 meters	
- Width	According to the project		According to the project		According to the project	
Wind load resistance EN 12424	Class 2	Class 3	Class 2	Class 3	Class 2	Class 3
Water penetration EN 12425	Class 3	Class 3	Class 3	Class 3	Class 3	Class 3
Air permeability EN 12426	Class 2		Class 2		Class 2	
Sound insulation	No requirements		No requirements		No requirements	
Thermal insulation (Annex B EN 12428) (U=W/m <sup>2</sup> K)	from 1.5 to 4.3		from 1.5 to 4.3		from 1.5 to 4.3	
Opening method - Electric door lifting with the possibility of manual opening.	Yes		Yes		Yes	
Possibility of natural lighting	Without possibility		Without possibility/ Not necessary		Without possibility/ Not necessary	
Corrosion protection	Yes		Yes		Yes	
Resistance to aggressive environment						
A) resistance to salts	Yes	No	Yes	No	Yes	No
B) oil resistance	Yes		Yes		Yes	
Safety – security against deterioration	Yes		Yes		Yes	
Number of opening and closing cycles	min 25,000 times		min 25,000 times		min 25,000 times	
5-year guarantee	Yes		Yes		Yes	

Region 1\* – Area of Bosnia, characterized by frequent occurrence of snow, low temperatures in the winter period, characteristic winter conditions for road maintenance.

Region 2\*\* – Area of Herzegovina, characterized by strong winds, rare occurrence of winter conditions for road maintenance.

The quality of thermal insulation is selected based on the specific needs of the project.

## **4. INSTRUCTIONS FOR DESIGN AND CONSTRUCTION OF CANOPY STRUCTURES ON CP BUILDINGS**

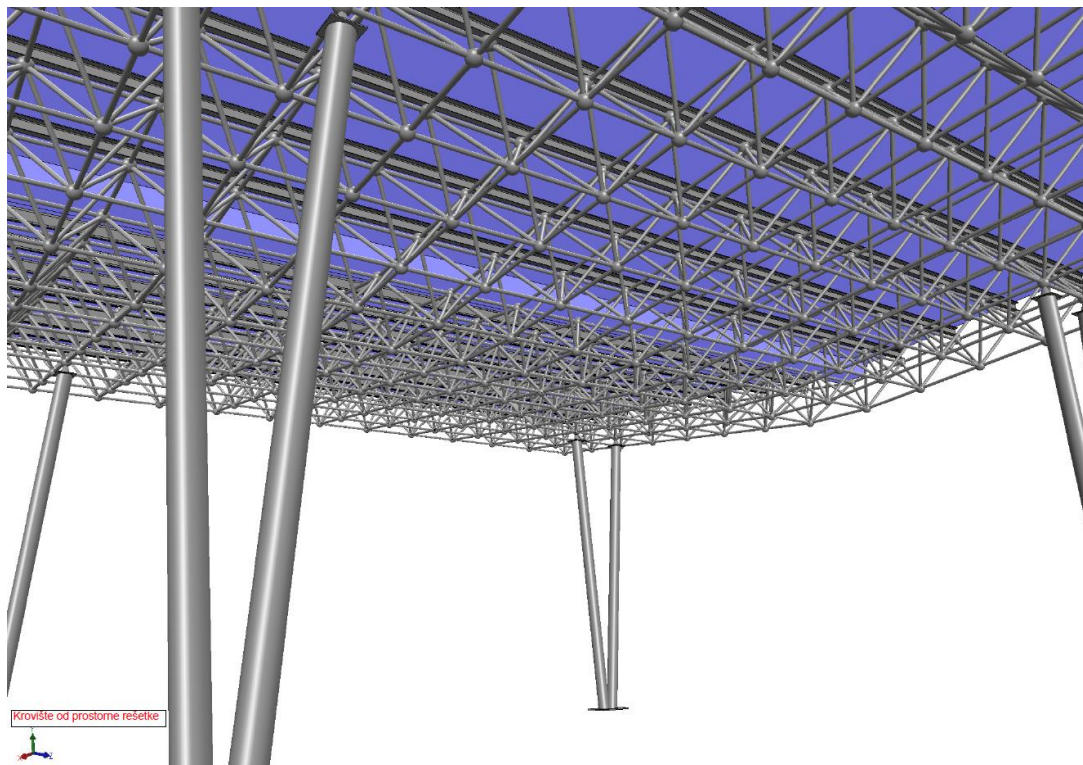
## Introduction

With the aim of unifying the solutions for canopy structures on CP buildings, this instruction has been prepared for all designers, supervisory teams, and contractors, i.e., for all projects in the design phase, preparation for construction, and those under construction.

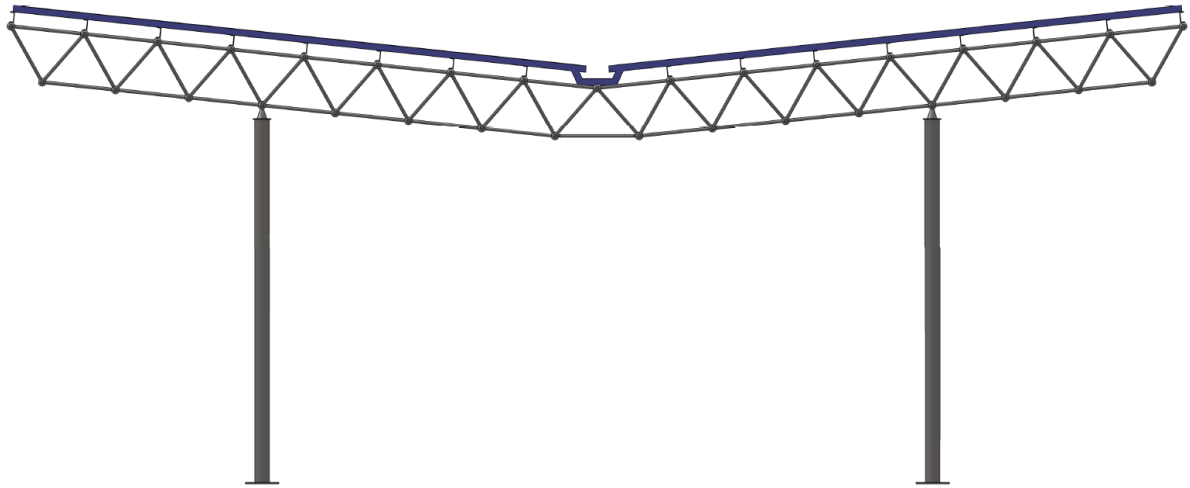
At the toll stations of the A1 motorway, two variants of the canopy are represented, namely:

- Canopy of space truss structures made of steel pipes (variant "A")
- Canopy of rolled steel sections (variant "B")

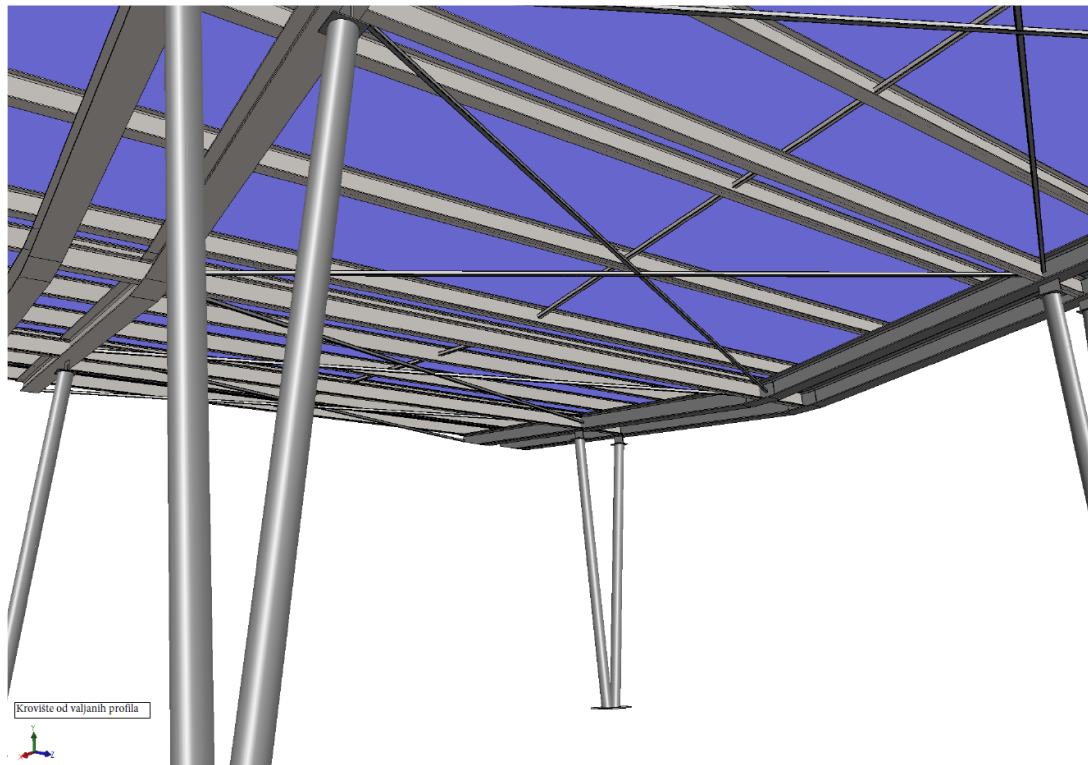
The mentioned types of canopies represented at the toll stations of the A1 motorway are shown in the figures below.



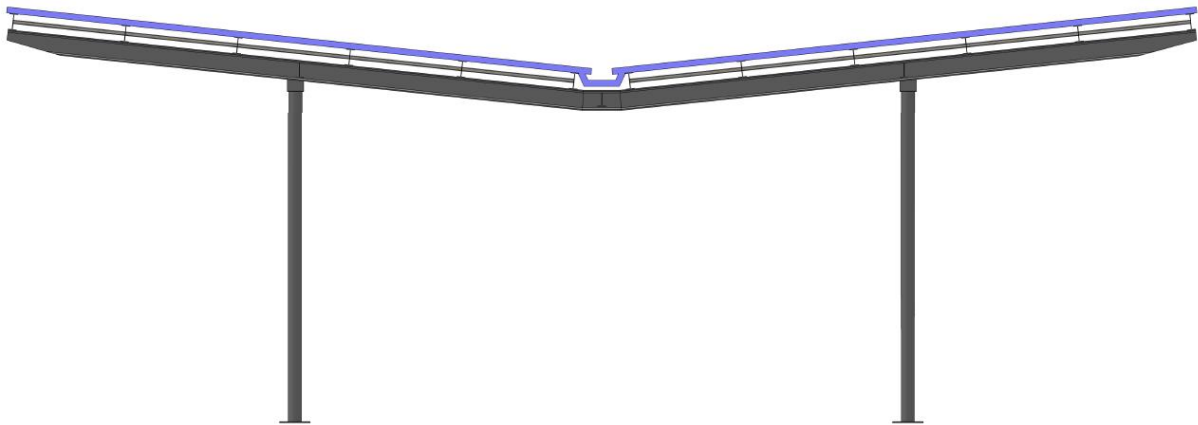
**Figure 1.** Canopy of space truss structures made of steel pipes (variant "A") – bottom view



**Figure 2.** Canopy of space truss structures made of steel pipes (variant "A") – cross section



**Figure 3.** Canopy of rolled steel sections (variant "B") – bottom view



**Figure 4.** Canopy of rolled steel sections (variant "B") – cross section

We must point out that both types are acceptable from the point of view of architectural design, as well as from the point of view of structural design.

The parameters considered with the aim of unification have been reduced to an economic analysis of the total investment. The economic analysis of the total investment is expressed through:

- Construction investments
- Maintenance investments

A detailed economic analysis of the mentioned parameters, conducted by experts, will not be presented in this document, but the conclusions are as follows:

- The economic analysis of the construction investment determined that the structure made of rolled steel sections (variant "B") is about 40% more expensive compared to the space truss structures (variant "A").
- The economic analysis of the maintenance investment, which includes the parameters of cleaning and applying anti-corrosion protection for a period of 40 years, determined that the structure made of rolled steel sections (variant "B") is up to 5 times cheaper compared to the space truss structures (variant "A").

## **Conclusion**

From all the above, we conclude that JP Autoceste FBiH should use canopy structures made of rolled steel sections, because the total investment, despite higher initial investment costs, is significantly cheaper, and such an instruction should be delivered to all designers, supervisory teams, and contractors.

**5. INSTRUCTIONS FOR THE DESIGN AND  
CONSTRUCTION OF FLEXIBLE GUARDRAILS ON THE  
MOTORWAY**

## Introduction

Legal regulations for protective guardrails on roads:

- Rulebook on Traffic Signs and Traffic Signalization, Method of Marking Works or Obstacles on the Road and Signs Given to the Participants in Traffic by Authorized Person (Official Gazette of BiH, number 16/07)
- (JUS U.S4.110, 1984 )
- (EN 1317) – European standard of 1993. European standard 1317 has been harmonized as of January 1, 2008, with three years transitional period, so as of January 1, 2011, only the use of guardrails certified according to that standard, i.e. the CE certificate, is allowed.

Rulebook on Traffic Signs and Traffic Signalization, Method of Marking Works or Obstacles on the Road and Signs Given to the Participants in Traffic by Authorized Person provides as described in the following Section H:

### 5.1. Section H. Guardrails

#### 5.1.1. Article 86 (Guardrails)

- 1) A guardrail is a technical safety structure whose main purpose is to prevent vehicles from sliding off the road (subgrade), i.e., to retain vehicles that have veered off the roadway.
- 2) The guardrail is made of steel, concrete (New Jersey type), or combined.
- 3) A guardrail must be installed:
  - in the central reservation, depending on traffic intensity
  - on a road structure,
  - when the road is on an embankment higher than 3.0 m
  - in front of a dangerous place (lateral hazard),
  - near another traffic surface (railway line, water surface), except for surfaces intended for pedestrian traffic.

The guardrail class depends on the road category:

Road category	Edge roadway	Central reservation	Structure
Motorway Expressway Road reserved for motor vehicles	H2–H1	H2	H3 – H2
Main road Regional road High-ranking urban roads	H1	–	H2
Other roads	N2	–	H1 – H2

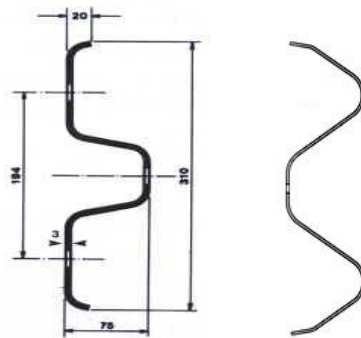
#### 5.1.2. Article 87 (Guardrail design)

The guardrail must be equipped with retroreflective markings – catadioptrics (VIII-3), red on the right side in the direction of travel, and white on the left side. On a roadway with one-way traffic, the retroreflective markings are red on both sides.

According to the BiH legislation, as prescribed in the Rulebook on Traffic Signs and Traffic Signalization, Method of Marking Works or Obstacles on the Road and Signs Given to the Participants in Traffic by Authorized Person, the guardrails shall be placed and mounted in accordance with EN 1317, and in compliance with the regulations.

### 5.1.3. Definition of bumper guardrail

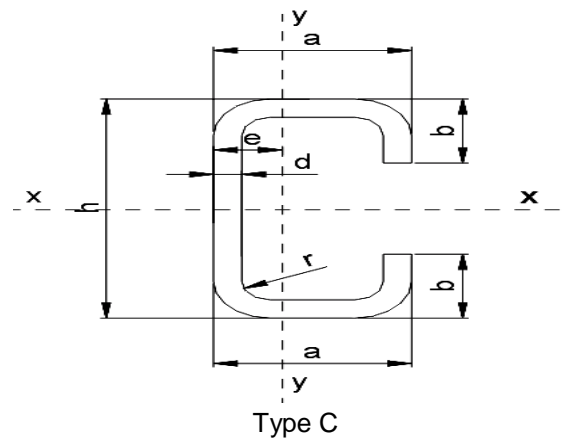
The mantle is one of the basic elements of steel guardrail. It is made of hot-rolled steel band Č.0361, 3 mm thick, cold-formed into a section. At the ends of the mantle there are openings for their mutual connection by screws. When needed, they are delivered curved to follow the road curve.



Type A



Type B



The height of the anti-glare system depends on general conditions, such as the relative levels of the main vehicle headlights and the eye height of drivers coming from the opposite direction. According to the European standard EN 12676-1, a system height of 1.18 m above the road surface will protect drivers of light motor vehicles from all incident rays that can cause glare, while a system height of 1.67 m fully protects drivers of heavy motor vehicles.

The height of the protective guardrails relative to the roadway varies depending on the barrier class.

Guardrails of protection class H2 (double-row type) and H3 (triple-row type) due to their height can serve (especially in populated areas) to prevent "people" from crossing the motorway.

## Conclusion

Starting from the European norms and standards used in our country, by reviewing chapter E of the main projects of sections in preparation and construction, surveying the protective guardrails on the constructed section of the A1 motorway, section Kakanj - Jošanica, and experience from the aspect of maintenance, protection, and traffic safety on the motorway, we have noticed the following:

- An overview of the main designs for construction of sections (Počitelj – Bijača, Lapenica – Tarčin, Vlakovo – Lepenica, Drivuša – Bilješevo) showed that the designers have provided for the guardrail on the open route of the high class H1 and H2, namely class H2 in the central reservation, and class H1 or H2 along the edge of the roadway, what is in accordance with the European norm 1317 and our regulations.
- A site visit to the already constructed section of the motorway A1 Kakanj-Jošnica showed that the sub-section Visoko-Jošnica single-sided guardrail without distancers was placed along the edge of the roadway, and a double-sided bumper guardrail with distancers was installed in the central reservation. Both guardrails were designed before the entry into force of the Rulebook on Traffic Signs and Traffic Signalization, Method of Marking Works or Obstacles on the Road and Signs Given to the Participants in Traffic by Authorized Person (Official Gazette of BiH, number 16/07), so we can only talk about them from a visual aspect.

On the subsection Kakanj - Visoko, a single-sided guardrail with distancers is installed both on the edges of the roadway and in the central reservation due to the drain trench that passes

along the central reservation. The fence is equipped with the “B” type mantle, and visually appears to belong to a high protection class.

Due to the construction period and changes in standards in this area, we cannot consider the constructed section as a reference for the basis of unifying bumper guardrails.

- The height of the anti-glare system depends on general conditions, such as the relative levels of the main vehicle headlights and the eye height of drivers coming from the opposite direction. According to the European standard EN 12676-1, a system height of 1.18 m above the road surface will protect drivers of light motor vehicles from all incident rays that can cause glare, while a system height of 1.67 m fully protects drivers of heavy motor vehicles. Bearing in mind the above, the installation of guardrails of class H2 double-row type (due to their height which is approx. 1100 mm) compared to barriers of classes H1 and H2 (height approx. 750 mm) in the central reservation, has its justification also from the aspect of raising the level of motorway service, protection against glare, and reducing the need for additional protection against glare for motorway users.
- Having in mind the experience of the operation of the constructed section of the motorway, installation of the H3 class bumper guardrail (height approximately 1650 mm) is worth considering in the areas where one might expect pedestrians to try to cross the road (resting sites, settlements etc.). In addition to improving safety of traffic, the guardrail would here also act as a physical barrier preventing any crossing of the motorway.

Therefore, the following conclusions may be inferred from the above considerations:

- **In the central reservation, insist on the use of bumper guardrail of at least H2 class, two-row type where possible, while Class H3 should also be used in special cases;**
- **Along the left and right edge of the motorway, install bumper guardrail with distancers of at least H1 protection class. When needed, and when so dictated by the terrain, the designer shall also foresee guardrail of higher protection classes: H2, H3 and, on exceptional basis, H4a and H4b.**

## **6. INSTRUCTIONS FOR DESIGN AND INSTALLATION OF NOISE PROTECTION PANELS (NOISE BARRIERS)**

## Introduction

The purpose of installing noise protection panels is to mitigate the consequences of noise pollution in urban areas and create a positive environment for human life.

The selection of the installation location for protective panels, the height of the panels, and the quality of noise absorption are chosen by the designer based on the noise calculation model. Protective panels are mainly installed in urban areas where the noise level caused by motor traffic exceeds the permitted legally prescribed noise level.

Given the relatively high costs of building and maintaining noise protection panels, in order to optimize costs, there is a need for the unification of noise protection panels.

To facilitate the selection of an appropriate structure, the basic requirements that noise protection panels must meet have been defined.

<b>Requirements for noise barriers.</b>	
Architectural requirements	> Visual integration into the environment.
	> Avoiding a monotonous wall appearance.
	> Creating an eco-friendly environment.
	> Creating a positive psychological aspect for drivers due to the change in the rhythm of repeating the same segments, the application of diverse textures and colours, broken forms, and changes in the height of noise barriers.
	> Installation of emergency exits.
Functionality requirement	> Fulfilling the requirements of noise absorption and reflection based on noise calculations.
Structural requirements	> Provided proof of stability for each individual part of the barrier as well as the barrier as a whole.
	> Application of standardized materials.
Application of prefabricated systems	> Increased execution speed.
	> Cost reduction.
	> Unification of assembly systems.
	> Unification of panel types.
	> Easier maintenance.
Material requirements	> Rust resistance.
	> Frost resistance.
	> Salt resistance.
	> UV resistance.
	> Good sound absorption.
	> Prescribed mechanical characteristics of materials in the construction.
Maintenance requirements	> Unified production system of sound barrier elements.
	> Unified assembly system.
	> Reduction of production, transport, and assembly costs.
	> Facilitated surface cleaning.
	> Facilitated transport and assembly of damaged or worn-out elements.
Durability requirements	> The durability of the system is 20 years.

Based on the experiences of neighbouring countries and design practice in our country, it has been established that panels, according to profitability and height, can be divided into 3 groups: low, medium, and high.

<b>Classification by the height of noise barriers.</b>			
	Height	System	
Low	from 0.0 to 3.0	Custom:	Foundation.
		Standardized:	Post.
			Prefabricated panels.
Medium	from 3.0 to 6.0	Custom:	Foundation.
		Standardized:	Post.
			Prefabricated panels.
High	> 6.0	Custom:	Complete construction depending on the architectural solution.

High barriers are quite complex structures, often with curved walls, extremely expensive, which are used in urban areas or near high residential buildings. Due to the low probability of the need for high noise protection panels, they will not be considered in these guidelines.

Low and medium-high barriers are suitable for the protection of rural areas through which Corridor Vc mainly extends.

Due to the possibility of an increase in noise levels during exploitation and the relatively small additional investment to increase the barrier height, the optimal solution is to dimension the column anchors and the foundation structure to a minimum barrier height of 5.0 meters, regardless of the actual calculated height.

Although there are several kinds of posts that are used for barriers, steel posts HEA(B) 120-280 are considered to best fulfil majority of the requirements.

The advantage of these posts is:

- Availability on the market;
- Possibility of mounting all types of panels;
- Simple and easy installation;
- Flexibility due to the replacement of damaged posts, or increasing the noise protection capacity;
- Possibility of recycling the posts;
- Relatively cheap maintenance;

The only serious drawback is the initial price of steel posts, which is 3-5 times higher compared to concrete ones.

Concrete posts, on the other hand, have a fairly low production cost. They are suitable for mounting only concrete panels. Due to their relatively high weight, transport and installation are more demanding. Because of the monolithization of the wall after installation, it lacks flexibility when increasing the wall height, nor does it offer the possibility of recycling the same posts.

The concluding recommendation for designers is to generally use steel posts, except in cases where the use of concrete ones is justified.

Noise protection panels can be made of various materials, depending on the needs of the environment in which they are installed. One of the basic conditions is that they meet the prescribed conditions for noise absorption and reflection. Another important thing is the standardization of panel dimensions and the method of attaching them to the posts.

Attached is a table of minimum requirements for all elements of protective barriers, as well as the standards in which they are defined.

### 6.1. Minimum technical requirements

Minimum requirements per structural element				
Structural element	Type of material	Requirements	Standards	
Foundation	Reinforced concrete	Material quality: C25/30 XC2	Eurocode 2	
Post	Reinforced concrete	Material quality: C30/37 XF2	Eurocode 2	
	Steel	Material quality: Č 0361 Surface protection: Hot-dip galvanized 85 µm	JUS	
Noise protection panels	Reinforced concrete	Material quality: C30/37 XF2	Eurocode 2	
		Sound absorption: $DL\alpha > 5$ dB	EN 1793-1	
		Sound insulation: $DLR > 24$ dB	EN 1793-2	
	Aluminium	Standard of dimensions and quality.		DIN 52210
				DIN 52212
				DIN 1725/1
				ZTV-LSW 88
			Sound absorption: $DL\alpha > 5$ dB	EN 1793-1
			Sound insulation: $DLR > 24$ dB	EN 1793-2
	Wood	Vacuum impregnation of wood Protection against fungi and insects Sound absorption: $DL\alpha > 5$ dB Sound insulation: $DLR > 24$ dB Use of construction timber for the production of elements.		DIN 68 800, T3
				DIN 68 800, T4
				EN 1793-1
				EN 1793-2
				DIN 4074
				DIN 52210
				DIN 52212
				DIN 1725/1
	Plexiglass	Standard of dimensions and quality.		ZTV-LSW 88
				DIN 52210
				DIN 52212
			DIN 1725/1	
Sound absorption: $DL\alpha > 5$ dB			EN 1793-1	
Sound insulation: $DLR > 24$ dB			EN 1793-2	

## **7. INSTRUCTIONS FOR DESIGN AND INSTALLATION OF PROTECTIVE WIRE FENCES**

## **Introduction**

The purpose of installing protective wire fences on motorways is to increase traffic safety by preventing the crossing of people and wildlife over the motorway, as well as the illegal entry of vehicles from surrounding roads onto the motorway itself.

A protective wire fence is installed along the entire length of the motorway route, except in places where natural or artificial obstacles already exist that functionally replace the protective wire fence.

Given that there was a need for the unification of design solutions for protective wire fences, we performed a technical analysis and defined the necessary requirements that the design solutions must meet.

During the analysis, the following norms were used:

- 1) BAS EN 10240; Internal and/or external protective coatings for steel pipes - Specification for hot dip galvanized coatings applied in automatic machines (supporting posts and angled support)
- 2) BAS EN 10244-2; Steel wire and wire products – coating of non-ferrous metallic coating on steel wire – Part 2: zinc or zinc alloy coating (drag wires, meshes, clips),
- 3) BAS EN 10204; Metal products – types of Inspection documents (turnbuckle hook and eye)
- 4) BAS EN 10219-1; Cold formed welded structural hollow sections of non-alloy and fine grain steels - Part 1: Technical delivery conditions
- 5) BAS EN 10016-1; Non-alloy steel rod for drawing and/or cold rolling - Part 1: General requirements
- 6) BAS EN 10016-2; Non-alloy steel rod for drawing and/or cold rolling - Part 2: Specific requirements for rods for general purpose
- 7) ISO 1461 - braces

This instruction prescribes the type and basic requirements for protective wire fences, and all other requirements that by their scope exceed the form of this document should be in accordance with the above-mentioned standards and regulations.

Upon consideration of all facts including all applicable standards, we propose the minimum technical conditions that protective wire fences need to satisfy.

## 7.1. Minimum technical requirements

Table 1. – Minimum technical requirements

All fence elements must be hot-dip galvanized, all in accordance with European Standards	
Zinc used for coating according to the BAS EN 10244-2 standard should have a purity of 99.95%.	
Description of fence elements	
Interim posts (line post)	<ul style="list-style-type: none"> <li>- The intermediate post has a diameter of <math>\varnothing 60.3</math> mm and a height of 2450 mm. Of this, 750 mm is in the foundation and 1700 mm is visible above ground.</li> <li>- The post is founded on a foundation footing with a depth of 80cm in concrete of strength class C16/20</li> <li>- The distance between the posts is 350-400cm.</li> <li>- The wall thickness of the post is 2mm according to BAS EN 10219-1</li> <li>- The galvanization of the post is according to BAS EN 10240-class A.1, 55<math>\mu</math>m</li> </ul>
Strainer post and supporting post	<ul style="list-style-type: none"> <li>- The strainer post and supporting post should be made of the same material as the line posts, and subject to same conditions regarding foundation, galvanization, and wall thickness</li> <li>- The distance between strainer posts is 25m and they are connected to each other with galvanized braces which are fastened with galvanized M8 screws.</li> </ul>
Mesh	<ul style="list-style-type: none"> <li>- The wire mesh shall have openings 60x60 mm, wire diameter 2.7 mm and height of 1400 mm.</li> <li>- The mesh shall be fixed to the strainer posts by staples of 2 mm and galvanized in accordance with EN10244-2. Connection shall be done on 3 strainer wires each 30-50 cm.</li> <li>- The mesh may be additionally fixed by wedges into the soil to prevent animals from going under it. The mesh may not be more than 5 cm above the soil. The wedges shall be galvanized with a hook at the top, and their dimensions shall be 50-80 cm and they shall be placed at the distance of 1.0 m. "Wedging" of the fence serves at the same time as grounding of the protective wire fence.</li> <li>- The mesh shall be galvanized in accordance with EN 10244-2 – Class A, 245g/m<sup>2</sup></li> </ul>
Straining wire	<ul style="list-style-type: none"> <li>- The mesh shall be affixed with help of three straining wires of 3.0 mm in diameter. Two wires shall extend along both ends of the mesh, and the third is in the middle.</li> <li>- Two additional straining wires shall be placed above the mesh, at the distance of 150 mm.</li> <li>- Straining wire for posts shall be fixed with self-cutting screws on pads, and they shall be strained by galvanized turnbuckles (hook-and-eye).</li> <li>- The tensile strength of the wire shall comply with BAS EN 10016-1 and BAS EN10016-2, meaning 350-500 N/mm<sup>2</sup></li> <li>- Galvanization shall comply with EN 10244-2-Class A, 245g/m<sup>2</sup></li> </ul>

## **8. INSTRUCTIONS FOR CONSTRUCTION OF CONCRETE PAVEMENT ON CP BUILDINGS**

## **Introduction**

Through a detailed analysis of the constructed toll plazas on the motorway, namely: Jošanica, Podlugovi, and Visoko, certain deficiencies in the construction of concrete pavements at toll plazas were identified. The biggest recorded problem was the placement of equipment used for control and management (installation pipes, inductive loops, etc...). Because of all the above, the constructed concrete pavement at the mentioned toll plazas had to be reconstructed, which caused additional costs, delays, and congestion at the toll plazas. In order to avoid the mentioned problems in the future, we have prepared these instructions for all designers, supervisory teams, and contractors, i.e., for all sections that are in the design phase, in the preparation phase for construction, or in the construction phase.

### **8.1. Minimum technical requirements**

#### **8.1.1. Geometry**

Without going into the unification of the architectural solution, which will be the subject of a future instruction or guideline, these instructions provide the minimum distance of the beginning of the concrete pavement at toll plazas in relation to the tip of the island. Therefore, if the length from tip to tip of the island is  $L=30$  m, the beginning of the concrete island is extended by 3 m in relation to the tip of the island, thereby providing sufficient space for placing equipment, as well as space for a high-quality transition from asphalt to concrete pavement. Along with the stated requirement, it is necessary to take into account the expansion of the concrete pavement slab every 6m, with the execution of expansion joints.

#### **8.1.2. Quality of concrete pavement**

Given that this area is not regulated by domestic regulations, norms, rules, and standards, these instructions provide a guideline to designers, supervisory teams, and contractors to use for the design and construction of concrete pavements, but not limited to, the General Technical Conditions (OTU) from the Republic of Croatia, specifically Book IV, part 7-02 Concrete Pavement, where the following is clearly described:

- 7-02.1. Quality of concrete for concrete pavement
- 7-02.1.1 Constituent materials
- 7-02.1.2 Concrete
- 7-02.2 Dimensioning of concrete pavement
- 7-02.3 Expansions
- 7-02.4 Dowels and anchors
- 7-02.5 Reinforcement
- 7-02.6 Construction
- 7-02.7 Control and confirmation of compliance of works performed
- 7-02.8 Calculation of work costs.

### **8.1.3. Special requirements**

Special requirements related to the design and construction of concrete pavements consist of the following:

- design the reinforcement of the concrete pavement in such a way as to obligatorily indicate a protective layer in relation to the upper edge of the pavement with a thickness of  $d=7$  cm.
- Ensure sufficient skidding resistance through surface treatment of the upper edge of the roadway.

## **9. INSTRUCTIONS FOR ENERGY CERTIFICATION OF BUILDINGS BELONGING TO JP AUTOCESTE FBIH**

## **Introduction**

The position of JP Autoceste FBiH is to build energy-efficient buildings of class A+ or A. These instructions issue an order to designers, supervisory teams, and contractors to comply with the requirements of applicable regulations related to building physics, thereby enabling the technical acceptance of buildings and ensuring that they achieve an energy class of A+ or A.

### **9.1. Instruction**

For all buildings that are in the design phase, it is necessary for designers to take the above conditions into account during design.

For buildings that are in the construction preparation phase, or where construction is ongoing, it is necessary to engage a consultant through a public procurement procedure who will analyse the buildings and offer a solution to meet the above requirements and ensure compliance with the "Rulebook on Technical Requirements for Thermal Protection of Buildings and Rational Use of Energy". The consultant's task is organized into four phases.

In the first phase, the consultant's task is to:

- perform an analysis of the existing documentation of buildings heated to temperature above 12°C,
- determine any deficiencies in the design in relation to the requirements of the Rulebook on Technical Requirements for Thermal Protection of Buildings and Rational Use of Energy.“ (hereinafter the Rulebook),
- perform calculation and verification of thermal characteristics in accordance with Article 7.

In the event that the existing solution does not meet the requirements prescribed by the Rulebook for that type of building, the consultant will proceed to the second phase of the task.

In the second phase, the consultant's task is to:

- propose an alternative solution for buildings that do not meet the requirements regarding the rational use of energy. The alternative solution will be based on the use of materials with different thermal properties compared to the existing project (e.g., the use of bricks or blocks instead of concrete where possible), different thicknesses of insulation materials, etc.
- after the Investor accepts the offered solution, develop an appropriate architectural project with a technical description, all necessary drawings, and a bill of quantities.

In the third phase, the consultant's task is to develop a technical solution that meets the requirements of the Rulebook, all in accordance with the provisions of Article 49 of the Rulebook:

- Technical description
- Calculation and verification of thermal characteristics in accordance with Article 7.
- Calculation of annual thermal energy for heating and cooling for actual climatic data
- Quality control and assurance program during construction
- Necessary drawings
- Methodology for monitoring the building during use
- Certificate of required thermal energy in accordance with Article 55 and Annex D.

In the fourth phase, the consultant's task is to:

- perform the energy certification of the building in accordance with the provisions of the Rulebook on energy certification of buildings
- fulfil all other obligations arising from the Rulebook on energy certification of buildings.

The consultant must hold authorization from the competent authority for energy certification of buildings. In addition, the consultant is obliged to provide in their expert team that will work on this task:

- at least one graduate mechanical engineer (MSc/BSc) authorized to conduct energy audits,
- at least one graduate architect (MSc/BSc) authorized to conduct energy audits.

In the event that Phase 2 of the task is carried out, the consultant is required to engage a subcontractor authorized to prepare architectural designs.

## **10. INSTRUCTIONS FOR DESIGN AND INSTALLATION OF LED LIGHTING**

## **Introduction and scope of application**

JP Autoceste FBiH, as a company committed to socially responsible operations in line with its mission of constructing, managing, and maintaining modern road infrastructure, while respecting the highest environmental standards and meeting the needs of service users, strives to align its activities with the latest technological advancements and to apply them in its daily operations.

The general position of JP Autoceste FBiH is to minimize energy consumption for lighting, and therefore this instruction has been prepared for all designers, supervisory teams and contractors, i.e., for all sections in the design phase, preparation for construction, and construction phase.

The subject of these instructions is the design and redesign of outdoor lighting at toll plazas, lighting of interchanges, rest areas and COKP facilities, as well as the design of lighting in tunnels longer than 1000 m.

The newly designed lighting solutions should be based on LED technology.

The advantages of LED technology are numerous, and some of the key ones include:

- reduced electrical energy consumption
- high efficiency of the chromatic spectrum
- long lifespan (approx. 50,000 working hours, under optimal conditions)
- negligible initial failure rate
- reduced luminaire dimensions
- high resistance to mechanical damage and vibrations
- direct light emission
- no IR and UV radiation
- reduced power absorption
- minimal heat dissipation
- reduced CO<sub>2</sub> emissions

As a critical component of LED lighting systems is the driver (control gear), special attention must be paid to its selection, as well as taking into account the origin of the LED chips and the selection of LED luminaire manufacturers (e.g., LED modules Philips, Osram...), and to require appropriate warranties from manufacturers as specified in official declarations within the project documentation.

If LED lighting is proposed for tunnels shorter than 1000 m, the design must include an economic feasibility analysis comparing the replacement of conventional lighting systems, high-pressure sodium lamps and metal halide lamps, with LED-based lighting.

The design must also include an economic and technical feasibility analysis for replacing the originally designed lighting system based on high-pressure sodium and metal halide lamps with a newly designed LED lighting system.

The project solution relating to toll stations and COKP facilities should retain the originally planned layout and number of lighting fixtures (where possible); if the parameters of the lighting calculation cannot be met, certain modifications are permitted in terms of the arrangement and number of newly designed luminaires.

### 10.1. Basis for project design

The project should be prepared in accordance with the terms of reference, applicable valid technical regulations, rulebooks, norms, guidelines, and recommendations.

The goal of highly efficient tunnel lighting is to enable the driver's visual perception to be maintained in night-time and daytime driving conditions, while avoiding sudden changes in the lighting level at the entrance and exit of the tunnel.

The subject of these instructions is the design and redesign of outdoor lighting at toll plazas, as well as the outdoor lighting of interchanges, rest areas, and COKP facilities.

#### 10.1.1. Photometric parameters of outdoor lighting

	Roadway (main direction)	Roadway (entry – exit ramps)	Toll plaza area
Road lighting class	M1	M2	C1
Minimum maintained value of average luminance	LaV = 2.0 Cd/m <sup>2</sup>	LaV = 1.5 Cd/m <sup>2</sup>	
Minimum overall uniformity of luminance	U <sub>0</sub> = 0.4 (40%)	U <sub>0</sub> = 0.4 (40%)	
Minimum longitudinal uniformity of luminance	U <sub>l</sub> = 0.7 (70%)	U <sub>l</sub> = 0.7 (70%)	
Minimum value of surroundings coefficient	SR = 0.5	SR = 0.5	
Maximum allowed value of glare threshold increment	TI = 10%	TI = 10%	
Average illuminance level of the parking lot			Em = 30 lx
General uniformity of parking lot illuminance			Jr = 40%

The specified quality criteria for road lighting are minimal. The project can provide a higher quality solution, but it must meet the criteria of economy and environmental impact.

#### 10.1.2. Tunnel lighting according to tunnel length

Requirements for tunnel lighting are different for short and long tunnels. Visibility through the tunnel depends primarily on the length of the tunnel, but also on other geometric parameters of the tunnel (width, height, horizontal and vertical curvature, etc.). In general, tunnels are classified as “long tunnels” and “short tunnels.”

The classification into long and short tunnels is not based solely on tunnel length, but also on the driver's ability to see the end of the tunnel from the entrance. Therefore, tunnels that are shorter in length but where the driver cannot see the exit from the entrance are also classified as long tunnels. The lighting of such tunnels should be treated in the same way as for long tunnels.

Based on lighting criteria, tunnels are classified into three categories:

- Geometrically long tunnels
- Optically long tunnels
- Short tunnels

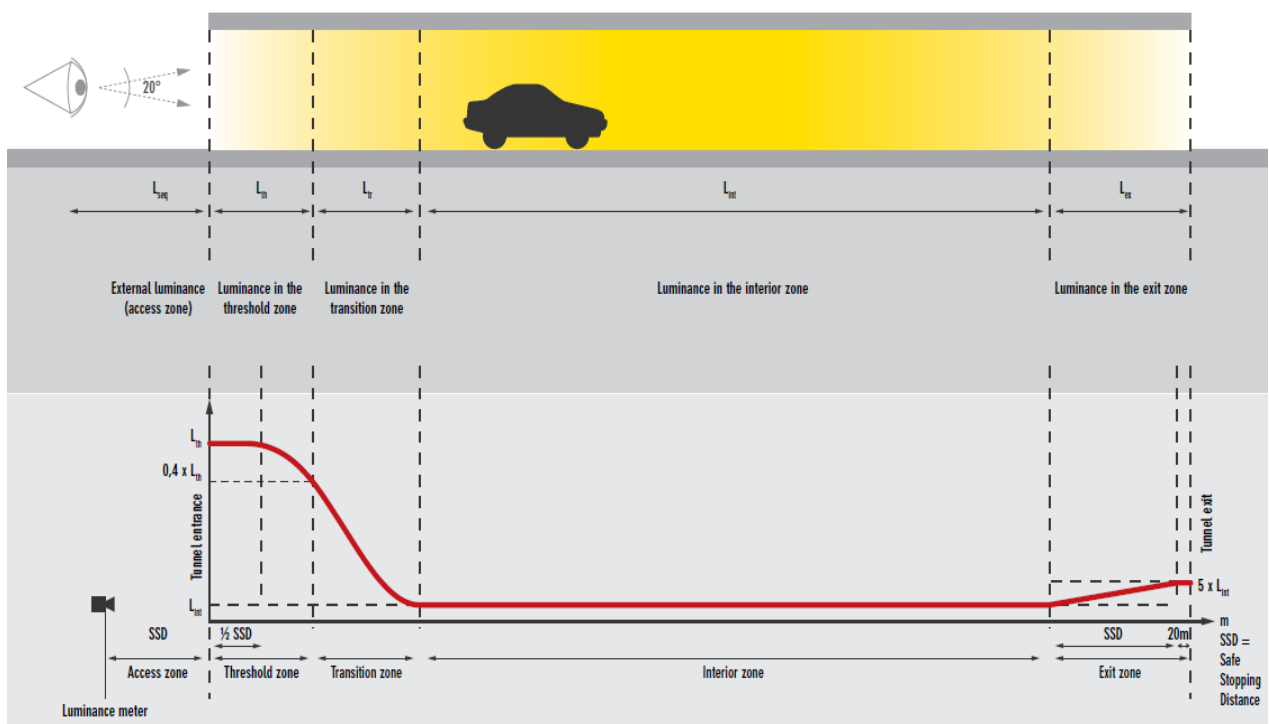
For detailed lighting design, tunnel visibility should be determined graphically.

### 10.1.3. Tunnel lighting according to the permitted vehicle speed

The permitted driving speed should be taken into account when designing the tunnel lighting system. In general, this is the speed on the basis of which the tunnel itself has been designed.

### 10.1.4. Division of tunnels into zones according to lighting levels

Below is a diagram of the division of tunnels into characteristic transition zones. When designing the required LED lighting, special attention must be paid to the proper definition of these zones, and the complete calculation should be based on them.



**Access zone (L20)** – the part of the road immediately in front of the tunnel entrance, from whose beginning it must be possible to detect potential obstacles inside the tunnel. The beginning of the access zone is at a distance equal to the stopping distance of the vehicle. The access zone should enable optimal and rapid visual adaptation before entering the tunnel.

**Threshold zone (Lth)** – the entrance part of the tunnel where it is necessary to provide a sufficiently high level of brightness that will allow the driver, still under the influence of external brightness, to detect possible obstacles before entering the tunnel. The length of the threshold zone is at least equal to the stopping distance of the vehicle, defined by the vehicle speed and pavement condition.

**Transition zone (Ltr)** – follows the threshold zone, along which the brightness in the tunnel gradually and properly decreases, without the danger of visual conditions becoming unstable.

**Interior zone (Lin)** – the part of the tunnel where the driver's vision is adapted to the lowest level of brightness in the tunnel, which remains constant up to the tunnel exit.

**Exit zone (exit zone - Lex)** – serves to adapt the driver's eyes when exiting the tunnel.

### 10.1.5. Flicker observed while driving through tunnel

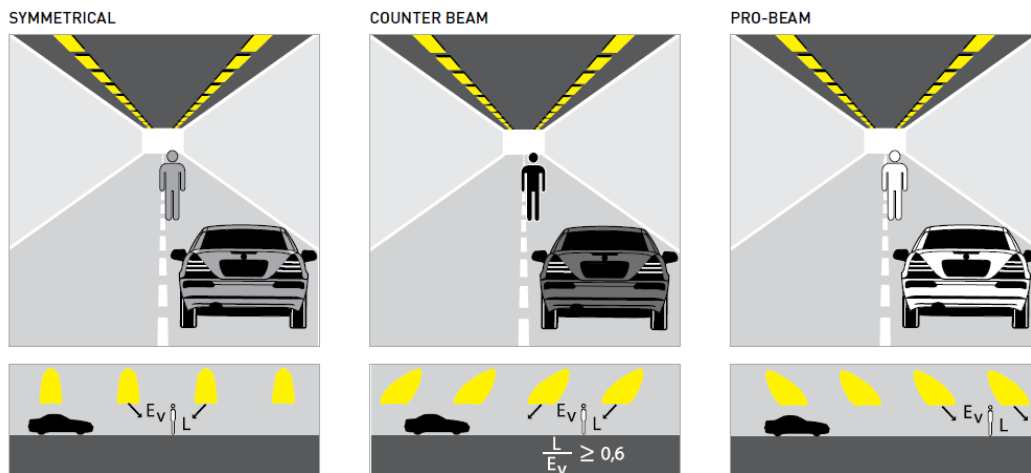
When driving through a tunnel, the driver must not be disturbed by the flickering of lights. Depending on the speed limit and the distance between the lamps, flickering may occur at certain perceptible frequencies. The lighting system must be designed and arranged in such a way as to avoid this effect.

### 10.1.6. Contrast according to tunnel lighting method

Drivers must be able to detect any obstacle, regardless of their position or location in different parts of the tunnel. For these purposes, a contrast must be created between the obstacle and its background. An obstacle can be emphasized either by being more illuminated than its surroundings or by appearing darker, which is achieved by directing the lights inside the tunnel. Three models of interior lighting have been developed, as shown below:

- Symmetrical lighting (both the vehicle and the obstacle are identically illuminated)
- Asymmetrical lighting with negative contrast (the obstacle appears darker)
- Asymmetrical lighting with positive contrast (the obstacle appears brighter)

Below is a schematic representation of vehicle and obstacle lighting.



### 10.1.7. Technical standards

As the primary document for preparing the photometric design, use the technical standards of the European Commission for lighting EN/CR 14380 – Annex A2. The specified road lighting quality criteria represent minimum requirements. The design may provide higher-quality solutions, but must also meet criteria of cost-effectiveness and environmental impact. Technical conditions

## **10.2. Technical conditions**

### **10.2.1. Technical solution**

In addition to the basic function (lighting), the technical solution must include the regulation of road and tunnel lighting, as well as measurement, monitoring and control.

### **10.2.2. Power supply for road lighting**

The power supply for road lighting should be provided from the nearest substation within the Motorway, i.e., from the nearest low-voltage (LV) distribution cabinet. The distribution should be designed so that the main road lighting cabinet is supplied from the substation with a single LV connection, and from that main cabinet, all other lighting distribution cabinets are supplied. The power supply for road lighting at toll plazas and platforms should be taken from the main distribution cabinet within the toll station facility.

The power supply for tunnel lighting, i.e., the corresponding distribution cabinet, should be provided from the nearest substation within the tunnel. When designing LV cabinets, it is necessary to ensure the redundancy of their power supply, in such a way that all outdoor lighting cabinets have the possibility of being supplied from both transformers of the corresponding substation (portal or tunnel).

### **10.2.3. Monitoring and control**

Control of road and tunnel lighting includes switching the lighting on and off, and managing operating modes. Monitoring refers to transmitting system status signals and measured values of road and tunnel lighting to the Traffic Control and Management Center (COKP). For road lighting, monitoring (only the necessary cable infrastructure) should be provided for interchange lighting. A workstation with a lighting control system is not part of this project.

The project documentation should provide the possibility of remote and local control. For the possibility of remote control, only cable infrastructure is required. Remote control applies only to the road lighting of the interchange.

Local control, at main road lighting distribution cabinets and tunnel cabinets, must enable:

- Selection between remote control from COKP or local control from the distribution cabinet
- Manual switching on and off of lighting for the selected local control mode
- Automatic switching on and off of lighting and regulation of luminous flux using predefined (programmed) daily - monthly schedules
- Control using an illuminance measuring device (lux meter) - photometer.

Local distribution cabinet of the toll station facility, including toll plaza and service facility lighting, shall enable the following:

- Manual switching on and off of lighting for local control
- Automatic switching on and off of lighting and regulation of luminous flux using predefined (programmed) daily - monthly schedules
- Control using an illuminance measuring device (lux meter)

#### **10.2.4. Measurement**

Measurement of electrical energy consumption of road lighting should not be considered separately, nor should individual meters be provided for road lighting. Electricity consumption of electrical energy consumption will be provided at the medium voltage of the corresponding substation, i.e., ultimately at one place for the complete section of the Motorway.

In distribution cabinets intended for the supply and control of tunnel lighting, the project should provide digital multimeters (current, voltage, and frequency measurement, active, reactive and apparent power measurement, electrical energy quality measurement, operating hours counter, data recording, communication RS485, Modbus protocol, Ethernet). In the event that lighting and ventilation are supplied from the same distribution cabinet, it is necessary to separate the busbars in order to ensure separate monitoring of electrical parameters for lighting and ventilation.

#### **10.3. Components of road and tunnel lighting installations**

The main components of the installation are: luminaires, drivers for luminaires, poles, cables, devices for power supply and distribution, regulation and control devices.

##### **10.3.1. Poles**

Road lighting poles must be made of steel and protected against corrosion by hot-dip galvanization. The structural design of the pole must include spigot for luminaire mounting, adapter for luminaire installation, access opening for the pole distribution unit, base plate, and foundation with installed galvanized anchor screws and cable conduits for cable entry.

##### **10.3.2. Luminaires**

Luminaires, in terms of photometric characteristics, shall be based on LED technology, and according to structural features, they must be resistant to environmental conditions, including mechanical loads due to wind, corrosion, dust, moisture, vibration, and temperature, and must also have good thermal properties to ensure effective cooling of the driver and all its constituent parts. The degree of mechanical protection must be at least IP55 for road lighting, and IP65 for tunnel lighting. In terms of maintenance, luminaires should be designed for easy installation with minimal use of tools.

Driver – control gear, must be accessible, of high quality and have a long service life.

They can be integrated into the luminaire or installed in a separate housing..

Adjustable output current in the range from 200 mA to 700 mA

Temperature range -40 °C to 80°C

Nominal input voltage 120V – 277V

Power factor > 0.9

Lifespan: minimum 50000 hr

Total harmonic distortion < 20%

Surge protection in accordance with the IEEE / ANSI C62.41.2 Transient Surge Requirements directive

## **LED Luminous Flux Maintenance**

Maintenance of 90% of nominal luminous flux after 5 years (45,000 hours) and 80% after 10 years (90,000 hours) at an ambient temperature range of -5°C to +28°C.

### **10.3.3. Cables**

Cables for power supply and signalling may be copper or aluminium with PVC insulation for road lighting, while for tunnel lighting they must be halogen-free. When selecting a cable, market prices should be carefully considered and the most economically favourable solution chosen. Cables for uninterrupted power supply must have flame-retardant, halogen-free insulation with functional integrity maintained for a minimum of 90 minutes. For monitoring and control purposes, signal cables should be installed and must be shielded to reduce environmental interference.

### **10.3.4. Distribution cabinets**

Power supply and distribution devices for road lighting should be designed as free-standing cabinets for outdoor installation with a degree of mechanical protection of at least IP55, and must have appropriate structural properties in accordance with environmental conditions and operating requirements.

### **10.3.5. Distribution boards**

Distribution cabinets for the supply and control of tunnel lighting should be installed in tunnel electrical niches, manufactured with a high degree of mechanical protection, at least IP54, and must meet structural requirements appropriate to environmental and operational conditions. In addition to busbars supplied from the main power grid, the distribution cabinets should also include busbars supplied via an uninterruptible power supply (UPS), through which a portion of the lighting system will remain operational in case of a power outage.

## **10.4. Visual guidance**

The design must also address the issue of visual guidance, which provides drivers with a clear perception of the road alignment and direction. This is achieved through an appropriate arrangement of lighting poles and light sources, based on established engineering practices.

## **10.5. Environmental impact**

The solution must consider the reduction of light pollution, which can disrupt natural biological cycles and contribute to environmental degradation. Design solutions should be optimized according to the following principles: illumination level should be sufficient for the functionality, but not exceed actual needs, only areas where lighting is truly required should be illuminated. These guidelines must not compromise safety levels. Additionally, the use of luminaires that unnecessarily disperse light is typically highly energy-inefficient—resulting in excessive electricity consumption, increased costs, and greater negative environmental impact.

## **10.6. Project documentation**

The project should be prepared at the level of a Main project and must include civil, electrical, and, where applicable, mechanical design components. The civil design must include, in addition to plan drawings of the structure, cross-sectional drawings of traffic surfaces with indicated foundations and lighting poles. The electrical engineering project shall include: technical description, quality control and assurance program, calculations, bill of quantities for materials and works, drawings, including: layout of traffic surfaces with indicated cable routes, cross-sections of trenches for cable installation, lighting poles and equipment, general schematic diagram, circuit diagrams of main and auxiliary circuits, diagram or table of operational sequence (e.g., for automatic control operation), control algorithm for automated system operation.

## **10.7. Deviation from Terms of Reference**

The designer may propose modifications to the Investor in relation to the Terms of Reference, and may deviate from the specified values only with the Investor's approval. Any proposed modification must include a professional justification for the proposed change.

## **11. INSTRUCTIONS FOR DESIGN AND IMPLEMENTATION OF LOW VOLTAGE SYSTEMS**

## **11.1. Instructions for design of low voltage systems**

### **11.1.1. Instructions for design of low voltage systems**

Within the building, it is necessary to plan a space for placing information and communication technology (ITC) infrastructure:

Plan a room (system room) for placing the IT and communication equipment. This room shall be designed in accordance with recommendations and standards for placing ITC equipment, with suspended ceiling and higher floor, appropriately ventilated and air-conditioned, fire protection applicable for fire extinguishing in radio communication system, supervision system and access control, and separate power supply system in a separate air-conditioned room. A redundant system for air conditioning and uninterrupted power supply needs to be planned, as well as a connection to the diesel generator.

The system room needs to have open communication with the existing ITC infrastructure of the motorways and with the public telecommunication network of the telecommunication services provider.

For reasons of safety and practicality, it is not recommended to locate the room in the basement (length of the cable to the end users, floods, etc.) or on the ground floor (length of the cables, security considerations); instead, it should be located in the middle part of the building.

Installations of individual systems should be created with the following recommendations:

#### **11.1.2. Structured cabling**

Installation of the ITC network shall be done by structural cabling FTP or SFTP of at least category 7. FTP cables shall be installed on the installation grooves or specially prepared cable channels. FTP cables shall end in the rooms with connectors RJ45 and on the panel of stackable ITC cabinet of minimal dimensions 2000x1000x600 and standard EIA 42U with perforated front and back door. It is recommended not to lean the cabinets against walls and instead put them at the central space of the room, so that one may go around them. Cable channels that lead to the communication cabinets should enter from the bottom part of the raised floor.

The number of connection points is 6xRJ 45 per work station.

In each logically separate wing of the building, and in each physically separate building that needs to communicate with the system room, there must be a wall-mounted communication cabinet of at least 12U height, with four multimodal optic fibre outlets, and four FTP cable outlets (where the conditions at the site allow for that in compliance with the TIA/EIA-568 standard). Each cabinet must be supplied with power from the central UPS. All cabinets should be used for possible addition of communication equipment in the form of the DECT antennas, WiFi APs, etc.

All multi-modal fibres for cross-connections of the cabinets must terminate with the other side in the main FO communication cabinet of the server room, together with all SM fibres from the main FO route and all other FO fibres for any other subsystem supervised by the COKP.

### **11.1.3. Network infrastructure**

All network infrastructure shall be done using advanced switching technologies, so that different services would be allowed to use different VLANs (special VLAN for telephony, video surveillance, Internet...)

VLAN Trunks should be implemented using FO local and MAN infrastructure.

### **11.1.4. Telephony**

All telephony should be based on VoIP. For structured cabling, it is necessary to use the structured cabling of the telephone network, although it is recommended that VoIP be implemented on a separate VLAN. The telephone exchange should be located in the communication cabinet as a rack-mounted device. If circumstances permit, the installation of local exchanges should be avoided, and the use of remote exchanges exclusively via VoIP (e.g., IP Centrex, etc.) should be encouraged.

### **11.1.5. Video surveillance**

The video surveillance system needs to be implemented using modern digital systems. Encourage use of PoE IP cameras, and if for realistic reasons the use of IP cameras is not possible, an appropriate reserve of FTB cables must be planned for possible upgrade at a later time. All FTP and possibly Coax cables of surveillance should end at a panel within the system room. In the same communication cabinet, it is necessary to provide for the placement of a rack-mountable DVR, and all further communication and monitoring over it must be done via the network infrastructure, i.e., a separate VLAN intended for video surveillance, as well as the communication of all IP cameras in the system.

### **11.1.6. Servers and server platform**

All server systems need to be designed with the aim of maximizing their reliability and availability. Special attention must be paid to resource consumption and consolidation. Where possible, the use of Blade chassis for servers is advised, as well as separate data servers in the form of Storage NAS and SAN servers. Plans should be made for virtualization of server resources with the aim of reducing costs and facilitating maintenance.

All communication of the server platform should be redundant with the communication infrastructure.

### **11.1.7. Other communication and sensory equipment**

All other systems, such as radio systems, various sensory and telemetry systems, should also be arranged in the system room cabinets, logically according to the function and interfaces they need to use.

## **12. INSTRUCTIONS FOR DESIGN AND CONSTRUCTION OF ROADS IN TUNNELS**

## **Introduction**

The requirements that road pavement in tunnels needs to meet are essentially the same as for road pavement structures in general. They should be:

- Safe
- Comfortable
- Durable
- Cost-effective

In the following text, we will conduct a comparative analysis of the basic requirements of the road structure for concrete pavement and asphalt pavement.

### **12.1. Skidding resistance of pavement structure**

The friction coefficient for Rubber-Asphalt materials is 0.6-0.85, and for Rubber-Concrete 0.5-0.80. From these ratios, it can be established that the adhesion of the tire to the surface is relatively uniform for both concrete and asphalt surfaces. A significant difference does not occur even in the case of wet pavement.

In the case of long tunnels, due to the retention of a large amount of dust and grease on the pavement structure, which would be washed away by rain or blown away by winds on an open road, there is an accelerated process of loss of roughness of the pavement surface, and thus a reduction in skidding resistance. The advantage of the asphalt structure over the concrete one is that the thin upper layer of the pavement structure can be removed very easily and cheaply and replaced with a new wearing course. In case of concrete pavement, the whole pavement would have to be reconstructed because it is not possible to remove and then pour anew the upper layer of the pavement. In this case, the costs of removing and building a completely new pavement structure would be far greater than replacing the wearing course.

### **12.2. Visibility, colour, and contrast**

In the case of colour, for tunnel pavements, a slight advantage can be given to concrete pavement due to its lighter colour. The reflection of light from the pavement surface affects the illumination level of the entire tunnel. Due to the lighter colour of the concrete pavement, it is possible to achieve the same degree of illumination of the entire tunnel with a smaller amount of lighting than in the case of a surface that poorly reflects light, and thereby achieve certain savings in electricity consumption. However, it has to be mentioned here that one can now achieve lighter colour of asphalt pavement by adding lighter aggregate and some additives to the mixture.

From the aspect of safety, overview, and visibility in the tunnel, better results are achieved in the case of a stronger contrast between the surface, the tunnel wall, and the road signalization. Road signalization is made of fluorescent or bright colours, precisely to emphasize the contrast and increase the visibility of adjacent moving objects. In this case, a darker surface provides better performance compared to a lighter one.

### **12.3. Longitudinal and transverse evenness of pavement**

The evenness of the top layer is the difference between the designed and finished state. The evenness of the finished layer of the pavement is measured by a 4-m-long bar. According to the applicable Guidelines, the permissible deviation is 4 mm per 4 m in the longitudinal and transverse directions.

By reviewing the proposed technology of the contractor, it was established that it is possible to meet the strict requirements of the Guidelines in terms of longitudinal and transverse pavement evenness for both types of materials.

The main difference between concrete and asphalt lies in the stiffness of the structure and, during execution, the need for construction joints. Both elements significantly contribute to or hinder the required conditions of the road pavement.

In the case of frequent occurrence of construction joints (in case of concrete pavement at every 5.5 m), in the event of an execution error or premature uncontrolled cracking of the concrete structure, due to the constant dynamic impact of cars on the construction joint, localized settlement of one slab relative to another may occur, which increases the chance that the strict conditions set by the Guidelines will not be met. All this leads to a reduction in driving comfort and can increase the possibility of causing a traffic accident.

On the other hand, it is very well known that due to continuous hot-mix paving, there are no construction joints as in the case of concrete pavement structures.

### **12.4. Impact of noise reduction**

The current technology of road vehicles is so much advanced that the predominant source of noise is actually the contact between the car tire and road surface. Experience has shown that pavement surfaces with a high proportion of voids and fine-grained materials are acoustically more favourable compared to traditional asphalt and concrete.

The main difference between concrete and asphalt pavement is the stiffness of the structure. The characteristic of concrete is exceptional hardness and inflexibility, while asphalt pavement can be considered a flexible structure. Another very important difference is the appearance of construction joints. Also, the impact of noise reduction or increase largely depends on the quality of the type and the quality of the execution of the final surface.

In the case of concrete pavement, due to the high stiffness of the pavement, there is an increase in vibrations, and thus an increase in noise. If we add to this the appearance of construction joints where a dynamic impact occurs every 0.3 s (for a speed of 100 km/h), it is clear that the amount of noise generated while driving is extremely significant.

On the other hand, the wearing course of the asphalt layer is SMA, which is actually bituminized material characterized by large share of crashed rough aggregate that intermingles and produces a load carrying grid ("skeleton") stone-on-stone. The role of this skeleton is to carry the load and to produce high resistance to lasting deformation. The space between large pieces of aggregates is filled with bitumen matrix with polymer fibres that provide for durability and longevity of the asphalt pavement.

The principal difference between SMA and other traditional asphalts is the lack of a medium aggregate fraction, which ultimately contributes to having more voids in the aggregate structure, and thereby creates a rougher structure.

The advantage of SMA asphalt is that it provides excellent driving conditions (evenness, skidding resistance), high resistance to permanent deformation and cracking, as well as a noise reduction effect. If compared to conventional asphalts, a noise reduction of up to 3dB can be expected.

There are technologies that can produce a rougher surface on concrete pavements in order to achieve a noise reduction effect; however, it is characteristic of these technologies that skidding resistance is lost and they are not recommended for high-speed roads.

## **12.5. Fire resistance and its effect on pavement**

According to the technical description of the tunnel project, the main reason for choosing a concrete pavement structure is fire protection. Significant tunnel fires that occurred between 1999 and 2005 initiated a series of discussions on fire protection in tunnels, which resulted in numerous studies on the impact of the pavement structure on fire intensity.

The official position of PIARC, published in the report "Fire and Smoke Control in Road Tunnels", resulting from a significant volume of research work and studies on the impact of pavement structure on fire intensity is that: **"Standard asphalt pavements do not have a significant negative influence on safety in case of fire and may be used in tunnels"**. From all the studies, it is clearly seen that asphalt, as the selected material for the pavement structure, does not significantly contribute to the size of the fire (the amount of heat release, nor the total fire load) in the event of a fire in tunnels. This especially applies to the first phase of the fire, when the evacuation of the tunnel takes place.

Each of the studies also brought some individual perspectives on this problem. The studies and their conclusions are listed below.

- "Performance of pavements in asphalt and concrete in tunnels, particularly in case of fire" Germany – There is no reason why Germany should adopt the Austrian decision not to use asphalt pavements in new tunnels longer than 1000 m.
- "Sustainable and Advanced Materials for Road Infrastructure: Review on Reaction to Fire of Pavements Materials " Samaris - Examining and investigating incidents does not suggest that choice of materials for road pavement may additionally increase the risk of fires, even in case of catastrophic fires, as well exemplified in the case of fire in the tunnel St. Gothard.
- "Fire behaviour of asphalt pavement in case of road tunnel fire" France - in case of fire in the Mont Blanc tunnel, and based on temperatures estimated during investigations, the asphalt pavement had not been the cause of fire spreading.
- "Fire performance of road tunnels" France – As a general rule, recommended is the use of non-combustible materials for the ceiling, and low-combustibility materials for side walls, and no recommendation is given with regards to materials for pavement. It is also

recommended to pay special attention to the possibility of existence of sub-pavement galleries.

- "Brief Introduction to Tunnel Pavements Technologies" China – There is a possibility of coating the concrete or asphalt pavement with epoxy coat in order to, among other things, achieve characteristics of non-combustible material.
- "Fire performance of asphalt concrete" France – Bitumen-based pavement is not easily flammable and it would take a significant exposure to heat to cause self-ignition. It is likely that such level of exposure may exist only in the vicinity of a vehicle that is already in fire. Research results suggest that in case of ignition of the bitumen layer, only the top coat is burning because the "inner crust" forms on the surface of the remnants of burned bitumen. Quantity of measured fire flow is very low compared to the one in case of a burning vehicle. Quantity of emitted gasses and temperature of burning asphalt seems not to be such that could significantly worsen the situation for users during evacuation.

## **12.6. Pavement maintenance and cost of construction**

Maintenance costs of the existing roads are a daily burden on the budget placing new demands from it. For that reason, it is of essential importance to create preconditions for as cost-effective maintenance of road pavement as possible by proper choice of technologies, technical solutions and materials.

Depending on the type of damage on the concrete pavement (cracks, worn joints, wear and tear, damage, deterioration), the appropriate repair method should be used, although the repair methods do not improve quality of the pavement, they may extend the life of the pavement..

The issue with spot-repairs of the pavement in whole depth, in case of non-reinforced pavements (as is the case foreseen here) is the formation of construction joints where they are not planned, which would allow for the possibility of one part of the pavement to sink, which may compromise road safety.

Partial repairs up to one third of the pavement thickness are done in the areas of construction joints or repairing the edges of concrete pavement. In case that the damage goes deeper than 1/3 of the thickness, it should be repaired in the whole depth.

Materials used for such repairs are characterized by high density, extremely high hardness, and very limited shrinking, or are based on epoxy resins and special cements. Because of special requirements they have to meet, the quality of materials used for repairs must be high, and so must be their price.

Evening of the top surface of the road poses a special problem because of high traffic load and wear that lead to reduced skid resistance. At present, there is no cost effective method available to overcome this problem as it is not possible to achieve sufficient quality of connection between the thin layer of new concrete and the already existing concrete structure. Another problem is the rigidity of concrete itself, which in thin layers may easily crack. So a general recommendation is given that the whole pavement structure should be completely reconstructed every 15-20 years.

Another important thing to mention is that there are no firms with relevant experience in the region when it comes to the construction and maintenance of concrete roads; this makes the costs of maintaining the road pavement significantly higher.

On the other hand, advantage of asphalt pavement is seen in its flexibility for maintenance and repairs. In case of local repairs, a very good connection between the new and old asphalt may be achieved by the use of common technologies and materials, what significantly reduces the maintenance costs. The estimated duration of asphalt road pavement is 7-10 years, upon expiration of which, it is recommended, the wearing course of the asphalt should be replaced

One additional advantage of asphalt becomes apparent during the winter maintenance. Although the largest part of the tunnel pavement is protected from snow, some salt will be spread at the entry part to prevent formation of ice. Contrary to asphalt, concrete is sensitive to salts and its top surface may deteriorate rapidly thus exposing the road surface to negative effects of frost and reducing the overall durability of the road pavement.

The estimated value of the works for concrete works, as well as for the asphalt works, was obtained on the basis of official bids submitted by contractors. Unit price for concrete roads amounts to EUR 28.32, while for asphalt roads amounts to EUR 21.40. The difference in price is 30% to the benefit of asphalt road. Taking into consideration the total quantity of asphalt needed for the whole tunnel, estimated savings would be around EUR 400,000.

It is extremely important to emphasize that in BiH, as well as in the region, there is no company with experience in the maintenance, repair, and construction of concrete pavement structures, because this technology has not been implemented in this area in the last few decades. For this reason, it is impossible to estimate the exact value of maintenance works on an annual basis, but according to available studies from Europe and America, maintenance costs are lower in case of asphalt pavement.

## **12.7. Evaluation of comparative criteria**

In cases where, when making decisions, we have several different criteria that are often contradictory, it is advisable to apply a decision-making method based on multi-criteria analysis. In order to better understand the issue and provide assistance in decision making, here is shown a Table with the Criteria Description and next to it the colour that signifies how well a specific criterion is met by the considered surface; this should provide a good visual illustration of suitability of the given type of construction for use in tunnels, as well as the suitability for specific requirements the road surface is expected to meet. Green represents a positive aspect, and red a negative one. This method is an attempt to present the issue, as well as advantages and disadvantages of each individual type of road surface.

Asphalt pavement					Criteria	Concrete pavement				
					1. Skidding resistance					
					2. Cost effective lighting					
					3. Contrast					
					4. Driving comfort					
					5. Noise reduction					
					6. Fire resistance					
					7. Construction cost					
					8. Maintenance experience					
					9. Maintenance cost					
					10. Durability					

## Conclusion

From all the above, it is clear and evident that the use of asphalt pavements in tunnels is better than the use of concrete pavements, and therefore an instruction is given to all designers, supervisory teams, and contractors to apply asphalt pavements in tunnels in accordance with valid norms, standards, and regulations, for all sections that are in the design phase, in the preparation phase for construction, or in the construction phase.

The pavement structure in the tunnels will follow the composition and dimensions of the pavement structure on the open route, outside the tunnel, in accordance with the principles given in Instruction No. 14 for Design and Construction of Road Structures on Motorway.

- SMA 11s (SBM11s), + PmB 45/80-65 + Er,
- AGNS 22s, + PmB 45/80-65 + Kr,
- AGNS 32s or AGNS 22s, + B 35/50 + Kr,
- Cement-stabilized layer, d = 20 cm, in accordance with applicable technical requirements
- NNS 0/45 mm,  $f_5$ ,  $E_{v2} \geq 120$  MPa,

The minimum thickness of the subbase (unbound bearing layer) is 25 cm. If the tunnel structure includes an invert (bottom arch), the space between the pavement structure and the invert shall be filled with a filter layer 25 cm thick, followed by a stone mixture 0/63 mm whose granulometric composition corresponds to a subbase mixture with  $d_{max}$  63 mm ( $U=d_{60}/d_{10}$  between 15 and 80), and fine particle content of up to 12% m/m (category  $f_{12}$ ); with physical and mechanical properties meeting the criteria for subbase materials. After transport and profiling, the filter layer is compacted with light machinery so as not to damage the drainage pipe. A geotextile is installed over the filter layer with overlaps in the direction of transport of the first fill layer up to 35 cm thick. Placement and levelling of fill material must be carried out from the front to avoid disturbance of the filter layer, geotextile, and drainage pipe. For the first fill layer, approximately 75% of the required subgrade bearing capacity should be achieved, i.e.,  $_{min}E_{v2} = 60$  MPa. For the second fill layer, the final subgrade bearing capacity should be ensured, i.e.,  $_{min}E_{v2} = 80$  MPa.

The quality of the subbase mixture, as well as the constructed bearing layer, must fully comply with the criteria of the applicable technical requirements. Particular emphasis is placed on the bearing capacity ( $E_{v2} \geq 120$  MPa) and frost resistance, i.e., limiting the content of fine particles in the subbase mixture (category  $f_5$ ).

Technical requirements for individual layers of the pavement structure are more precisely defined in Instruction No. 14 for Design and Construction of Road Structures on Motorway.

### **Substructure drainage**

In order to prevent the inflow of groundwater from the rock mass into and onto the pavement structure (inflow is possible through cold joints of the unreinforced concrete invert vault or directly from the rock mass in case the tunnel is constructed without an invert vault), the filter layer must ensure good permeability and the possibility of draining seepage or groundwater through a drainage pipe. The geotextile membrane has a dual function: to prevent clogging of the filter layer by fine particles from the fill material, and to increase bearing capacity and prevent mixing of the fill material with the filter layer.

The longitudinal drainage pipe of the tunnel has an internal diameter of D150mm, with perforations over the upper 120° (200 cm<sup>2</sup>/m), which allows the reception and transport of water in the longitudinal direction of the tunnel.

If water sources are encountered in the invert zone during tunnel construction, they shall be captured as necessary and connected via transverse pipes (D150 or larger, depending on the inflow) directly to the central collector system, either through the main drainage pipe or a central drainage shaft (where location conditions allow). In such cases, protection against backflow must be ensured by installing non-return valves.

Characteristic cross-sections for tunnels with and without an invert vault are shown in Figures 1 and 2.

TYPICAL CROSS-SECTION OF A TUNNEL WITH AN INVERT

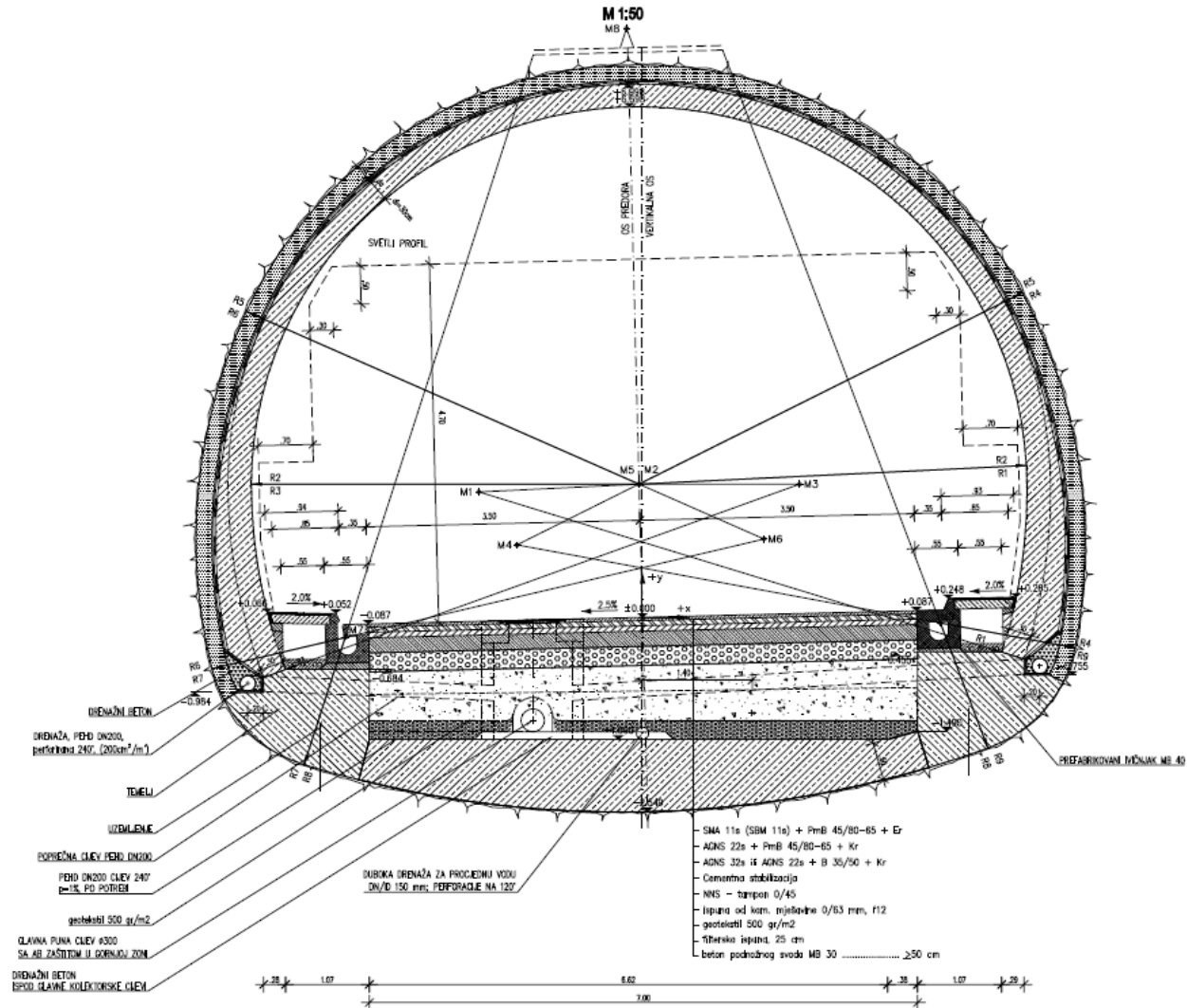


FIGURE 1

TYPICAL CROSS-SECTION OF A TUNNEL WITHOUT AN INVERT

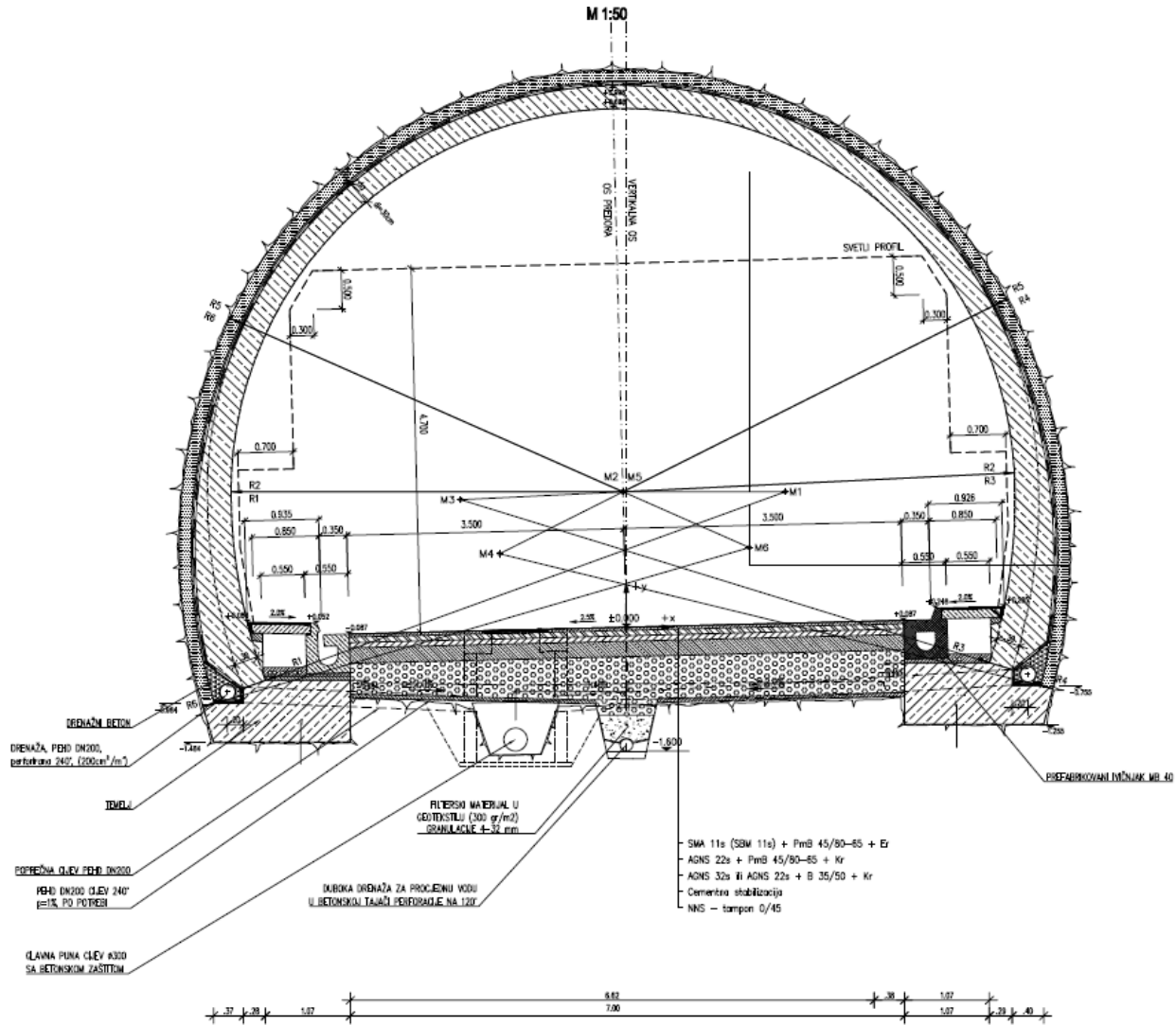


FIGURE 2

**13. INSTRUCTIONS FOR DESIGN AND CONSTRUCTION  
OF ROAD STRUCTURES ON MOTORWAY**

## Introduction

At this level of organization of JP Autoceste FBiH, the need for harmonization of design solutions for individual motorway elements has emerged. The tendency is that in the near future all essential motorway elements: geometric elements, geotechnical structures, bridges, overpasses, underpasses, pavement structure, drainage, tunnels, equipment, and all other elements will be the subject of harmonization of design solutions in order to avoid unnecessary wandering and diversity on the motorway.

The subject of the first harmonization of design solutions is the motorway pavement structure. With the desire to use the previous experiences, knowledge, difficulties, and advantages of all participants in the realization of motorway construction from design, audit, construction, and quality control of executed works, JP Autoceste FBiH sent a letter on June 13, 2012, to all known and relevant addresses for the submission of proposals, suggestions, and remarks on the previously designed, executed, and pavement structure solutions under construction.

Based on the collected information, available knowledge, and experiences, the following is a framework for pavement structure solutions on motorways in FBiH, from which deviations cannot be made without the special consent of JP Autoceste.

### 13.1. Framework for unified road structure of main motorway route

#### 13.1.1. Composition and types of layers on main motorway route (traffic and overtaking lanes)

- A. SMA 11s (SBM11s)  $d = 3.5$  to  $4.5$  cm, + PmB 45/80-65 + Er,
- B. AGNS 22s,  $d =$  according to calculation, but not less than 7 cm, + PmB 45/80-65 + Kr,
- C. AGNS 32s,  $d =$  according to calculation, but not less than 9 cm + B 35/50 + Kr or AGNS 22s  $d =$  according to calculation, but not less than 7 cm + B 35/50 + Kr<sup>1</sup>
- D. Cement stabilized layer,  $d = 20$  cm in accordance with the requirements of valid TU
- E. NNS 0/45 mm,  $d = 20$  do 30cm,  $f_5$ ,  $M_s \geq 100$  MPa, or  $E_{v2} \geq 120$  MPa,
- F. Road base  $M_s \geq 60$  MPa, ili  $E_{v2} \geq 80$  MPa,

#### Explanation

- A. SMA (SBM) discontinued mixture made on the basis of igneous aggregates of required physical, mechanical and volumetric properties, as prescribed in applicable guidelines for the design, construction, maintenance and supervision of roads. Preparation of the sample, testing, evaluation of results and quality assessment of different layers to be done in accordance with requirements of the applicable TU<sup>2</sup>. In case that design foresees mixtures that are not provided in the applicable TU, the quality requirements of the mixture: granulometry, physical and mechanical and volumetric properties shall be determined in accordance with original documents (OTU or other) they had been taken from, but the valuation and calculation mechanisms shall be done in accordance with the applicable TU

<sup>1</sup> When the total thickness of bituminous base layers obtained by calculation does not exceed 16 cm, a mixture with  $d_{max} = 22$  mm shall be used in both base layers.

<sup>2</sup> Guidelines for Design, Construction, Maintenance, and Supervision of Roads

- Guidelines. Use of stabilizing binder and polymer modified binder is mandatory, subject to local climate. Technological thickness for the mixture with  $d_{\max}$  11mm, according to our TU, for this layer are 3 to 5 cm; however, based on experience, recommended thickness range from 3.5 to 4.5 cm, without going into extreme values.
- B. Upper bearing layer with  $d_{\max}$  22 mm, of thickness no less than 7 cm, and thicker if so required due to traffic load. Designed and made on the basis of carbonate-limestone aggregate and polymer modified binder, subject to climate conditions. Preparation of samples, testing, evaluation of test results and quality assessment of the layer to be done in accordance with requirements of applicable TU, for the class of extremely heavy traffic load. In case that design foresees mixtures that are not provided in the applicable TU, the quality requirements of the mixture: granulometry, physical and mechanical and volumetric properties shall be determined in accordance with original documents (OTU or JUS standards) they had been taken from, but the valuation and calculation mechanisms shall be done in accordance with the applicable TU – Guidelines.
- C. Upper bearing layer with  $d_{\max}$  32 mm (or  $d_{\max}$  22 mm), of thickness as calculated, depending on traffic load, but not less than 9 cm (or not less than 7 cm if  $d_{\max} = 22$  mm). When the asphalt layers are installed on top of a layer stabilized by cement, or the section is closer to the southern part of the corridor, use of a harder bitumen binder B 35-50 is mandatory. Preparation of samples, testing, evaluation of test results and quality assessment of the layer to be done in accordance with requirements of applicable TU, for the class of extremely heavy traffic load. In case that design foresees mixtures that are not provided in the applicable TU, the quality requirements of the mixture: granulometry, physical and mechanical, and volumetric properties shall be determined in accordance with original documents (OTU or JUS standards) they had been taken from, but the valuation and calculation mechanisms shall be done in accordance with the applicable TU – Guidelines.
- D. Cement-stabilized layer is recommended as an integral part of the road structure, except when special conditions prove it as an unnecessary part of the road structure, and with the approval of the JP Autoceste it may be omitted. The thickness of this layer, for the reason of easy installation and compatibility, should not exceed 20 cm, but it should neither be less than 15 cm. For the purpose of preliminary testing, when establishing the mixing ratios of composites of cement stabilization, as well as for the needs of producing and installing the course, use the compacting energy in accordance with requirements of BAS EN 13286-2 of 2,70 MJ/m<sup>3</sup>. Quality and properties of the aggregate mixture for design, production and installation of the cement stabilizing course should fully comply with requirements applicable TU for NNS mixtures of granulometry (size) 0/45. The cement stabilized course must be made by appropriate devices, depending on applied technology, that shall produce homogenous course of prescribed geometric and carrying properties. When producing the mixture in a central plant, installation must be done using suitable spreaders that shall ensure homogeneity of the spread course. All requirements with respect to physical-mechanical, carrying and geometric properties must be complied with, and all prescribed measures of care for the fresh layer must be applied.
- E. Loose base layer (NNS) of the road structure to be made in accordance with specifications from the applicable TU concerning the mixture declared as 0/45, calculation and

technological thickness. Construction of the loose base layer in the thickness exceeding 30 cm is not recommended, and if thicker layer is designed, it should be made in two layers, or the technology used must prove even compactness in full thickness of the layer. When placing the layer, all requirements for optimal humidity of the aggregate mixtures must be met, within prescribed limits of  $\pm 2\%$ . Physical and mechanical properties of the aggregate mixture to be used for making the NNS must comply with the requirements of the applicable TU, with special restrictions concerning the content of small particles (particles under 0.063 mm) max category  $f_8$  without the option of such values reaching category  $f_8$  at installation. 10% of the results may show excess of 10%, or max 6% $m/m$ . The content of dusty component (particles less than 0.02 mm) up to max 3% $m/m$ . All other requirements concerning physical-mechanical properties and volumetric properties prescribed in applicable TU are valid.

- F. Wherever possible, and when the quality of materials used at the base level permits, ensure as high as possible carrying capacity by applying standard technological processes and materials designated for making the base layer. The smallest carrying capacity of the base is limited to  $E_{v2} = 80$  MPa,  $E_{dyn} = 40$  MPa or  $M_s = 50$  MPa. In up to 10% of total number of measurements the above value may be 85% of the prescribed value. With regards to small particles, the applicable TU shall apply, defined depending on Hazen coefficient of unevenness and local hydrology.

### 13.1.2. Composition and types of layers on main motorway route – emergency lane

- A. BB11 k (AB 11),  $d$  = same as thickness of the wearing course HS of the main route, B 50/70, with parameters for medium traffic load,
- B. AGNS 22A, (BNS 22),  $d$  = as thickness of the top layer (VS) or upper binding carrying layer (BNS) of the traffic lane, B 50/70, with parameters for medium traffic load,
- C. NNS 0/45 mm,  $d$  = in accordance with the overall thickness of the road pavement (KK) on the main route,  $f_5$ ,  $M_s \geq 100$  MPa, or  $E_{v2} \geq 120$  MPa,
- D. Base width  $M_s \geq 60$  MPa, or  $E_{v2} \geq 80$  MPa,

#### **Explanation**

All instructions given for different layers and materials on traffic and overtaking lanes of the main route apply here too, with the exception concerning parameters of designed, produced and performed layers that must be in accordance with traffic load – medium traffic load. Technological thickness of the wearing and carrying asphalt layers must comply with the designed thicknesses of appropriate layers of the traffic lane they are in contact with.

**14. INSTRUCTION FOR PLANNING AND EXECUTION  
OF ASPHALT WORKS**

## Introduction

Asphalt is a product whose basic characteristic of workability is provided by the bitumen binder. The workability of bitumen, depending on the type of bitumen, is directly dependent on temperature, so depending on the type of applied bituminous binder, minimum as well as optimal temperatures for the installation of bituminous mixtures are prescribed. Table 3.39 of the valid Technical Conditions (TU) in the text below provides the recommended temperature ranges for bituminous mixtures depending on the type of applied bituminous binder:

**Tabela 3.39: Preporučena i najveća temperatura proizvedene smjese bitumenskog betona**

Tip bitumena	Priporučeno područje temperature °C	Najviša temperatura °C
B 160/200	130 do 150	165
B 100/150	135 do 155	170
B 70/100	140 do 160	175
B 50/70	150 do 170	180
B 35/50	160 do 180	190
B 20/30	170 do 190	195

In addition, it is very important to ensure good adhesion between the asphalt layer and its sub-layer, and good adhesion between two asphalt layers. Only pavements where all layers adhere well to each other during operation work as a structure that is capable of carrying the planned traffic load without unwanted defects. In this sense, a mandatory technological phase of “making a binding layer to bind the bituminized layers together” is done – the so-called sprinkling with bitumen emulsion.

Wet, cold and windy weather reduce the temperature of the produced mixture and have negative effect on adhesion of layers and make the proper placement of the produced asphalt mix significantly harder or impossible. In connection with this, all technical requirements, including the current TU, prescribe minimum temperatures of air and sub-layer, they proscribe work during wet weather, prescribe conditions for the transport of the produced asphalt mix that provide for optimal conditions for the placement of the bitumen mixes.

Considering that the greater part of our country has a continental climate, and only the southern parts have something between a continental and Mediterranean climate, there have always been calendar restrictions for planning the execution of asphalt works. In this regard, JP Autoceste FBiH prescribes the following:

### 14.1. Calendar framework for planning and executing asphalt works on motorways

For planning and execution of asphalt works on motorways, the Contractors of asphalt works are instructed to focus on the period from April 15 to October 15.

Works prepared for execution before April 15, provided that the conditions regarding air and surface temperature are met; as well as works that are in the execution phase and exceed the planned framework of October 15, while the air and surface temperature conditions are still satisfied, may be executed with the special approval of the Engineer.

All Contractors, and their material suppliers or subcontractors, are directed to use the period from October 15 to April 15 for adequate preparations. Arrangement of quarries, overhaul and repair of equipment and plants, obtaining approvals, testing and preparation of preliminary laboratory compositions, and preparation of accompanying documentation such as technological elaborates, etc., in order to be ready for the start of asphalt works.

For already contracted works, this instruction is applied in such a way as to comply with the requirements prescribed by the valid technical conditions, such as air temperature, base temperature, windy weather, wet weather etc., as well as other responsibilities that are approved by the Engineer are met.

**15. INSTRUCTIONS FOR MATERIAL APPROVAL-  
AGGREGATE FRACTIONS**

## Introduction

The Law on Construction Materials and the Rulebooks based on that Law or other legal grounds, which concern the procedures of issuing certificates and other documents defining quality, prescribe conditions and procedures for the control of production and issuance of certificates for construction products (including aggregate fractions and other quarry products).

Due to numerous systemic shortcomings (the existence of regulations but the lack of mechanisms for their consistent implementation, an insufficient number of authorized legal entities, etc.), producers of quarry products fulfil their obligations with varying levels of consistency and seriousness in terms of providing adequate production control and ensuring proof of quality. In order to avoid the application of different criteria when making decisions on the approval of sources and quarry products: aggregate fractions for asphalt and concrete, mixtures for unbound base layer (NNS), bound base layer (VDNS), and others, JP Autoceste FBiH defines the minimum requirements for producers of quarry products with this document.

### 15.1. Minimum requirements for producers of aggregate fractions

All producers of quarry materials who have not obtained **product compliance certificates** for their products for their intended purpose (use in asphalt, concrete mixtures for NNS, VDNS) in accordance with the Law on Construction Products and its accompanying rulebooks, until they obtain this certificate, must as a minimum provide the following:

- General documents: registration certificate of the company, activity, concession contract, environmental permit and any other documents proving the legality of their business.
- Appropriateness of the main resource (the rock) for the production of quarry products proven by relevant tests (tests by the JUS standards as taken over are acceptable), in accordance with the intended purpose, issued by authorized or qualified and adequately equipped national bodies<sup>3</sup>.
- Tests of the main raw material and assessment of its appropriateness is based on at least three aspects: physical and mechanical properties of the material in relation to its intended purpose, mineral and petrography composition, with assessment of its suitability for intended purpose, and chemical analysis, with the emphasis on content of harmful or prohibited substances in relation to the intended purpose of the material.
- Product suitability: of aggregate fractions or aggregate mixture proven by adequate testing (for NNS and VDNS in accordance with BAS EN 13242; for concrete BAS EN 12620 and for asphalt in accordance with BAS EN 13043), depending on its intended purpose, issued by licensed or trained and appropriately equipped national bodies. The assessment, opinion on usability or suitability of the product must be based, relative to the intended use of materials, on the parameters of physical and mechanical properties of the material, its mineral and petrography analysis and chemical analysis of the product.

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<sup>3</sup> The term “qualified and adequately equipped national bodies ” shall mean legal entities which, in terms of equipment, competence, and staffing, possess the capacities prescribed by the Rulebook on Conditions for Bodies Performing Conformity Assessment of Construction Products, but which, for objective or other reasons, have not yet obtained authorization from the competent Ministry to carry out conformity assessment procedures, perform individual tasks within the conformity assessment process, issue certificates of factory production control, or issue certificates of conformity of construction products.

## 15.2. Assessment of acceptability of aggregate fractions produced from dolomite rocks

Valid TU, except in some special cases<sup>4</sup>, do not exclude the use of aggregate fractions obtained from solid dolomite rocks exploited by blasting. Some of the properties due to which aggregate fractions of dolomite origin are not in non-selective use are:

- Content and origin of small particles,
- Content of weak and worn kernels,
- Water absorption,
- Insufficient mechanical resistance to additional crushing under the construction mechanization (LA, MD or crushability)
- Unsatisfactory value of polishing resistance (PSV for wearing course),
- Mineral and petrography and chemical suitability for use in concrete mixtures exposed to wet and aggressive environments.

Therefore, the dolomite materials are not explicitly forbidden for use in road construction; however, their usability needs to be proven by adequate testing with special consideration of their above indicated properties, all relative to the intended use of the materials.

Provided ongoing control of production with statistic indicators of quality parameters for the period of at least 6 months prior to the submission of application for use for the construction of the motorway. The acceptable level of production control is 1 + (trained staff and adequately equipped laboratory of the Manufacturer), or Agreement with an Institution that would periodically make statistical analyses on the basis of their own and manufacturer's test results (system 2+), even if the Institution has not finalized the process of obtaining the license, but the process has started.

When, upon review of the documentation, it is determined that the aggregates, according to their composition, belong to aggregates with a potential risk of harmful alkali reactions in concrete, i.e. siliceous aggregates, dolomites, dolomitized limestones, limestone dolomites, and other aggregates which, by composition, fall into the category of aggregates with a potential for alkali-silica reaction (ASR) or alkali-carbonate reaction (ACR) in concrete, it is necessary to carry out additional testing in accordance with DIN EN 12620 and the German guideline for the prevention of harmful alkali reactions in concrete - "Alkali Guideline". The requirements and testing procedures for aggregates with regard to alkali reactivity are given in Annex 1 of this Instruction..

Approval for the mentioned aggregates, with respect to alkali reactivity, shall be granted for materials which, according to the classification of the "Alkali Guideline" (DAfStb-Richtlinie, Vorbeugende Maßnahmen gegen schädigende Alkalireaktion im Beton- Alkali Richtlinie), are classified as follows:

E I - "X" - <b>non-reactive</b> with respect to alkali reactivity	<b><u>"APPROVED"</u></b>
E III - "X" - <b>reactive</b> with respect to alkali reactivity	<b><u>"NOT APPROVED"</u></b>

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<sup>4</sup> For the wearing course of roads with heavy and very heavy traffic loading, the exclusive use of aggregates with high resistance to polishing is required – corresponding to rocks of igneous origin.

"X" - indicates mineralogical-petrographic affiliation classification E II - "X" - **conditionally suitable** with respect to alkali reactivity "**APPROVAL UNDER SPECIAL CONDITIONS**"

E II- "X" classification applies only in the case of testing for alkali-silica reactivity, i.e., dolomites, dolomitized limestones, calcareous dolomites cannot be "approved under special conditions". "Approval under special conditions" implies the limitations defined in the certificate.

If it is assessed that the "special conditions" according to the certificate cannot be consistently implemented for technological or other reasons, approval shall not be granted for such an aggregate.

### **15.3. Assessment of acceptability of aggregate fractions for wearing course of motorway**

For the design, production, and installation of asphalt mixtures intended for the construction of the wearing course of heavily and very heavily trafficked roads, in accordance with all applicable technical conditions in this region, the following shall apply:

- Contract documents for the construction, reconstruction, and modernization of roads in SR BiH, Book II/74 and Book II/77;
- adopted and applied JUS standard which prescribes technical conditions for wearing courses U.E4.014;
- General Technical Conditions (OTU) of the Republic of Croatia,
- Technical conditions for asphalt works on the maintenance of pavement structures on motorways, issued by Hrvatske autoceste d.o.o.,
- Guidelines for design, construction, maintenance, and supervision of roads, which prescribe the use of aggregate fractions with pronounced skid-resistant properties, i.e. aggregate fractions with high resistance to loss of skidding resistance.

The listed technical conditions (TU) define the physical and mechanical properties of the rock for the production of aggregate fractions as well as the physical and mechanical properties of aggregate fractions. In general, all listed technical conditions are consistent and define, to a similar extent, the criteria for the assessment of both the rock and the aggregate fractions.

The need for further specification of criteria has arisen from the fact that the applicable Technical Conditions and Guidelines for design, construction, maintenance, and supervision of roads:

- shift the limit of acceptability in the assessment of resistance to the harmful effects of frost, and
- do not define criteria for the rock from which aggregate fractions are produced

In Section A, an overview of the criteria in individual technical conditions for the assessment of resistance of materials to the harmful effects of frost is provided, and in order to eliminate potential ambiguities, avoid the application of different criteria, and ensure that adequate materials are incorporated into the wearing course of the motorway, Section B prescribes the criteria for the assessment of the suitability of the rock and aggregate fractions intended for the construction of the wearing course of the motorway.

In Section C, guidelines are provided for the procedure for approval of aggregate fractions prior to and during the execution of works on the wearing course..

### A) Overview of criteria and prescribed limits of acceptability of mass loss in sodium sulfate testing

Table 1 contains the criteria – the limit of acceptability of mass loss in the test procedure for frost resistance in sodium sulfate ( $\text{Na}_2\text{SO}_4$ ). The stated values represent the mass percentage of the allowed loss after testing according to the procedure described in the standard B.B8.044 after 5 alternating exposure cycles to the chemical agent.

Table 1. Overview of different criteria regarding resistance to the harmful effects of frost

Technical Condition	Criterion: max. allowed mass loss for heavy traffic load % m/m
Contract documents for the construction, reconstruction, and modernization of roads in SR BiH, Book II/77	3
Applicable JUS U.E4.014	3
OTU of the Republic of Croatia	3
Technical conditions for asphalt works on the maintenance of road structures on motorways, issued by Hrvatske autoceste d.o.o.	3
Guidelines for the design, construction, maintenance and supervision of roads, BiH 2005	5

### B) Special requirements for assessment of suitability of rock and aggregate fractions for wearing course of motorway

Tables 2 and 3 prescribe special quality requirements for the rock and aggregate fractions intended for the construction of the wearing course of the motorway:

Table 2. Requirements for technical stone used for the production of aggregate fractions

Property	Unit of measurement	Required
Compressive strength in dry state (min)	MPa	180
Permissible reduction in compressive strength after water saturation (max)	%	20
Water absorption (max)	% m/m	0,75
Abrasion by grinding (max)	$\text{cm}^3/50 \text{ cm}^2$	12
Resistance to freezing (25 cycles)		Resistant
Frost resistance 5 cycles (max)	% m/m	3

Aggregate fractions intended for the production and construction of the wearing course of the motorway shall comply with BAS EN 13043 and the requirements of the applicable Technical Conditions – Guidelines for design, construction, maintenance, and supervision of roads. For certain parameters, additional specific quality requirements are prescribed:

Table 3. Special requirements for aggregate fractions

Property	Unit of measurement	Required
Content of particles < 0.09 mm in intermediate fraction 0/2 mm or fraction 0/4 mm	% m/m	5 (7,5) <sup>5</sup>
Sand equivalent (min)	%	70
Water absorption (max)	% m/m	1,2
Content of particles of unfavourable shape (3:1)	% m/m	10
Frost resistance 5 cycles	% m/m	3 (3,45) <sup>6</sup>

### C) Guidelines for approval of materials and asphalt works on construction of wearing course of motorway

Prior to the commencement of asphalt works for the construction of the wearing course of the motorway, the Contractor shall, in accordance with the requirements of the Technical Conditions, submit to the Engineer (Supervisory Team) the necessary documentation for approval (technological design report, documentation for stone, aggregate fractions, filler, bitumen, additives, laboratory mix designs, working mixtures, etc.).

In addition to the requirements defined by the Technical Conditions, for the approved aggregate fractions to be used in the production and installation of the wearing course of the motorway, the Contractor shall ensure:

- **stockpiled quantities of aggregate fractions, tested for frost resistance, sufficient for 15 days of installation.** Verification of frost resistance testing in accordance with standard B.B8.044 shall be carried out, upon instruction of the Engineer, through internal and/or external quality control.
- Newly delivered quantities shall be controlled in a timely manner according to the same principle, within the regular procedure in accordance with the approved Testing Program, and more frequently if required by the Quality Engineer.

### Conclusion

Candidate materials intended for the design, production, and installation of concrete mixtures, asphalt mixtures, and pavement structure layers that do not meet the requirements of this instruction shall not be subject to approval on construction sites under the jurisdiction of JP Autoceste F BiH.

<sup>5</sup> For multiple tested samples of the same fraction, a maximum of 20% (1 out of 5) of the tested samples may reach a value of 7.5% m/m (50% exceedance), provided that the sand equivalent criterion is satisfied.

<sup>6</sup> For multiple tested samples of the same fraction, the average value may be up to a maximum of 3.45% m/m (15% exceedance), whereby a maximum of 20% (1 out of 5) of the tested samples may reach a value of 3.75% m/m (25% exceedance).

## Annex 1.

### 1. Testing program and certification of aggregates with respect to alkali reactivity

- *Testing program*

The testing program is defined in accordance with DIN EN 12620 and the German "Alkali Guideline" (DAfStb-Richtlinie, Vorbeugende Maßnahmen gegen schädigende Alkalireaktion im Beton- Alkali Richtlinie).

For testing the alkali reactivity of dolomite, dolomitized limestone, and calcareous dolomite, in addition to testing in accordance with the "Alkali Guideline", initial testing in accordance with ASTM C295 standard shall also be performed.

- *Certification of aggregates with respect to alkali reactivity*

Certification involves sampling (exclusively by an authorized representative of the institute), in the presence of representatives of JP Autoceste FBiH, the supervising team, and the contractor (producer); providing transport of samples to the institute's address; testing and issuing certificates; production control (at least once every 6 months)

All costs incurred in the certification process shall be borne by the contractor (producer).

### 2. Criteria for selection of the institute responsible for certification of aggregates with respect to alkali reactivity

A legal entity performing certification with respect to alkali reactivity must meet the following criteria:

- Testing laboratories in accordance with EN ISO/IEC 17025:
- Calibration laboratories in accordance with EN ISO/IEC 17025:
- Inspection body Type A in accordance with EN ISO/IEC 17020:
- Certification body in accordance with EN 45011
- Accredited for testing in accordance with European standards (EN) for testing cement, aggregates, concrete and testing in accordance with the Alkali Guideline of the German Committee for Reinforced Concrete (DAfStb)
- Professionally qualified for testing the alkali reactivity of aggregates and concrete according to the "Alkali Guideline" of the German Committee for Reinforced Concrete (DAfStb)

The legal entity must be approved by J.P. Autoceste FBiH. Along with the request for approval, it is necessary to submit:

- Documents proving the stated competencies
- Statement confirming that testing and production control will be carried out in accordance with the relevant reference documents and in the interest of JP Autoceste FBiH;
- Appointment of a coordinator for certification and production control

## **16. INSTRUCTIONS FOR APPLICATION OF MICRO-REINFORCED SHOTCRETE**

## Introduction

Micro-reinforced shotcrete (MRS) is a “new” material that is continuously developing in terms of fibre types, modern concrete technologies, and new shotcrete application techniques. Over the past decade, micro-reinforced shotcrete (MRS) has been widely accepted as an integral part of the primary support system in tunnel construction by designers, engineers, contractors, and investors worldwide.

If we analyse the properties of concrete, it can be quickly concluded that concrete, by its nature, is a brittle material and, as such, when used in most structures, exhibits various types of cracks and fissures. The same applies to shotcrete. The occurrence of cracks or fissures in concrete may be of a structural or “economic” nature; however, the fundamental cause lies in the absence (or very low level) of tensile strength in concrete. The transfer of tensile forces in concrete is achieved through reinforcement, regardless of whether reinforcement meshes, bars, or fibers are used. Further analysis of reinforcement shows that micro-reinforced shotcrete has several advantages compared to conventionally reinforced shotcrete (reinforcement mesh or bars). Fibers used in shotcrete are significantly smaller in size than conventional reinforcement and, as such, are closer in scale to cracks and fissures, making them more effective in forming the mechanism of tensile force transfer from concrete to reinforcement. Another important advantage is their uniform distribution within the concrete cross-section. These two key characteristics make micro-reinforced shotcrete a viscous and ductile material, distinguishing it significantly from conventionally reinforced concrete.

### 16.1. Technical advantages of micro-reinforced shotcrete

The mechanical properties of shotcrete are defined by the water-cement ratio (w/c) or the water-cement ratio with the addition of microsilica fillers (w/c+s), the type of accelerator additives for sprayed concrete, spraying conditions, and curing of the shotcrete. The main reason for the application of fibers in shotcrete is **increasing ductility (toughness)**.

The ductility of shotcrete depends exclusively on the amount and type of fibers used. When considering the mechanical and technical advantages of micro-reinforced shotcrete, the following can be stated:

- increased impact resistance (sudden rock mass fallout)
- increased resistance to abrasion and erosion
- increased impermeability
- increased frost resistance
- increased adhesion to the substrate

From a technical standpoint, it is also important to highlight additional advantages of micro-reinforced shotcrete compared to conventionally reinforced shotcrete in tunnel construction. During tunnel construction, sudden loads and deformations of rock masses frequently occur. The most effective way to ensure an adequate level of safety during tunnel works is to provide a high level of fracture energy (ductility/toughness) of the shotcrete.

For comparison, the use of “conventional” steel fibers in shotcrete improves the primary support system by providing approximately two times higher fracture energy compared to unreinforced shotcrete, while “modern” fibers improve the support system by achieving 50 to 200 times higher fracture energy. In simplified terms, support systems with modern micro-reinforced shotcrete technology can withstand significant cracking and deformations while still maintaining a high level of load-bearing capacity (post-cracking performance/toughness).

This characteristic enables timely identification of changes and deformations in the support system and provides sufficient time for an appropriate response without compromising the safety of personnel involved in tunnel construction.

## 16.2. Types of fibers

This section defines:

- types of fibers permitted for use in the primary support system;
- standards defining fibre characteristics.

### 16.2.1. Glass fibers

#### ***Not permitted.***

Glass fibers are not permitted because, after a certain period, they become brittle and are degraded by the cement matrix within the concrete structure.

### 16.2.2. Plastic fibers (Synthetic fibers)

*Micro-synthetic fibers* **are not permitted** are not permitted as load-bearing (structural) reinforcement. They may be used as an addition to shotcrete for the purpose of improving certain mechanical properties, but only in combination with conventional reinforcement. Micro-synthetic fibers contribute to improving fire resistance, reduced rebound during wet-mix shotcrete application, reduction of microcracking during the plastic phase of hardening, and reduced shrinkage of shotcrete.

Macro-synthetic fibers **are permitted** as load-bearing reinforcement, provided that dimensioning and verification of post-cracking performance are carried out in accordance with the standards defined in the following sections. An additional requirement for the use of macro-synthetic fibers is the possession of the necessary certificates and test reports, as defined in the following sections.

### 16.2.3. Carbon fibers

From a technical standpoint, the mechanical properties of carbon fibers are highly suitable for primary support systems in tunnel construction; however, in practice, they are not used due to economic reasons (high cost).

### 16.2.4. Steel fibers

Steel fibers are the most commonly used fibers in shotcrete; however, in practice, they have not always proven to be the optimal solution due to a number of undesirable effects during application. In recent years, they have increasingly been replaced by macro-synthetic fibers. Although a wide variety of steel fibers is available on the market, it should be emphasized that only a limited number of types possess satisfactory characteristics for use in shotcrete. Steel fibers are typically required to be thin (small diameter), long, and made of high-quality steel.

Critical and important parameters in the selection of steel fibers include:

- Geometry
- Length
- Length/thickness ratio (L/D)
- Steel quality

#### **16.2.5. Applicable standards**

The use of standards **EN 14889-1** and **EN 14889-2** is mandatory.

### **16.3. Structural design – definition of characteristics**

Structural design and definition of characteristics shall be carried out by an authorized, qualified, and experienced professional (expert-engineer).

#### **16.3.1. Assumptions in structural design**

The structural design and definition of characteristics of micro-reinforced shotcrete (MRS) shall be carried out taking into account the post-cracking residual strength at different levels of deformation. The deformation level shall be assumed in accordance with the ultimate limit state.

#### **16.3.2. Defining micro-reinforced concrete**

It is necessary to define the concrete characteristics through the mix design, i.e., characteristics of fresh concrete, characteristics of hardened concrete, early strength, post-cracking performance or energy absorption, type of fibers, durability requirements, environmental requirements, execution conditions, curing conditions, and a series of other characteristics prescribed according to the shotcrete guideline of the Austrian Society for Construction Technology **ÖVBB "Richtlinie Spritzbeton"**.

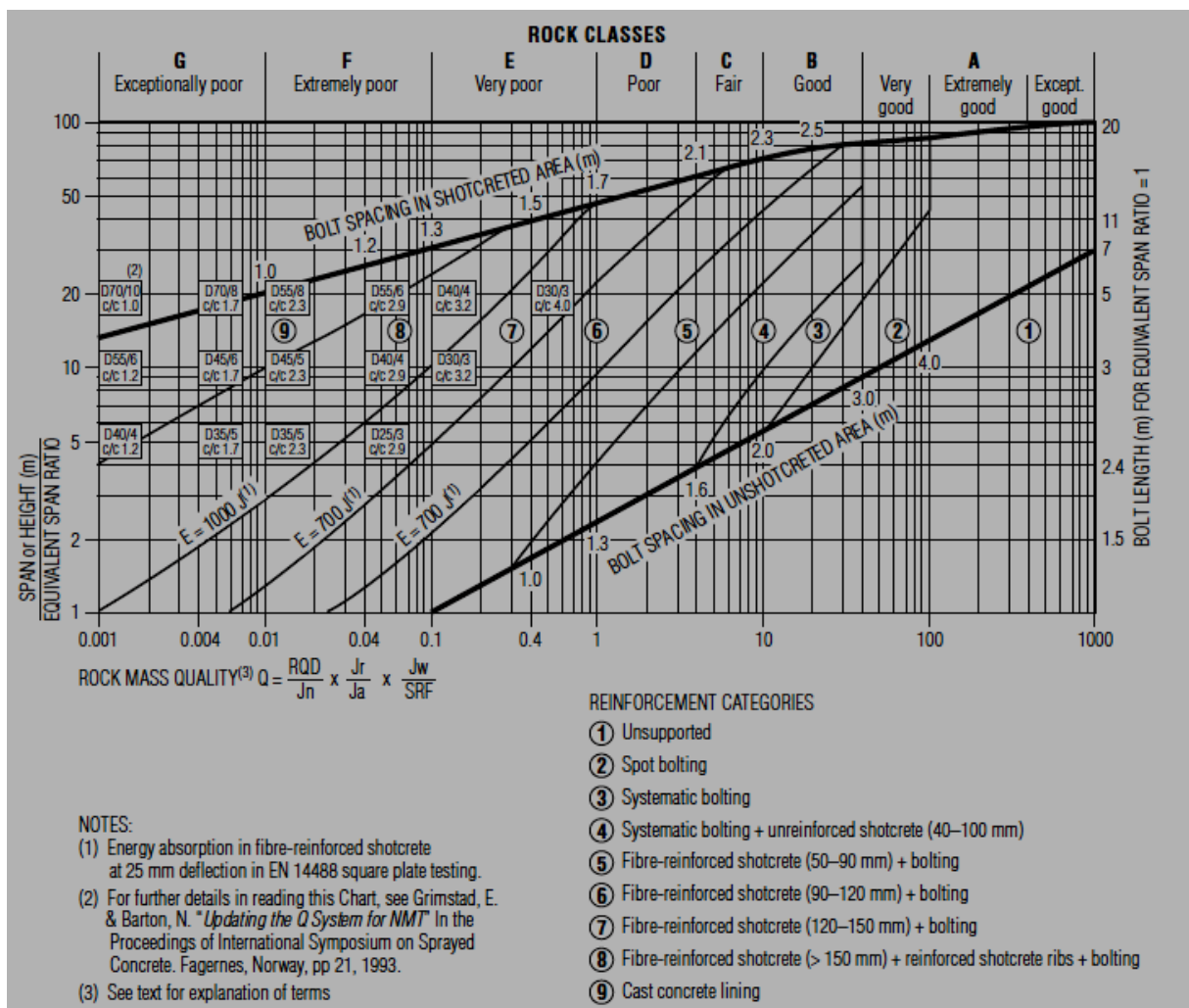
#### **16.3.3. Preliminary tests**

The preliminary testing procedure must be carried out according to the shotcrete guideline of the Austrian Society for Construction Technology **ÖVBB "Richtlinie Spritzbeton"**. Preliminary testing shall be used to verify the defined characteristics of micro-reinforced concrete as specified in Section 4.2.

### 16.3.4. Primary support category

The selection of the primary support category shall be carried out in accordance with a diagram based on the Q-classification (Tunnelling Quality Index) developed by Grimstad and Barton. The application of the Q-system defines a diagram through which the support category is determined based on the Q-index (Diagram 1). In order to establish a relationship between the Q-index and the required tunnel support, additional parameters have been defined, referred to as the equivalent dimension of excavation,  $D_e$ . This dimension is obtained by dividing the span, diameter, or height of the tunnel by a value referred to as the Excavation Support Ratio (ESR). The ESR values are derived empirically and are presented in Table 1.

$$D_e = \frac{\text{Span, diameter or tunnel height (m)}}{\text{ESR}}$$



**Diagram 1-** Determination of support categories based on the Q index (Grimsted and Barton, 1993)

Table 1 - Values of the Excavation Support Ratio (ESR)

Excavation Category		ESR
A	Temporary mine openings	3–5
B	Vertical shafts: • circular cross-section • rectangular cross-section	2.5 2.0
C	Permanent mine workings, hydraulic tunnels (excluding high-pressure tunnels), pilot tunnels, tunnels during profile enlargement for larger excavations	1.6
D	Storage facilities, water treatment plants, minor road and railway tunnels, access tunnels, etc.	1.3
E	Oil storage facilities, machinery halls, main road and railway tunnels, shelters, portals, intersections	1.0
F	Underground nuclear power plants, railway stations, sports and public facilities, industrial plants, etc.	0.8

### 16.3.5. Correlation between RMR and Q-classification

If classification is carried out according to the RMR system, a correlation between the RMR and the Q-index (Tunnelling Quality Index) may be established using the following expression:

$$\text{RMR} = 9 \log_e Q + 44$$

### 16.4. Quality control

It is necessary to develop an internal and external control plan (Quality Management System) according to the guideline for shotcrete of the Austrian Society for Construction Technology ÖVBB "Richtlinie Spritzbeton".

## GUIDELINES, STANDARDS AND APPENDICES

### Guidelines

- 1) Guideline for shotcrete of the Austrian Society for Construction Technology ÖVBB "Richtlinie Spritzbeton" (from December 2009) - **BASIC DOCUMENT**

### Standards

- 1) All standards from the Guideline for shotcrete of the Austrian Society for Construction Technology ÖVBB "Richtlinie Spritzbeton" (from December 2009) - **BASIC DOCUMENT**, as listed in Chapters 15.1, 15.2, and 15.3 of the referenced document, are mandatory.

### Appendices

- 1) Guideline for shotcrete of the Austrian Society for Construction Technology ÖVBB "Richtlinie Spritzbeton" (from December 2009) - **BASIC DOCUMENT**

## **17. INSTRUCTIONS ON OPTICAL CONVERGENCE MEASUREMENTS IN TUNNELS**

## **Introduction**

During tunnel construction, depending on the rock mass characteristics, smaller or larger deformations and displacements of the tunnel walls occur. In order to predict the behaviour of the material and to apply an optimal primary support system, markers or reflectors suitable for high-precision optical measurements are installed in the tunnel lining. Following the initial measurement (the so-called zero measurement), it is necessary to monitor the displacement of the markers relative to this initial (zero) measurement. Measurements of the markers provide convergence values of points along all three axes, enabling the monitoring of tunnel wall settlement until stabilization occurs. The concreting of the secondary lining in the tunnel shall be carried out only after stabilization of the tunnel walls (i.e. when the increase in convergence is less than 4 mm over a period of one month). For this reason, monitoring of deformations is one of the key aspects during tunnel construction.

### **17.1. Required documentation**

Prior to the commencement of excavation works in the tunnel, the contractor shall submit a detailed convergence monitoring program, which shall include at least:

- Description of installation, fixing, and protection of anchors (pins)
- Complete overview of all phases of instrument handling: equipment for main and auxiliary measuring sections, section locations, distances, and monitoring schedule
- List of personnel responsible for carrying out convergence measurements
- Specifications and catalogues of instruments and reading equipment intended for use
- Proof of regular calibration/verification of instruments
- Basic characteristics of the software package for the evaluation of geotechnical measurements, as well as the reference file containing original and collected data in a defined format
- Contractor's references for convergence monitoring
- Format of deformation measurement report.

All submitted documentation is subject to the approval of the Supervising Engineer.

### **17.2. Required equipment**

Geodetic equipment shall include, at a minimum, the following:

- holders (anchors/pins) for installation of markers or prisms, with a minimum length of 50 cm
- reflective markers for measurements at distances up to 150 m
- or prisms for measurements at distances from 150 to 500 m
- geodetic instrument, electronic theodolite with an integrated coaxial distance measurement system
- software package for data interpretation (Eupalinos – Geodata or similar)

The required accuracy of the distance measuring instrument shall be  $\geq \pm 1$  mm. Measurements are usually performed as part of an integrated tunnel monitoring system, which also includes settlement measurements and verification of tunnel cross-section positioning.

### 17.3. Installation of control measuring profiles

Control measuring profiles shall be installed as close as possible to the tunnel excavation face. The marker holder shall be installed in unsupported rock, where conditions permit, or after the application of the first layer of shotcrete. After installation, the reference points (benchmarks) shall be clearly marked and protected to prevent damage. Measuring profiles must be identified by chainage and profile number, while the reference points (markers) within the profile shall be numbered, maintaining the same numbering for a given marker position in all profiles.

A control measuring profile shall consist of a minimum of five measuring points positioned along the perimeter of the underground excavation (Figure 1). A measuring point consists of a holder installed in the shotcrete or rock mass, onto which a bi-reflex target or prism target is mounted.

The installation of control measuring profiles shall be carried out in two stages: after excavation of the crown and after excavation of the bench. The locations for installation of control measuring profiles shall be determined by the Supervising Engineer during construction.

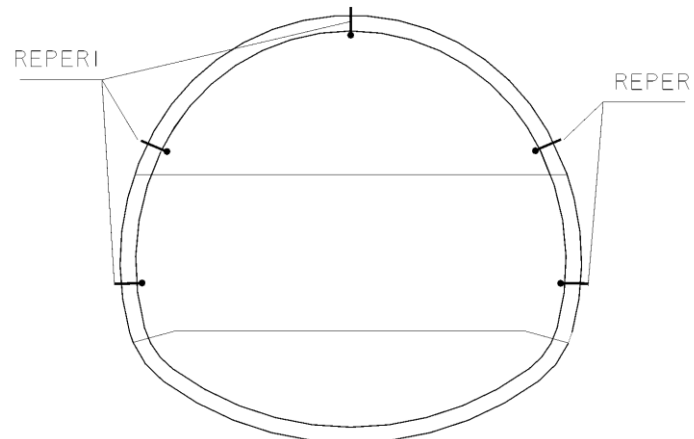


Figure 1. Control measuring profile

In tunnels excavated in rock masses, control measuring profiles shall be installed in zones corresponding to rock mass categories IV and V. In rock mass categories I to III, one control measuring profile shall be installed every 30 to 100 m of tunnel length. In tunnels excavated in soil, control measuring profiles shall be installed at intervals of 10 to 15 m, depending on the construction method.

In addition to the measuring profiles defined in the design, additional measuring profiles shall be installed in accordance with local variations in geological conditions and experience gained during tunnel excavation. The locations for installation of additional control measuring profiles shall be determined by the Supervising Engineer.

### 17.4. Frequency of measurements

Immediately after the installation of a control measuring profile, the zero measurement shall be carried out. The first measurement shall be performed no later than 24 hours after excavation. Measurements will be carried out until the movements completely stop. The frequency of measurements shall be defined by the Supervising Engineer, taking into account

that displacements depend not only on time but also on the construction process, i.e. the distance of the tunnel face from the measuring profile. Measurement frequency shall be increased in cases of rapid deformation development or when signs of instability of the underground excavation are observed.

The frequency of subsequent measurements or data readings, under conditions of standard behaviour of the surrounding rock mass, may be defined for each measuring section as follows:

- up to 40 m behind the excavation face: daily
- 40 to 100 m behind the excavation face: every other day
- up to 200 m behind the excavation face: once a week
- more than 200 m behind the excavation face: monthly
- upon clear stabilization of settlement: monthly or bimonthly

The frequency of data readings is influenced by the excavation stages of the tunnel crown and bench. If the excavation of the bench approaches a section where instruments were installed during crown excavation, the frequency of data readings shall be increased accordingly. If a parallel tunnel tube approaches a section where instruments were installed during the excavation of the first tunnel tube, data readings shall be reactivated and the frequency increased accordingly.

The frequency shall be increased at any location during and after the installation of support elements or excavation works, subject to the approval of the Supervising Engineer.

At sections where increased deformation rates are observed, measurements shall be carried out frequently (at least once per day) until the rate of deformation decreases over time.

Measurements shall be intensified in cases of rapid deformation increase or when signs of instability of the underground excavation are observed. The measurement frequency shall be defined by the designer, subject to the approval of the Supervising Engineer for tunnels.

## **17.5. Measurement**

General requirements:

- Geotechnical instruments and the monitoring program are always subject to changes if such changes are required by the existing geological or geotechnical conditions.
- Installation of instruments and devices shall be carried out near the excavation face, as part of the final stage of excavation.
- Installed measuring equipment, as well as the space required for performing measurements, shall always remain unobstructed and easily accessible, up to the installation of the waterproofing membrane.
- All instruments shall be protected from damage that may be caused by blasting or traffic within the tunnel. If necessary, protective covers or housings shall be used to prevent damage.
- Instruments damaged during construction activities shall be replaced immediately at no additional cost.
- Data reading units for high-precision theodolites shall be available at all times during tunnel construction. Spare parts and backup units shall be kept on site.
- The contractor shall be responsible for providing, installing, and maintaining the equipment required for establishing and monitoring measuring sections throughout the construction period.

- The Contractor shall also provide and maintain adequate lighting, ventilation, and access platforms, including personnel responsible for access to all instruments.

The recorded measurement results shall be processed immediately on a personal computer using specialized data interpretation software and submitted to the Supervising Engineer for review and, if required, to the Designer in electronic form.

For optical monitoring of displacements, a software package such as Eupalinos by Geodata, or an equivalent system enabling direct data transfer, shall be used. The software shall, at a minimum, perform the following analyses:

- Time-dependent analysis for absolute displacements
- Displacement differences and displacement rates
- Cross-section analyses
- Analyses related to tunnel excavation progress with constant measurement intervals or time difference relative to the zero measurement (influence lines, ratios of individual displacement components)
- stereographic projection analysis
- Numerical and graphical output of total deformation, including deformation rates
- Calculation of shotcrete weight
- Determination of coordinate components or any derived values (e.g. tangent of vertical/horizontal displacement), etc.

In addition to the aforementioned features, the program should allow the entry of the following data:

- Date and time of profile excavation
- Profile chainage
- Excavation face chainage
- Excavation face distance
- Observation direction
- First measurement
- Last measurement
- Date of data processing
- Appropriate scaling of deformation display;
- Name of the Contractor and the Investor
- Tunnel name, including identification of the tunnel tube and portal where measurements are carried out.

#### **17.6. Final provisions**

Deformation measurements shall be carried out on a daily basis, or in accordance with the specified frequency of convergence measurements as defined by geotechnical reports or the main design. The Contractor shall record the measurement results in Form MK 1 and submit them to the Supervising Engineer for review.

The coordinates of the monitored measuring profile shall be stored in a database immediately after the measurements are performed.

The Contractor shall also submit to the Supervising Engineer the instrument output in DXF format or an ASCII file for verification purposes.

In the event of an unplanned suspension of tunnel excavation works, the Contractor shall perform convergence measurements at least once per month.

The Contractor shall maintain a qualified geodetic team on site throughout the entire tunnel construction period. If the Contractor's geodetic team fails to perform convergence measurements of the primary support in accordance with this Instruction and/or contractual obligations, the Supervising Engineer shall have the right to remove or replace the team. All consequences arising from the above shall be borne by the Contractor at their own expense.

Appendix  
- Form MK 1

**18. INSTRUCTIONS FOR DESIGN OF SAFETY SYSTEMS  
IN TUNNELS ON CORRIDOR V<sub>c</sub>**

**REPORT ISSUE OVERVIEW**

Project name: **MOTORWAY ON CORRIDOR VC, BIH, TUNNEL SAFETY GUIDELINES**

Project number: -

Report name: **GUIDELINES FOR DESIGN OF TUNNEL SAFETY SYSTEMS**

Issue number: **DRAFT (1)**

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<b>Reviewed by</b>				
<b>Approved by</b>				

## **Introduction**

The motorway project on Corridor Vc began with the preparation of the Preliminary Design in 2005 and 2006. At that stage, the basic motorway alignment was defined, along with the foundations for the design of all electrical installations. Following the adoption of the Preliminary Design, which also served as terms of reference, the preparation of the Main Designs commenced. These were developed by different companies in accordance with public procurement procedures. As a result, variations in technical solutions occurred, both in civil and traffic engineering designs, as well as in installation projects.

JP Autoceste FBiH Mostar, with the aim of standardizing technical solutions on the motorway in Corridor Vc, prepared the “Set of Instructions for Design, Supply, Installation and Maintenance of Motorway Elements, Structures or Parts Thereof”.

Within this Set of Instructions, the following electrical systems have been addressed: external LED lighting at toll plazas, toll lanes, interchanges, rest areas, and COKP facilities, with detailed guidelines provided for the design of external lighting systems. The following low-voltage systems are also covered: structured cabling, network infrastructure, telephony, video surveillance, servers and server platforms, as well as other communication and sensing equipment.

Given that the motorway on Corridor Vc includes a significant number of tunnels, JP Autoceste FBiH Mostar intends to pay particular attention to these structures. In order to achieve high safety standards, it is necessary to ensure that the design solutions for different systems are harmonized with the best international standards and guidelines applicable to this field.

This set of instructions aims to provide guidelines for tunnel design in order to ensure optimal solutions for tunnel safety systems.

## 18.1. Basic data on motorway tunnels

On Corridor Vc, a number of tunnels of varying lengths have been designed. It is important to note that no tunnels longer than 3 km have been designed, for which special rules apply regarding construction, ventilation systems, and electrical installations.

There are no national (BiH) regulations governing the design of tunnel projects. In such cases, international regulations and standards are applied in accordance with the law. To date, designers have primarily based their solutions on Austrian RVS guidelines. In accordance with these guidelines, tunnels are classified by length into tunnels shorter than 500 m, tunnels with a length between 500 m and 1000 m, and tunnels longer than 1000 m. The following table shows which projects should be included in the main tunnel project considering its length.

Tunnel length	0-350 m	350-500 m	500-1000 m	1000-3000 m
Portal transformer substation design	+	+	+	+
Tunnel transformer substation design	-	-	-	+
UPS system design	+	+	+	+
MV supply of transformer substation	+	+	+	+
Tunnel lighting and LV supply	+	+	+	+
Mechanical and electrical design of ventilation	-	-	+	+
Fire detection with sensor cable	-	-	+	+
Automatic fire detection system	+	+	+	+
Automatic incident detection system	+	+	+	+
Tunnel radio communication system	-	-	+	+
Tunnel public address system	-	-	-	+
Emergency telephone system	+	+	+	+
Remote tunnel control system	+	+	+	+
Traffic information system	+	+	+	+
Heating of hydrant network pipes	according to hydrotechnical design			

Further guidelines for the preparation of individual projects listed in the table are provided below.

## 18.2. Portal transformer substations

### Introduction

For the purpose of supplying tunnel consumers, so-called portal transformer substations shall be designed on the plateaus defined within the civil engineering design, located in front of the entrance/exit portals of the tunnel. The minimum bearing capacity of the ground at the selected location shall be 100 kN/m<sup>2</sup>. The selected location of the transformer substation, as a standalone structure, must provide direct and unobstructed access. Vehicle access must be ensured for servicing the power transformer. Portal transformer substations shall be designed as cable-type installations, housed in concrete enclosures, with internal access for operation and maintenance.

### 18.2.1. Civil engineering design

The transformer substation shall be designed as a standard prefabricated reinforced concrete structure, intended to accommodate the transformer substation in one section and other equipment (UPS units, UPS switchboards, communication cabinets, and tunnel control system cabinets) in another section. The external dimensions of the facility are approx. 7.70x5.00x2.60m. The useful depth of the foundation opening below the floor slab is 0.80 m.

Within the section intended for the installation of transformer substation components, power transformers, high-voltage (HV) and low-voltage (LV) equipment shall be installed in accordance with the layout, which shall form an integral part of the design documentation. Unobstructed access and operation from within the facility shall be ensured for both medium-voltage (MV) and low-voltage (LV) equipment.

The transformer substation structure shall be constructed from prefabricated concrete elements of class MB30, with waterproofing class V4, and reinforcement steel grades GA 240/360, RA 400/500, and MA 500/560. Reinforcement of all structural elements shall be interconnected by welding and grounded via a grounding sleeve and an equipotential bonding busbar, ensuring galvanic continuity of all elements.

Openings for equipment installation shall be provided in the floor slab. In the foundation section beneath the power transformer, a partition shall be provided to form an oil collection pit, ensuring containment of any potential oil leakage. The walls and bottom of the oil pit shall be coated with a water-dispersed, two-component epoxy coating. Openings shall be provided in the foundations for the installation of plastic ducts for routing HV/LV cables. Depending on the location of the structure, provision for drainage of stormwater shall be mandatory. The roof of the structure shall be designed with a minimum slope.

The structure shall be equipped with four double-leaf doors and one single-leaf door, made of anodized aluminium, fitted with cylinder locks and a master key system. All doors shall be provided with louvers at both upper and lower sections to enable adequate cooling and ventilation of the transformer substation. On the inner side of the louvers, a fine aluminium mesh shall be installed to prevent the entry of small animals.

The structural foundation depth shall be set at an elevation of  $-0.90$  m relative to the finished surrounding ground level, ensuring a height difference of 20 cm between the surrounding terrain and the finished floor level of the structure.

Below the foundation of the transformer substation, a concrete slab of minimum thickness 10 cm, made of concrete class MB20, shall be provided to enable foundation on soil with a minimum bearing capacity of  $100 \text{ kN/m}^2$ . For soils with lower bearing capacity, soil replacement up to the required level shall be carried out using a thicker blinding concrete layer or gravel.

### **18.2.2. Electrical design**

Transformer substations supplying consumers located in tunnels shall meet the requirement of redundant power supply. This shall be achieved by installing two transformers with associated low-voltage switchboards interconnected via a coupling field, so that in the event of failure of one transformer, the other fully assumes its load. Transformers shall be oil-filled, tap-changeable 10–20/0.42 kV units, with installed capacity determined by application requirements (250 to 1000 kVA, depending on the installed load of consumers).

Transformers shall comply with standards for three-phase oil-filled distribution transformers DIN 42523 and IEC Publication 726.

Basic technical characteristics:

Rated power (kVA)	250	400	630	1000
Rated transformation ratio (kV)	10-20/0,42 (tap-changeable)			
Frequency	50Hz			
Connection	Dyn 5			
Short-circuit voltage	up to 4%		up to 6%	
Voltage regulation	±2x2,5% of rated primary voltage			
Test voltage	125/50 kV			
Cooling	ONAN			
Degree of protection	IP00			

The transformer shall be equipped with:

- thermometer pocket
- grounding connection
- oil drain valve
- lifting hooks
- nameplate
- thermal protector
- safety valve
- wheels
- oil filler opening

Transformers shall be positioned in the side section of the structure, with connection terminals oriented towards the HV/LV equipment. A wooden barrier shall be installed behind the doors to prevent accidental contact with live parts. Cooling of transformers shall be ensured by natural air circulation through louvers installed on the doors of the transformer substation.

The 20 kV switchgear shall be of RMU (Ring Main Unit) type, consisting of two feeder fields and one transformer field. For redundancy purposes, two such units shall be installed in each transformer substation.

The switchgear shall be designed as a free-standing cabinet made of stainless steel, fully enclosed and protected against contact with live parts. The insulation and arc-quenching medium shall be SF<sub>6</sub> gas.

Basic technical data of the switchgear:

- rated voltage	24kV
- rated busbar current	630A
- rated frequency	50Hz
- insulation and arc-quenching medium	SF <sub>6</sub> gas
- lightning impulse withstand voltage	125kV
- power frequency withstand voltage (1 min)	50kV
- short-time withstand current (1s)	20kA
- peak withstand current	40kA

Transformer fields should be equipped with:

- three-pole disconnecting switch 24kV, 200A, 20kA,
- fuses 24(12)kV, rated according to transformer current, ensuring three-phase disconnection of the switch in case of one or more fuse failures;
- earthing switches,
- auxiliary equipment for remote control.

Feeder fields should be equipped with:

- motor-operated three-pole disconnecting switch, 24 kV, 630 A, 16 kA
- earthing switches
- auxiliary equipment for remote control.

Each field shall have an accessible cable compartment. Cables shall be connected from the front side of the unit by removing the protective sheet metal cover.

A mimic diagram with status indication of individual switching devices shall be installed on the front side of the switchgear unit. A trip push-button shall be provided on the front side of the transformer field.

The switchgear unit shall be equipped with an operating mechanism incorporating internal, integrated mechanical interlocking.

As standard, the fields shall also be equipped with:

- bushing for cable connection of the unit
- internal interlocks to prevent incorrect operations of earthing switches under load
- interlocking system to prevent access to fuses and cable connections unless the respective field is earthed, and preventing operation of disconnectors when the cable cover is not in place
- capacitive voltage indicator.

For the purpose of remote control implementation, the installation shall allow for the installation of motor drives on switching devices and associated remote control equipment. Feeder cells shall additionally be equipped with short-circuit indicators with a minimum sensitivity of 400 A.

The connection of the transformer to the 20 kV switchgear shall be carried out via a cable line using single-core cables 12/20 kV, type XHE 49-A, 3x(1x50/16) mm<sup>2</sup>. Cable connections to transformer bushings and 20 kV equipment shall be made using cable terminations and Al-Cu lugs, and to the switchgear via T-type plug-in connectors.

The low-voltage installation shall consist of two LV switchboards and one coupling cell. The LV switchboards shall be free-standing, constructed from steel profiles and double pickled sheet steel of 2 mm thickness, with anti-corrosion protection applied by electrostatic coating. The approximate dimensions of a single cabinet shall be 1,850 × 500 × 1,800 mm. On the operating side, the installation shall be enclosed and protected against accidental contact with live parts.

Basic technical data of the low-voltage installation:

- rated voltage (V)	400
- rated busbar current (A)	1250
- rated frequency (Hz)	50
- short-time withstand current (kA)	25
- peak withstand current (kA)	50
- degree of mechanical protection	IP 00

One LV switchboard consists of an incoming and a distribution field.

The LV installation shall consist of three functional units: Transformer I, coupling section, and Transformer II. The installation shall be designed to operate in the following modes, with mechanical interlocking preventing parallel operation of transformers:

- Normal operation: Transformer I and Transformer II operate independently; the circuit breaker in the coupling section is open;
- In case of failure or maintenance of one transformer: the entire load of both transformers is supplied by the remaining transformer; the circuit breaker in the coupling section is closed;
- Due to potential adverse effects on the distribution network, the equipment is not designed for parallel transformer operation.

Main equipment of the LV installation (LVSB1 and LVSB2):

- LV moulded-case circuit breaker with motorized drive, 500 V, 1250 A, with microprocessor-based LS/I protection adapted to the rated transformer capacity and mechanical interlocking (Transformer I and II incomers) – 2 pcs
- LV moulded-case circuit breaker with motorized drive, 500 V, 1250 A, with mechanical interlocking (coupling field) – 1 pc
- fuse switch disconnectors 400 A – quantity according to number of outgoing feeders
- compact switch 160A, 3-pole – 2 pcs
- LV moulded-case circuit breakers with manual operation, 500 V, rated current according to installed load, with microprocessor-based LS/I protection – quantity according to number of outgoing feeders
- Single-pole miniature circuit breakers
- Fuse disconnectors with fuse failure indication
- Current transformers
- Network analyser for electrical measurements - 6 pcs
- Four-pole surge arrester 3p+N, 65 kA
- Additional equipment: outlets, fuses for lighting and cooling circuits, protection and measurement devices, complete internal wiring.

The connection between the LV side of the transformer and the LV distribution shall be carried out using single-core conductors insulated with PVC resistant to temperatures up to 378.15 K (105 °C), with rated voltage up to 1 kV, selected according to the transformer rated power.

Depending on the installed transformer capacity and the type of consumers, automatic power factor correction shall be provided within the transformer substation. The automatic compensation equipment shall be installed in two separate cabinets located adjacent to the MV switchgear.

Protection of the power transformer against short-circuit currents shall be provided by high-voltage high-performance fuses, with rated current corresponding to the transformer rated current and rated voltage corresponding to the network voltage, installed in the transformer fields of the HV switchgear. The operation (blowing) of one or more fuses shall cause three-pole disconnection of the disconnecting switch in the transformer field.

Protection of the transformer against overload and internal faults shall be ensured by a contact thermometer, which shall also trip the disconnecting switch in the 20 kV transformer field. Additional protection against transformer overload shall be provided by a thermal trip unit on the LV circuit breaker in the incoming fields of the LV switchgear.

Protection of LV outgoing feeders against short circuits shall be provided by low-voltage high-performance fuses with rated current determined according to the rated load of the consumers. Backup protection of the LV installation and outgoing feeders against overload and short circuit shall be provided by LV circuit breakers. Protection against atmospheric and other overvoltages shall be ensured by surge arresters installed on the LV busbars. Indication measurements of electrical quantities at low voltage (current, voltage, and other electrical parameters) shall be performed within the LV switchgear using a multifunction measuring instrument.

Operation of MV switchgear equipment shall be performed by verifying the status of the switching device on the mimic diagram and executing the operation by rotating the operating handle. The position of the switching device shall be clearly indicated on the front panel, including the direction of handle rotation. For emergency disconnection, the switchgear shall be equipped with a dedicated emergency push-button.

A combined grounding system shall be designed within the transformer substation, i.e. interconnection of the operational and protective earthing systems. As part of the grounding system, an equipotential bonding installation shall be provided, connecting all exposed conductive parts not normally under voltage to the equipotential bonding system. The equipotential bonding system shall be implemented using FeZn strips of dimensions 25x4 mm. The equipotential bonding ring of the transformer substation shall be galvanically connected to the grounding system of the structure, i.e. the site grounding system. The grounding system of the transformer substation shall generally be constructed using two grounding rings around the structure and connected by FeZn strips installed along the entire length of the cable trench. In addition to local manual operation, remote control of MV and LV equipment shall be enabled from the Control and Maintenance Center (COKP). All safety requirements for operation shall be fulfilled, including interlocking systems preventing incorrect operation. All components subject to frequent human contact shall be insulated and protected in such a way as to ensure maximum protection against dangerous touch voltages. Equipment for remote monitoring and control shall be installed in a separate communication cabinet of appropriate dimensions.

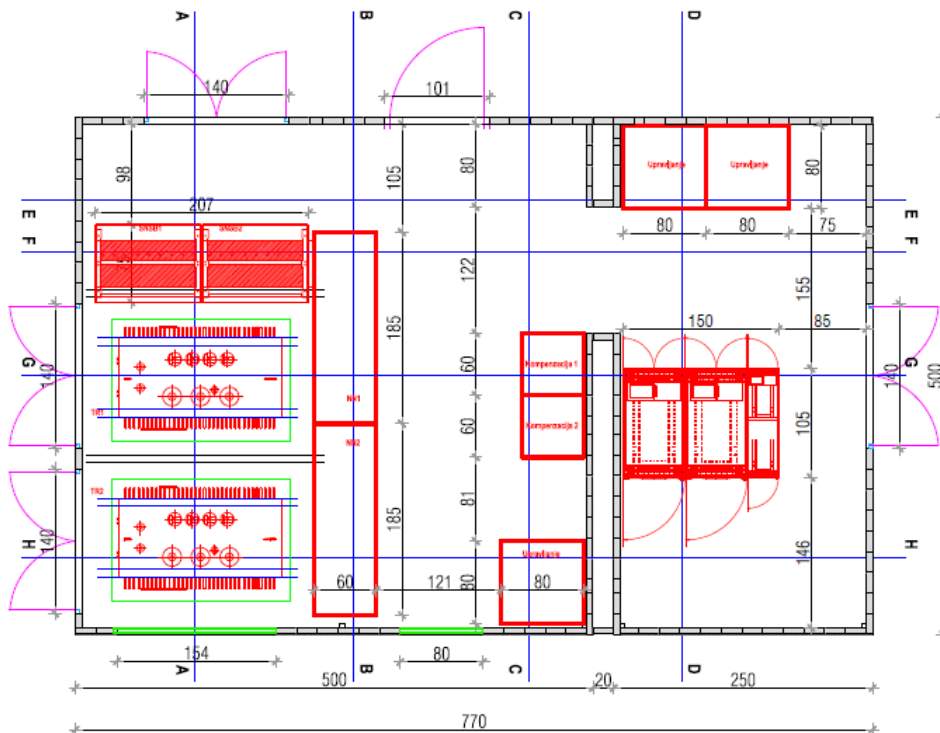


Figure 1 - Portal Transformer Substation – Equipment Layout

### 18.3. Tunnel transformer substations

In cases where the tunnel length is such that supplying tunnel equipment from portal transformer substations is not feasible, or is not economically justified, the design of tunnel transformer substations shall be undertaken. It is estimated that tunnel transformer substations should be designed for tunnels longer than 1000 m. However, where justified by techno-economic analysis, tunnel transformer substations may also be designed for shorter tunnels. Conversely, portal transformer substations may, in some cases, adequately supply consumers in tunnels longer than 1000 m.

The same guidelines applicable to the design of portal transformer substations shall apply to tunnel transformer substations. The following section outlines only the differences between them.

#### 18.3.1. Civil engineering design

Tunnel transformer substations shall be located in cross-passages for vehicles, between the left and right tunnel tubes. The substation shall be of cable-type design with internal access for operation and maintenance. Accordingly, the tunnel civil design shall provide a dedicated room forming a separate fire compartment, with dimensions sufficient to ensure safe and unobstructed operation of personnel and equipment.

The approximate internal dimensions of the rooms for accommodating the transformers are approx. 5.30x2.10x2.70 m (width x depth x height), rooms for MV switchgear (MVSB), LV switchgear (LVSB), and UPS approx. 5.80x4.30x2.70 m (width x depth x height), control equipment rooms approx. 3.40x2.10x2.70 m (width x depth x height), depth of cable trenches 0.6 m. The selected location of the transformer substation shall provide direct and unobstructed access. Since access doors are located on one side of the structure, vehicle access is required only from the service side of the power transformer. As tunnel-type transformer substations must, in accordance with regulations, represent a single fire compartment, three double-leaf fire-resistant doors shall be installed, equipped with cylinder locks and a master key system.

Cooling and ventilation of the transformer substation shall be ensured by forced air circulation, using exhaust fans and appropriately sized openings equipped with fire dampers. The internal walls and ceiling of the transformer substation shall be finished with white dispersion paint.

#### 18.3.2. Electrical design

The tunnel transformer substation shall be equipped with two **dry-type switchable power transformers** 10-20/0.4 kV, with rated power corresponding to the installed load, including an appropriate reserve.

Transformers shall comply with standards for three-phase dry-type distribution transformers DIN 42523 and IEC Publication 726.

Basic technical characteristics:

Rated power (kVA)	250	400	630	1000
Rated transformation ratio (kV)	10-20/0.4 (switchable)			
Frequency	50Hz			
Connection	Dyn 5			
Short-circuit voltage	up to 4%		up to 6%	
Voltage regulation	±2x2,5% of rated primary voltage			
Test voltage	125/50 kV			
Cooling	ONAN			
Degree of protection	IP00			

The transformer shall be equipped with:

- grounding connection
- lifting hooks
- nameplate
- PTC sensors
- protective relay
- wheels.

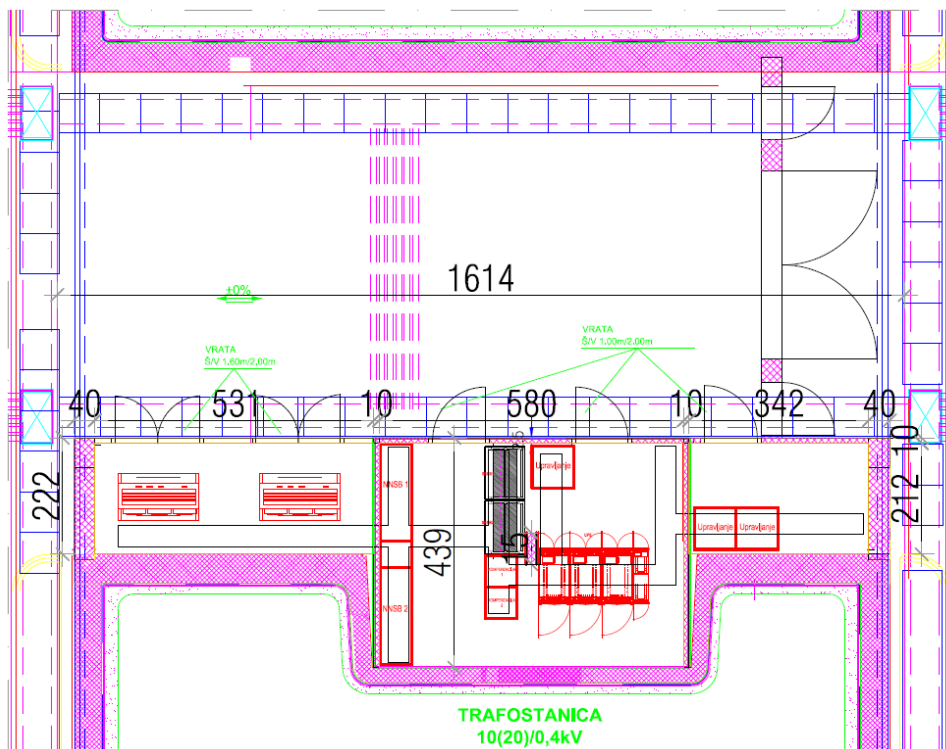


Figure 2 - Tunnel Transformer Substation – Equipment Layout

Provision shall be made for installation of transformers with wheels mounted on steel supports of type **UNP160**.

Due to the location of the transformer substation, as well as the equipment layout within the substation, the connection between the transformer and the LV switchgear shall be realized using cable 3x(2x(P/FT(1x240)) mm<sup>2</sup> + P/FT 1x(1x240)) mm<sup>2</sup> for all installed capacities, in order to ensure maximum standardization. A note shall be included in the technical specification and bill of quantities stating that, due to multiple cables per phase, there is a possibility of uneven load distribution among individual cables. Therefore, particular attention shall be paid during the execution of the connection between the transformer and the LV installation.

Protection of the power transformer against short-circuit currents shall be provided, as in portal transformer substations, by high-voltage high-performance fuses with rated current corresponding to the transformer rated current and rated voltage corresponding to the network voltage, installed in the transformer fields of the HV switchgear. The operation (blowing) of one or more fuses shall result in three-pole disconnection of the disconnecting switch in the transformer field.

Protection of the power transformer against overload and internal faults shall be ensured by means of PTC sensors and an appropriate relay, which shall also trip the disconnecting switch in the 20 kV transformer field.

Additional protection against transformer overload shall be provided by a thermal trip unit on the LV circuit breaker in the incoming fields of the LV switchgear..

#### **18.4. Uninterruptible power supply (UPS) system**

For the purpose of supplying priority consumers in the event of a failure of the distribution network supply, a tunnel UPS system shall be designed. The UPS system shall supply the following consumers:

- safety and emergency lighting in the tunnel
- all equipment for management and control of all systems
- distribution cabinets in SOS niches and cross-passages

The tunnel UPS system shall consist of UPS units installed in dedicated rooms forming part of the transformer substations, as described in the guidelines for the design of transformer substations.

UPS units shall be modular and shall meet the requirement of redundant power supply. Redundancy shall be achieved by installing UPS units with multiple power modules for consumers in each tunnel tube. UPS systems shall be dimensioned and interconnected in such a way that the UPS supplying consumers in one tunnel tube is capable of supplying the corresponding consumers in the other tunnel tube, while maintaining the required autonomy. The required autonomy, under the condition of redundant supply, shall be 60 minutes.

#### **18.5. Medium voltage supply of transformer substations**

The supply of transformer substations from the power system shall be defined by the Independent System Operator of BiH and Elektroprijenos BiH, via new and existing 110/10(20) kV substations.

The cable line connecting distribution transformer substations shall be implemented according to an in-out (loop) configuration and constructed using halogen-free power cables rated 12/20 kV. The medium-voltage cable system shall consist of three single-core cables arranged in a triangular formation. Within tunnels, MV cables shall be installed in cable ducts and protected by PEHD pipes.

In soil, MV cables shall be installed freely in trenches at a depth of 80 cm in triangular arrangement, while crossings beneath roadways shall be executed using PEHD pipes of Ø200 mm at a depth of 120 cm. Along the entire route, a PEHD pipe Ø50 mm shall be installed in the trench for installation (blowing) of optical fibre cables.

## 18.6. Tunnel lighting

### Photometric design and operating modes of tunnel lighting

The Technical Report of the European Standard EN/CR 14380 – Annex A2 shall be used as the primary reference document for the preparation of the tunnel photometric design. Based on the cross-section of the entrance portals and the longitudinal profile of the tunnel entrance, the proportions of sky, roadway, rock, and vegetation within the driver's field of view shall be assessed for both tunnel tubes. Using these values, together with data on tunnel orientation and driving speed, the luminance levels of the access zones for both tunnel tubes shall be calculated. The threshold zone luminance ( $L_{th}$ ) shall be determined based on the coefficient  $k$ , which defines the ratio between  $L_{20}$  and  $L_{th}$ , in accordance with EN/CR 14380 – Annex A2, taking into account the permitted driving speed (stopping distance) and traffic flow. The luminance of the interior zone of the tunnel shall also be determined in accordance with EN/CR 14380 – Annex A2. During night-time conditions, a luminance level of  $2 \text{ cd/m}^2$  shall be ensured throughout the entire tunnel. To achieve safety lighting, it is necessary to provide an average and minimum road illuminance level of  $E_{sr}=10 \text{ lx}$  and  $E_{min}=2 \text{ lx}$ , respectively.

Depending on the luminance of the access zone, the following operating modes shall be defined in the design:

#### Daytime lighting

- Mode I – 100% luminance of the threshold zone
- Mode II – 75% luminance of the threshold zone
- Mode III – 50% luminance of the threshold zone
- Mode IV – 25% luminance of the threshold zone
- Mode V (twilight) – 12.5% luminance of the threshold zone

The design shall ensure continuous luminance control (reduction) along the CIE curve, so that the driver does not perceive abrupt changes in luminance and to achieve maximum efficiency.

In addition to daytime lighting modes, the following shall also be provided:

- Mode VI –  $4.0 \text{ cd/m}^2$  (increased traffic during night-time and emergency situations)
- Mode VII –  $2.0 \text{ cd/m}^2$  (standard night lighting)
- Mode VIII –  $10 \text{ lx}$  (safety lighting)

Tunnel luminaires shall fully comply with the lighting design calculations. In addition, they shall be of robust construction, ensuring a high degree of protection against corrosion, impact, and vibration. Luminaires shall be manufactured from stainless steel or high-strength extruded aluminium. The degree of protection shall be IP66. The light source shall be protected by a tempered (thermally and mechanically strengthened) glass cover with impact resistance IK08. Connectors within the luminaire shall be manually disconnectable without the use of tools. Energy-efficient light sources shall be used, such as high-pressure sodium lamps and/or LED light sources.

Analyses have shown that for tunnels longer than 1000 m, it is economically justified to use LED luminaires. As LED technology is relatively new in the field of lighting, some of the advantages, as well as disadvantages, of LED lighting are briefly outlined below.

- LED technology is gaining more and more momentum in the lighting market. It is expected that by 2014, 44% of the outdoor lighting market will be realized with LED source luminaires, and by 2020, as much as 74%.
- The efficiency (luminous efficacy) of LED sources increases year by year. This efficiency is approaching that of sodium lamps and is even higher for all power ratings up to 150 W (for 250 W, the efficiency of sodium lamps is 122.67 lm/W, and for 400 W it is 130.78 lm/W).
- The lifespan of LED sources is significantly longer than that of sodium light sources. For most high-quality LED luminaires, after 100,000 operating hours, the luminous flux decreases to 90% of the nominal value. This means that, for a design maintenance factor of 0.8 (i.e. luminous flux reduced to 80% at the end of the service life), an even longer operational life can be expected. For high-pressure sodium lamps, the service life is typically in the range of 16,000–20,000 hours for the highest-quality products available on the market—approximately five times shorter—significantly impacting maintenance costs of tunnel lighting installations (LED sources are typically replaced only after approximately 10–15 years of continuous operation (24 h/day)).
- LED sources eliminate the so-called flicker effect, which is often present in installations using conventional HID sources. The use of high-quality drivers avoids operation in the frequency range of 70–130 Hz, which is critical in terms of flicker.
- LED sources can be dimmed down to 10% of the initial luminous flux (with approximately linear reduction of power), whereas due to physical limitations, sodium lamps can operate only down to approximately 20% of initial flux (or 35% of power).
- Thanks to their dimming capability, LED sources allow more efficient regulation of luminous flux and improved control of tunnel lighting systems, resulting in significant energy savings. In addition, LED sources provide an almost instantaneous response during switching and dimming, whereas sodium lamps require 5–10 minutes to reach nominal luminous flux (warm-up period).
- LED sources emit white light (colour temperature approximately 4000 K), which is more comfortable for the human eye compared to the yellow light (approximately 2200 K) produced by sodium lamps.
- The colour rendering index (CRI)—the ability to reproduce object colours close to their natural appearance under daylight—is higher for LED sources (minimum value of 70), whereas for sodium lamps it is approximately 40.
- Due to high-quality drivers that enable operation of LED chips over a wide voltage range (typically 120–277 V), fluctuations in supply voltage have a significantly lower impact on LED operation compared to sodium lamps.
- LED sources start practically at nominal current (excluding inrush current, which is limited by appropriate resistors in the luminaire circuit), whereas sodium lamps typically have a starting current approximately 50% higher than the nominal value, which is an important factor in the design and dimensioning of tunnel lighting systems.
- Thanks to programmable drivers integrated in luminaires, it is possible to regulate luminous flux throughout the service life.

In addition to numerous advantages, one disadvantage of LED technology should also be mentioned:

- LED sources are significantly more sensitive to temperature (under operating conditions with PN junction temperature of approximately 75 °C, the luminous flux may be reduced by more than 10% compared to laboratory conditions (25 °C)). Furthermore, LED drivers

are also temperature-sensitive and may be damaged if the ambient temperature (i.e. temperature inside the luminaire) exceeds the maximum permissible value. In contrast, sodium lamps, combined with robust electromagnetic ballasts, are largely unaffected by temperature variations.

When determining the positioning of luminaires, consideration shall be given to the number of traffic lanes, tunnel geometry, maintenance requirements, and potential conflicts with other installations (e.g. tunnel ventilation systems). Luminaires shall be positioned to satisfy photometric requirements, ensure proper visual guidance, and provide an acceptable aesthetic appearance. When selecting and technically describing the luminaires, it is mandatory to prescribe measures for the periodic maintenance of the lighting.

In addition to general and safety lighting luminaires, the project must provide for the installation of **guidance markers**. These markers indicate the edge of the roadway in the tunnel, are implemented in light-emitting diode (LED) technology, and are supplied by an uninterruptible power source (UPS). Markers installed on the right-hand side in the direction of travel shall emit red light, while those on the opposite side shall emit white light, ensuring proper visual guidance in the case of bidirectional traffic within a single tunnel tube. Markers installed on the left-hand side in the direction of travel shall emit red light on both sides. Markers shall be installed at intervals of 25 m within the tunnel, and at 15 m intervals at the tunnel entrance and in curves. Installation shall be on the curb of the service walkway.

In the tunnel, it is necessary to provide for the installation of **luminaires for determining distance**. The lights are also made in LED technology and are placed on the right side in the direction of driving on the tunnel wall (at a height of 1 m from the ground), at a distance of 50 m. The light colour is blue.

On the left side of the tunnel tube in the direction of driving, **luminaires for visual guidance and marking of evacuation routes** are placed at a mutual distance of 25m. These may include tempered glass covers with evacuation direction and distance markings or illuminate retroreflective signs.

Above cross-passage doors, LED luminaires shall be installed (sign type III-128 – “Emergency Exit”). It is necessary to provide **luminaires for marking doors of SOS niches** and doors of cross passages. Waterproof (IP65) fluorescent luminaires with PMMA covers and electronic ballasts shall be installed for lighting SOS niches and pedestrian passages. **Exit zones** of the tunnel need to be illuminated using outdoor lighting luminaires mounted on lighting poles, ensuring a luminance level of 2 cd/m<sup>2</sup>.

## Lighting control

Tunnel lighting luminaires shall be supplied with electrical power and interconnected in such a way as to enable both manual and automatic control.

Manual control shall be both local and remote. Local control shall be provided from tunnel lighting distribution cabinets. Remote control shall be implemented via the remote control system (RCS), from the Traffic Control and Management Center. For this purpose, tunnel lighting distribution cabinets shall be equipped with control and status indication equipment, interfaced via potential-free (dry) contacts.

The lighting maintenance service in the COKP needs to be enabled to:

- monitor the current lighting operating mode
- fault signalling per distribution cabinet and per fault group within each cabinet
- remote selection of lighting operating modes.

Automatic lighting control shall be implemented using photoluminance meters installed in front of the tunnel at a distance corresponding to the stopping distance. A photoluminance meter continuously measures the luminance of the access zone and generates a number of relay outputs accordingly. The signal shall be transmitted via signal cable to the first tunnel lighting distribution cabinet. Communication between individual lighting cabinets shall be established via the tunnel control system.

### 18.7. Low-voltage power supply and cable distribution

For the supply of individual tunnel equipment consumers, distribution cabinets shall be installed in tunnel electrical niches, the construction of which is provided for in the civil engineering design. The required dimensions and layout of the niches are provided in the drawings attached to this document. The niches are functionally divided into electrical niches used for power supply and control of tunnel ventilation and lighting equipment, and SOS niches used for power supply and installation of RTS devices, SOS cabinets, and public address system cabinets. For supplying equipment in pedestrian and vehicle cross-passages, distribution cabinets shall be installed within the walls of the passages.

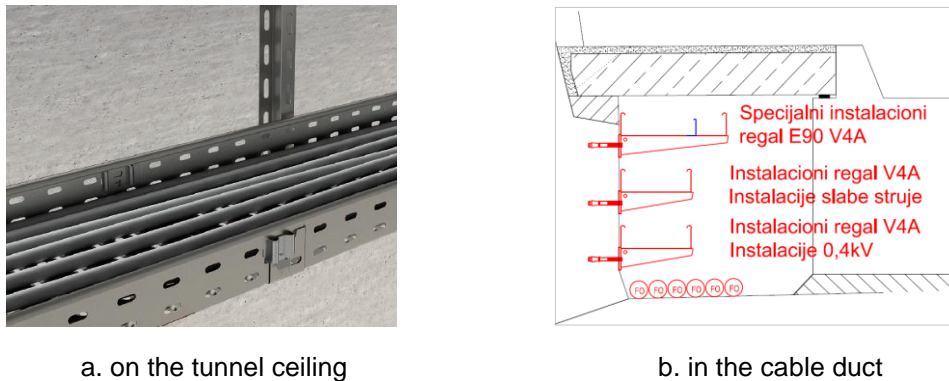
Low-voltage supply to distribution cabinets shall be provided from portal and tunnel transformer substations. Certain consumers shall be connected to an uninterruptible power supply (UPS); therefore, distribution cabinets shall include both mains and UPS sections.

Power cable routing from LV switchboards in transformer substations to distribution cabinets shall be carried out through cable ducts located beneath the service walkway, on the right-hand side of the tunnel tube (in the direction of travel). Crossings beneath the roadway structure shall be executed through cable conduits provided in the civil engineering design.

Cable trays shall be installed within the cable ducts (the number of trays depending on the number of cables). Cable trays, supports, and installation accessories shall be made of stainless steel grade V4A in accordance with DIN 4102.

Exceptionally, cable trays within the cable ducts may be made of galvanized material, provided that the cable duct is covered with concrete slabs and sealed with liquid asphalt. In such cases, cable trays shall be protected against corrosion by hot-dip galvanization in accordance with DIN EN ISO 1461, with a zinc layer thickness of 40–60 µm. All subsequent cuts on cable trays shall be additionally protected against corrosion using zinc coating. Screws shall also be hot-dip galvanized. Concrete anchors shall be made of stainless steel.

Cable trays supporting fire-resistant installations shall have certification confirming fire resistance as a complete system.



a. on the tunnel ceiling

b. in the cable duct

**Figure 3** - Cable trays

The aggressive tunnel environment results from increased presence of combustion by-products from vehicle engines, local climatic influences, high humidity, and increased vibration levels. Combustion processes in vehicle engines produce the following compounds: sulphur dioxide (SO<sub>2</sub>), nitrogen dioxide (NO<sub>2</sub>), and hydrogen sulphide (H<sub>2</sub>S). These substances make the tunnel atmosphere highly corrosive. The European directive “*Directive 2004/54/EC of the European Parliament and of the Council*” which prescribes minimum safety requirements for tunnels longer than 500 m within the Trans-European Road Network (TERN), to which Corridor Vc belongs, requires the use of stainless steel as the material for installation support structures. Stainless steel grade V4A is recommended for cable trays, support structures, and all associated installation elements and accessories, as it is corrosion-resistant, non-toxic in case of fire, and suitable for structures that must meet fire resistance requirements. Systems required to maintain functionality in case of fire shall possess system-level fire resistance, verified by a “Certificate of System Fire Resistance”. An additional requirement for all tunnel cable support structures and their components is that they must not emit toxic (halogen) substances during combustion.

Cables for enhanced tunnel lighting shall be installed on cable trays. The trays shall be mounted on ceiling brackets with adjustable inclination. Cable trays and associated suspension accessories shall be made of stainless steel grade V4A (1.4571). After selecting the type of tray and luminaires, a structural (static) calculation of the cable tray system shall be performed within the Detailed Design, including the exact arrangement and number of supports, as well as all associated connection and suspension elements. Distribution of enhanced lighting and base (safety) lighting shall be separated, as the safety lighting system must maintain functionality in case of fire (fire resistance class E90). All elements of the cable tray system shall be galvanically connected using integrated connectors and bonded to protective busbars in distribution cabinets in accordance with DIN EN 61573.



a. Installation of luminaires for base lighting    b. Installation of luminaires for enhanced lighting

**Figure 4 - Principle of luminaire installation**

Routing of cables from the distribution cabinet located in the electrical niche to the cable tray mounted on the tunnel crown shall be provided using PEHD pipes installed within the concrete lining of the tunnel (the number of pipes shall be determined based on the number of cables and provided as input data to the civil design engineer).

All cables for mains power supply shall have halogen-free insulation. Cables for uninterruptible power supply shall have flame-retardant, halogen-free insulation with functional integrity maintained for a minimum of 90 minutes. Cables supplying safety lighting shall additionally have fire-resistant insulation in accordance with IEC 60092-353, IEC 60331-21 (90), and IEC 60754, with fire resistance class E90.

The cable installation in the tunnel must not transmit fire from one fire zone to another. Therefore, all cable penetrations from electrical niches and cable passages beneath cross-passage walls shall be sealed using special fire-resistant mortar.

### **Distribution cabinets**

In tunnel electrical niches, it is necessary to plan the installation of distribution cabinets for tunnel equipment, namely distribution cabinets for: lighting (ROR-XX), ventilation (ROV-XX), cross passages (RO-PPX, RO-IVX), and SOS niches (RO-S-XX).

Lighting distribution cabinets shall supply lighting groups divided according to lighting zones, permissible voltage drop, and maximum cable lengths within zones. Each cabinet shall include separate mains and UPS sections, supplied independently. Cabinets shall be of free-standing design with a degree of protection IP54. Enclosures shall be made of double pickled sheet steel with a thickness of 2 mm. All components installed within the cabinet shall be mounted on a mounting frame or mounting plate, allowing removal and reinstallation of individual components without dismantling other equipment. All cabinet components shall be fully assembled and wired in the workshop. All internal wiring conductors shall be neatly arranged in perforated PVC cable ducts with covers.

All metal doors of the cabinets containing electrical equipment shall be connected to the protective earthing conductor. When wiring, neutral conductors must be blue, and protective conductors must be yellow-green. All other conductors cannot be of these colours. Busbars must be marked according to the standard with L1, L2, L4 phases, N for neutral busbar, and PE for protective busbar. Cable lugs at conductor ends shall be crimped.

The use of lugs with longitudinal seams formed by bending is prohibited. Screws used for conductor connections to busbars shall be equipped with spring washers. All cable connections shall be made via terminal blocks of appropriate size. All terminals shall be labelled in accordance with applicable standards. All cable cores shall also be marked, corresponding to the terminals to which they are connected.

All equipment within the cabinet and on the cabinet doors shall be identified using engraved nameplates, which shall not be glued.

For fuse links, a nameplate indicating the maximum permissible fuse rating shall be provided. All cables shall be introduced into the distribution cabinet exclusively from the bottom side. The degree of protection of the cabinet shall be at least IP54. External and internal surfaces of the cabinet, as well as auxiliary structures and accessories, shall be protected against corrosion and painted.

Cabinets shall be anchored. Each distribution cabinet shall have a document holder mounted on the inner side of the door. The cabinet documentation shall include a single-line diagram and a control (functional) diagram. All necessary minor installation materials shall be deemed included. Functional testing and acceptance of distribution cabinets shall be carried out at the manufacturer's workshop in the presence of the supervising authority.

Distribution cabinets for cross-passages shall include only the UPS distribution section.

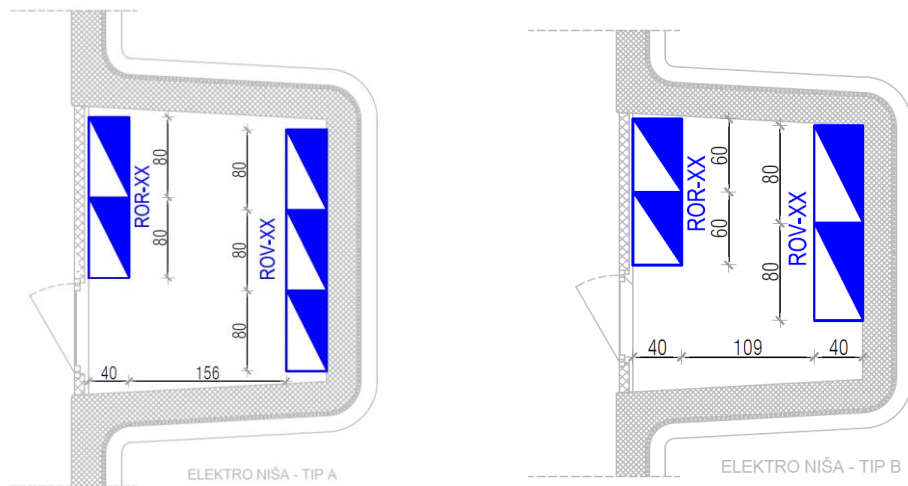
Cabinets shall be installed in the walls of cross-passages at locations indicated in the design drawings, equipped in accordance with the single-line diagrams. The same general requirements applicable to tunnel lighting distribution cabinets shall apply to cross-passage cabinets.

Measures to be implemented to ensure operational safety:

- Distribution equipment in special hermetically sealed niche.
- Equipment in the cabinet protected against condensation by installing heater with thermostat.
- Luminaires of individual operating stages connected in multiple circuits, instead of one higher-capacity circuit.
- Cables coming from outside protected by surge arresters.
- Auxiliary control circuits extending outside the tunnel (photometer) supplied from UPS.
- Control solution for main contactors ensures lighting is turned on in the event of failure of auxiliary relay.

Measures for easier and faster maintenance:

- Switchgear in a separate niche.
- Fault signalling of individual groups provided by signal lamps located in the cabinets, with signals transmitted to the control center.
- Recording of operating time by means of hour counters.



**Figure 5** - Electrical Niche - Equipment Layout

### 18.8. Electrical design of ventilation system

The electrical design of the tunnel ventilation system shall be based on the mechanical design of the ventilation system. The mechanical design defines the exact positions and number of fans for each tunnel tube, the motor power of the fans, and the method of operation.

The low-voltage distribution of the ventilation system shall be designed in accordance with the positions of electrical niches and fan locations. During design, the principle shall be applied that multiple fans are supplied and controlled from a single electrical niche, taking into account electrical constraints such as maximum cable lengths, optimal cable cross-sections, and permissible distances for transmission of control and sensor signals.

Fan motors are three-phase asynchronous motors. The fans operate reversibly (bidirectionally), and switching is performed via soft-start devices.

Automatic operation of the ventilation system shall be carried out through a control program developed in the Detailed Design, based on the algorithm defined in the mechanical design of the ventilation system. Process control shall be performed via remote stations (RS) of the tunnel control system, which shall ensure local autonomous operation of the ventilation system for each tunnel tube. The central control unit of the ventilation system shall be installed at a location determined by the topology of the remote control system. The operator in the control and monitoring center shall have the possibility of manual remote control.

There are three groups of signals transmitted between the control cabinets and the remote stations:

- 1) System status signals
- 2) Process sensor signals
- 3) Control signals for system operation

Particular attention shall be paid during design to the protection of motors and equipment, as well as to monitoring and signalling of system component status. Each fan shall be provided with overload and short-circuit protection, overheating protection, excessive vibration alarm, and winding heating when the motor is not running. In the case of fire operation mode, the action of motor overheating protection shall be disabled.

Main high-power consumers, such as fan motors and heaters, shall be supplied from the main busbars, while all automatic control system equipment and process sensors shall be supplied from the uninterruptible power supply (UPS) system.

All cables of the ventilation system that may be exposed to open flame within the tunnel tube shall be halogen-free and fire-resistant in accordance with DIN 4102-12. All cable trays and covers for cable ducts shall be made of stainless steel grade V4A (1.4571).

Cable trays installed in ducts carrying fire-resistant systems shall be of fire-resistant design in accordance with DIN 4102-12.

Electrical cables with fire resistance class E90 installed on clamps shall be mounted using fire-resistant clamps of class E90.

All exposed conductive parts not normally under voltage shall be interconnected and connected to the tunnel grounding system.

**Process sensors.** The number and position of process sensors for the ventilation system primarily depend on the type of tunnel profile, ventilation system type, traffic characteristics, and local regulations. Considering that one-directional tunnels with longitudinal ventilation systems are constructed on Corridor Vc, the positions of process sensors shall be defined in accordance with the German guidelines for equipment and operation of road tunnels RABT.

**Fog detectors** are installed in the zone of each tunnel portal (10m).

**CO and visibility sensors.** It is recommended that the first CO concentration and visibility sensors be installed at a distance of 150 m from the tunnel portals. Additional measurement points shall be determined depending on the tunnel length. The spacing between measurement points within the tunnel tube shall not be less than 200 m and not greater than 500 m.

**Airflow velocity and direction sensors,** shall be optimally arranged based on the established layout of CO and visibility sensors. The spacing between measurement points within the tunnel tube shall not be less than 200 m and not greater than 500 m.

Process sensors and all associated equipment shall be installed in full accordance with the manufacturer's technical instructions.

Analog signals from sensors shall be transmitted to the analogue input modules of the controller and processed via software. Based on the values of levels and concentrations defined in the mechanical design of the ventilation system, the control algorithm for automatic operation shall be executed.

## 18.9. Automatic fire detection system

Considering that tunnels are locations with an increased risk of fire, particularly strict fire protection measures shall be applied. The purpose of the design is to ensure an efficient and reliable fire detection system in the tunnel and to enable detection of fire in its initial stage, which is of crucial importance for the evacuation of road users and the preservation of the stability and integrity of the structure, as well as other systems implemented in the tunnel.

The tunnel fire detection system shall be designed in accordance with the provisions of the following documents:

- Directive 2004/54/EC of the European Parliament and of the Council; 29 April 2004.
- Austrian guidelines for tunnel design RVS 9.281 (2004-08)
- Austrian guidelines for tunnel design RVS 9.282 (2004-08)

The fire detection system shall be implemented for all twin-tube tunnels on the motorway.

The equipment of the tunnel fire detection system depends on tunnel length and is treated as follows:

- Tunnels up to 500m shall be equipped with:
  - Fire detection control panel located in the portal transformer substation (TS) in the UPS room, analogue addressable fire detection loop with point-type optical-thermal fire detectors, remote indicators, input/output modules, inductive contacts in fire extinguisher cabinets, and associated cabling.
- Tunnels from 500-3000m shall be equipped with:
  - Depending on tunnel length, one or more fire detection control panels located in portal TS, pedestrian cross-passages, or UPS rooms at dedicated widened sections in the tunnel tubes (vehicle turnarounds), multiple analogue addressable fire detection loops with point-type optical-thermal fire detectors, remote indicators, input/output modules, inductive contacts in fire extinguisher cabinets, and associated cabling.
  - Linear fibre-optic sensing cable installed on the ceiling of both tunnel tubes, with associated fibre-optic controllers. Controllers shall be installed in the same type of rooms as VDC equipment.

At the detection level, the system is generally implemented using two main types of detectors – a fibre-optic sensing cable installed along the tunnel tubes, and point-type automatic fire detectors installed in transformer substations, UPS rooms, and electrical niches.

Manual call points shall be installed in SOS niches and at the entrance and exit portals of the tunnel tubes. Considering the tunnel length, each tunnel tube shall be divided into multiple detection zones, taking into account the locations of pedestrian and emergency vehicle cross-passages. Transformer substations, UPS rooms, electrical niches, and fire detection control panel rooms shall form separate detection zones.

Interconnection of the system into a functional unit shall be carried out using non-combustible cables, red in colour, type J-H(St)H 2x2x0.8 mm, installed as follows:

- In the tunnel installation duct, cables shall be installed in halogen-free PEHD pipes of appropriate cross-section
- In electrical and SOS niches, as well as at tunnel portals, cables shall be installed in halogen-free PE pipes embedded in grooves cut into the concrete wall and finished with mortar, or mounted on the surface and protected with stainless steel cable channels (V4A class)
- The fibre-optic sensing cable shall be mounted on the tunnel ceiling in accordance with the manufacturer's instructions, using clamps and spacers designed for operating temperatures up to 400°C
- For connection of the fire detection control panel and optical sensing cable (OTS) controller to the power supply, cable type NHXH-J 3x1.5 mm<sup>2</sup> shall be used.

The organization and operation of the fire detection system for longer tunnels shall be implemented in a decentralized manner, based on two or more fire detection control panels (FACP).

The fire detection system shall be based on a microprocessor-controlled fire detection control panel with the capability to program detector labels (assignment of textual descriptions), continuous monitoring, verification and processing of feedback from each detector in the system (detector status – activated, fault, etc.), and an appropriate program with defined action scenarios (required actions for different detector states, command execution, monitoring and indication of the status of connected detectors, devices, fire detection loops, etc.).

Fire detection control panels shall be interconnected locally at tunnel level via a system bus to form a network. The panels shall also be connected to the fire detection supervisory system in the COKP. Network modules of the panels shall be connected via IP-based media converters to the local multimode ring network of the tunnel traffic management system, and subsequently connected via single-mode optical cable to the COKP. The local loop ensures communication between control panels and, in case of a loop interruption at one point, maintains both local communication and communication with the COKP.

Fire detection control panels shall transmit signals via the network to remote stations (RS) located in remote control stations (RTS), which are capable of local tunnel control. In doing so, each control panel shall transmit, a general fault signal, a general alarm signal, and one signal for each detection zone it covers, as well as zone alarms of the sensor cable. An alarm signal from a detection zone shall activate an audible alarm in the COKP. The fire detection system interface shall display the detection zone and the exact address of the detector that triggered the alarm, while intervention monitors shall display the corresponding location. The fire detection system in the tunnel shall operate autonomously and independently of the supervisory systems in the COKP.

All transmission lines shall be designed and selected so as not to distort transmitted signals and to prevent external interference that could affect system operation. Transmission lines for fire detection loops shall consist of non-combustible, halogen-free cables, red in colour. For connection of the fire detection control panel to the power supply, cables shall be non-combustible and fire-resistant for at least 90 minutes.

Power supply of the system shall be ensured from two independent sources. The primary supply shall be from the stationary tunnel network (220 V) via the UPS section (dedicated circuit with a clearly marked fuse), while the secondary supply shall be from built-in accumulator batteries (with a minimum autonomy of 30 hours, including at least 0.5 hours in alarm condition), connected to the fire detection control panels and maintained in charging mode during normal operation.

As part of the fire detection system, dry powder fire extinguishers shall be provided, using CO<sub>2</sub> cartridges as the propellant. Fire extinguishers shall be installed in emergency stations, i.e. SOS niches, and at the entrance and exit portals of the tunnel. Appropriate signage indicating the presence of fire extinguishers shall be used. Fire extinguishers shall be capable of extinguishing all classes of fire except fires involving metals and their alloys. Cabinets for fire extinguishers shall be made of sheet steel, protected with a primer coating and finished with red paint. Cabinet doors shall bear fire extinguisher markings, and the interior shall be equipped with holders for two fire extinguishers.

#### **18.10. Automatic video incident detection**

The construction of modern road infrastructure and the continuous increase in traffic require a higher level of safety. In accordance with applicable international recommendations and guidelines, the most advanced systems shall be planned when equipping tunnels. Particular attention shall be given to tunnels, where collisions, fires, or explosions may result in a large number of casualties.

The video system is one of the most important safety components in a tunnel. Its primary function is the monitoring and supervision of traffic within the tunnel and its approaches, as well as alerting the operator in the event of an incident.

In addition to standard video system features, such as continuous image transmission from all parts of the tunnel and its approaches, and temporary storage of video recordings (with the possibility of review and permanent storage), tunnels shall be equipped with an Automatic Incident Detection (AID) system, capable of forwarding alarm messages to the remote control system.

The purpose of the AID system is the automatic detection of incident situations both within the tunnel and on its approaches, and the rapid transmission of information to the operator, enabling prompt and appropriate response and ensuring maximum safety for all road users.

An automatic incident detection system based on image processing technology shall be implemented using a hardware-software platform installed in the COKP.

The automatic incident detection shall detect the following alarms:

- sudden traffic slowdown
- stopped vehicle
- vehicles driving in the wrong direction
- lost cargo left on the roadway (debris)
- obstacles on the roadway or sidewalk (pedestrians, fallen objects, etc.)
- smoke in the tunnel

The alarm shall be transmitted as:

- Audible alarm
- Automatic display of camera image under alarm
- Automatic start of the incident recording process

The system shall also have the ability to generate technical alarms:

- Camera displacement
- Loss of camera signal
- Poor video signal quality
- Network connection failure

The most important requirements for the automatic incident detection system are:

- High incident detection rate
- Short detection time
- Low frequency of false alarms
- Fast incident verification

The Automatic Incident Detection (AID) system in the tunnel consists of fixed cameras for incident detection and movable cameras for monitoring the situation at tunnel portals and parking niches where such niches are provided.

Cameras for incident detection shall be installed on the tunnel crown at intervals of 65 to 80 m. Cameras at tunnel exits shall be oriented in the opposite direction of the incoming light at the tunnel entrance, in order to avoid negative effects of high contrast in the image. Movable PTZ (Pan/Tilt/Zoom) cameras shall be installed at each tunnel entrance and exit, mounted on dedicated poles or lighting poles where feasible, and positioned to provide a clear overview of the entire roadway and tunnel portal area. PTZ cameras shall allow rotation along x-axis and y-axis, and provide the ability to zoom and focus the image.

### **Cameras**

Installation of IP digital video cameras shall be planned. Video cameras form the basis of the AID system and must meet high image quality requirements::

- Image sensor: 1/3" colour / monochrome CCD or CMOS sensor
- Horizontal resolution: 520 TV lines
- Sensitivity min. 0.37 lux
- Minimum illumination 0.7 Lux @ F1.4 | 0 Lux with IR illumination
- Focusing system: Automatic or manual
- Infrared day/night filter for clear colour during the day and good visibility at night under low-light and IR conditions
- Integrated overvoltage protection
- Connection via 10/100 Mbps Ethernet, RJ-45, ONVIF support
- Supported protocols: IPv4, IPv6, TCP/IP, HTTP, HTTPS, UPnP, RTSP/RTP/RTCP, IGMP, SMTP, FTP, DHCP, NTP, DNS, DDNS, PPPoE, CoS, QoS, SNMP and 802.1X

Considering climatic and mechanical requirements, as well as high chemical resistance requirements for outdoor cameras (detection and PTZ cameras at tunnel portals), camera housings and mounts shall be made of aluminium with a minimum protection rating of IP66.

For tunnel cameras, housings made of stainless steel with IP66 protection shall be provided, containing the camera with lens, power supply, heater, and silica gel. Mounts for tunnel cameras shall also be made of stainless steel, including mounting adapters for installation on the tunnel lining.

Specific requirement for cameras:

- Operation within temperature range from -20 °C .... +40 °C.

Additional requirements for PTZ (pan/tilt/zoom) cameras:

- 360° continuous horizontal rotation (pan) and 180° vertical rotation (tilt) with position memory capability
- Pan/tilt speed control to enable smooth rotation and fine position control even at maximum zoom (rotation speed continuously decreases with zoom depth)
- Total zoom min 200x (20x optical, 10x digital)
- Ability to memorize at least 10 preset positions

Cameras shall comply with the following standards:

- EN 550022:1998+A1:2000+A2:2003
- EN 61000-3-2:2000+A2:2005
- EN 61000-3-3:1995+A1:2001+A2:2005
- EN 50130-4:1995+A1:1998+A2:2003
- EN 60065:2002
- EN 50121-4:2006

Optical glass shall comply with the following standards:

- EN 50130-4: 1995+A1: 1998+A2:2003
- EN 61000-4-3: 2002+A1: 2002
- E 61000-4-2: 1995
- E 61000-4-4: 1995
- E 61000-4-5: 1995
- ENV50141: 1993
- EN61000-4-11: 1994
- EN61000-6-3: 2001
- EN55022: 1998 (Class B)

Cameras shall be connected via SFTP cable (halogen-free, fire-resistant), category 6a, to the nearest Ethernet switch of the video system located in the traffic control station, substation, or communication cabinet in an SOS niche.

Cameras shall be supplied using NHXH-J E90 3x1.5 mm<sup>2</sup> cable from the power distribution board located in the traffic control station, substation, communication cabinet, or from the low-voltage distribution cabinet in the SOS niche. The mentioned power supply sources shall include protection against electric shock, overcurrent protection, and surge protection.

Video system cables in the tunnel shall be installed in PEHD pipes Ø40 on cable trays within the cable duct intended for communication installations. At locations where cables exit the installation duct toward the camera installation point, they shall be protected by stainless steel pipes up to the point of entry into the camera mount.

## **Video recording technology**

The system shall enable recording of each video signal for 7 days, at a minimum quality as follows:

- Resolution: min 360 x 240 NTSC, 360 x 288 PAL
- Frame rate: min. 5 frames per second.

For recording incident situations, the recording device shall be capable of short-term recording at higher quality:

- Resolution: 720 x 480 NTSC, 720 x 576 PAL
- Frame rate: min. 25 frames per second.

Recorded video shall be compressed using H.264 compression or equivalent..

In addition to the recording capability described above, the recording device shall also provide playback functionality, i.e. retrieval of recorded video for a selected time interval upon request.

## **Software support**

The software shall enable monitoring of all field devices through a unified interface.

The graphical user interface shall enable the following:

- Display of cameras in alarm
- Display of live video of the current alarm
- Deactivation and acknowledgment of alarms
- Display of any live camera view
- Display of system alarms

Video signals shall be transmitted to the control center as Video over IP using an Ethernet network. This method enables video monitoring from any location within the local network.

The operator shall be provided with the ability to select image sizes from selected cameras and to freely arrange them on the video wall or CCTV monitors.

In the event of receiving an alarm from the AID system, the software shall automatically adjust the layout and video sources so that the road section where the incident has been detected is immediately and clearly displayed to the operator.

### **18.11. Radio communication system in tunnel**

Communication and information systems, including the radio communication system, are an important factor in tunnel safety. Radio communication in tunnels is difficult because tunnels represent shadow zones for the propagation of radio waves.

Because of this, there is no direct electromagnetic wave component within the tunnel, but rather multiple reflected waves that attenuate the primary signal. Therefore, tunnels are equipped with specialized radio systems that ensure reliable transmission of radio signals within the tunnel and uninterrupted communication with external systems, thereby significantly contributing to traffic safety.

The radio system should be planned in accordance with the *"Guidelines for Tunnel Equipment Design RVS 9.282, section 9.5.3 – Tunnel Radio System"*, *"Tunnel Radio System RVS 9.286"*, and Directive 2004/54/EC of the European Parliament, and shall be planned for tunnels longer than 500 m.

The primary purpose of the tunnel radio system is to enable reliable radio communication from the tunnel to the outside and vice versa, as well as communication between radio units within the tunnel for all emergency and safety services (maintenance, police, fire brigade, emergency medical services), on their respective radio frequencies.

A particular advantage of this type of communication is its independence from public communication networks, which is especially important in the event of incidents in the tunnel, when public communication networks may become congested.

In addition, the system shall enable transmission of one or more public FM radio programs, as well as the possibility of broadcasting information to motorway users who are listening to these programs while driving through the tunnel. The radio system shall allow recording of VHF communication as well as messages transmitted via FM broadcasting, thereby increasing system reliability and assisting in identifying operator and safety service errors.

The radio system shall enable rebroadcasting of at least the following radio services and two public FM stations:

- 1 channel for police
- 1 channel for fire services
- 1 channel for emergency medical services
- 1 channel for tunnel operator
- 2 channels for public FM radio.

The system shall also allow future upgrade to digital radio communication systems, such as TETRA. It shall also support a Break-In function for selected channels. Break-In may be performed live or via pre-recorded messages.

The radio system shall consist of the following components:

- master radio station for radio services and public FM broadcasting, installed in the control center
- remote radio substations planned in SOS niches
- antennas for individual services
- leaky feeder cable (radiating cable) and coaxial cable of appropriate length, including installation accessories in the required quantities
- Break-In functionality for selected channels, with control from the control center.

The central part of the system shall be located in the COKP. For equipment installation within the tunnel, SOS system rooms in tunnel niches shall be used.

For routing of optical and coaxial cables, low-voltage (communication) cable ducts or pipes installed beneath the roadway shall be used. Radiating cables shall be mounted on the tunnel wall at a height of 5.30 to 5.50 m.

An uninterruptible power supply shall be provided for the radio system. For connection between the central system and tunnel radio substations, single-mode optical cable shall be used.

### 18.12. Tunnel public address system

The tunnel public address system is intended to provide necessary information or instructions to tunnel users who are stopped in the tunnel in the event of an incident.

It is extremely important to provide an appropriate arrangement of loudspeakers in order to eliminate reverberation effects and minimize the influence of noise caused by ventilation system operation and traffic density. Since traffic noise is a relatively constant factor, and acoustic treatment of tunnel walls is extremely expensive, a good understanding of acoustic theory is required when designing an effective public address system.

The public address system shall be designed so that a combination of loudspeakers achieves a sound pressure level of 110 dB(A) at a distance of 3 m, within the frequency range from 1 kHz to 4 kHz. The system consists of amplifiers and a combination of loudspeakers installed in SOS niches, in the open tunnel space, and in pedestrian cross-passages between the two tunnel tubes.

In accordance with “*Guidelines for Tunnel Equipment Design RVS 9.282, section 9.5.2 – Public Address System*”, and Directive 2004/54/EC of the European Parliament, the tunnel public address system shall be installed in tunnels longer than 1000 m and shall include the following elements:

- control terminal, located at the operator desk in the system room of the COKP,
- public address control unit located in the system room of the COKP,
- public address substations, located in the tunnel,
- loudspeakers distributed throughout the tunnel.

Control of the public address system shall be possible from the system room in the COKP, where the operator has full situational awareness, as well as from within the tunnel via a microphone console installed in each cabinet of the PA sub-units.

In order to enable the coverage of the tunnel with an audio signal, loudspeakers and sound columns need to be planned along the tunnel. The layout of the loudspeakers should be planned according to the layout of the traffic lights and cross passages in the tunnel, because the stopping of vehicles in the event of an accident can be expected mainly next to the traffic lights, i.e., next to the pedestrian passages and in them.

To connect the main public address center with each public address sub-unit in the tunnel, single-mode optical fibre cables installed along the motorway shall be used.

Speaker columns shall be connected via junction boxes using flame-retardant speaker cables 2x4 mm<sup>2</sup> LSOH, routed from the speaker columns to the cable duct via stainless steel cable channels along the tunnel wall.

Low-voltage cables 2x4 mm<sup>2</sup> shall be armoured, flame-retardant (in accordance with IEC 60332-1 and IEC 60332-3/Category A), low-smoke (IEC 61034), halogen-free, and of construction compliant with IEC 60092-350 and IEC 60092-353 standards.

### **18.13. Emergency Telephone System (ETS)**

Communication between road users and emergency services or information providers is established via the emergency telephone system.

The emergency telephone system on the motorway is defined by the following directives and guidelines:

- Directive 2004/54/EC of the European Parliament and of the Council on minimum safety requirements for tunnels in the trans-European road network, April 2004,
- RVS 9.282 GUIDELINES FOR TUNNEL DESIGN – Operational and Safety Installations; Tunnel Equipment, Federal Roads Administration of the Republic of Austria, July 2002.

The emergency telephone system (ETS) shall be provided for all tunnels and consists of ETS units installed at tunnel entrance and exit portals, as well as SOS units located in tunnel SOS niches at intervals of 130–150 m. The system is based on TCP/IP technology. All telephone devices shall be connected to the traffic information system equipment (nearest Ethernet switch in RTS, CPPS or communication cabinet) via halogen-free SFTP cables or multimode halogen-free optical cables. Power supply for ETS units outside the tunnel shall be provided by power cables connected to busbars in cabinets of KS or RTS equipment along the route. In SOS niches, SOS telephones shall be supplied from the SOS niche distribution cabinet (connected to UPS) using fire-resistant cables with a minimum fire resistance of 90 minutes.

The system providing voice communication, in accordance with recommendations of the International Telegraph and Telephone Consultative Committee, CCITT, consists of:

- emergency call pillars and SOS units
- telecommunication links (optical and SFTP cables)
- control center equipment and operator IP telephone.

The ETS system shall provide:

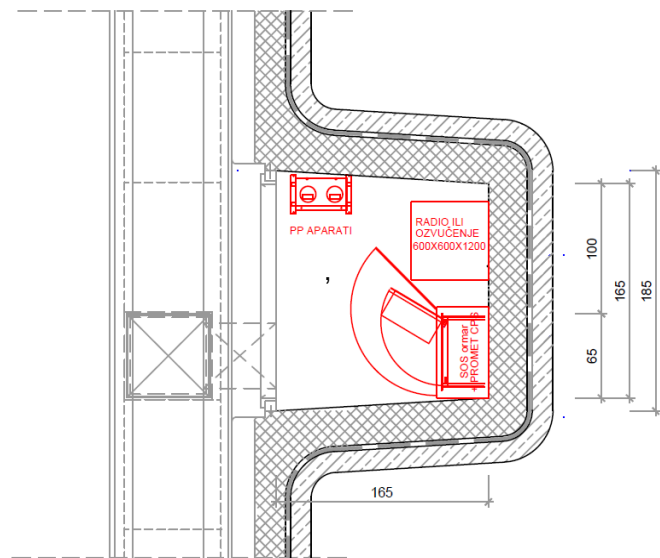
- Emergency call to the central receiving station
- Reception of calls from the central receiving station
- Putting calls on hold
- Retrieving call on hold
- Call termination

The components of the ETS and SOS units are:

- call button,
- electrodynamic microphone,
- loudspeaker,
- interface and protection elements
- mounting pole (for ETS units)

The enclosure shall be designed to ensure an increased level of safety for road users, minimizing the consequences of impact in case of an accident, and marked with appropriate pictograms for high visibility under vehicle headlights.

The position of SOS units within the tunnel shall be marked in the same manner using appropriate pictograms.



**Figure 6 - SOS Niche – Equipment Layout**

#### 18.14. Traffic information system

The Traffic Information System (TIS) in the tunnel, as part of the traffic information system of a motorway section, is responsible for controlling variable traffic signalling installed within the tunnel and in front of tunnel portals, using data obtained from other subsystems.

The objective of the Traffic Information System, as a traffic control and management system at motorway level, is to increase traffic safety through dynamic response to current traffic and environmental conditions. Therefore, data acquisition from traffic and the environment, as well as the generation of control commands (warnings, speed limits), are key system functions influencing each motorway section.

The normative description of the traffic control and management system on motorways is defined in the Guidelines for Variable Message Sign Equipment (RWVA) and the Guidelines for Variable Message Signs (RWVZ) of the Federal Republic of Germany, harmonized with CEN-EN provisions. In tunnels, local traffic control centers (LTC) are an integral part of a more complex supervisory system – the Central Remote Control System (CRCS).

Road traffic stations (RTS), as components used within the traffic control and management system, shall comply with the relevant technical requirements defined in the Technical Guidelines for Road Traffic Stations (TLS 2003) of the Federal Republic of Germany, including testing and verification performed in the country of origin. This ensures that the required levels of protection – safety, health, and usability – as well as full system compatibility, are continuously achieved.

According to the TLS standard, the traffic information system shall be divided into the following hierarchical levels:

- main traffic control center (abbr. MTC),
- regional traffic control center (abbr. RTC),
- sectional traffic control center (abbr. STC),
- road traffic station (abbr. RTS),
- road traffic substation (abbr. RTSS) and
- end device (abbr. ED).

The highest level of the TIS is the main traffic control center (MTC).

Regional and sectional traffic control centers shall be planned within the COKP (Traffic Control and Maintenance Center).

The communication network interconnecting the main, regional, and sectional traffic control centers forms the backbone communication network of the motorway and shall be implemented using Ethernet technology over the motorway optical fibre network.

The communication network connecting the regional traffic control center with road traffic stations along the route and within tunnels is referred to as the local motorway communication network and shall also be implemented using Ethernet technology over optical fibre.

Traffic data between STC and RTS shall also be transmitted using Ethernet technology via local optical fibre.

Communication modules (abbr. CM) shall be installed in road traffic stations and connected to input/output modules (abbr. I/OM) and to road traffic substations via a local bus. Depending on the distance between RTS and RTSS, the local bus shall be physically implemented using multimode (MM) or single-mode (SM) optical fibre. Optical cables used for local connections within tunnels shall be halogen-free.

RTS and RTSS units in tunnels shall be installed in SOS niches and, where necessary and depending on civil engineering conditions, in front of tunnel portals.

End devices of the traffic system connected to the corresponding RTS or RTSS within and in front of the tunnel include:

- variable traffic signalling (variable message signs, information displays, lane control signals)
- traffic lights and blinkers (abbr. TB),
- internally illuminated signs (abbr. IIS),
- traffic counters,
- AID (Automatic Incident Detection) cameras (abbr. AID)

## **Variable traffic signalling**

Variable traffic signs, information displays, and lane control signals installed in the tunnel shall comply with the following requirements:

- Compliance with classes L3, B4, C2, R3, T1, T2, T3 in accordance with EN 12966-1, which shall be demonstrated by a manufacturer's certificate issued by an authorized certification body for the production technology of the proposed sign
- Electromagnetic compatibility in accordance with EN 50293:2000 Electromagnetic compatibility – Road traffic signal systems
- Electrical safety ensured in accordance with harmonized standards HD 638 and HD 384
- Housing with protection degree IP65, made of AlMg3 aluminium, protected by electrostatic powder coating, with front panel painted
- Communication interface supporting TCP/IP protocol.

Variable traffic signs in the tunnel shall be connected to the nearest local device (RTS/RTSS) via Ethernet cable, flame-retardant, halogen-free SFTP, minimum Category 6a.

Power supply for the signs shall be provided from the distribution board of the local device or from the low-voltage distribution cabinet of the nearest SOS niche using NHXH-J cables of appropriate cross-section.

Cables shall be routed from the local device through installation ducts in halogen-free PEHD conduits, and at exit points toward the signs, they shall be additionally protected by stainless steel (V4A) cable channels of appropriate dimensions.

## **Traffic lights**

Standard traffic light heads shall be provided as signal emitters, manufactured from black polycarbonate resistant to environmental influences. Traffic lights for vehicles shall be equipped with LED light sources. The optical system of traffic lights shall be designed to prevent retroreflection while ensuring 100% transmission of light generated within the signal housing.

The luminous intensity, light distribution, and uniformity of the traffic light heads shall comply with EN 12368. Power supply for traffic lights shall be provided from the distribution board of the nearest local device (RTS/RTSS) using NHXH-J cables of appropriate cross-section.

## **Internally illuminated signs**

Internally illuminated traffic signs (IIS) shall be single- or double-sided and suitable for wall mounting in tunnels. The sign shall be made of self-extinguishing polycarbonate, class B1. Internal lighting shall be based on LED technology.

The housing (IP65) shall be made of aluminium with electrostatic powder coating, and the front panel shall be finished in matte black.

Signs shall comply with classes L3, B4, C2, R3, T1, D3 in accordance with EN 12966 (Vertical road traffic signs – Part 1: Variable message signs), demonstrated by certification issued by an authorized certification body.

### **Road traffic stations and substations**

Road traffic stations (RTS) and substations (RTSS) are intended for local control of variable traffic signs and for collecting traffic and meteorological data on the roadway. RTS/RTSS shall be designed fully in accordance with TLS 2003 recommendations.

RTS/RTSS shall enable local data acquisition and control of field devices via a user interface. RTS/RTSS shall be housed in enclosures with IP54 protection and designed for operation in the temperature range from -20°C to +60°C.

For surge protection, gas discharge arresters shall be installed on the power supply, while communication lines shall be protected by both coarse protection (gas arresters) and fine protection (semiconductor suppressors). Power supply shall be provided from the low-voltage distribution cabinet of the SOS niche using self-extinguishing, halogen-free NHXH cables of appropriate cross-section.

### **Software support**

Basic software support should include the management of devices connected to the RTS via user interface, as well as support for all communication protocols required for communication with vehicle detectors, communication with variable message signs, and communication with higher-level control center.

Communication protocols toward variable signs and the higher-level control center shall comply with TLS standards. Further development of the software shall be carried out in accordance with device configuration requirements and overall traffic system configuration.

### **Operating modes**

RTS shall operate in three basic modes.

#### **a) Local mode**

The device shall operate in local mode for servicing, routine inspection, or maintenance purposes. Local mode shall have the highest priority and cannot be overridden by remote control.

When the cabinet door of the RTS is closed, a control switch on the door shall automatically transfer the road traffic station into remote mode.

## **b) Remote mode**

During normal operation, the RTS shall operate in remote mode. This mode shall enable communication between the COKP and the RTS. The communication protocol between RTS and COKP shall comply with TLS requirements.

## **c) Automatic mode**

In the event of loss of communication with the higher-level control center, the RTS shall switch to automatic mode. In this mode, the RTS shall independently determine the operating regime based on locally collected data. Automatic mode shall only be applied in specific situations, depending on the traffic design solution, and only when clearly defined control algorithms are implemented. RTS/RTSS shall comply with the following:

- Electrical safety in accordance with EN 60950-1 Information technology equipment- Safety
- Electromagnetic compatibility in accordance with EN 50293:2000 Electromagnetic compatibility – Road traffic signal systems
- In accordance with TLS2002 recommendations – communication protocols for FG1, FG3, FG4, FG6, FG254.

## **Traffic counters**

Traffic data shall be collected at tunnel entrance and exit portals.

Traffic flow measurement is performed for two purposes:

- a) data for analysis and short-term forecasting for traffic management
- b) data for statistics and long-term traffic forecasting

Local traffic data collected at measurement points shall include vehicle classification. Data acquisition shall be performed using sensors based on inductive loop technology embedded in the asphalt pavement. For vehicle classification and direction detection, two inductive loops shall be installed at each measurement point. Traffic counters may be installed as standalone devices or integrated into RTS/RTSS units. If installed as standalone devices, they shall have a minimum protection degree of IP55. The device must meet electrical safety in accordance with the EN 60950-1 standard - Information technology equipment - Safety - Part 1: General requirements. The device must meet electromagnetic compatibility in accordance with standards EN61000-2, EN61000-6 and EN55022, class B.

## **Inductive loops**

Traffic data collection shall be performed using inductive loops embedded in the asphalt pavement. For vehicle classification and direction detection, two inductive loops shall be installed at each measurement point. The installation geometry of inductive loops shall be as follows:

- loop width 1.0 m.
- distance from lane separation line: 0.35 m
- distance from edge line: 0.35 m
- distance between loop heads: 2.5 m, i.e. between loops 1.5 m
- distance to adjacent lane loop: min. 0.7 m

## **Traffic detector**

A traffic detector is a device for individual vehicle detection and classification. Using a measurement structure based on the two-loop principle and appropriate data processing, it is possible to determine vehicle speed, length, class, and the distance between two vehicles. The collected data shall be stored in a protocol and made available to the higher-level system for further processing and evaluation. The use of widely adopted loop geometry in accordance with TLS II guidelines is recommended.

According to TLS guidelines, vehicles shall be classified into nine categories:

- 1) motorcycles
- 2) passenger cars
- 3) passenger cars with trailers
- 4) buses
- 5) light commercial vehicles / camper vans
- 6) trucks
- 7) trucks with trailers
- 8) tractor units, three-axle tankers, towing vehicles
- 9) special vehicles

## **Software support of Traffic Information System in COKP**

Software and hardware support in the COKP shall enable operators to manage traffic on motorway sections and within tunnels in a simple and efficient manner. To achieve this, the following functional requirements shall be met:

- Information received by the operator must be precise, up-to-date, and accurate.
- Execution of commands issued by the operator to the system must be ensured by an automatic control mechanism that will warn the operator with an audio and visual alarm in case of non-execution of the command.
- All events detected in the traffic information system must be stored in a relational database in a way that allows later reproduction of events, analysis, and statistical data processing.
- All conversations conducted via the SOS call system must be recorded in such a way that searching by time and date is possible during playback.
- Video recordings from all CCTV cameras must be recorded for at least 24 hours, and all alarm events must be recorded in the highest quality format with the possibility of saving to an external medium.
- Complete hardware support (computers, central processing units, communication equipment) must be supported by a backup battery power supply that enables the autonomous operation of the system for a minimum of 30 minutes from the moment of power failure..
- Complete software support must be designed to allow expansion and adaptation to new or additional TIS subsystems.
- Software support for individual systems must enable data exchange with the central TIS software platform.
- Software and hardware support in the COKP must be implemented in such a way that the system startup process is fully automated and requires no operator intervention.

- System operation and TIS control shall be managed via operator authentication with different access levels, using encrypted passwords.
- Event history logs shall clearly indicate which operator was logged in at the time of each event.
- Automatic system reactions initiated by software support in the COKP must take place based on algorithms defined in the central software support (SCADA system of the TIS). It is necessary to ensure that all relevant data on the current status and events can be used for the realization of automatic algorithms, regardless of which subsystem generated them.
- COKP controlling tunnels shall be additionally equipped with software and hardware support for functional and ergonomic integration of all subsystems.

Main functional requirements for this system are:

- Relevant data from all subsystems must be accepted, processed, and stored within the software support for functional and ergonomic integration
- Status display and operation management of all subsystems must be enabled through the integration system
- Based on input data and built-in automatic operation algorithms, the integration system must enable operator interaction, through a graphical user interface, on the execution flow of the automatic procedure when foreseen by the project
- The integration system must enable the display of interactive instructions for crisis situations on the graphical user interface.

#### **18.15. Basic principles of ventilation system design**

Tunnel ventilation shall ensure that concentrations of harmful gases remain within permissible limits under conditions of maximum traffic intensity, minimum vehicle speed, and unfavourable meteorological conditions. Adverse effects caused by vehicle engine emissions include risk of poisoning, irritation, and reduced visibility. The same system shall also ensure compliance with regulatory requirements in the event of a fire in the tunnel. This means that tunnel ventilation shall dilute the combustion products (emissions and particulate matter) generated by vehicles to acceptable levels for tunnel users, prevent excessive pollution of the tunnel surroundings, and control spread of smoke in the tunnel in the event of a fire, i.e., enable extraction of smoke from the tunnel and supply fresh air with the aim of safely evacuating the tunnel. In case of a tunnel fire, when no longitudinal airflow is present, smoke spreads equally in both directions from the fire source over a distance exceeding 700 m. Smoke remains above a height of approximately 2.5 m above the roadway for about 8–10 minutes. After this period, due to cooling, it mixes with lower air layers, and after approximately 20 minutes the entire tunnel cross-section is filled with smoke on both sides over a length of up to 1 km. If permissible limits of harmful gas concentrations are exceeded, or visibility falls below acceptable levels, or in case of fire, traffic shall be stopped in front of the tunnel by traffic light signalling.

Verification shall be carried out for each tunnel where mechanical ventilation is required. Tunnels temporarily used for two-way traffic (e.g. due to closure of the second tube) shall be treated as one-way tunnels.

The principles that must be considered in relation to the ventilation system are:

- In case of normal operation
  - tunnel users and operating personnel shall not suffer negative health effects, taking into account the required duration of exposure in all traffic situations occurring during operation,
  - required field of vision when stopping must be maintained.
- In case of fire
  - evacuation routes must be smoke-free during evacuation,
  - emergency services must be able to use favourable conditions for a sufficient time interval,
  - reduction in the extent of damage (persons, vehicles, tunnel structure) must be ensured,
  - in case of fire in one tube, the other tube is used for evacuation. Positive pressure must be ensured in the evacuation tube.

If mechanical ventilation is required, it must be dimensioned to take into account fire scenarios, since in one-way motorway tunnels fire safety is the governing criterion for the design of the ventilation system. A system dimensioned in this way satisfies ventilation criteria with respect to CO and particulate matter.

## **Determination of required air quantity**

### **Traffic data**

#### Traffic density

The definition of hourly traffic density, expressed as the value Q30, is the basis for calculating the required air quantity. It represents the value that is reached or exceeded during 30 hours per year. This value, as well as traffic composition, should be adopted based on a traffic forecast study for the road section where the tunnel is located. The calculation should take into account data for the year of planned tunnel opening, as well as for a period of ten years thereafter. These data should be compared with the maximum capacity of the tunnel tube, so that the result is a flexible ventilation system throughout the entire service life of the tunnel structure.

#### Traffic composition

The calculation of exhaust gas emissions is carried out taking into account:

- percentage share of passenger vehicles, and
- percentage share of heavy goods vehicles.

The calculation should be performed separately according to the percentage share of each vehicle type and taking into account the tunnel gradient relative to the direction of travel. Specific emissions should be taken from relevant European guidelines (e.g. RVS).

### Traffic conditions

Only normal traffic conditions ( $v \geq 30$  km/h) are considered in the calculation, which should be ensured by traffic light signalling. Congested traffic ( $v < 30$  km/h) is not considered, unless its occurrence is expected to be regular. The average speed in tunnels or tunnel sections with gradients should be calculated based on the average speed of trucks.

### **Design limit values**

The required quantity of fresh air for mechanical ventilation is defined by the described traffic conditions, in accordance with the traffic forecast study. The following limit values are taken as the basis for the calculation.

#### CO concentration

The design limit value for CO concentration is 100 [ppm].

#### NOx concentration

During design, NOx emissions do not need to be considered, except upon explicit request of the Investor. In that case, specific emissions shall be taken from relevant European guidelines (e.g. RVS).

#### Reduced visibility

The extinction coefficient of  $7 \times 10^{-3}$  [ $\text{m}^{-1}$ ] represents the design limit value for reduced visibility.

#### Maximum longitudinal velocity

The longitudinal air velocity in the tunnel, including the influence of traffic and meteorological conditions, shall not exceed 10 m/s.

### **System selection**

Key factors in selecting a ventilation system are cost efficiency and safety analysis during operation and in case of fire. From an economic perspective, a service life of 20 years is assumed for electromechanical components and fastening elements. The service life of the tunnel structure can generally be considered as 80 years.

## Selection criteria

The criteria to be taken into account are:

- type of traffic (one-way, two-way, temporarily two-way ...)
- tunnel structure conditions (length, gradient, cross-section, evacuation routes...)
- environmental conditions (immissions, protective measures...)

### Criteria related to traffic type and tunnel conditions

The longitudinal ventilation system is permitted, depending on tunnel length and traffic density, for one-way tunnels according to the following:

Annual average daily traffic intensity per lane [vehicles/day]	Tunnel length [m]	Ventilation type
Regardless of value	≤ 500	Natural ventilation
< 5 000 and low congestion frequency	≤ 700	Natural ventilation
≥ 5 000 to < 10 000 and medium congestion frequency	500 to ≤ 3,000	Longitudinal ventilation
≥ 5 000 and high congestion frequency	500 to ≤ 1,500	Longitudinal ventilation

For tunnels exceeding these values, longitudinal ventilation is not permitted.

Low congestion frequency is considered for a standard congestion duration of less than 25 hours/year and refers to tunnels and surrounding road sections that are sufficiently efficient and without indications of recurring congestion causes.

Medium congestion frequency is considered for congestion duration in the range of 25 to 75 hours/year and refers to tunnels and surrounding road sections that are generally efficient but occasionally overloaded (holiday traffic, seasonal peaks).

High congestion frequency is considered for congestion duration greater than 75 hours/year and refers to tunnels and surrounding road sections that are frequently congested due to daily traffic demand.

A congested hour is defined as a traffic standstill lasting longer than 20 minutes per hour.

### Environmental condition criteria

If the tunnel portals are located in an area with significantly stricter requirements regarding pollution protection (immission limits), the ventilation system must be specially considered.

## **Ventilation systems**

Ventilation systems must provide a solution that is acceptable from technical, economic, and safety aspects. Ventilation systems differ in terms of their mode of operation and possible application.

### Longitudinal ventilation

In the case of longitudinal ventilation, longitudinal air flow is generated within the tunnel either naturally or with the assistance of fans. The conditions that must be fulfilled in this regard are:

- maximum longitudinal air velocity in the clear cross-section,
- fans should be made in a reversible design, in such a way that they can ensure an air flow fans shall be of reversible design, capable of ensuring an air velocity of 2 m/s or an air flow rate of 120 m<sup>3</sup>/s in case of fire — the more unfavourable value is decisive,
- fans shall be distributed along the entire tunnel length in order to increase safety in case of fire and reduce turbulence,
- each fire section must have at least two fans.

### Semi-transverse ventilation

In the case of semi-transverse ventilation, air supply is provided through tunnel portals, while exhaust air is extracted above the tunnel ceiling and discharged outside the tunnel through air ducts. So far, the construction of tunnels requiring this ventilation system has not been planned. If the need for this system arises, the required conditions shall be adopted from relevant European guidelines (e.g. RVS).

### Transverse ventilation

In the case of transverse ventilation, fresh air is supplied along the tunnel tube, while exhaust air is extracted along the tunnel tube and discharged outside the tunnel. So far, the construction of tunnels requiring this ventilation system has not been planned. If the need for this system arises, the required conditions shall be adopted from relevant European guidelines (e.g. RVS).

## **Technical requirements**

In the case of longitudinal ventilation and risk classes I to III, a temperature resistance of the fans of 250°C for 120 minutes is sufficient. For risk class IV, a temperature resistance of 400°C for 120 minutes is required (the tunnel risk assessment procedure shall be carried out in accordance with RVS 09.02.31 (12/08). If the difference in length of individual tunnel tubes exceeds 10%, the risk assessment procedure shall be carried out for each tunnel tube separately).

The fan casing, suspension equipment, and silencers shall be made of corrosion-resistant material or protected by an anticorrosion coating. The fan casing shall be made of steel sheet with a minimum thickness of 6 mm, and the silencer casing shall be made of steel sheet with a minimum thickness of 3 mm, in accordance with ISO 1461.

The fan motor and terminal box shall have a protection degree of at least IP65. The electric motor shall be equipped with a winding heater. Tunnel fans shall have CE marking and comply with BAS EN 12101-3. Fan characteristics shall comply with ISO 13350. The impeller shall be made of aluminium alloy, factory-tested in accordance with ASTM E155-05, and balanced according to ISO 1940-1 (minimum required balance quality grade G6.3). The minimum tensile strength of the impeller with blades shall be greater than 100 MPa at 250°C. The fan suspension shall be designed to reduce vibrations. Additionally, the fan shall be secured against falling using a steel safety cable mounted on dedicated supports. Failure of one fan shall not affect the operation of other fans.

Considering that tunnel fans are dominant electrical energy consumers, both in tunnels and along the entire motorway section, special attention shall be paid to the installed motor power when selecting the fan type. In order to standardize fan types, fans with rotor diameters of 1250 mm and 1400 mm shall be considered. In accordance with the adopted clearance profile of the tunnel, fans with a rotor diameter of 1250 mm shall be installed individually or in pairs, and fans with a rotor diameter of 1400 mm shall be installed individually.

### **Aerodynamic calculations**

The required air quantity for ventilation is taken as the basis for aerodynamic calculations. The pressure drop in the tunnel tube, i.e. the thrust force defining the ventilation concept, as well as the type and number of fans, is determined through calculation.

The following parameters and influences shall be considered when calculating pressure drop:

- required air quantity,
- meteorological conditions at the micro- location (barometric pressure differences, wind effects, thermal conditions, etc.),
- structural influences (portal shape, built-in elements in the tunnel,...),
- traffic data,
- piston effect caused by vehicle movement,
- fire scenario: for tunnels with longitudinal gradient < 3%, two traffic lanes and standard cross-section, the design fire shall be assumed as a fire involving one truck and two passenger vehicles, with a heat release rate of 30 MW and resulting smoke flow of 120 m<sup>3</sup>/s. In this case, a fire section length of 800 m and a temperature increase of 65 K shall be assumed,
- fan position,
- system economy.

Jet fans shall be arranged to achieve optimal thrust distribution within the tunnel cross-section. Reduction of thrust due to fan positioning within hot smoke zones shall be taken into account. Mutual interference between fans shall be avoided; if this is not possible, the resulting losses must be considered. When determining the number of fans, it shall be assumed that fans located in the fire zone may not operate at full capacity or may be completely out of service. For tunnels with complex structural conditions or high design fire loads, validated 3D computational software may be used as a supplement (backup) to fire testing.

## **Control and operation of ventilation system**

The ventilation system must be controlled in accordance with economic criteria, taking into account safety during normal operation and in case of fire. The system must operate fully automatically, but the possibility of continuous manual intervention under all operating conditions must also be ensured.

### Measured values and data

Data that must be measured and recorded during the control and optimization of the ventilation system are:

- CO concentration,
- visibility (inside and outside the tunnel),
- longitudinal air velocity,
- airflow direction,
- number of vehicles in the tunnel (for each tube),
- vehicle speed (for each tube),
- congestion detection,
- fan vibration.

### Limit values for tunnel closure and reopening

The tunnel shall be automatically closed if:

- CO value  $\geq 100$  ppm for a period longer than ten minutes
- CO value  $\geq 150$  ppm
- visibility (extinction) coefficient  $\geq 12 \cdot 10^{-3} \text{ m}^{-1}$  for a period longer than one minute

The tunnel shall be automatically reopened if:

- CO value is 90 ppm, or
- visibility (extinction) coefficient is  $7 \cdot 10^{-3} \text{ m}^{-1}$  for a period longer than one minute and shows a decreasing trend.

### Theoretical values during normal operation

- theoretical CO value is 30 ppm
- theoretical opacity value is  $4 \times 10^{-3} \text{ m}^{-1}$ .

These values should be aligned with an economically acceptable operating regime.

### Limit values during maintenance

- CO value is 20 ppm
- opacity value is  $3 \cdot 10^{-3} \text{ m}^{-1}$ .

Occupational safety regulations must be taken into account.

### 18.16. Applied regulations and standards

- Regulation on technical standards for power installations with nominal voltage above 1000 V (Official Gazette of SFRY No. 4/74)
- Regulation on technical standards for protection of low-voltage networks and associated transformer substations (Official Gazette of SFRY No. 13/78)
- Regulation on technical standards for low-voltage electrical installations (Official Gazette of SFRY No. 53/88)
- Technical recommendations for power cables with nominal voltage from 1 to 35 kV (Public Utility Elektroprivreda BiH, 1997)
- Technical recommendations for the application of foundation earthing systems and equipotential bonding in facilities and transformer substations (Public Utility Elektroprivreda BiH, 1983)
- Directive of the European Parliament on safety in road tunnels in the trans-European road network 2004/54/EC
- Set of guidelines for design, procurement, installation, and maintenance of elements, structures, or parts of structures on motorways (Public Enterprise Autoceste FBiH, 2012)
- European Standard for tunnel lighting systems EN/CR 14380 – Annex A2
- Austrian national guidelines for tunnel equipment RVS 09.02.22
- Austrian national guidelines for tunnel ventilation RVS 09.02.31
- Austrian national guidelines for tunnel ventilation system calculations RVS 09.02.32
- German national guidelines for equipment and operation of road tunnels RABT
- Standard for fire-resistant system functionality DIN EN 4102-12
- Standard for equipotential bonding of electrical equipment DIN EN 61573

**19. INSTRUCTIONS FOR DESIGN AND CONSTRUCTION  
OF SUSTAINABLE DRAINAGE SYSTEMS ON  
MOTORWAYS IN FBiH**

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## General Project Information

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## Introduction

Drainage of water from motorways is addressed in the document “Guidelines for Design, Construction, Maintenance and Supervision of Roads, Sarajevo/Banja Luka 2005” (hereinafter referred to as the “2005 Guidelines”), which defines the basic technical conditions and requirements to be followed during the design and construction of drainage systems. The fundamental technical requirements and conditions related to motorway drainage, as presented in the aforementioned 2005 Guidelines, are covered in the following books:

- Book I - Design, Part 1: Road Design, Chapter 6: Road and Environment;
- Book I - Design, Part 1: Road Design, Chapter 7: Road Structural Elements;
- Book I - Design, Part 2: Bridge Design, Chapter 5: Drainage and Conveyance of Road Structures;
- Book I - Design, Part 3: Design of Road Structures, Chapter 2: Culverts;
- Book II - Construction, Part 2: Special Technical Conditions, Chapter 4: Drainage;
- Book II - Construction, Part 3: Special Technical Conditions for Tunnels;

Given that the above-mentioned volumes do not fully address or clearly define the management of stormwater from motorways, and considering that new experience has been gained during motorway construction, this document represents an extension of the existing “2005 Guidelines”.

Accordingly, the objective of the Guidelines for Design and Construction of Sustainable Drainage Systems on Motorways in the Federation of Bosnia and Herzegovina (hereinafter referred to as the “Guidelines”) is to establish a unified concept for stormwater management through the introduction of a comprehensive approach to the design and construction of drainage systems, while applying current legislation, relevant standards and regulations, and incorporating best modern practices from Europe and worldwide.

In accordance with terms of reference<sup>7</sup> for the preparation of Guidelines, the definition of appropriate stormwater drainage systems (SuDS – Sustainable Drainage Systems) is conditioned by the application of reference standards and regulations, with due consideration of applicable legal requirements.

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<sup>7</sup> Terms of Reference for the Preparation of the Guidelines for Design and Construction of Sustainable Drainage Systems on Motorways in the Federation of Bosnia and Herzegovina, JP Autoceste FBiH, Sarajevo, March 2014.

Terms of Reference<sup>7</sup> states that the "Guidelines" shall define the type, conditions, methods, and principles of operation of SuDS systems, taking into account the following:

- Individual approach to solving drainage and water protection issues depending on the type, category, and geometry of motorway structures (alignment, bridges, tunnels, underpasses, overpasses, etc.);
- Hydrogeological characteristics of the terrain and the level of area sensitivity, which is highly significant from the aspect of defining the level of water environment protection in the Federation of Bosnia and Herzegovina;
- Spatial arrangement and positioning of all elements of the drainage and water protection system (inlets, manholes, collectors, open channels, sand filters, drainage systems, devices for controlling pavement runoff pollution, etc.) along the motorway;
- Recommended materials and dimensions for all elements of the drainage and water protection system depending on expected (possible) structural and hydraulic loads, as well as resistance to external impacts (climate, pollutant emissions, etc.);
- Efficiency of individual pollution control measures with the aim of protecting the water environment;
- Protection against accidental (sudden) pollution. For this purpose, it is necessary to carry out an analysis of the probability of occurrence and the magnitude of impact of accidental pollution depending on the determined level of area sensitivity, and to apply optimization methods when selecting the appropriate SuDS concept.

Due to the complexity of motorways, different types of drainage systems are present. Therefore, in this document, drainage systems are addressed individually according to the type of motorway structures, namely for:

- Alignment,
- Structures (bridges, viaducts, overpasses, underpasses, etc.), and
- Tunnels.

## **19.1. Stormwater drainage from motorway route**

### **Introduction**

Stormwater drainage from the motorway can be realized using the following stormwater drainage systems:

- External drainage system;
- Internal drainage system or
- Combined system.

The external drainage system is used to protect the motorway from stormwater flowing from the surrounding terrain (embankment slopes, cuttings, etc.) or from flood waves of existing watercourses along the motorway alignment.

The internal drainage system is used for the collection and conveyance of stormwater from the motorway pavement and/or for drainage of the motorway structure.

The combined drainage system represents stormwater drainage achieved through a combination of external and internal drainage systems.

### 19.1.1. Design criteria

#### 19.1.1.1. Rainfall return period

Hydrological analyses and calculations within the planning and design of motorways are used to determine stormwater runoff that must be collected and conveyed by drainage systems. Drainage systems are designed to convey design stormwater quantities and thereby reduce the risk of flooding. Design stormwater quantities are determined based on the required level of protection of motorway structures.

The basic hydrological parameter required for the design of stormwater drainage systems is the rainfall intensity corresponding to a specific return period (**Error! Reference source not found.**

The European standard BAS EN 752:2010 specifies requirements for flood protection recommended for the design of new and existing drainage systems.

Table1

Frequency of rainfall occurrence – return period (1:n years)	Location	Flooding frequency – return period (1:n years)
1:1	Rural areas	1:10
1:2	Residential areas	1:20
1:2	City centers, industrial and commercial areas: - with flood frequency analysis - without flood frequency analysis	1:30
1:5		-
1:10	Underground road structures, underpasses.	1:50

The rainfall return period used for the design of drainage systems on motorways is typically 1:5 years, without flood frequency analysis.

#### 19.1.1.2. Calculation of design flows

The design flow (Q) is calculated for the purpose of determining the hydraulic load of the drainage system in order to design its geometric elements (bottom slope, cross-sectional geometry).

Various methods may be used to calculate design flow from the pavement. For practical calculations, the use of the Rational Method is recommended. The assumption underlying the Rational Method is that the design flow occurs when the time of concentration ( $t_c$ ) is equal to the rainfall duration ( $t_k$ ).

The time of concentration ( $t_c$ ) is defined as the time required for a drop of rainfall from the most distant point of the catchment area to reach the design point/profile, or the time from the beginning of rainfall until the moment when the entire catchment area simultaneously contributes to runoff at the profile.

The time of concentration ( $t_c$ ) is equal to the sum of: the time required for rainfall runoff to reach the drainage system network ( $t_o$ ), the longest travel time of the runoff through the upstream sections of the network ( $L_i/v_i$ ) and the travel time through the section for which the design flow is calculated:

$$t_c = (t_o + \sum_i \frac{L_i}{v_i}) + \frac{L}{v} \quad (19.1.1)$$

The calculation of the design flow using the Rational method is iterative. To calculate the time of concentration  $t_c$ , it is necessary in the first iteration to assume the velocity  $v$  on the section for which the design flow is being calculated. Based on the calculated time of concentration  $t_c$ , the design flow  $Q$  is calculated according to the following formula:

$$Q = i_e \times F \quad (19.1.2)$$

$$i_e = C \times i_k \text{ za } (t_k = t_c) \quad (19.1.3)$$

where:

F - total upstream area from which stormwater runoff reaches the considered section;

C - runoff coefficient;

$i_e$  - design rainfall intensity.

Based on the calculated flow, the design elements are adopted: cross-section geometry and longitudinal slope of the section, taking into account hydraulic, geometric, and engineering constraints. After that, the flow velocity  $v$  is recalculated and a new calculation iteration is performed with the corrected time of concentration ( $t_c$ ), i.e., the new rainfall duration and intensity ( $t_k = t_c$ ). The catchment area of the drainage system (internal and external drainage) is determined using a Digital Terrain Model (DTM) and/or topographic maps.

### 19.1.2. External drainage system

The external stormwater drainage system from the motorway route involves the collection and drainage of stormwater from the surrounding terrain along the motorway route (slopes, cuts, berms, water drainage from the motorway route embankment, etc.). For this purpose, it is necessary to foresee the construction of perimeter channels along the motorway route, which collect stormwater. The discharge of water from the perimeter channels can be carried out into culverts located under or next to the motorway structure or directly into watercourses if they are located in the immediate vicinity of the motorway. Water drainage from channels and culverts is discharged through open channels and/or collectors to the nearest appropriate recipient.

The external drainage system has the role of protecting against waters flowing towards the motorway structure from the corresponding catchment areas. The construction of the external drainage system contributes to the stabilization of the motorway structure, the elimination of erosive processes, and the prevention of various negative construction impacts through the application of best water management practices such as minimizing surface runoff, increasing the infiltration capacity of the soil, regulating water flow, etc. When designing the external drainage system, it is necessary to adhere to all conditions and requirements specified in the "2005 Guidelines"<sup>8</sup> and chapter 19.1.1

<sup>8</sup> Book I - Design, Part 1: Road Design, Chapter 7: Road Structural Elements; and

The characteristics of materials for open channels, gutters, and channels located in the berm, which serve for stormwater drainage, are specified in the "2005 Guidelines"<sup>9</sup>.

It is important to emphasize that during the design and construction of the drainage system for monolithic and prefabricated concrete elements of the system, concrete strength class C35/45 should be selected, which is prescribed by the European standard BAS EN 1433:2005. To define other requirements (resistance to frost, salt, dimensional deviation, and similar), apply the "2005 Guidelines"<sup>10</sup>.

### 19.1.3. Internal drainage system

The internal stormwater drainage system from the motorway route involves the collection and drainage of stormwater from the motorway pavement. In the internal drainage system, stormwater from the pavement is collected using longitudinal concrete gutters or concrete segmental channels. The collected water is led to catch basins, which are positioned in the gutter/concrete segmental channel itself. In addition to catch basins, it is also possible to use a manhole-catch basin element (appendix), which should be positioned outside the gutter in a separate protrusion (pocket) connected to the gutter, due to its larger dimensions. The mentioned manhole-catch basin element has a dual role, namely the role of an inspection manhole and the role of a catch basin with a settling tank. Catch basins are connected/attached to the main collector of the internal drainage system, through which the collected stormwater is drained outside the motorway corridor. Manhole-catch basins are connected as inspection manholes directly to the drainage collectors, whether it is one or more collectors, and will have a settling tank at least 50 cm deep, measured from the lowest common point with the connection to the collector. The collection of stormwater ultimately flowing through the gutter can be achieved by any combination of the two aforementioned elements, catch basins and manhole-catch basins.

The transverse and longitudinal slope of the pavement is of great importance for the collection of stormwater from the pavement. Therefore, it is necessary that, in addition to other conditions, drainage conditions be one of the criteria for defining the geometric parameters of the motorway route.

Within the observed return period, the internal stormwater drainage system from the roadway must be designed so that water from the roadway is drained outside the motorway corridor by the shortest route and without ponding.

#### 19.1.3.1. Variant solutions of internal drainage system

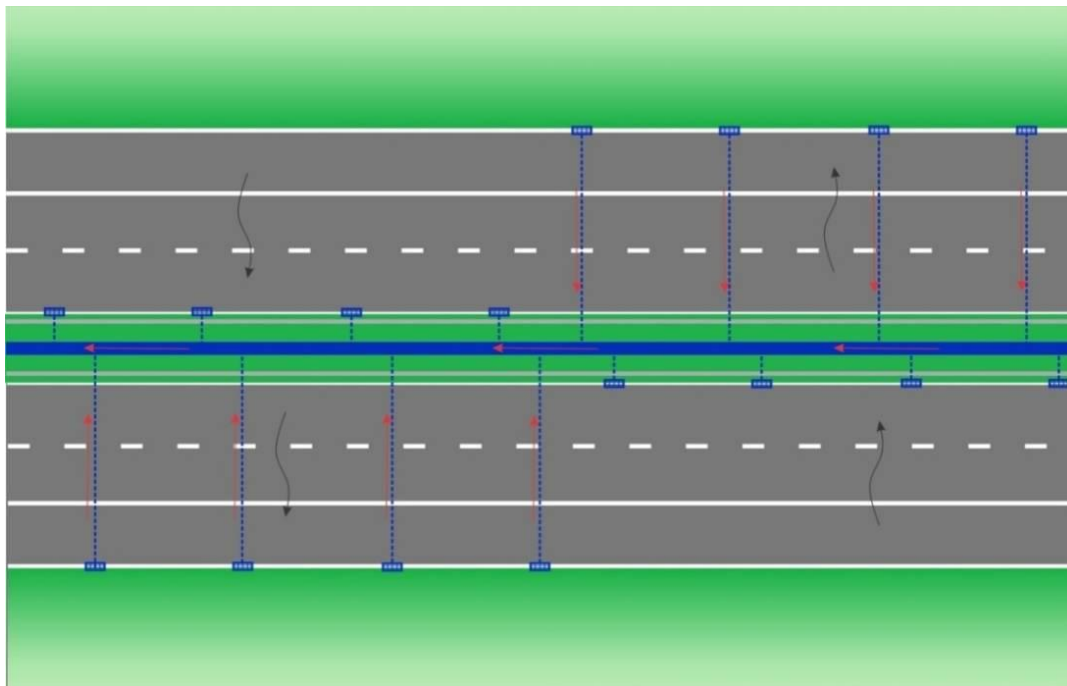
Depending on the position of the internal drainage system collector, two variants may be applied for the collection and conveyance of stormwater from the motorway pavement:

**Variant I** - The internal drainage system collector is located in the central median (Figure 1), and stormwater is collected via catch basins connected to the collector or to inspection chambers. The position of the catch basins depends on the transverse slope of the roadway. In the case of transverse slope towards the median, catch basins are located along the central median (adjacent to the main collector) and are directly connected to the collector and/or inspection chambers. In the case of transverse slope towards the verge, catch basins are

<sup>9</sup> Book II – Construction, Part 2: Special Technical Conditions, Chapter 4: Drainage

<sup>10</sup> This area is currently regulated by: Regulation on Technical Requirements for Construction Products Used in Concrete Structures ("Official Gazette of FBiH", No. 86/08).

located on the opposite side (in the verge area), and are connected to the collector via pipes passing through the motorway embankment. Pipes passing through the motorway embankment (cross-connection pipes and cross connection of collectors) must be executed in a way that involves the construction of a concrete base and a reinforced concrete (RC) encasement around the pipe. For the construction of the concrete base, concrete of strength class C25/30 should be used, while for the construction of the RC encasement, in addition to concrete of strength class C25/30 around the pipe, it is necessary to use reinforcing meshes Q 188 and reinforcing bars/anchors  $\Phi 12$  mm.

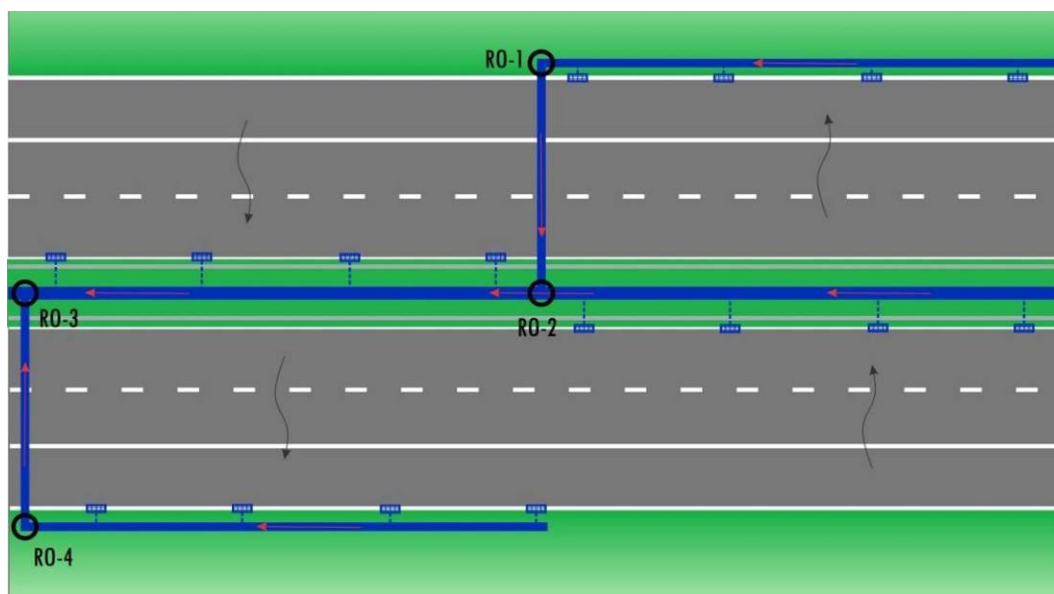


**Figure 1.** Internal drainage system - Variant I

When this solution is selected, in sections of the motorway alignment with transverse slope towards the verge, crossings through the motorway embankment are required at intervals corresponding to the spacing between catch basins. Accordingly, the system consists of a main collector and a series of individual secondary collectors (cross connections). At the connection points between cross-connection pipes and the collector (via a saddle connection), inspection from both sides is not possible, which complicates system maintenance during the operation phase. If this variant is selected, it is necessary to avoid direct connection of cross-connection pipes to the collector via saddle connections. Instead, connections should be made at inspection chambers in order to facilitate maintenance and management of the drainage system.

**Variant II** - The internal drainage system collectors are located in the central median and the verge of the motorway alignment (Figure 2). In this case, stormwater from the pavement is collected via catch basins that are directly connected, or connected via inspection chambers, to the collectors. The connection between collectors in the median and verge is carried out at the locations of inspection chambers, prior to the discharge of water from the collectors into the water protection system. Sections of collectors passing through the motorway embankment (due to the connection of collectors in the median and verge) are constructed with a concrete base and reinforced concrete (RC) encasement around the pipes. The materials used for the construction of the concrete base and RC encasement are the same as in Variant I (concrete class C25/30, reinforcing mesh Q188, reinforcing bars/anchors  $\Phi 12$  mm). The advantage of this variant solution compared to Variant I lies in the fact that all catch basins are connected to a collector located in their immediate vicinity, which ultimately eliminates the need for a large number of cross connections through the motorway embankment. As a result of eliminating a large number of cross connections within the motorway

embankment, greater structural stability and improved functionality of the drainage system are achieved, and the likelihood of pipe deformation and failure is reduced.

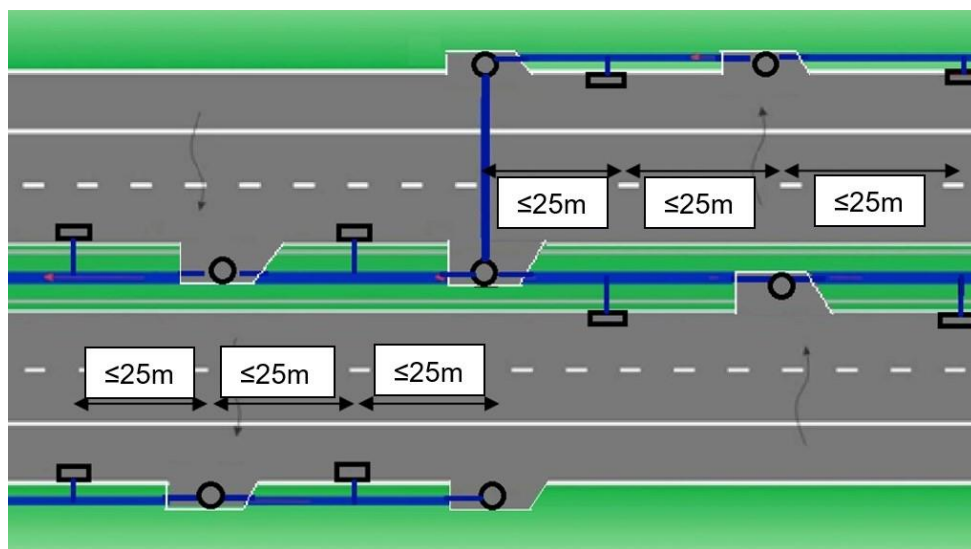


**Figure 2.** Internal drainage system - Variant II

When designing the internal drainage system, Variant II is recommended, for the reasons mentioned above, but also because the maintenance and management of the system is significantly simpler and there is less possibility of compromising the functionality of the system during the motorway exploitation phase. Investment costs in the planning and construction of Variant I and Variant II are of approximately the same order of magnitude.

**Variant III** - The collectors of the internal drainage system are located in the median and shoulder strip of the motorway route (Figure 3). In this case, the collection of water from the roadway is carried out using catch basins and combined manhole–catch basins alternately, which are directly connected to the collectors. The connection, i.e., joining of the collectors from the median and shoulder strip is done at the locations of the combined manhole–catch basins before discharging the water from the collector into the water protection system. The sections of the collector that pass through the motorway structure (due to the connection of the collectors in the median and shoulder strip) are constructed with a concrete base and RC lining around the pipe. The materials used for the construction of the concrete base and RC lining are the same as in Variant I (concrete C25/30, reinforcing meshes Q 188 and reinforcing bars/anchors  $\Phi 12$  mm). The advantage of this variant solution compared to Variant I is reflected in the connection of all catch basins and combined manhole–catch basins to the collector located in their immediate vicinity, which ultimately eliminates the need for constructing a large number of cross connections in the motorway structure. Due to the elimination of a large number of cross connections in the motorway structure, greater structural stability and functionality of the drainage system are ensured, and the probability of pipeline deformations and fractures is reduced. Compared to Variant II, this variant can provide certain improvements in terms of shortening the construction time. There are many other combinations of Variant II and Variant III that can be executed using all 3 elements (catch basin,

inspection chamber, combined manhole–catch basin) which would provide a technically correct solution. Certainly, there are also combinations of Variant I and Variant III, i.e., introducing the combined manhole–catch basin element into Variant I, but in that case, much more expensive construction is expected, and no technical benefits are gained. The most important determinant of combining Variant II and Variant III, as well as Variant I and Variant III, is that the water intake elements (catch basins and/or combined manhole–catch basins) in the drainage system on straight sections must not be at intervals greater than 25m and no greater distance than 60m between the collector inspection elements (inspection chambers or combined manhole–catch basins). Other conditions related to superelevation and longitudinal slopes of less than 1% are specified in Table 2 Technical requirements for design and construction of internal drainage system elements and overview of applicable standards.



**Figure 3.** Internal drainage system - Variant III

### 19.1.3.2. Elements of internal drainage system

The elements of the internal drainage system are:

- Gutters and concrete segmental channels;
- Catch basins;
- Inspection chambers/manholes;
- Collectors/pipelines.

In the following, each of the mentioned system elements will be described in detail, and an overview of the applicable relevant standards and regulations will be given.

#### **Gutters and concrete segmental channels**

Gutters and concrete segmental channels serve to drain water flowing from both or only one side of the motorway roadway. The cross-sectional dimensions of the gutter and concrete segmental channel must be determined hydraulically. The longitudinal slope of the gutter and

concrete segmental channel should be equal to the longitudinal slope of the roadway, respecting the condition that the minimum values of the longitudinal slope of the gutter should be 0.5%. If the longitudinal slope of the roadway edge is less than 0.5%, the required longitudinal slope of the gutter bottom should be provided by alternative modifications to the gutter bottom.

The dimensioning of gutters and concrete segmental channels is detailed in the "2005 Guidelines"<sup>8</sup> Furthermore, the requirements to be considered during the construction of gutters and precast concrete channels are also detailed in the "2005 Guidelines"<sup>9</sup>

### **Catch basins**

Catch basins have the function of directly collecting water from the motorway roadway. The distance between catch basins and the efficiency of the catch basins must be determined by an appropriate hydraulic calculation. Due to the uniformity of the shape and dimensions of prefabricated catch basin pots, and for simpler and easier installation, it is necessary to install prefabricated catch basin pots.

The catch basin (catch basin pot) should have a sump with a minimum depth of 100 cm if the internal diameter of the catch basin pot is DN/ID 400 mm, and a sump with a minimum depth of 50 cm if the internal diameter of the catch basin pot is DN/ID 500 mm or more.

There are several types of inlets that are in standard use for collecting water from the roadway:

- 1) Gutter inlets placed next to the curb
  - a) openings parallel to the curb;
  - b) openings perpendicular to the curb;
- 2) Curb-opening catch basins
- 3) Combined curbs;

For drainage of water from the motorway pavement, gutter catch basins installed along the curb are most commonly used. The disadvantage of curb-opening catch basins is a larger spread of surface flooding and increased maintenance costs. Accordingly, when designing the internal drainage system for collecting water from the motorway pavement, it is necessary to select gutter catch basins installed along the curb.

### **Calculation of catch basin efficiency**

The intake capacity of the inlet ( $Q_i$ ) depends on the type of inlet, its geometry, and the velocity of the water flow going towards the inlet. The efficiency of the inlet  $E$  is defined as the ratio between the flow that the inlet receives and the inflow that reaches the inlet by flowing along the curb:  $E=Q_i/Q$ .

The efficiency of catch basin depends on:

- geometric elements of the alignment (longitudinal slope  $S_p$  and cross slope  $S_x$ ),
- type and geometry of the catch basin (width  $w$  and length  $L$ ), and
- Inflow  $Q$ .

When calculating the efficiency of a catch basin on a motorway, it is necessary to calculate the part of the flow that frontally approaches the catch basin of width  $w$  ( $Q_w$ ) and the remaining, lateral part of the flow, which moves parallel to the inner edge of the catch basin ( $Q_s$ ):

$$Q_w = Q \times E_0 \quad (19.1.4)$$

$$Q_s = Q - Q_w = (1 - E_0) \times Q \quad (19.1.5)$$

The parameter  $E_0$  (a dimensionless quantity used to determine the portion of the total flow that approaches the catch basin frontally over width  $w$ ) for the case of a constant cross slope of the roadway is calculated using the following formula:

$$E_0 = 1 - \left(1 - \frac{w}{b}\right)^{8/3} \quad (19.1.6)$$

where:

$b$  - allowable spread of surface water (m)

$w$  - width of the catch basin (m)

The portion of flow captured by the catch basin ( $Q_i$ ) depends on the efficiency of capturing frontal ( $R_w$ ) and lateral ( $R_s$ ) inflow:

$$Q_i = R_w \times Q_w + R_s \times Q_s \quad (19.1.7)$$

$$E = R_w \times E_0 + R_s (1 - E_0) \quad (19.1.8)$$

The coefficient of efficiency of frontal inflow capture ( $R_w$ ) is determined using the following formula:

$$R_w = \begin{cases} 1 - 0,295(v - v_0) & v \geq v_0 \\ 1 & v < v_0 \end{cases} \quad (19.1.9)$$

where:

$v$  - velocity of the inflow  $Q$  reaching the catch basin

$v_0$  - maximum velocity beyond which the efficiency of the catch basin decreases

The coefficient of efficiency of lateral inflow capture ( $R_s$ ) is determined using the following formula:

$$R_s = \frac{1}{1 + \frac{0,0828 \times V^{1,8}}{S_x \times L^{2,3}}} \quad (19.1.10)$$

### **Calculation of manhole–catch basin efficiency**

The calculation of intake capacity and efficiency of manhole–catch basins is performed in the same manner as for standard catch basins. In order to prevent a portion of the frontal flow from

bypassing the grate through the gutter, the pockets in which the grates are installed shall be designed as follows: The inlet openings of the pockets (branch sections from the gutter) containing the manhole–catch basin grates shall be trapezoidal in shape (Figure 3) with an upstream inclination at an angle of no more than 45° relative to the longitudinal axis of the gutter, with a horizontal bottom and the grate positioned at the bottom of the pocket. The downstream end of the pocket shall be perpendicular to the longitudinal axis of the gutter. Additionally, sufficient space shall be provided around the pocket to allow unobstructed opening of the grate and access for inspection of the collector. The elevation (curb height) forming the pocket shall be selected in such a way that the capacity of the grate complies with the manufacturer’s certified performance data.

### **Determination of spacing between catch basins and/or manhole–catch basins**

It is evident that there is a part of the flow which the catch basins and manhole–catch basins cannot accept :  $Q_b = Q - Q_i$

This flow should not be greater than 30% of the flow immediately upstream of the catch basin -  $Q$ , and most importantly, catch basins and manhole catch basins should be placed at such a distance ( $L_s$ ) that this flow does not increase:

$$L_s = \frac{Q_i}{B \times C \times i_k} \quad (19.1.11)$$

where:

$B$  - width of the roadway contributing runoff (m),

$i_k$  - design rainfall intensity (m/s)

$C$  - runoff coefficient (-).

The determination of spacing between catch basins is inherently iterative, since rainfall intensity depends on rainfall duration, which in turn depends on the calculated travel time of runoff to the catch basin ( $t_0$ ). At locations where the road geometry changes (intersections, interchanges, changes in cross or longitudinal slope), additional catch basins shall be installed to capture the remaining flow ( $Q_b$ ) not intercepted by the last catch basin in the series. A combination of catch basins and manhole–catch basins may be applied.

### **Connection of catch basins to the collector**

In the case of Variant II (Figure 2), catch basins may be connected directly to the collector, as the connection pipe is short and can be easily maintained.

To ensure watertightness at the connection point, the connection shall be executed using factory-made connection fittings (“saddles”). These fittings shall be made of the same material as the collector pipe. Also, it is important to emphasize that the "saddles" for connecting the catch basin to the collector are selected depending on the diameter of the catch basin connecting pipe and the diameter of the collector pipe, as well as the angle of connection of the catch basin to the collector pipe (90° or 45°).

The connection of the catch basin pipe to the inspection chamber shall be performed using connection adapters. If the connection section (up to 20 cm) is not factory-installed on the catch basin unit, the connection shall also be made using adapters.

For collector pipe diameters DN/ID 300 mm, it is recommended to connect the catch basin to the collector via an inspection chamber, rather than directly to the collector pipe. In this case, two catch basins can be connected to each other (choose a catch basin pot diameter of DN/ID 500 mm), so that every second catch basin is connected to the collector inspection chamber.

### **Installation of catch basins**

During the installation of catch basins, it is necessary to perform compaction testing of the trench bottom. The subgrade on which the catch basin is installed shall have a deformation modulus of  $E_{vd} \geq 45 \text{ MN/m}^2$ . The catch basin unit shall be installed on a 10 cm thick concrete base, beneath which a sand bedding layer of minimum thickness 10 cm shall be provided. Backfilling around the catch basin up to ground level shall be carried out using fill and subbase material in layers of 30–50 cm, with compaction to the required density.

Catch basin pots have a circular cross-section. The top section of the catch basin shall be constructed by installing two reinforced concrete rings in two levels (Figure 4).

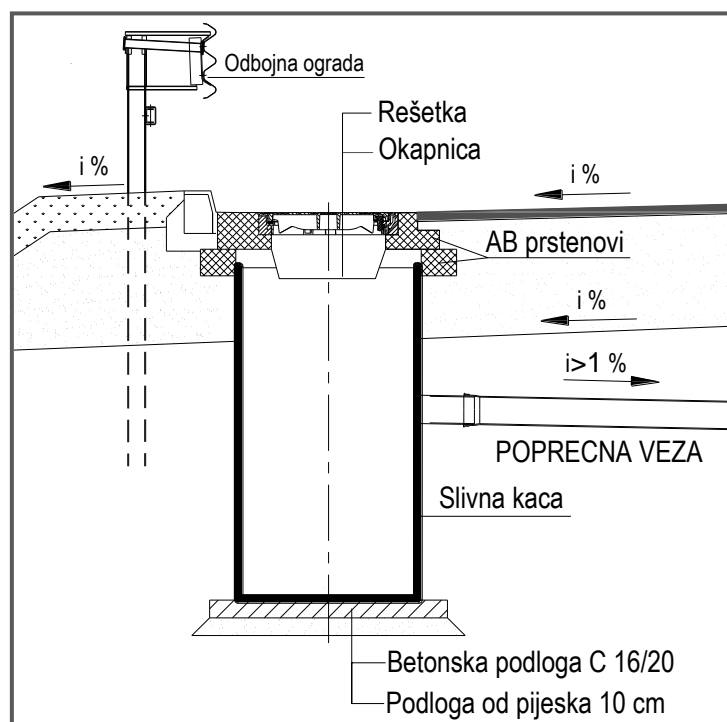


Figure 4: Gully detail

As can be seen from the previous figure, the lower reinforced concrete (RC) ring is approximately 15 cm wider than the upper RC ring, into which the frame of the catch basin grate is installed. The thickness of the RC rings shall be not less than 15 cm. Based on the above, a catch basin consists of the following components: catch basin unit (body), RC rings, and catch basin grate. Since the catch basin is not constructed as a single monolithic element, but rather from the body and RC rings, it is necessary to ensure a watertight connection between all components. Watertightness is achieved by using appropriate sealing materials.

To prevent water infiltration between the catch basin unit and the RC rings, it is necessary to provide a drip edge (“drip ring”) on the upper RC ring. The drip edge may be made of thermoplastic materials or concrete. Its purpose is to prevent water ingress from the outside of the catch basin when smaller quantities of water reach the structure.

The material used for RC rings shall be concrete of strength class C35/45, resistant to frost and de-icing salts, with reinforcement of minimum diameter  $\Phi 12$  mm, arranged in both reinforcement zones. This reinforcement may be used when the catch basin is located outside the roadway, while in cases where the catch basin is exposed to traffic loads, a structural calculation shall be performed to determine the required reinforcement and dimensions.

### **Inspection chambers/manholes (IC) / combined manhole–catch basins (MCB)**

Inspection chambers (manholes) are structures that ensure proper connection, diversion, and changes in slope and diameter of collectors. Additionally, during operation and maintenance, their role—together with manhole–catch basins—is to provide access to the collectors.

Accordingly, inspection chambers and/or manhole–catch basins shall be installed:

- a) at the beginning and junctions of collector sections;
- b) at places where the diameter of the collector pipe changes;
- c) at changes in the longitudinal slope of the collector;
- d) at places where the collector changes direction;
- e) on straight sections, at maximum distance intervals of 60 m;
- f) in the case of installation of manhole–catch basins, attention must be paid to ensure that all water intake elements in the internal drainage system, including the aforementioned manhole–catch basins, in addition to the above conditions, must not have spacing greater than 25 m (this also refers to possible combinations of catch basins and manhole–catch basins).

Inspection chambers (manholes) and manhole–catch basins (MCB) must be designed to withstand various loads to which they may be exposed (self-weight, direct loads, soil pressure, water pressure, buoyancy forces) during both construction and operation, without loss of function or damage to the environment, and must be protected against possible displacement even when empty. The selected types of inspection chambers must also meet other prescribed requirements regarding permissible deformations. The basis for the structural design of manholes is provided in the technical regulation ATV-A 127 – Guidelines for Structural Design of Drainage Channels and Structures.

During the installation of inspection chambers and manhole–catch basins, it is necessary to perform testing of the compaction of the trench bottom, where the soil on which the manhole is installed must have  $E_{vd} \geq 45$  MN/m<sup>2</sup>. Installation of inspection chambers (IC) is carried out on a prepared bedding layer and concrete base, first preparing the connecting pipelines and then checking vertical alignment. Backfilling is carried out using fill and base materials in layers of 30–50 cm with proper compaction. In the presence of water in the trench, backfilling of the IC must be carried out using concrete or material of appropriate granulometry until the chamber is fully anchored, in order to prevent flotation. Special attention must be given to resisting buoyancy forces in the case of manhole–catch basin elements (due to the additional sump of minimum 50 cm depth).

The top of the inspection chamber or manhole–catch basin can be constructed in two ways. One of the methods more commonly used in practice is to finish the inspection chamber with a conical top (Figure 5). When applying this solution, the upper part of the inspection chamber is reduced to the diameter of the cover frame, and the cover frame, or grille with the possibility of opening (in the case of a manhole–catch basin), is installed into the conical section.

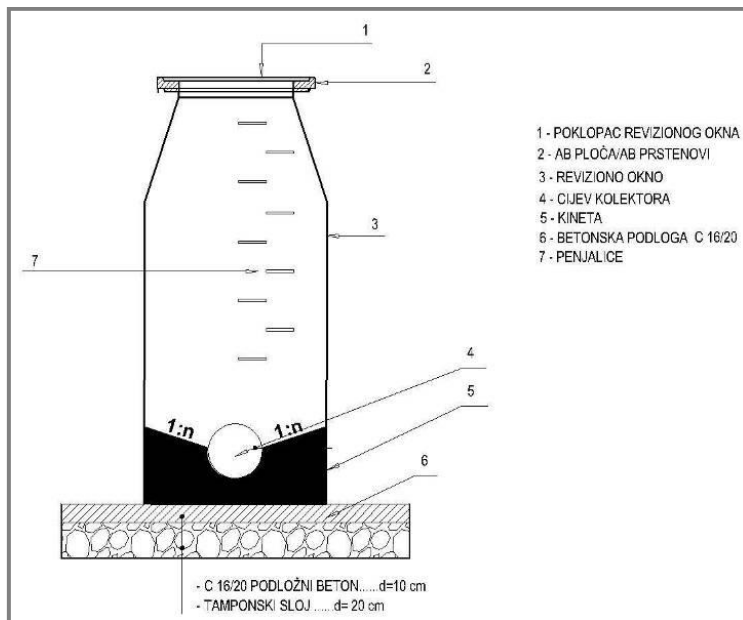


Figure 5. Detail of inspection chamber with a conical termination

The second method of finishing an inspection chamber/manhole–catch basin is by installing RC slabs/rings, where an opening is left in the upper RC ring for the installation of the cover frame, or a grate with the possibility of opening (in the case of a manhole–catch basin) (Figure6).

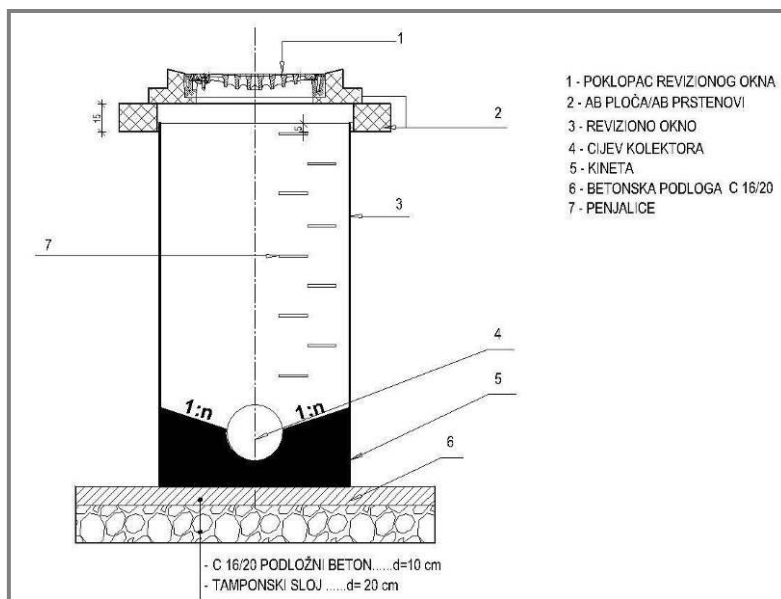


Figure6 Detail of inspection chamber with AB slabs/rings

When selecting this solution (Figure6), prefabricated RC slabs/rings should be used due to easier installation and higher-quality execution. In order to achieve a better connection between the slab/ring and the cover frame, the cover frame should be concreted into the RC ring during the manufacturing phase in the factory.

After the installation of RC slabs/rings on site, the installation of covers is carried out. Inside the chamber, step irons are installed to allow access during maintenance. At the bottom of the inspection chamber, a benching is formed, made of the same material as the inspection chamber. In the case of a manhole–catch basin, there is no benching, but instead a sump of the same diameter as the manhole–catch basin body, with a minimum depth of 50 cm from the lowest connection point to the collector.

The benching is constructed to direct the flow of wastewater, and its height is up to 2/3 of the height of the collector pipe, while the sides of the benching towards the chamber walls are constructed with a slope of 1:3 to 1:5 up to the full profile height.

At locations where it is necessary to overcome elevation differences between inlet and outlet pipes in the inspection chamber, cascade inspection chambers or cascade manhole–catch basins should be provided. The need for cascade inspection chambers commonly occurs at locations where water is discharged from the collector into the receiving body.

### **Collectors/pipelines**

Collectors serve to convey the collected water from the roadway to the discharge point. Collectors must have sufficient capacity to convey the design flow, while additional requirements relate to flow velocities ( $V_{min}$  and  $V_{max}$ ) and the degree of filling of the flow profile.

For the purpose of sizing collectors/pipelines, the flow rate can be determined using the Chezy-Manning formula:

$$Q = \frac{0,312}{n} \times D^{8/3} \times \sqrt{S} \quad (19.1.12)$$

where:

$Q$  - design flow ( $m^3/s$ )

$n$  - Manning's roughness coefficient ( $s/m^{1/3}$ );

$D$  - internal diameter of the collector (m)

$S$  - longitudinal slope of the collector (m/m).

This formula can be applied under the assumption that the flow in collectors is steady and uniform, and it applies to collectors with a circular cross-section flowing full (full-flow conditions).

The Manning roughness coefficient is adopted depending on the selected collector material. In practical calculations, Manning coefficients in the range of 0.011 to 0.013 ( $s/m^{1/3}$ ) are used, which correspond to absolute roughness values of pipe/channel walls in the range of 0.55 to 1.5 mm. A coefficient value of 0.013  $s/m^{1/3}$  (i.e., roughness of 1.5 mm) is typically used in

calculations. The minimum absolute roughness that can be used in calculations is 0.4 mm and is applied only for new small-diameter collector pipes made of thermoplastic materials.

Formula (20.1.13) applies to collectors flowing full (full-flow conditions). However, considering that collectors are most often not completely filled, it is necessary to calculate the flow velocity and discharge in partially filled sections, depending on the degree of filling. From the diagram below, the discharge  $Q$  and velocity  $v$  can be read for a circular pipe profile at partial filling height  $h$ .

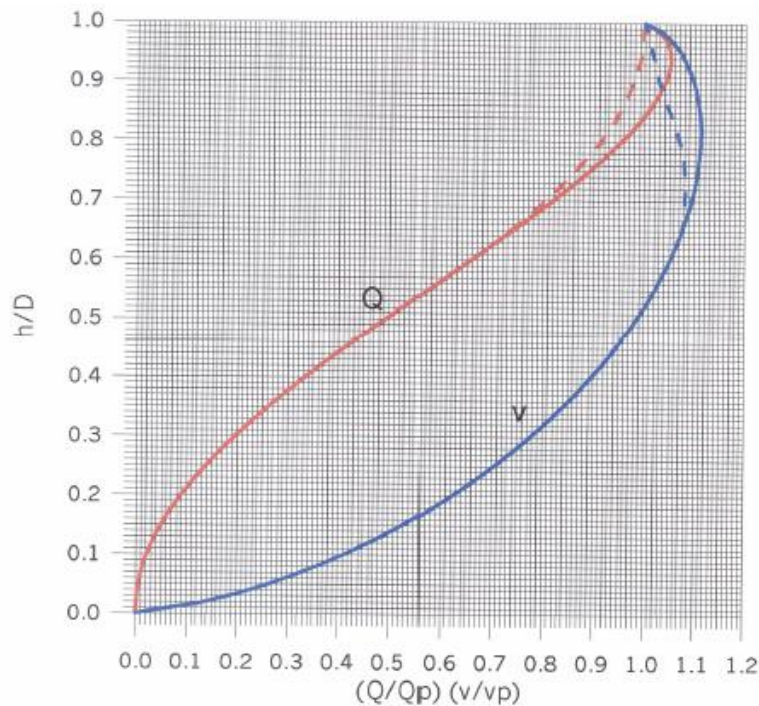


Figure 7. Relationship of  $Q/Q_p$  and  $v/v_p$  versus  $h/D$  for circular pipe profile

In order to ensure proper connection of catch basins to the collector, it is necessary to comply with the conditions related to the degree of filling of the collector, noting that for a pipe diameter DN/ID 300 mm, catch basins are not connected directly to the collector pipe.

DN/ID = 300 mm	$h_p = 0,60 \times \text{DN/ID}$	
DN/ID = 400 mm	$h_p = 0,70 \times \text{DN/ID}$	
DN/ID = 500–900 mm	$h_p = 0,75 \times \text{DN/ID}$	(19.1.13)
DN/ID > 900 mm	$h_p = 0,80 \times \text{DN/ID}$	

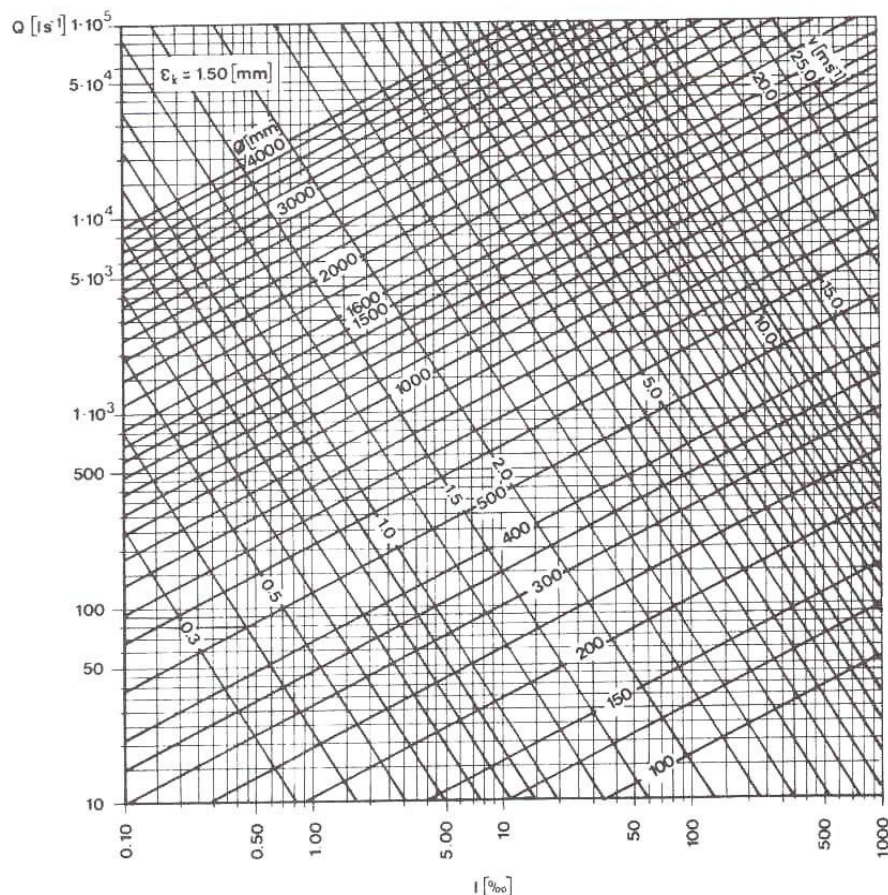
where:

DN/ID - internal pipe diameter;

$h_p$  – filling height;

The above limitations of the collector pipe filling height apply in the case of direct connection of catch basins to the collector. Filling heights may be greater when the connection of catch basins to the collector is carried out via an inspection chamber; however, in such cases, the influence of air on the flow regime in the pipes must be taken into account.

In the "2005 Guidelines"<sup>8</sup>, pipeline sizing using the Colebrook equation is presented. As an example, the nomogram of hydraulic parameters according to the Colebrook–White formula for a fully filled circular sewer pipe, with a roughness of 1.5 mm, is shown below.



**Figure 8.** Nomogram of hydraulic parameters for fully filled circular sewer pipes according to Colebrook-White formula, for roughness of 1.5 mm

When sizing collectors, the dimensions (diameter) and slopes of the collectors are selected so that the design conditions for the required flows are satisfied. For the construction of collectors, the most favourable case is when the invert slope corresponds to the road alignment slope. In this case, the burial depth is constant and may correspond to the minimum burial depth, thereby reducing trench excavation and, consequently, construction costs. This can be achieved if the road alignment slope is greater than the minimum allowable channel slope and less than the maximum allowable channel slope. In cases where the alignment slope is less than the minimum allowable channel slope, the channel is laid with the minimum slope and progressively buried deeper in the downstream direction, which has direct implications for the number of locations<sup>5</sup> where outlets must be provided.

In cases where the alignment slope is greater than the maximum allowable channel slope, the channel is laid with the maximum allowable slope, and the excess drop is regulated by the construction of cascades/cascade inspection chambers.

The dimensions and other characteristics of factory-produced pipes are defined by numerous standards (ISO, EN, DIN, BAS, etc.) and recommendations. In addition, each pipe manufacturer provides product catalogues containing the necessary data on available pipe types. Before pipe installation, it is necessary to test the compaction of the trench bottom, where the soil on which the pipes are installed must have  $E_{vd} \geq 45 \text{ MN/m}^2$ .

### **Minimum collector dimensions**

Minimum dimensions are prescribed due to the need for inspection, cleaning, and maintenance of collectors. It is recommended that the minimum internal diameter (circular profile) of the main collector pipe be DN/ID 300 mm, while for cross-connection pipes (connection between catch basins and the collector), a minimum internal diameter of DN/ID 200 mm is recommended.

### **Maximum and minimum slopes of collectors (pipelines)**

The minimum and maximum allowable slopes of the collector invert are defined in such a way that flow velocities remain within the range of minimum and maximum permissible values. Minimum slopes are prescribed to ensure the required minimum transport capacity of the flow, enabling self-cleansing and preventing sediment deposition in collectors. Maximum flow velocities (i.e., maximum collector slopes) are prescribed to prevent erosion and wear of the internal pipe surface caused by excessive flow velocities.

For partially filled collector profiles, the minimum flow velocity must not be less than 0.4 m/s at a filling height of 2 to 3 cm, while for full pipe flow, the minimum velocity is 0.8 m/s. The maximum velocity is limited to 3 m/s under full-flow conditions, if the pipe is almost always filled to the top or if the filling depth is consistently high. It is considered that continuous flow at this velocity will not cause harmful wear. If high velocities occur only occasionally (which is usually the case, as collectors are only occasionally filled to the top), the maximum velocity may reach up to 5, and at most 6 m/s.

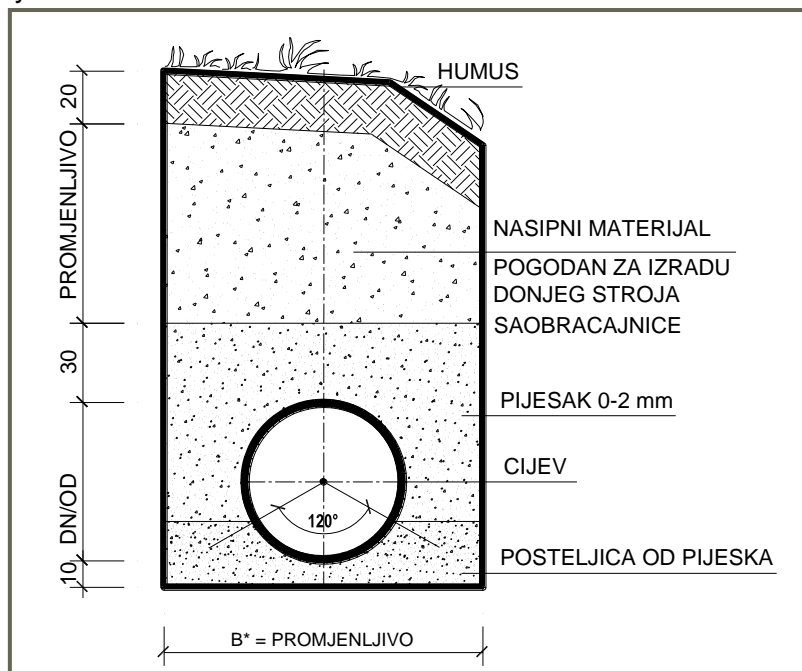
### **Conditions for collector trench excavation**

Minimum trench widths, depending on the nominal pipe diameter and trench depth, are prescribed by BAS EN 1610:2002. The slope of the trench sides depends on trench depth, and for trenches deeper than 2.00 m, shoring must be provided, with detailed shoring specifications included in the design documentation, containing all characteristics necessary for execution.

The minimum trench depth for collectors is 80 cm from the crown of the pipe, in order to ensure adequate pipe protection and prevent possible freezing of water within the collector. The maximum trench depth is limited due to excavation conditions and depends on soil characteristics, groundwater level, and construction technology. It is typically limited to approximately 7 m (4–5 m in the case of high groundwater levels). If greater trench depths are required, these sections of the collector are constructed using one of the tunnelling methods.

## Collector installation

Pipe installation in the median and/or shoulder strip is carried out on a previously prepared sand bedding layer with a minimum thickness of 10 cm.



**Figure 9.** Trench details in median/shoulder strip

After installation of the collector pipes in the median/shoulder strip, the pipes are backfilled with a layer of sand (grain size 0–2 mm), 30 cm thick above the pipe crown, using manual tampers to compact the sand around the pipe, while the remaining trench is backfilled with material suitable for the construction of the road subgrade, compacted to the required density.

Installation of collector pipes passing through the roadway structure is carried out by constructing a concrete base and an RC encasement around the pipe. The thickness of the concrete base is 10 cm and it must be constructed using concrete of strength class C25/30.

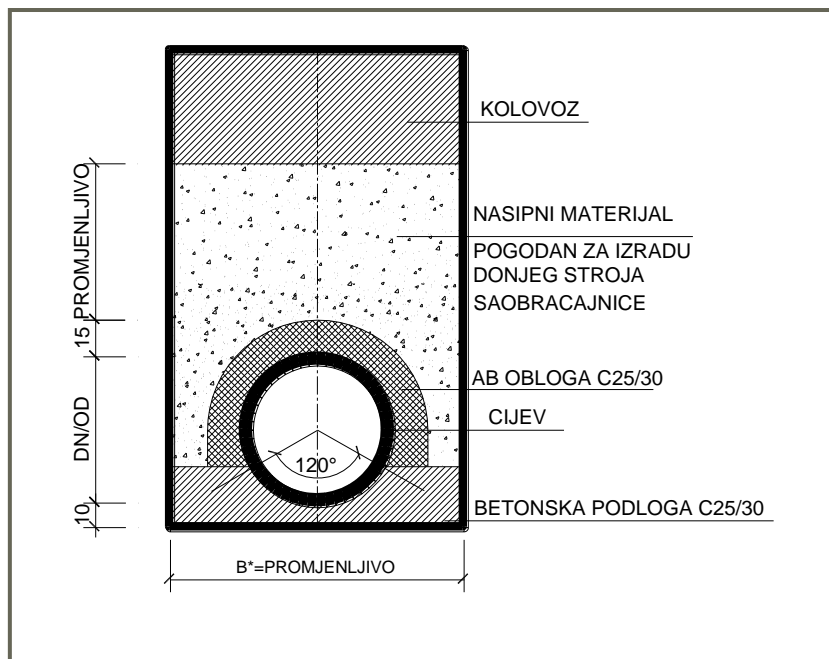


Figure 10. Trench details in roadway

Reinforcement of the concrete encasement is carried out in such a way that anchors are installed during the construction of the concrete base, onto which reinforcing meshes of the RC encasement are connected. After placing the pipe on the concrete base and installing the reinforcing meshes, concreting of the RC encasement is performed. The thickness of the RC encasement is approximately 15 cm and it must be constructed using concrete of strength class C25/30, reinforcing meshes Q188, and reinforcing bars/anchors  $\Phi 12$  mm. Before backfilling the remainder of the trench, the concrete of the RC encasement must harden. Backfilling of the remaining collector trench is carried out using fill material with a grain size of 0–63 mm in layers of 30 cm, with compaction to the required density. In cases where the entire collector trench is located within an embankment, the excavated material is deposited along the trench edge and later reused for backfilling the trench up to the design ground level. Excess material is used for constructing the road embankment. If the invert level of the trench is below the embankment base level, i.e., if excavation is partially carried out in natural soil, the excavated material must be sorted. Soil material is transported to a disposal site, while suitable fill material is set aside and used for backfilling the trench. If, during excavation, it is determined that the existing embankment material is of insufficient quality and cannot be reused (e.g., excavation under poor weather conditions, excessive grain size, etc.), the material must be removed and replaced with suitable fill material, including procurement, transport, and installation. All additional works and activities related to the use of suitable fill material must be included in the base construction cost. If collector pipes are installed in areas with a high groundwater level, geotextile is placed in the trench, within which a sand bedding layer is constructed, the pipe is installed, and sand backfill is placed around and above the pipe. The geotextile is then closed, and the remainder of the trench is backfilled to ground level. All construction works for collector installation must be carried out in accordance with the requirements of BAS EN 1610:2002. All materials used in collector construction that come into contact with conveyed fluids must be resistant to mineral oils, fuels (i.e., diesel), petrol, crude oil, detergents, and their degradation products, or must be adequately protected.

### **Impermeability testing of internal drainage system**

Given that the impermeability of the internal drainage system is one of the basic conditions the system must fulfil, impermeability testing is undertaken after the pipe installation is completed. The impermeability testing of the internal drainage system must be carried out entirely in accordance with the requirements of the BAS EN 1610:2002 standard. It is important to note that the impermeability testing of the system is performed immediately after the installation of the pipes, and before the backfilling of the pipes, because all joints must be visible to allow for their inspection.

### **CCTV inspection of internal drainage system**

CCTV inspection (testing and assessment of the drainage system), i.e., inspection of collectors using a robotic camera, must be performed after pipe installation and backfilling, but before laying the final asphalt layer on the motorway section. During inspection, all system elements must be cleaned. If any material is observed inside the collector, the inspection must be repeated after cleaning, so that any damage, deformation, or defects in the pipeline can be detected and properly recorded in the inspection report.

CCTV inspection must not be performed at a speed greater than 15 cm/s. *The minimum resolution of the CCTV inspection recording must be 768x576 pixels.* The robotic camera used for CCTV inspection must be equipped with pan & tilt functionality and an option for measuring the actual slope of the channel. The actual slope of the channel for each section of the collector must be an integral part of the report. The CCTV inspection report must be analysed and reviewed together with the supervising engineer. If any irregularities are identified that require remediation, i.e., if the report records codes in accordance with BAS EN 13508-2+A1:2012 describing defects related to watertightness, structural stability, or functional performance, such defects must be remedied. The contractor is obliged to rectify all identified deficiencies in order to achieve compliance of the constructed pipeline with all three conditions. After remediation, the correctness of the rehabilitated pipeline must be verified by repeated CCTV inspection and a corresponding report.

The unit price item includes all necessary work, equipment, and auxiliary means required for the execution of the described work, as well as the final report in both hard copy and electronic format, issued and certified by a specialised company/tester that performed the CCTV inspection in accordance with BAS EN 13508-2+A1:2012. Measurement is carried out per linear meter (m') of inspected collector.

CCTV inspection must be performed in accordance with all requirements and instructions specified in BAS EN 13508-1:2014 and BAS EN 13508-2+A1:2012.

#### **19.1.3.3. Technical requirements for design and construction of internal drainage system elements**

An overview of the basic technical characteristics of the elements of the internal drainage system (gutters, concrete segmental channels, catch basins, inspection chambers/manholes, manhole–catch basins, and collectors), as well as an overview of the applicable standards, is provided in the following table. These requirements must be complied with during the design and construction of the system, in accordance with applicable regulations and standards.

ELEMENTS OF THE INTERNAL DRAINAGE SYSTEM		
DESCRIPTION	CHARACTERISTICS	Relevant standards/norms
<b>GUTTERS</b>		
Location	- Along the edge of the roadway of the overtaking or emergency lane of the motorway;	
Dimensions and basic conditions	- The dimensions of the gutters must be determined in accordance with the hydraulic calculation; - Cross slope of the gutter 10-20%; - Longitudinal slope of the gutter identical to the longitudinal slope of the roadway, but must not be less than 0.5%;	
Materials	- Concrete C35/45, XC4/XD3/XF4 <sup>11</sup> ;	BAS EN 1433:2005 BAS EN 1433/A1:2010
Type of construction	- Monolithic by trimmer;	
Maintenance	- Maintenance to be performed in parallel with the maintenance of the internal drainage system ;	
<b>CONCRETE SEGMENTAL CHANNELS</b>		
Location	- In median	
Dimensions and basic conditions	- Minimum width of the concrete segmental channel 80cm, depth 20 cm;	
Materials	- Concrete C35/45, XC4/XD3/XF4 <sup>11</sup>	BAS EN 1433:2005 BAS EN 1433/A1:2010
Type of construction	- Prefabricated or monolithic with a trimmer.	
Maintenance	- Maintenance to be performed in parallel with the maintenance of the internal drainage system;	
<b>CATCH BASINS</b>		
Location	- In the gutter and/or concrete segmental channel;	
Dimensions and basic conditions	- Catch basin with an internal diameter of DN/ID 400 mm, minimum sump depth 100 cm; - Catch basin with an internal diameter of DN/ID 500 mm, minimum sump depth 50 cm; - An internal diameter of the catch basin pot DN/ID 500 mm is recommended due to easier maintenance of the catch basin and the connection of the catch basin to the collector; - The minimum internal diameter for connection pipes is DN/ID 200 mm, with a ring stiffness $SN \geq 8 \text{ kN/m}^2$ .	
	- Minimum one catch basin per 400 m <sup>2</sup> ; <b>The maximum spacing of catch basins is:</b> - 25 m - for longitudinal road slope >1 %; - 10.0 m - for transverse slope 2.5%, and longitudinal 0.5 %; - 4.0 m at places of slope change (superelevation) of the road.	

<sup>11</sup> Construction products incorporated into concrete structures must comply with applicable legislation. This field is currently regulated by the Rulebook on Technical Requirements for Construction Products Incorporated into Concrete Structures ("Official Gazette of the Federation of Bosnia and Herzegovina", No. 86/08).

<b>ELEMENTS OF THE INTERNAL DRAINAGE SYSTEM</b>		
<b>DESCRIPTION</b>	<b>CHARACTERISTICS</b>	<b>Relevant standards/norms</b>
Materials	- Catch basin pot: thermoplastic (Polypropylene - PP) and duroplastic (glass-fibre reinforced polyester - GRP);	BAS EN 476:2012 BAS EN 13598-2:2010 BAS EN 15383+A1:2014
	- Catch basin pot top: Reinforced concrete rings;	DIN 4052-10a, DIN 4052-10b and DIN 4052-11.
	- Catch basin grating: nodular cast iron (ductile iron), load class DN 400 kN, with traffic locking, and additional anti-theft locking;	BAS EN 124: 2002/ DIN 1229,
	- Connection material (elbows, couplings, saddles, connection adapters, pipes) made of polypropylene - PP, polyvinyl chloride - PVC and glass reinforced polyester - GRP; All connecting elements of the catch basin (seals, couplings, saddles, elbows, connection pipes, etc.) must be from the same manufacturer, and must ensure impermeability at the joint. All materials used for the construction of the catch basin, which are in contact with the liquids being poured in, must be resistant to mineral oils, fuels (i.e. diesel oil), petrol, petroleum, detergents and their decomposition products, or appropriately protected.	BAS EN 1852-1:2010 BAS EN 1401-1:2010 BAS EN 14364:2014 BAS EN 12666-1+A1:2012 BAS EN 13476-1:2009 BAS EN 14457:2008; BAS EN ISO 9969:2010; DIN 4262-1
Type of construction	- All parts of the catch basin (catch basin pot, reinforced concrete rings and grating) are installed as prefabricated elements.	
Maintenance	- All parts of the catch basin must be accessible at all times and regularly maintained; - Maintenance of the internal drainage system must be carried out at least every six months, entirely in accordance with the instructions for cleaning and maintaining the system; - Cleaning and flushing of the system is performed with a vacuum pump at a pressure of 1-2 bar;	System maintenance instructions, prepared by the manufacturer and delivered to the end user
<b>COMBINED MANHOLE-CATCH BASINS</b>		
Location	- Combined manhole-catch basin gratings immediately adjacent to the gutter in a separate projection with a horizontal base made of the same material as the gutter; - At the beginning and junction of the collector section; - At places where the collector pipe diameter changes; - At changes in the longitudinal slope of the collector; - At collector turning points; - On straight sections at distances $\leq 25\text{m}$ (can be less than 25m in combination with catch basins, but respecting the condition that at least every 60m there must be an element, either RO or ŠS, regardless of the combination with catch basins)	

ELEMENTS OF THE INTERNAL DRAINAGE SYSTEM		
DESCRIPTION	CHARACTERISTICS	Relevant standards/norms
Dimensions and basic conditions	<ul style="list-style-type: none"> <li>- Combined manhole–catch basin of internal diameter: For pipes with a diameter up to DN/ID 600 mm: minimum internal diameter of ŠS DN/ID 1000*; For pipes with a diameter <math>\geq</math> 600 mm: minimum internal diameter of ŠS DN/ID 1200 mm for a circular cross-section of ŠS.</li> <li>- minimum sump depth 50 cm;</li> <li>- installed like RO, directly connected to the collector with a grating in the projection at the contact of the gutter to receive precipitation into the collector.</li> </ul>	
	<ul style="list-style-type: none"> <li>- Minimum of one combined manhole–catch basin per 400 m<sup>2</sup>;</li> <li><b>The maximum spacing of the combined manhole–catch basin is:</b></li> <li>- 25 m - for longitudinal road slope <math>&gt;1</math> %;</li> <li>- 10.0 m - for transverse slope 2.5%, and longitudinal 0.5 %;</li> <li>- 4.0 m at places of slope change (superelevation) of the road.</li> <li>- the specified spacings take into account both Catch basins and Combined manhole–catch basins and any combination thereof.</li> </ul>	
Materials	<ul style="list-style-type: none"> <li>- Combined manhole–catch basins should be made of the materials listed as follows:</li> </ul>	
	<ul style="list-style-type: none"> <li>- Thermoplastic (polypropylene - PP) and Duroplastic materials (glass-reinforced polyester - GRP).</li> </ul>	BAS EN 476:2012 BAS EN 13598-2:2010 BAS EN 15383+A1:2014
	<ul style="list-style-type: none"> <li>- Combined manhole–catch basin finish Reinforced concrete rings or RC conical finish;</li> </ul>	DIN 4052-10a, DIN 4052-10b and DIN 4052-11.
	<ul style="list-style-type: none"> <li>- Combined manhole–catch basin grating/cover in the roadway: ductile iron, load class DN 400 kN with traffic locking, and additional anti-theft locking;</li> </ul>	BAS EN 124:2002/ DIN 1229,
	<ul style="list-style-type: none"> <li>- Stainless steel steps for access to the combined manhole–catch basin.</li> </ul>	BAS EN 14396:2008
	<ul style="list-style-type: none"> <li>- For a combined manhole–catch basin made of thermoplastic (polypropylene - PP) and duroplastic materials (glass-reinforced polyester - GRP), the settling tank is made of the same material as the combined manhole–catch basin;</li> </ul>	

<b>ELEMENTS OF THE INTERNAL DRAINAGE SYSTEM</b>		
<b>DESCRIPTION</b>	<b>CHARACTERISTICS</b>	<b>Relevant standards/norms</b>
	<p>All connecting elements of the combined manhole–catch basin (seals, couplings, etc.) must be from the same manufacturer and must ensure impermeability at the joint.</p> <p>All materials used for the construction of the combined manhole–catch basin, which are in contact with the inflowing liquids, must be resistant to mineral oils, fuels (i.e., diesel oil), gasoline, petroleum, detergents and their decomposition products, or be appropriately protected.</p>	<p>BAS EN 1852-1:2010  BAS EN 1401-1:2010  BAS EN 14364:2014 (EN 4364:2006+A1:2008)  BAS EN 12666-1+A1:2012 (BAS EN ISO 9969:2010)  BAS EN 13476-1:2009  BAS EN 14457:2008;  BAS EN ISO 9969:2010;  DIN 4262-1</p>
Type of construction	- All parts of the combined manhole–catch basin (body, RC rings, and grating) are installed as prefabricated elements.	
Maintenance	<ul style="list-style-type: none"> <li>- All parts of the combined manhole–catch basin must be accessible at all times and regularly maintained;</li> <li>- Maintenance of the internal drainage system must be carried out at least every six months, entirely in accordance with the instructions for cleaning and maintaining the system;</li> </ul> <p>Cleaning and flushing of the system is performed with a vacuum pump at a pressure of 1-2 bar;</p>	System maintenance instructions, prepared by the manufacturer and delivered to the end user
<b>INSPECTION CHAMBERS/ MANHOLES</b>		
Location	<ul style="list-style-type: none"> <li>- At the beginning and junction of the collector section;</li> <li>- At places where the collector pipe diameter changes;</li> <li>- At changes in the longitudinal slope of the collector;</li> <li>- At collector turning points;</li> <li>- On straight sections at distances <math>\leq 60\text{m}</math> (for IC);</li> </ul>	
Dimensions	<ul style="list-style-type: none"> <li>- For pipes with a diameter up to DN/ID 600 mm: minimum internal diameter of IC DN/ID 1000*;</li> <li>- For pipes with a diameter <math>\geq 600</math> mm: minimum internal diameter of IC DN/ID 1200 mm for a circular cross-section of IC.</li> </ul>	BAS EN 752: 2010
Materials	- Inspection chambers (manholes) should be made of the materials listed as follows:	
	<ul style="list-style-type: none"> <li>a) Thermoplastic (polypropylene - PP) and</li> <li>b) Duroplastic materials (glass-reinforced polyester - GRP).</li> </ul>	<p>BAS EN 476:2012  BAS EN 13598-2:2010  BAS EN 15383+A1:2014</p>

<b>ELEMENTS OF THE INTERNAL DRAINAGE SYSTEM</b>		
<b>DESCRIPTION</b>	<b>CHARACTERISTICS</b>	<b>Relevant standards/norms</b>
	<ul style="list-style-type: none"> <li>c) Reinforced concrete for inspection chambers located in the roadway (traffic areas of the maintenance and control center, plateaus and traffic areas of toll stations, rest areas, interchanges, etc.) of strength class C30/37;</li> </ul>	BAS EN 1917:2007 BAS EN 1917/Cor2:2010
	<ul style="list-style-type: none"> <li>- Inspection chamber finish: Reinforced concrete rings or RC conical finish;</li> </ul>	DIN 4052-10a, DIN 4052-10b and DIN 4052-11.
	<ul style="list-style-type: none"> <li>- IC cover in the roadway: ductile iron, load class DN 400 kN with traffic locking, and additional anti-theft locking;</li> <li>- IC cover in green areas and outside the impact of traffic load: RC cover with an opening handle.</li> </ul>	BAS EN 124:2002/ DIN 1229,
	<ul style="list-style-type: none"> <li>- Stainless steel (Inox) steps for access to the IC.</li> </ul>	BAS EN 14396:2008
	<ul style="list-style-type: none"> <li>- For ICs made of thermoplastic (polypropylene - PP) and duroplastic materials (glass-reinforced polyester - GRP), the invert channel is made of the same material as the IC;</li> <li>- For ICs made of reinforced concrete, the invert channel is made of C30/37 concrete.</li> </ul>	
	<ul style="list-style-type: none"> <li>- Connection material (elbows, couplings, saddles, connection adapters, pipes) made of polypropylene - PP, polyvinyl chloride - PVC and glass reinforced polyester – GRP; All connecting elements of the inspection chamber (seals, couplings, saddles, elbows, etc.) must be from the same manufacturer, and must ensure impermeability at the joint. All materials used for the construction of catch basins, which are in contact with the inflowing liquids, must be resistant to mineral oils, fuels (i.e. diesel oil), petrol, petroleum, detergents and their decomposition products, or be appropriately protected.</li> </ul>	BAS EN 1852-1:2010 BAS EN 1401-1:2010 BAS EN 14364:2014 (EN 4364:2006+A1:2008) BAS EN 12666-1+A1:2012 (BAS EN ISO 9969:2010) BAS EN 13476-1:2009 BAS EN 14457:2008; BAS EN ISO 9969:2010; DIN 4262-1
Type of construction	<ul style="list-style-type: none"> <li>- All parts of the inspection chamber are installed as prefabricated elements.</li> </ul>	
Maintenance	<ul style="list-style-type: none"> <li>- All parts of the inspection chamber must be accessible at all times and regularly maintained;</li> <li>- Considering that the inspection chambers are located on the collector of the internal drainage system, maintenance and cleaning are performed together with the maintenance and cleaning of the collector.</li> </ul>	System maintenance instructions, prepared by the manufacturer and delivered to the end user

<b>ELEMENTS OF THE INTERNAL DRAINAGE SYSTEM</b>		
<b>DESCRIPTION</b>	<b>CHARACTERISTICS</b>	<b>Relevant standards/norms</b>
<b>COLLECTORS</b>		
Location	<ul style="list-style-type: none"> <li>- Median;</li> <li>- Shoulder;</li> <li>- Motorway structure (transverse connection of collectors).</li> </ul>	
Dimensions	<ul style="list-style-type: none"> <li>- The pipe diameter is determined by hydraulic calculation, while the recommended minimum pipe diameters are:</li> <li>- Minimum internal pipe diameter DN/ID 300 mm;</li> <li>- Minimum internal pipe diameter DN/ID 200 mm for connection lines;</li> </ul>	
Materials	Collectors should be made of the following materials:	
	a) Thermoplastic materials ( $SN \geq 8 \text{ KN/ m}^2$ ) <ul style="list-style-type: none"> <li>✓ corrugated polypropylene - PP;</li> </ul>	BAS EN 1852-1:2010
	<ul style="list-style-type: none"> <li>✓ polyvinyl chloride - PVC (solid wall);</li> </ul>	BAS EN 1401-1:2009
	b) Duroplastic materials <ul style="list-style-type: none"> <li>✓ glass fibre reinforced polyester pipes - GRP, <math>SN \geq 5000</math>).</li> </ul> All collector connection elements (seals, couplings, etc.) must be from the same manufacturer and of the same quality as the collector pipes, and must ensure impermeability at the joint.	BAS EN 14364:2014

ELEMENTS OF THE INTERNAL DRAINAGE SYSTEM		
DESCRIPTION	CHARACTERISTICS	Relevant standards/norms
Pipe installation	<ul style="list-style-type: none"> <li>- Pipe installation must be carried out in a previously compacted trench and a prepared sand bed;</li> <li>- Minimum trench width depending on pipe diameter and burial depth;</li> <li>- Pipe installation should be carried out according to the manufacturer's instructions;</li> <li>- <u>For pipes installed in the median and shoulder areas:</u></li> <li>- Installation is carried out on a sand layer with a minimum thickness of 10 cm;</li> <li>- Backfilling with sand is carried out above and around the pipe, 30 cm thick above the pipe crown and with a granulation of 0-2 mm;</li> <li>- Backfilling of the rest of the trench is carried out with selected excavated material, granulation 0-63 mm in layers of 30 cm, with compaction;</li> <li>- <u>For pipes installed in the road body:</u></li> <li>- Installation is performed on a 10 cm thick concrete base;</li> <li>- After pipe installation, an RC casing up to 15 cm thick is executed around the pipe;</li> <li>- Material characteristics for the concrete base and RC casing around the pipe: concrete C25/30 and reinforcement Q188;</li> <li>- Backfilling the rest of the trench with excavated fill material can only be done after the concrete reaches a strength of 60% of the total required concrete strength;</li> <li>- The final layer must have the degree of compaction required for the embankment subgrade (<math>E_{vd} \geq 45 \text{ MN/m}^2</math>).</li> </ul>	BAS EN 1610:2002
Quality of executed works	<ul style="list-style-type: none"> <li>- Before backfilling the pipes, it is necessary to perform an impermeability test of the system. The test can be performed with water or air;</li> <li>- The impermeability test of the system is performed after all connections have been made, in order to test the entire system for impermeability (catch basins, connection links, collector and inspection chambers);</li> </ul>	BAS EN 1610:2002
	<ul style="list-style-type: none"> <li>- CCTV inspection of completed works;</li> <li>- Before the CCTV inspection, it is necessary to clean and flush the pipelines under a pressure of min. 150 bar (nozzle pressure);</li> <li>- CCTV inspection is performed for the entire internal drainage system (catch basins, connection links, secondary collectors, main collector and RO);</li> <li>- CCTV inspection on the motorway must be carried out after the completion of works performed in the immediate vicinity of the collector (installation of protective fences, foundations of lighting poles, portals, etc.), but before the application of the final asphalt layer;</li> </ul>	BAS EN 13508-1:2014 BAS EN 13508-2+A1:2012

ELEMENTS OF THE INTERNAL DRAINAGE SYSTEM		
DESCRIPTION	CHARACTERISTICS	Relevant standards/norms
Maintenance	<ul style="list-style-type: none"> <li>- All parts to be maintained must be accessible at all times;</li> <li>- The quality of the pipe material should ensure stability during flushing under a pressure of min. 150 bar (nozzle pressure);</li> <li>- Maintenance must be carried out in accordance with the instructions for cleaning and maintaining stormwater collectors;</li> <li>- Maintenance of the internal drainage system must be carried out at least every six months, entirely in accordance with the instructions for cleaning and maintaining the system.</li> </ul>	System maintenance instructions, prepared by the manufacturer and delivered to the end user
<p><i>*The stated minimum diameter of the inspection manhole does not apply to the monitoring manhole. The dimensions of the monitoring manhole are determined based on water management conditions, i.e., the valid legislation regulating the field of water protection.</i></p>		

Table 3. Technical requirements for design and construction of internal drainage system elements, including an overview of applicable standards

#### 19.1.4. Shallow and deep drainage system

Shallow and/or deep drains are used for the collection and drainage of seepage water or for draining the motorway. Shallow (sub-gutter) drains are used for draining the motorway body and are located beneath the gutters, while deep drains are used for collecting seepage water from slopes and the surrounding terrain along the motorway route. Due to the positioning of shallow and deep drains, in most cases shallow drains discharge into the internal drainage system, while deep drains discharge into channels, culverts, or watercourses.

Drainage by means of drains prevents water inflow into the roadway body and ensures drainage and lowering of the groundwater level. This accelerates consolidation and stabilization and improves the bearing capacity of highly compressible, low-permeability, and weak cohesive soils. Drainage of water from the road body is ensured by drains and associated structures connected to the drainage system.

The following are used for draining the road body:

- Shallow, deep, longitudinal, and transverse drains;
- Vertical drains and drainage wells.

After trench excavation, shallow and deep longitudinal and transverse drains shall be installed on a lean concrete layer. The dimensioning of drainage collectors shall be carried out in accordance with hydraulic calculations, with the condition that the internal pipe diameter shall not be less than DN/ID 200 mm. The reason for adopting a minimum internal pipe diameter of DN/ID 200 mm is to facilitate easier maintenance and inspection of the drainage collector during motorway operation. Hydraulic calculations of the drainage collector shall be performed based on hydrological data and soil characteristics (permeability, geomechanical characteristics, etc.) from which the water is collected.

During the preparation of the design solution for drainage systems, all necessary details shall be provided to enable unobstructed execution of works (layout plan with the arrangement of inspection chambers and outlets, longitudinal profile, cross-sections, trench detail, inspection chamber detail, outlet detail, etc.). Furthermore, during the design phase, inspection chambers shall be planned at a maximum spacing of 60 m, and the discharge of water from the drainage collector into receiving bodies shall be adequately resolved.

#### **19.1.4.1. Shallow (sub-gutter) drains**

Sub-gutter drains are used to collect water from the motorway body in cases where the roadway has a cross slope towards the central median. Accordingly, shallow drains are installed beneath the gutter located along the central (median) strip of the motorway. In the case of a cross slope of the roadway towards the shoulder, water from the subsoil freely percolates through the embankment, and sub-gutter drainage is not required.

The design of sub-gutter drainage shall be conceived so that the discharge of water from drainage pipes is carried out independently or via the external or internal drainage system. In order to ensure adequate drainage of the roadway subgrade, the final level of the roadway subgrade must be at the level of the perforations of the drainage pipe.

#### **19.1.4.2. Deep drains**

Deep drains are used to prevent seepage of water into the motorway body in areas where the motorway route passes through cuttings and deep excavations, to provide drainage, and to lower the groundwater level.

If, in a specific case, drainage water is discharged into the internal or external drainage system, it is very important to consider the actual depth of the drainage. The actual depth of drainage is determined during earthworks, depending on the excavation depth in unsuitable material (if greater than the designed depth).

In general, for any replacement of subsoil and/or other modifications within the motorway body, an analysis of the impact on the drainage system shall be carried out to determine whether adjustments to the designed solution are necessary.

#### **19.1.4.3. Materials for shallow and deep drainage systems**

The “2005 Guidelines” 9 define the materials used for drainage of the motorway body, as well as the required quality of materials before and during installation. In the continuation of this document, the basic characteristics of pipe materials to be used for drainage collectors are presented, while the characteristics of materials for bedding layers and filter materials shall be applied in accordance with the conditions and requirements prescribed in the “2005 Guidelines”.

For the construction of drainage collectors, pipes made of thermoplastic materials (polypropylene – PP, polyethylene – PE) shall be used, while pipes made of cement concrete shall not be used, as they require significantly longer installation time compared to thermoplastic pipes and involve a considerably higher number of joints.

The cross-section of drainage pipes should be circular. The pipes must be perforated. Drainage pipes made of thermoplastic materials must meet the requirements for:

- Dimensions: pipe diameter and wall thickness;
- Mass;
- Arrangement and area of water drainage openings (drainage capacity);
- Stiffness.

The quality of pipes and fittings made of thermoplastic materials for drainage must comply with the requirements of DIN 4262-1. For all drainage pipes and fittings made of thermoplastic materials, the following data must be specified in the technical documentation:

- Pipe diameter;
- Perforation type;
- Pipe category depending on the required ring stiffness.

#### **19.1.5. Roadway stormwater treatment systems / water protection systems**

Polluted waters flowing from the roadway and surrounding terrain have large temporal oscillations in registered quantities, as well as in the degree of pollution.

Previous research indicates the presence of the following pollution in stormwater from the roadway:

- Organic pollution, expressed as five-day biochemical oxygen demand (BOD<sub>5</sub>), is present in low concentrations in runoff from roadways, but its concentration can be elevated in the case of runoff from green areas;
- Suspended solids are considered the most pronounced pollution in stormwater, as they can be present in significant concentrations;
- Heavy metals, such as copper, lead, cadmium, nickel, chromium, and zinc, are present in stormwater from roadways in a wide range of concentrations; their concentration shows a good correlation with the concentration of suspended solids, and primarily depends on traffic intensity;
- Oils and greases are present in stormwater from the roadway, and their presence is an indicator of accidental pollution (leakage of oil and fuel from motor vehicles, accidental spills, etc.);

Studies have also indicated that the concentration of pollution in stormwater on the roadway is, in most cases, highest at the beginning of the rain (first flush). Since a part of the pollution occurs as a result of the deposition of particles from the air, the quality of stormwater can also depend on the time period between two precipitation episodes, or the total time without precipitation during the considered period.

For the discharge of stormwater from the motorway, it is necessary to obtain water conditions from the competent water management authority (competent water agency). Depending on the requirements of water legislation, a solution for the stormwater treatment system is designed.

The "2005 Guidelines"<sup>12</sup> state the basic requirements and conditions related to the protection of water and soil. Protection measures that serve to limit and prevent the direct impact of traffic on the quality of water resources are based on hydrological foundations and the assessment of the area's sensitivity.

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12 Book I – Design, Part 1: Road Design, Chapter 6: Road and Environment

With the development and construction of road infrastructure in the territory of FBiH in the past period, there has been an increase in the number of pollution sources from the roadway under the influence of various factors such as: traffic characteristics, atmospheric precipitation, local catchment conditions (land use, motorway surface area, maintenance method, etc.), and incident liquids. Bearing the aforementioned in mind, the need arose to introduce a new, comprehensive approach in order to increase the contribution in terms of long-term protection of water and the environment<sup>13</sup>.

The required quality of water discharged from the roadway into recipients depends on local conditions<sup>14</sup>. If the discharge of stormwater from the motorway into the public sewage system is planned, it is necessary to obtain discharge conditions from the competent public utility company that manages it.

#### **19.1.5.1. Elements of the water protection system**

Generally, bearing in mind the need to adequately protect the area through which the road infrastructure passes, it is necessary to provide an appropriate water protection system with the ultimate goal of reducing pollution and preserving water and water-dependent ecosystems.

The elements of the water protection system are:

- Inlet or distribution shaft;
- Tank for receiving incident liquid;
- Oil and grease separator and/or lagoons, and
- Monitoring shaft

##### **Inlet or distribution shaft**

All water from the internal drainage system is drained to the inspection or distribution shaft, and then distributed to the oil and grease separator and/or the tank for receiving incident liquid. Sizing and material selection of the inspection/distribution shaft must be carried out entirely according to the requirements and instructions presented in the chapter: „**Inspection shafts/manholes**„ of this document.

##### **Tank for receiving incident liquid**

Depending on the conditions and requirements for the discharge of stormwater from the motorway, issued by the competent water management authority, as well as the possibility of incident pollution, it is necessary to provide a tank for receiving incident liquid. When sizing the tank, it is necessary to ensure an available tank space with a minimum capacity of 20 m<sup>3</sup> in case of an incident load. The tank for receiving incident liquid must be sized so that during

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13 Depending on the hydrogeological characteristics of the terrain and the degree of area sensitivity, the critical discharge ( $Q_{crit}$ ) shall be calculated, and based on it, the optimal level of water and environmental protection shall be adopted. In addition, the possibility of accidental situations must be considered, and accordingly, an appropriate water protection system shall be established for the specific case.

14 The Regulation on Conditions for Discharge of Wastewater into Natural Receiving Bodies and the Public Sewerage System ("Official Gazette of the Federation of Bosnia and Herzegovina", No. 04/12) currently prescribes the conditions for wastewater discharge into the environment.

installation and operation it withstands all loads to which it may be exposed, without losing its function and causing damage to the environment.

Also, the area around the tank must be secured against possible flooding (being carried away by water) when it is empty. In the design phase of the tank for receiving incident liquid, it is necessary to perform all necessary calculations, and provide execution details within the project documentation.

## **Separators**

Oil, gasoline, gas oil, lubricants, heating oil and some other substances have a lower specific gravity than water. This property is used by the oil and grease separator, which separates the above-mentioned liquids from water using gravity. The purpose of the oil and grease separator is to separate all light liquids, i.e. oils and greases, and prevent their discharge into the environment. By valid legal regulations<sup>14</sup>

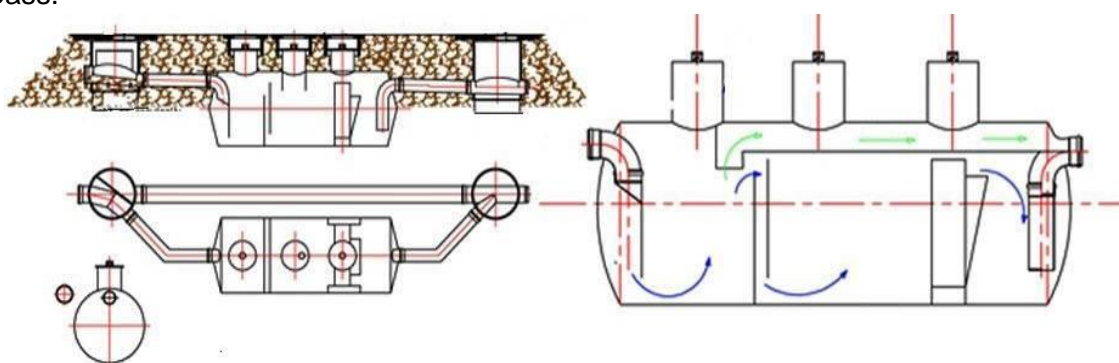
Depending on the water management conditions, the oil and grease separators that are installed can be:

- Separators with non-integrated bypass
- Separators without bypass

### **Separators with non-integrated bypass**

Separators with non-integrated bypass (Figure 11) are used for the treatment of stormwater in moderately sensitive areas (outside high-risk zones). In this way, the first flush of polluted water is directed into the separator, while the remaining runoff from the drainage surface is conveyed via the bypass. This mode of operation enables optimization of the system capacity and significantly reduces overall investment costs.

The following figure shows a schematic representation of a separator with a non-integrated bypass.



**Figure 11** Schematic representation of a separator with a non-integrated bypass

## Separators without bypass

Separators without bypass (Figure12) are used for the treatment of stormwater in areas where the discharged water must be completely purified. The installation locations for separators without a bypass are as follows:

- Sanitary protection zones;
- Protected areas;

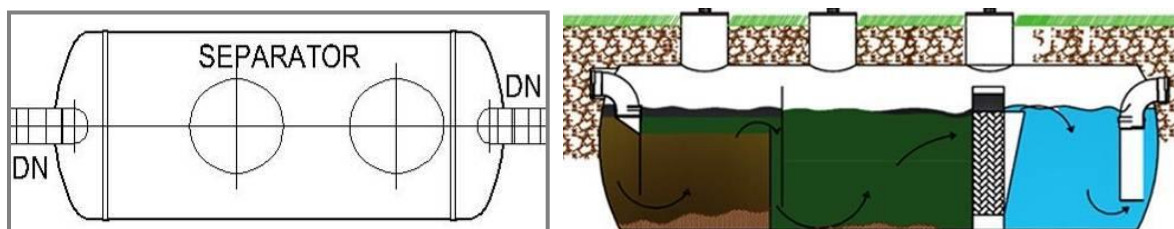


Figure12 Schematic representation of a separator without a bypass

## Design and installation of separators

Determining the capacity of the separator is done in the design phase, based on the amount of stormwater flowing into the separator (during the hydraulic calculation of the collector) and the required degree of purification. From a static aspect, the separator must be dimensioned so that during installation and operation it withstands all loads to which it may be exposed without losing its function and causing damage to the environment. The area around the separator must be secured against possible flooding (being carried away by water) when it is empty.

The structural stability of the separator must be ensured in accordance with applicable norms and standards, and in accordance with the instructions prescribed by the European norm EN 858-1:2005. The separator should have equipment that ensures adequate water purification and proper operation of the separator.

The separator equipment includes:

- Coalescing filter used for the separation of light petroleum derivatives (separation of water and oily liquids);
- A closure device that ensures the collected liquid does not pass to the separator outlet. Automatic closure devices operating with a float must be adjusted and marked for densities of 0.85 g/cm<sup>3</sup>, 0.90 g/cm<sup>3</sup>, or 0.95 g/cm<sup>3</sup> in accordance with the expected density of the light liquid;
- An alarm device for warning in case of float submersion should be provided only in areas where stricter conditions for stormwater treatment are prescribed;
- Pre-installation for the connection of a set intended for taking samples;
- Openings (manholes) and separator covers with a locking mechanism against unauthorized access;
- Settling tank, separated from the oil separator;

Depending on the volume and load of the separator, it is necessary to perform a static calculation for the lower and relief (upper) reinforced concrete (RC) slab of the separator. The

RC relief (upper) slab is constructed if there is an overburden of earth material greater than 2 m above the separator.

When dimensioning the RC slabs, take into account that the thickness of the lower RC slab should not be less than 20 cm, while the minimum thickness of the relief RC slab must not be less than 15 cm. For the construction of RC slabs, the use of C25/30 concrete and Q335 reinforcing mesh (two reinforcement zones) is recommended. In addition to the above, the installation of the oil and grease separator must be carried out in accordance with the specific instructions provided by the device manufacturer in the specific case.

When installing and choosing the position of the separator, the following must be taken into account:

- The separator should be installed only on drainage systems where light liquid needs to be separated from water and retained in the separator;
- The separator should be installed near the source of the light liquid, in a well-ventilated area that is easily accessible for cleaning and maintenance;
- If there are electrical warning devices for light liquids and other electrical devices located in the separator, they must always be functional and suitable for operation (requirements from Directive 94/9/EC);
- All drainage to and from the separator system must comply with BAS EN 752:2010. Pipes and joints to the separator system must be resistant to light liquids;
- Before backfilling the separator, it is necessary to check the impermeability of the installed device;

In cases of installing the separator in soil with groundwater, pay attention to the occurrence of buoyancy force. The method of installation in terrain with high groundwater is achieved by anchoring the separator to the RC slab. The dimensions of the RC are determined according to the thrust force. The number of anchoring points, dimensions of the anchors, and the strength of the binding straps are dimensioned based on stability conditions.

### **Hydraulic calculation of the separator**

Usually, the calculation of the required capacity of the oil and grease separator with a settling tank is not performed when it comes to prefabricated separators, because the required amount of pollution flowing into the separator is obtained through the dimensioning of the water drainage pipeline.

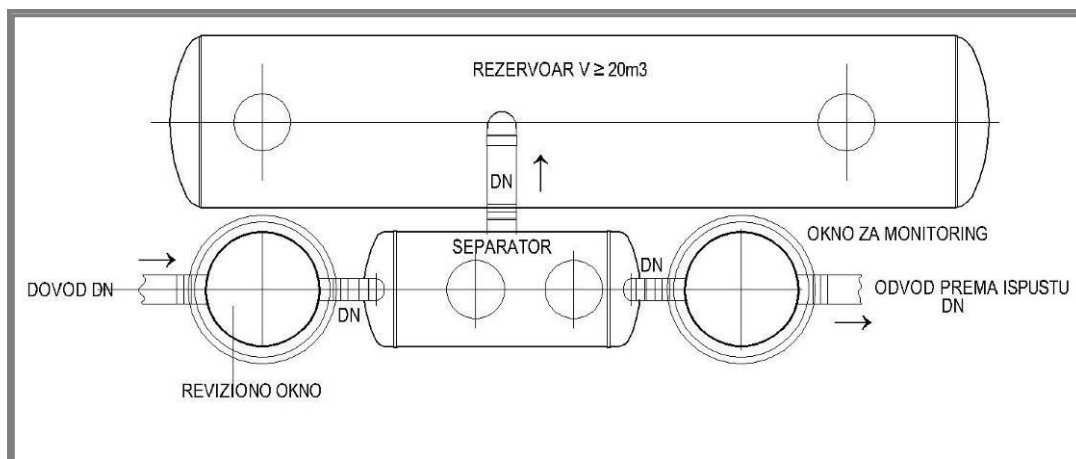
For surface wastewater, a design solution of standard devices is adopted such that the effluent from the device must meet the limit values prescribed by the valid legislation for the discharge of wastewater into the recipient<sup>14</sup>

### **Monitoring shaft**

In accordance with the requirements of valid regulations, immediately before discharging water into the recipient (public sewage system, natural watercourse, etc.), it is necessary to provide a monitoring manhole. The dimensions of the monitoring manhole are determined based on valid legislation, which in FBiH is the Decree on wastewater discharge<sup>14</sup>

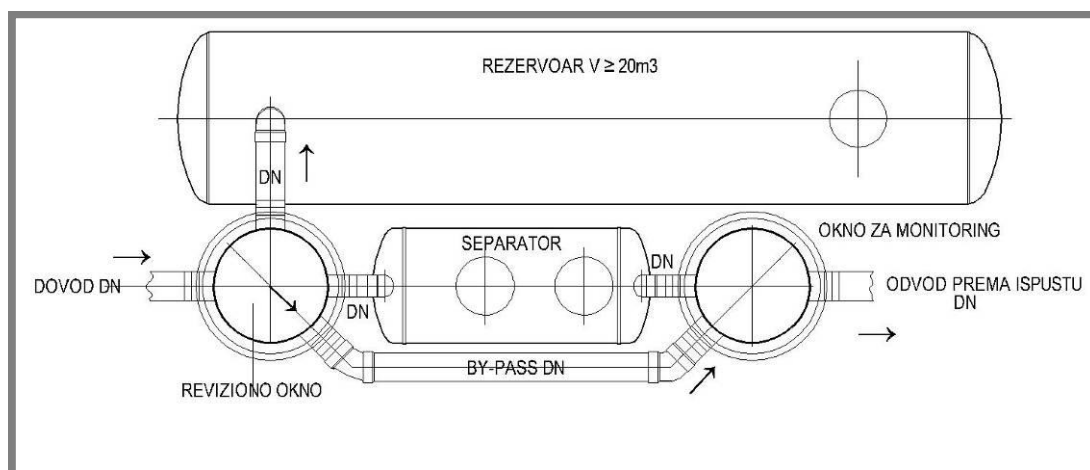
#### **19.1.5.2. Conceptual solutions of the water protection system**

Conceptually, the water protection system depends on the hydrogeological characteristics of the terrain and the degree of sensitivity of the area through which the motorway route passes, as well as the conditions prescribed by the competent water management authority. The solution concept shown in Figure 13 is applied when the competent water authority requires and prescribes stricter conditions for stormwater treatment, i.e., when the motorway route passes through high-risk zones where the most stringent criteria for water and environmental protection must be applied. In such cases, the installation of separators without a bypass and a reservoir for accidental liquid retention is provided.



**Figure13** Schematic representation of the elements of the water protection system in case of installation of a separator without a bypass

The solution concept that includes the implementation of a separator with a non-integrated bypass is applied if it concerns areas outside high-risk zones. In doing so, it is necessary to take into account that the minimum degree of water purification should be 10%<sup>13</sup>



**Figure14** Schematic representation of the elements of the water protection system in case of installation of a separator with a non-integrated bypass

### 19.1.5.3. Technical requirements for the design and construction of elements of the water protection system

An overview of the basic technical characteristics for: elements of the water protection system (inlet/distribution shaft, oil and grease separator, tank for receiving incident liquids, and monitoring shaft), as well as an overview of applicable norms, is given in the following table and must be adhered to during the design and construction of the system, all in accordance with applicable regulations and standards.

ELEMENTS OF THE WATER PROTECTION SYSTEM		
DESCRIPTION	CHARACTERISTICS	Relevant standards/norms
<b>INLET/DISTRIBUTION CHAMBER</b>		
A detailed description of the inspection chambers is given in the chapter "Inspection chambers/manholes (RO)", while an overview of the basic characteristics of the inspection chambers is given in the chapter 19.1.3.3 Table 3		
<b>OIL AND GREASE SEPARATOR</b>		
Class	- I	
Maximum possible residual oil content	- 5.0 mg/l	BAS EN 858-1:2005
Recommended nominal sizes (l/s)*	- 1.5; 3; 6; 10; 15; 20; 30; 40; 50; 65; 80; 100; 125; 200; 300; 400; 500	
Recommended materials	- Thermosetting materials (glass-reinforced polyester - GRP) that guarantee impermeability and resistance to the aggressive action of polluted water; - Thermoplastic materials (polypropylene - PP) that guarantee impermeability and resistance to the aggressive action of polluted water. <b>Note:</b> The materials from which the separator is made must be resistant to mineral oils, fuels (diesel oil), petroleum, gasoline, detergents and their degradation products.	
Quality of executed works	- Before backfilling the oil and grease separator, it is necessary to perform an impermeability test;	BAS EN 1610:2002

ELEMENTS OF THE WATER PROTECTION SYSTEM		
DESCRIPTION	CHARACTERISTICS	Relevant standards/norms
Maintenance	<ul style="list-style-type: none"> <li>- All parts to be maintained must be accessible at all times;</li> <li>- System maintenance must be performed at least every 6 months;</li> <li>- Maintenance must be carried out in accordance with the manufacturer's instructions, and must include at least the following details:               <ul style="list-style-type: none"> <li><b>a) Sludge trap:</b> <ul style="list-style-type: none"> <li>✓ Determination of sludge volume;</li> </ul> </li> <li><b>b) Separator:</b> <ul style="list-style-type: none"> <li>✓ Measuring the thickness of light liquids;</li> <li>✓ Checking the operation of the automatic closure device;</li> <li>✓ Checking the permeability of the coalescing device,</li> <li>✓ Checking the function of the warning device.</li> </ul> </li> <li><b>c) Sampling port</b> <ul style="list-style-type: none"> <li>✓ Cleaning the drainage channel.</li> </ul> </li> </ul> </li> </ul> <p>At intervals of up to 2 years, the separator must be emptied and subjected to a general inspection which includes the following:</p> <ul style="list-style-type: none"> <li>- checking the leak tightness of the system;</li> <li>- Condition of the structure;</li> <li>- Condition of the inner lining, if any;</li> <li>- Condition of the built-in parts;</li> <li>- Condition of electrical devices and installations;</li> <li>- Checking the adjustment of automatic closing devices, e.g., floating bodies.</li> </ul>	System maintenance instructions, prepared by the manufacturer and delivered to the end user.
<b>TANK FOR RECEPTION OF INCIDENT LIQUID</b>		
Dimensions	<ul style="list-style-type: none"> <li>- The total capacity of the tank must be determined based on calculations;</li> <li>- The minimum capacity of the available tank space for the reception of incident liquid is 20 m<sup>3</sup>.</li> </ul>	
Materials	<ul style="list-style-type: none"> <li>- Thermoplastic and thermosetting materials that guarantee impermeability and resistance to the aggressive action of polluted water;</li> <li>- The materials used must be resistant to mineral oils, fuels (i.e., diesel oil), gasoline, petroleum, detergents and their decomposition products, or be appropriately protected;</li> </ul>	BAS EN 976-1 and BAS EN 976-2

ELEMENTS OF THE WATER PROTECTION SYSTEM		
DESCRIPTION	CHARACTERISTICS	Relevant standards/norms
Quality of executed works	- Before backfilling the incident liquid tank, an impermeability test must be performed;	BAS EN 1610:2002
Maintenance	- All parts of the system (pipes, inspection chambers, separator, tank) must be regularly maintained and accessible at all times; - Flushing and cleaning of the system should be performed every 6 months;	System maintenance instructions, prepared by the manufacturer and delivered to the end user
MONITORING CHAMBER		
A detailed description of the inspection chambers is given in the chapter "Inspection chambers/manholes (RO)" of this document, while an overview of the basic characteristics for inspection chambers is presented in the chapter 19.1.3.3 Table 3 <sup>14</sup>		

Table 4. Technical requirements for the design and construction of water protection system elements and overview of applicable standards

**\*Note:**

*In accordance with the requirements of BAS EN 858-1, the maximum capacity of the separator is 500 l/s. For systems with a higher flow rate, it is necessary to modify the concept of the water protection system. One of the solutions for the water protection system at flow rates greater than 500 l/s is to distribute the water supply from the distribution shaft and enter two or more separators of the same or similar capacity. The discharge of water from the separator is carried out into the monitoring shaft and further from the monitoring shaft to the recipient*

#### 19.1.6. Extended retention lagoons

Lagoons with extended retention are used to remove pollution from stormwater, as retentions to reduce peak flow to the level prior to the construction of the road, and as recipients.

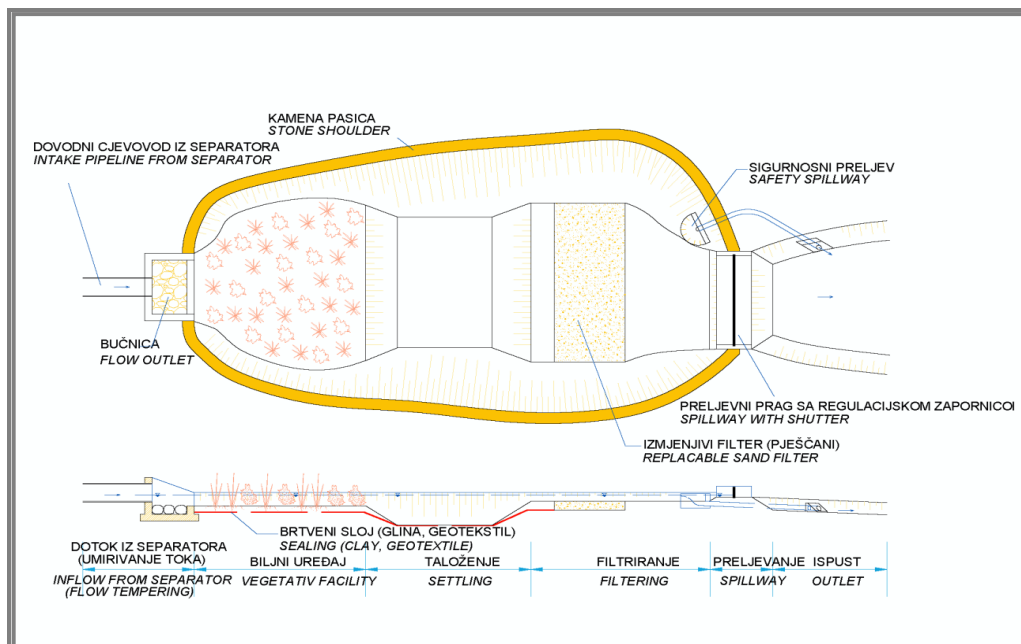
For the removal of pollution from stormwater, lagoons can be used in cases where there is a high concentration of suspended solids, as well as in the case of heavy metal removal. Settleable and floating substances are removed from stormwater, and along with them nutrients, heavy metals, and toxic substances, while runoff regulation protects downstream structures from erosion and reduces the possibility of flooding. The efficiency of pollution removal in lagoons increases with an increase in water retention time.

In areas where the discharge of treated water is difficult (no suitable recipient nearby) from the internal and/or external drainage system, lagoons can be used as recipients.

It is important to emphasize that the construction of lagoons for the purpose of pollution removal cannot be planned in sensitive and protected areas, karst areas, as well as in the immediate vicinity of source protection zones or in areas where underground drinking water abstraction is performed.

In addition to the above, before developing a project solution for lagoons, it is necessary to obtain water management requirements from the competent water management authority, and to fully comply with all conditions and requirements specified in the water management act.

The most common types of lagoons are: dry lagoons with extended retention and wet lagoons with extended retention. A schematic representation of the lagoon is shown in the following figure.



**Figure 15.** Schematic representation of a lagoon with extended retention

#### 19.1.6.1. Dry lagoons with extended retention

Dry extended detention lagoons are lagoons that do not require a constant inflow of stormwater and can be applied in the following cases:

- When particularly high pollution of the receiver is expected (usually when the average daily traffic load is over 30,000 vehicles/day);
- When water management authorities require that the water regime is not disturbed due to a change in land use.

The land required for dry extended detention basins is 0.5-2.0% of the total catchment area. Due to their most frequent location within the motorway expropriation zone, these basins are geometrically narrow and elongated. The construction of these basins should be planned in areas with permeable soil, so that water filters into the ground, but excluding the areas listed in chapter 19.1.6

#### 19.1.6.2. Wet extended detention basins

Using the constant presence of water from stormwater runoff from the roadway, a wet basin removes conventional pollutants through sedimentation, biological degradation, and plant filtration. Biological processes taking place in the basin remove metals and dissolved nutrients such as nitrates and orthophosphates. Wet extended detention basins are used to remove heavy metals and suspended solids from stormwater, provided that oil and grease must be removed beforehand.

Wet basins can also be regulatory structures and control the inflow via the so-called live retention volume above the permanent operating level. A wet basin is suitable for use in catchments with a reliable water source larger than 4 ha, up to a maximum of 260 ha. For wet basins, a reliable water source must be ensured throughout the year. Due to possible water loss, the basin must be located on low-permeability soil, or secured with a geomembrane or clay liner. For wet basins, it is necessary to provide 1-3% of the total corresponding catchment area.

#### **19.1.6.3. Basin maintenance**

Regular inspections are necessary to check for leaks over the embankments, deep-rooted vegetation, and erosion along the embankments and sides of the basin. If the basin is not well maintained, the water can become stagnant, covered with algae and floating debris, foul-smelling, and infested with insects. Over time, sediment accumulation can significantly reduce the capacity of the basin. Sediment can reduce the storage volume in the basin by up to 20% over a 10-year period. The sediment should be tested to determine if it is a hazardous material.

#### **19.1.7. Culverts**

In the "2005 Guidelines"<sup>15</sup> detailed guidelines for the design of culverts are given. During the development of design solutions, it is necessary to adhere to all instructions presented in the mentioned chapter of the 2005 Guidelines.

#### **19.1.8. Water discharge from the external and internal drainage system**

Depending on local conditions, collected water from the roadway can be discharged into the public sewage system or into natural recipients.

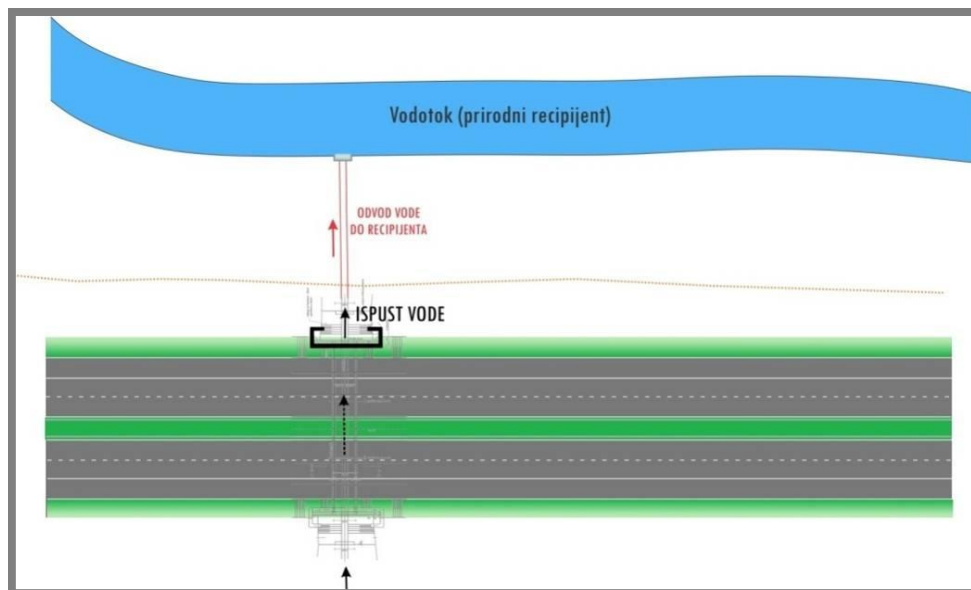
In the case of discharging water from the internal drainage system into the public sewage system, the technical documentation must be prepared in accordance with the previously obtained conditions of the competent public utility company. These conditions will define the connection point, elevation levels, and the manner in which the connection facility to the public sewage system should be designed and constructed.

In the case of discharging water from the external and internal drainage system into a natural recipient, an outfall structure should be provided whose task is to discharge the collected stormwater and accelerate its mixing with the water in the recipient. The structure at the outfall must be secured against undermining and collapse, so it is necessary to fortify the bank in the vicinity of the outfall.

The outfall should be positioned taking into account the high water level of the recipient (natural watercourse). In this way, the occurrence of backflow of water into the drainage system is prevented, i.e., it allows the free outflow of water from the drainage system during high water levels in the natural recipient. In addition to the above, special attention should be paid when designing and constructing the drainage system on the section between the outfall and the recipient (Figure 16).

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<sup>15</sup> Book I – Design, Part 3: Design of Road Structures, Chapter 2: Culverts



**Figure 16.** Drainage system on the section between the outfall and the recipient

Conceptually, the drainage system on the section from the outfall to the recipient depends on the location of the recipient and the outfall from the external and/or internal drainage system, as well as on the terrain configuration. Accordingly, the drainage system in this part can be designed as a closed system (collector system) and/or an open system (open channels). When developing the design solution and constructing the stormwater drainage system from the outfall to the recipient, the requirements and regulations presented in Chapter 19.1.2 (in the case of open channels) and/or Chapter 19.1.3 (in the case of a collector system) of this document shall be followed.

If the recipient for receiving stormwater from the external and/or internal drainage system is located at a great distance from the discharge point or is unavailable, when determining the water discharge solution, it is possible to consider a discharge solution with an "absorption well". Before developing such a solution, it is necessary to carry out appropriate hydrogeological soil investigations, and a solution with an "absorption well" can only be planned in the case of highly permeable soil and a low groundwater level.

The dimensioning of the "absorption well" is carried out in accordance with the available parameters (depth of permeable soil, amount of water received from the culvert, etc.). One example of an "absorption well" shown at the outlet of the culvert, i.e., the external drainage system, is given in the figure below.

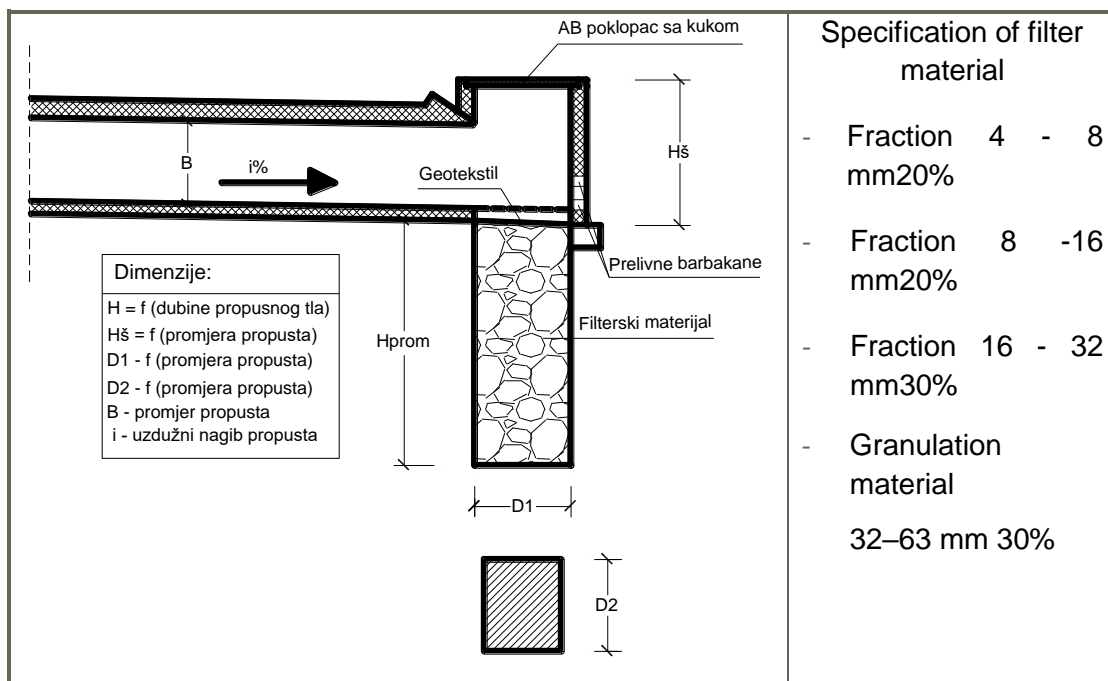


Figure 17. Example of absorption well detail at the culvert outlet

## 19.2. Drainage system of facilities on motorways (Bridges, Viaducts, Underpasses and Overpasses)

### Introduction

The water drainage system from motorway structures (bridges, viaducts, underpasses, overpasses, etc.) is one of the most important elements from the aspect of traffic participant safety, as well as the protection and durability of the structure. An adequate solution for water drainage from structures ensures the designed service life of the structure, but also reduces the maintenance costs of the structure.

Besides other irregularities in the execution of individual parts of the structure of facilities (e.g., poor execution of waterproofing, concrete segregation, etc.), most damage to facilities occurs due to a poorly designed, executed, or maintained drainage system. In order to improve traffic conditions, as well as to protect the structure and the environment, it is necessary to design and build a drainage system that will perform controlled drainage of water from the facilities.

The drainage system of facilities on the motorway includes several parts or subsystems, which are:

- Part of the drainage system from traffic surfaces (drainage of water from the roadway);
- Part of the drainage system from the reinforced concrete (RC) slab, specifically the part under the waterproofing and the release of vapor pressure (drainage of seepage water);
- Part of the drainage system of the embankment behind the abutment;
- Connection of the drainage system from the facility to the public sewage system or a natural recipient

Conceptually, the water drainage system from motorway facilities consists of longitudinal and vertical pipes through which the water inflow is drained to the nearest recipient.

For smaller facilities (facilities up to 20 m in length, e.g., passages, facilities on motorway service roads, etc.), it is sufficient to provide catch basins or open drainage channels in front of and behind the bridge. For larger facilities, surface water is collected by built-in catch basins, the number and arrangement of which are determined by hydraulic calculation, and then it is drained outside the facility through pipes.

When planning and designing a drainage system, one of the basic rules is that: all elements must be accessible for inspection and cleaning, replaceable, and must not "encroach" on the load-bearing structure in the area of the main reinforcement and prestressing cables of the facility. Also, the conditions for adequate water drainage from the pavement structure are: appropriate slopes and flatness of the pavement structure. The transverse slopes of the roadway should be a minimum of 2%, with a recommended slope of 2.5%.

### **19.2.1. Elements of drainage systems of facilities**

The elements of the facility drainage system are:

- Catch basins
- Manhole catch basins
- Drainage pipes (longitudinal collector pipes and vertical pipes) with associated fittings (couplings, branches, elbows, etc.) and elements for suspending and fastening the pipes to the structure (rods, braces, screws);

#### **Catch basins**

Catch basins are among the most important elements of structure drainage and consist of: a grating, a waste collection basket, and the lower part of the catch basin. Given that there are several types of catch basins depending on the installation, it is recommended to use catch basins with direct vertical discharge, which are favourable from the standpoint of efficiency in evacuating the design flow, as well as maintenance and management during the exploitation phase of the structure. Taking the above into account, the characteristics of catch basins with direct vertical discharge are described below.

Catch basins must have the possibility of subsequent adjustment of the grating position in terms of height and slope. In order to be subsequently adaptable to corrections of the pavement structure (e.g., when replacing asphalt), it is recommended that they also have the possibility of road displacement. They must also have a peripheral band with a width of  $\geq 80$  mm by which they are connected to the insulation (establishing the continuity of the insulation).

The mutual spacing of catch basins on structures depends on the longitudinal slope of the deck slab and is determined by hydraulic calculation, provided that the spacing must not exceed 25 m. At expansion joint locations, it is necessary to place catch basins on both sides at a maximum distance of 4 m from the expansion joint, thereby reducing the inflow of water into it.

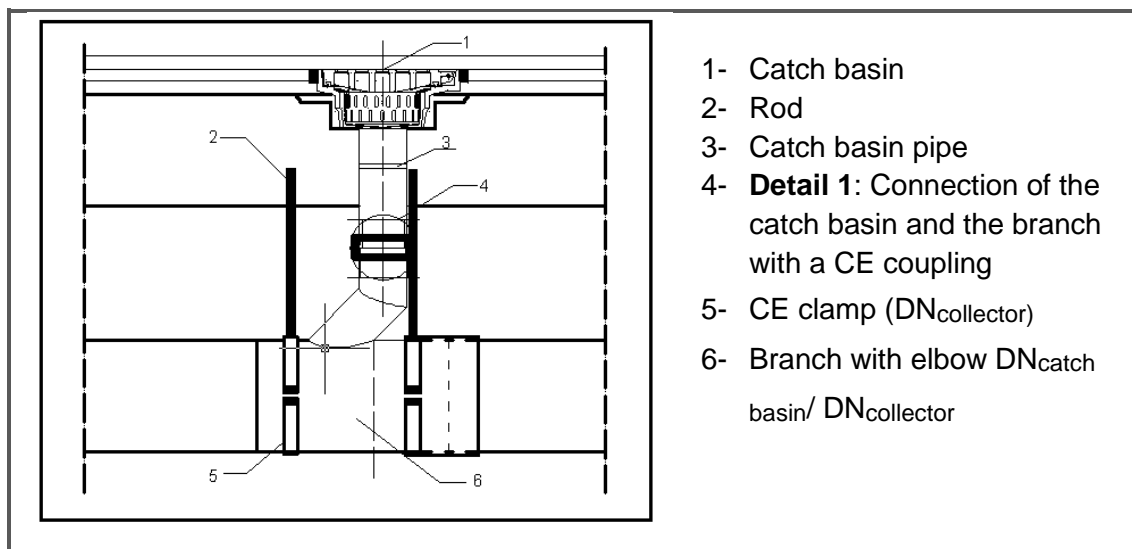
Depending on the structure of the object, the shape and type of catch basin are selected. The method of installing the catch basins must be carried out entirely according to the description

given in the "2005 Guidelines"<sup>16</sup>, with the following addition: When creating the design solution and installing the lower part of the catch basin, it is necessary to provide for the extension of the catch basin drainage pipe. This is achieved by welding a section of ductile iron pipe onto the existing catch basin pipe. The length of the welded pipe depends on the thickness of the structure's deck slab, provided that the total length of the catch basin pipe (catch basin pipe + welded pipe section) extends about 10 cm below the lower edge of the RC slab. The purpose of the catch basin pipe extension is to enable the unhindered connection of the catch basin to the longitudinal collector drainage pipes. The minimum internal diameter of the catch basin drainage pipe is 125 mm.

Catch basins and cleaning eyes (counter-catch basins installed at a maximum spacing of 70 m)<sup>16</sup> are installed directly above the longitudinal collector pipes and are connected to them at an angle of 45°. The connection/jointing of catch basins to the longitudinal collector pipes is carried out as follows:

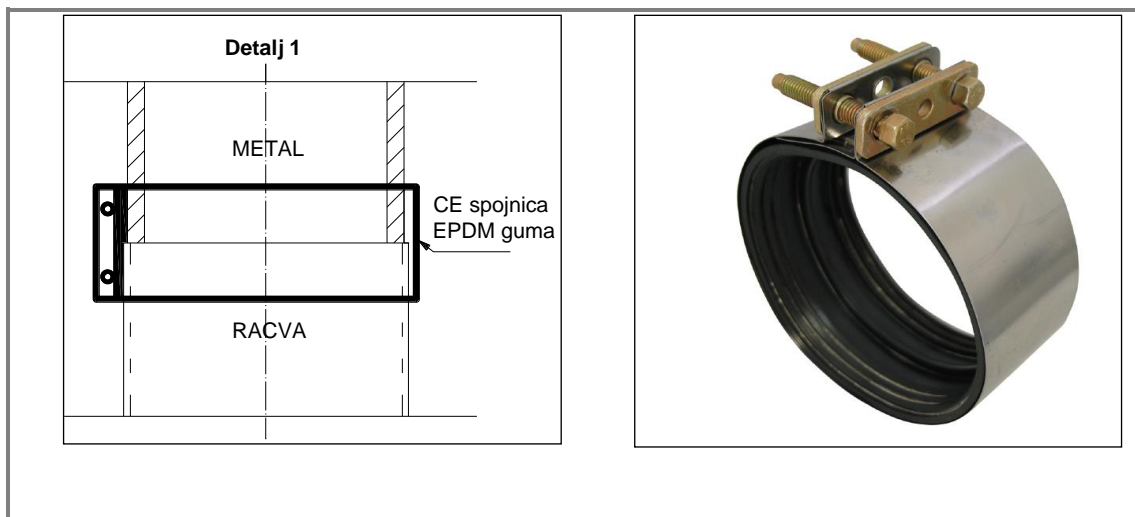
- Connecting the catch basin drainage pipe and the branch with a CE coupling (Figure18)
- Connecting the branch with the longitudinal collector pipes at an angle of 45°,

Connecting/joining the catch basin and the collecting longitudinal pipes at an angle of 45° is more favourable from a hydraulic aspect, because during heavy rainfall (when larger amounts of water occur) the possibility of pipeline "choking" at the connection point is reduced (Figure18)



**Figure18** Connection of the drain and branch to the longitudinal collector on the facility

The detail of the connection of the catch basin and the branch using a CE coupling is given in the following figure, as well as a 3-D view of the CE coupling.



**Figure 19** Detail 1: Connection of the catch basin to the branch using a CE coupling and a 3D view of the coupling

When selecting a CE coupling (as a transitional flexible piece) which is installed to connect the catch basin with the branch, the characteristics of the CE coupling must be entirely in accordance with the standard BAS EN 877:2001 and BAS EN 877/A1:2009.

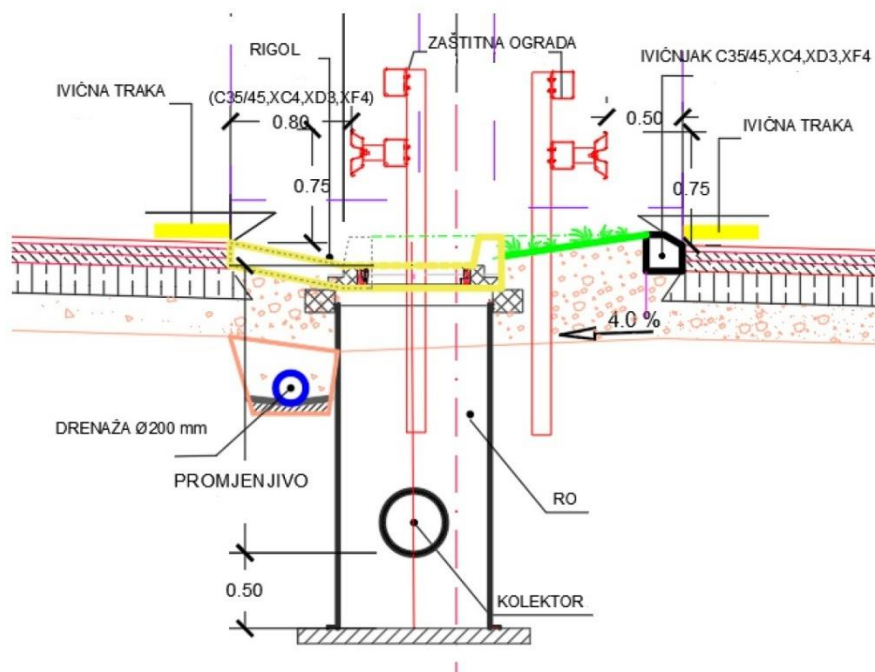
The material from which the CE coupling is made is Rostfrei "A4", and on the inside of the CE coupling there is EPDM rubber. In order to fully achieve impermeability at the connection point, when selecting a CE coupling, it is necessary to take into account the ratio between  $DN_{\text{catch basin}}/DN_{\text{branch}}$ . In practice, it is a very common case that the diameter of the catch basin pipe is DN 150 mm, while the diameter of the branch at the connection point is DN 160, so when selecting a CE coupling, it is stated that it is an Inox CE coupling DN150/DN160 mm. Inside the catch basin, the installation of a waste collection basket is mandatory, which prevents the penetration of spreading material and/or other particles into the collector of the drainage system.

Catch basins with direct vertical runoff are positioned along the edge of the roadway, which can have a one-sided or two-sided slope. The amount of water passage of the catch basin depends on the type of grating (size, area, shape of the grating bars), the surface of the roadway, the slope, etc. The discharge capacity of the catch basin is a minimum of 10 l/s. The catch basin grating is designed to allow safe traffic on the road. The outer edge of the grating frame must be 1.0-1.5 cm away from the curb/New Jersey barrier to prevent water from collecting and seeping next to the catch basin.



## Manhole catch basins

Manhole catch basins, like standard catch basins, are among the most important drainage elements of structures and consist of: a grate, an inspection chamber body, and a settling basin with a minimum depth of 50cm. These are elements with direct vertical drainage, favourable from the standpoint of efficiency in evacuating the design flow, as well as maintenance and management during the operational phase of the structure. As water intake elements, they act as catch basins, and their installation conditions are the same as for inspection chambers, given that they also serve for the inspection of main collectors. The grates must meet the same conditions as catch basin grates. They should be installed on straight sections at intervals no greater than 25m, and it is also possible to combine drainage solutions with catch basins and manhole catch basins if the previous condition is met. All elements of the manhole catch basin must meet the standards related to impermeability and be resistant to chemicals such as oils, fats, fuels, detergents, etc. The following figure shows a detail of the manhole catch basin location.



**Figure 21.** Detail of the manhole catch basin position

### 19.2.1.1. Pipes for water collection and drainage

Pipes for water collection and drainage from structures can be: longitudinal collector pipes and vertical pipes. The connection angle of the drainage pipe from the catch basin to the longitudinal collector pipes is made via a branch at an angle of 45°.

**Longitudinal collector pipes** receive water directly from the catch basins (roadway with a one-sided cross slope). The minimum internal diameter of the longitudinal collector pipes is 250 mm, while the minimum slope of the longitudinal collector pipes should be 1%. The installation of glass-fibre reinforced thermosetting plastic pipes produced by the centrifugal casting process – CCGRP, according to the provisions of BAS EN 14364:2014 and B 5161, is

recommended. Also, all connecting elements used during the construction of the drainage system (couplings, additional couplings, elbows, branches, etc.) must meet the characteristics and conditions prescribed by the provisions of BAS EN 14364:2014 and B 5161.

**Vertical pipes** are, as a rule, installed along the pillars in structures of great length. The rule is that they are attached to the pillar, and never concreted inside the pillar, as this would make their maintenance impossible. The installation of vertical pipes is done in a straight line along the pillar, with expansion joints every 20-30 meters in the case of very tall structures. At the lower part of the pillar, it is necessary to provide an inlet manhole to absorb the energy of the falling water, as well as for the maintenance and cleaning of the vertical drainage pipes. The pipe diameter is determined based on a detailed hydraulic calculation.

At expansion joints as well as vertical joints (the joint of the abutment and the span structure), it is necessary to install a flexible piece (EPDM rubber) on the pipeline, so that the pipeline can move together with the movements of the bridge, and to prevent the occurrence of additional stresses in the pipeline.

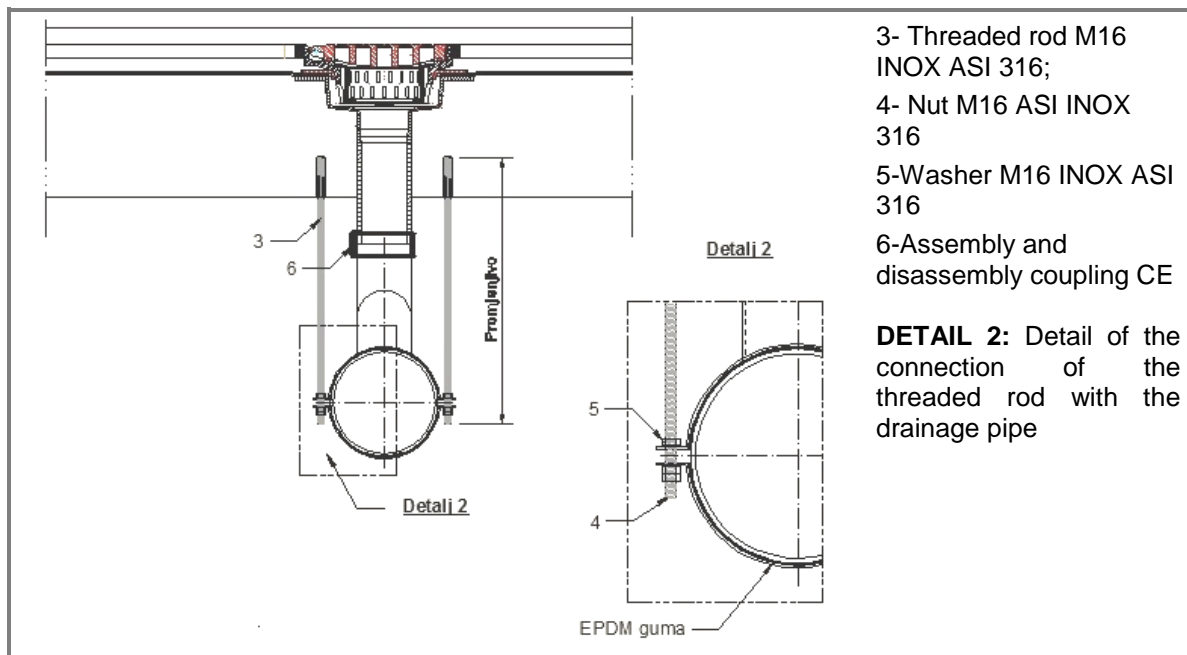
Drainage of water from expansion joints, bearings, drainage of seepage water and release of vapor pressures is detailed in the „Guidelines from 2005“<sup>16</sup>

### **Conditions for installing and fastening pipes to the structure of the facility**

Conditions for installing and fastening pipes to the structure of the facility are given in the „Guidelines from 2005“<sup>16</sup>. Longitudinal collector pipes shall be suspended and fixed to the underside of the structural slab. Suspension of the longitudinal collector pipes to the structure is carried out using threaded rods, which may be installed vertically (vertical threaded rods) or at an angle (inclined threaded rods). The installation of threaded rods is performed by anchoring (drilling and fixing) the rods into the underside of the reinforced concrete (RC) slab, while on the other side the threaded rods are fastened with screws to clamps installed around the longitudinal pipes.

The load-bearing capacity and stability of the threaded rods must be determined based on calculations for the case when the collecting longitudinal pipes are fully filled with water in their entire profile. To determine the spacing and number of rods, it is necessary to perform a static calculation and determine the number of rods, so that the permissible load on the supports is not exceeded, while also taking into account the movements of the supports. Also, on fittings/branches, it is mandatory to install threaded rods on both sides. The detail of the suspension of the collecting longitudinal pipes with vertical threaded rods is shown in the figure **22**.

For all connection elements, it is necessary to perform a stress control, and after that to adopt the dimensions of the elements. When choosing the dimensions of the elements, care should be taken not only of the load from the full pipeline (filled with water) but also of additional influences, such as vibrations, temperature oscillations as well as possible loads from regular maintenance and servicing.



**Figure 22.** Method of suspending pipes for the lower part of the building structure

Suspension and support elements must allow height adjustment, which is achieved by means of braces and screws on vertical supports. All elements for suspending and supporting or fastening pipes must be made of Rostfrei "A4" material.

#### 19.2.1.2. Technical requirements for the design and construction of elements of the building drainage system

An overview of the basic technical characteristics for the elements of the building drainage system is given in the following table. These must be adhered to during design and construction, all in accordance with applicable regulations and standards.

<b>ELEMENTS OF THE BUILDING DRAINAGE SYSTEM</b>		
<b>DESCRIPTION</b>	<b>CHARACTERISTICS</b>	<b>Relevant standards/norms</b>
<b>CATCH BASINS</b>		
Location	- Along the New Jersey barrier/curb (Figure20	"2005 Guidelines" <sup>16</sup>
Dimensions and basic conditions	<ul style="list-style-type: none"> <li>- The layout of the catch basins needs to be determined by hydraulic calculation;</li> <li>- Minimum one catch basin per 400 m<sup>2</sup>;</li> <li>- For a slope &gt;1%, the maximum spacing is 25.0 m, and 10.0 m if the transverse slope is 2.5% and the longitudinal slope is 0.5%.</li> <li>- Catch basin drainage pipe min. DN 125 mm;</li> <li>- Determine the dimensions of the catch basins by hydraulic calculation.</li> </ul>	"2005 Guidelines" <sup>16</sup>
Materials	<ul style="list-style-type: none"> <li>- The lower part or body of the catch basin ("hat") ductile iron with a bituminous coating;</li> <li>- Catch basin grating: ductile iron grating with bituminous protection, load class DN 400 kN, with traffic locking, and additional anti-theft locking;</li> <li>- Stainless steel waste collection basket,</li> <li>- Drainage pipes from the catch basin, ductile iron with bituminous protection.</li> </ul>	BAS EN 124:2002/ DIN 1229,  DIN 4052-C3 BAS EN ISO 1461:2010
Type of construction	- All parts of the drain are installed as prefabricated elements.	"2005 Guidelines" <sup>16</sup>
<b>COLLECTING LONGITUDINAL AND VERTICAL PIPES AND ELEMENTS FOR SUPPORTING AND SUSPENDING PIPES</b>		
CE COUPLING	<ul style="list-style-type: none"> <li>- Installed for connecting the catch basin pipe with the branch on the collecting longitudinal pipes;</li> <li>- Material: stainless steel - Rostfrei "A4", and on the inside of the CE coupling there is EPDM rubber, diameter DN<sub>catch basin</sub>/DN<sub>branch</sub>.</li> </ul>	BAS EN 877:2001 BAS EN 877/A1:2009

<b>ELEMENTS OF THE BUILDING DRAINAGE SYSTEM</b>		
<b>DESCRIPTION</b>	<b>CHARACTERISTICS</b>	<b>Relevant standards/norms</b>
SCREWS, NUTS AND RODS, BRACES	<ul style="list-style-type: none"> <li>- Fastening of pipes and fittings to the concrete structure;</li> <li>- The spacing of the rods is determined by static calculation. It is recommended that the spacing between the rods is not greater than 3 m;</li> <li>- The clamp on the inside should have EPDM rubber that is resistant to salt and UV radiation;</li> <li>- The connection between the concrete structure and the threaded rod should be made at an angle of 45 or 90°, depending on the calculation;</li> <li>- Material: Stainless steel – Rostfrei "A4".</li> </ul>	<p>BAS EN 10088-2:2007</p> <p>BAS EN 10088-3:2007</p> <p>BAS EN 10088-4:2010</p> <p>BAS EN 10088-5:2010</p>
LONGITUDINAL AND VERTICAL PIPES	<ul style="list-style-type: none"> <li>- The pipe diameter is determined by hydraulic calculation. The minimum internal pipe diameter is DN/ID 250 mm for longitudinal and vertical pipes;</li> <li>- Material: <ul style="list-style-type: none"> <li>- Centrifugally cast glass-fibre-reinforced polyester pipes - CCGRP, which are resistant to salt and external influences (UV radiation, frost, temperature fluctuations, etc.);</li> <li>- All connecting materials used for joining longitudinal and vertical pipes should be made of centrifugally cast glass-fibre-reinforced polyester - CCGRP), and must meet the same conditions prescribed for the specified type of pipe;</li> </ul> </li> <li>- The quality of the executed works of the longitudinal pipes is proven by CCTV inspection. Before the CCTV inspection of the longitudinal pipes of the drainage system, it is necessary to clean and flush the pipeline under a pressure of at least 150 bar (nozzle pressure).</li> </ul>	<p>"2005 Guidelines"<sup>16</sup></p> <p>BAS EN 14364:2014 and B 5161</p> <p>BAS EN 13508-1:2014 i</p> <p>BAS EN 13508-2+A1:2012</p>
<b>ELEMENTS FOR DRAINAGE OF SEEPAGE WATER AND RELEASE OF VAPOR PRESSURES</b>		
	<ul style="list-style-type: none"> <li>- Ductile iron pipes should be distributed over the entire insulated surface so that they are at the lowest point of the roadway, e.g. along the corridor (25 cm from the curb) at a distance of 3.0 to 10.0 m, depending on the longitudinal slope of the roadway.</li> <li>- One pipe covers about 15-25 m<sup>2</sup> of the structure's surface.</li> </ul>	<p>"2005 Guidelines"<sup>16</sup></p> <p>C.B5.226</p>
<b>CLEANING AND MAINTENANCE OF DRAINAGE SYSTEMS ON STRUCTURES</b>		
	<ul style="list-style-type: none"> <li>- Cleaning and maintenance of the water drainage system from the structures must be carried out in accordance with the instructions for cleaning and maintenance of storm sewers;</li> <li>- Flushing of the pipeline should be done under a pressure of min 150 bar (nozzle pressure).</li> </ul>	<p>Instructions on system maintenance, prepared by the manufacturer and delivered to the end user; "2005 Guidelines"<sup>16</sup></p>

Table 5. Technical requirements for the design and construction of drainage system elements for structures and overview of applicable standards

### **19.2.2. Hydraulic calculation of structure drainage system**

Hydraulic calculation of the drainage system (water quantities, determining the number and spacing of catch basins, dimensioning of collecting longitudinal and vertical pipes, etc.) of stormwater from structures is detailed in the „Guidelines from 2005“<sup>16</sup>

### **19.2.3. Purification and discharge of water from structure drainage system**

Purification and discharge of water from the drainage system of structures should be carried out in accordance with water management requirements. These requirements relate to the prevention and reduction of water and soil pollution by waters coming from the roadway. Given that the structures on the motorway together with the motorway route represent a single entity, it is necessary to adhere to all requirements, conditions, and regulations specified in Chapter 19.1 of this document.

## **19.3. Drainage in tunnels**

### **Introduction**

The design solution for the tunnel water drainage system should be conceived so that all liquids, which in any way reach the roadway and other surfaces inside the tunnel, are collected by the shortest route and guided to the tunnel portals, and further to the recipient, i.e., the device for receiving or treating the collected motorway waters. Tunnel drainage must be designed in a way that involves the construction of a drainage system for the reception and evacuation of groundwater and seepage water, as well as the reception and evacuation of incident liquids.

#### **19.3.1. External drainage system - lateral drains**

The external drainage of the tunnel includes a system of lateral drains with perforations at 220° (water receiving zone 200 cm<sup>2</sup>/m') which serve the purpose of receiving rock (ground) water along the tunnel. In order to ensure adequate cleaning, maintenance, and functionality of the lateral drains, the construction of inspection niches at a maximum spacing of  $L \leq 60.0$  m' is planned. In the event of non-functioning (clogging) of the lateral drainage system (at any point of the cross-section), it is necessary to provide cross connections with the aim of evacuating groundwater in the zone between the primary and secondary lining. The cross connections are positioned at the level of the perforations of the lateral drainage pipes, and they have the function of an overflow. The pipes of the cross connections are executed without perforations with a minimum slope of 2% and an internal pipe diameter of DN/ID 200 mm. All cross connections passing through the roadway body in the tunnel must be executed in a way that involves the construction of a concrete base and RC lining around the pipe. The quality of the concrete for the construction of the concrete base and RC lining is C25/30. Reinforcement is done using Q188 reinforcing meshes. The thickness of the concrete base is about 10 cm, while

the minimum thickness of the RC lining is 15 cm. An illustration of the lateral drainage (cross-section and plan) with inspection niches is presented below.

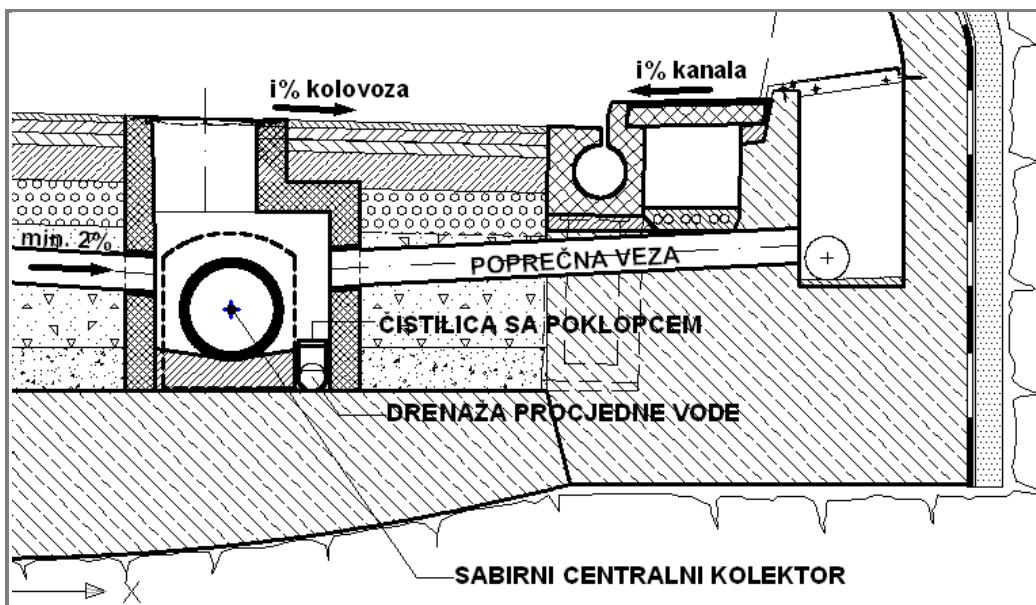


Figure 23. Lateral drainage with connection to the central collector-Cross section

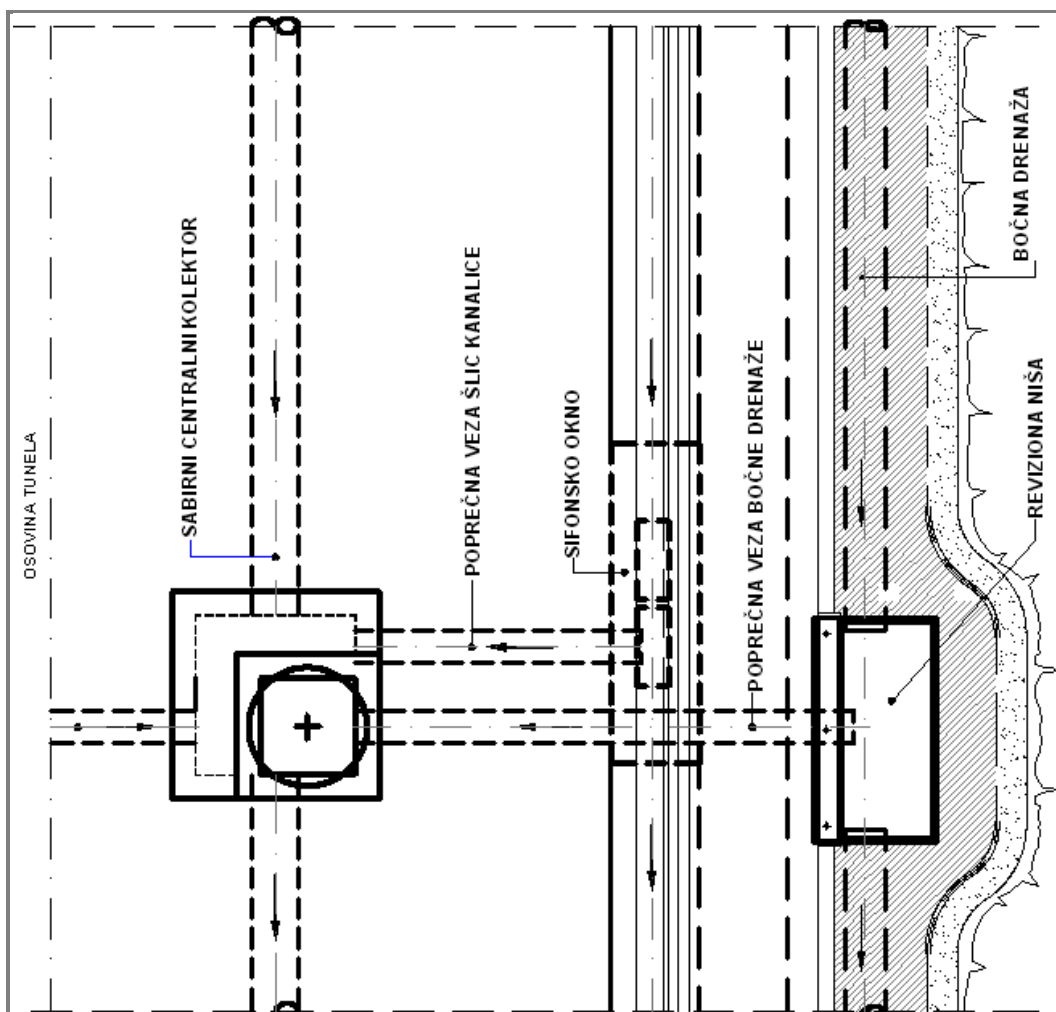


Figure 24 Lateral drainage with connection to the central collector - Layout

In the phase of developing the design solution, the diameter of the lateral drainage pipe is determined by hydraulic calculation, in accordance with the available data on groundwater quantities. In the project documentation, it is necessary to provide the longitudinal profile of the lateral drainage pipe, cross-section, layout, and execution details, as well as the specification of the pipe material which must be entirely in accordance with DIN 4262-1, BAS EN 14364:2014 and ÖNORM B5161, BAS EN 1401-1:2010 and BAS EN 1852-1:2010, depending on the choice of material.

During the tunnel construction phase (tunnel excavation and primary lining construction), and prior to the construction of lateral drainages, it is necessary to monitor the quantity of groundwater and conduct additional hydrological tests, and based on these, verify the designer's hydraulic calculation.

In addition to the above, during the construction phase, it is necessary to test the quality and quantity of groundwater (flowing to the lateral drainage), and analyse the possibility of using water from the lateral drainage for the purpose of tunnel water supply (water for fire protection). Any potential additional works and activities arising from the adaptation of the external drainage system to the field conditions must be included in the bid amount for the basic works.

During the construction phase, special attention must be paid during the concreting of inspection niches and pipe inverts, in order to prevent the penetration of concrete and cement milk into the lateral drainage system. The installation of lateral drainage pipes is carried out in such a way that a layer of concrete is installed on a previously cleaned concrete base, and after placing the pipe in fresh concrete, the construction of the concrete invert begins. The installed lateral drainage pipes are backfilled with drainage concrete.

Drainage (porous) concrete is made of cement, 16/32 mm fraction, and water. The amount of water used must not exceed the amount necessary to cover all aggregate and cement particles. The quality of the installed lateral drainage is proven by CCTV inspection, including cross connections.

#### **19.3.1.1. Technical requirements for the design and construction of lateral drainages in tunnels**

An overview of the basic technical characteristics for the external drainage system - lateral drainages is given in the following table. These must be adhered to during design and construction, all in accordance with applicable regulations and standards.

EXTERNAL DRAINAGE SYSTEM - LATERAL DRAINAGES		
DESCRIPTION	CHARACTERISTICS	Relevant standards/norms
<b>LATERAL DRAINAGES</b>		
Location	- At the connector of the primary and secondary tunnel lining.	
Dimensions and basic conditions	- The pipe diameter is determined by hydraulic calculation, and a minimum internal pipe diameter of DN/ID 200 mm is recommended; - Spacing of inspection niches $\leq 60$ m'.	
Materials	<b>Lateral drainage pipes:</b>	
	- Lateral drains should be made of material <b>with a solid wall</b> , 220 ° perforations, perforation width 1.2 mm, and ring stiffness $SN \geq 8$ kN/m <sup>2</sup> and permeability of 200cm <sup>2</sup> /m'.	DIN 4262-1
	- Materials that can be used are: - Polypropylene pipes - PP with solid wall and smooth interior, Type R3, $SN \geq 8$ kN/m <sup>2</sup> )	BAS EN 1852-1:2010 DIN 4262-1 Type R3
	<b>Inspection niches</b>	
	- Reinforced concrete C30/37 with sulfate cement; - Cover on inspection niches: Stainless steel in the full width of the niche opening; - Stainless steel climbing steps for access to the inspection niche;	BAS EN 124:2002 BAS EN 14396:2008
Quality of executed works	- CCTV inspection of completed works; - Before the CCTV inspection, it is necessary to clean and flush the pipeline under a maximum pressure of 360 bar (nozzle pressure), including chain cleaning if necessary; - CCTV inspection is performed for the entire system, including cross connections;	BAS EN 13508-1:2014 BAS EN 13508-2+A1:2012
Maintenance	- All parts of the lateral drainage must be regularly maintained and accessible at all times; - Flushing and cleaning of the system should be performed every 3 months, or in accordance with the system maintenance instructions; - The quality of the pipe material should ensure stability during flushing under a maximum pressure of 360 bar (nozzle pressure), including chain cleaning.	System maintenance instructions, prepared by the manufacturer and delivered to the end user

EXTERNAL DRAINAGE SYSTEM - LATERAL DRAINAGES		
DESCRIPTION	CHARACTERISTICS	Relevant standards/norms
<b>PIPES FOR THE CROSS CONNECTION OF THE LATERAL DRAINAGE WITH THE CENTRAL COLLECTOR</b>		
Location	<ul style="list-style-type: none"> <li>- In the pavement structure of the tunnel (from the inspection niche of the lateral drainage to the inspection manhole of the central collecting collector)</li> <li>- Longitudinally every <math>L \leq 60.0</math> m of the tunnel length;</li> </ul>	
Dimensions	<ul style="list-style-type: none"> <li>- The inner diameter of the pipe is determined by hydraulic calculation, and a minimum inner pipe diameter of DN/ID 200 mm is recommended;</li> <li>- Minimum pipe slope 2 %.</li> </ul>	
Materials	<ul style="list-style-type: none"> <li>- Pipes used for cross connections should be made of material <b>with a solid wall</b>, without perforations, ring stiffness <math>SN \geq 8</math> kN/m<sup>2</sup>. The quality of the pipe material should ensure stability during pressure flushing of min 150 bar (nozzle pressure).</li> </ul>	DIN 4262-1
	<ul style="list-style-type: none"> <li>- Materials that can be used are:               <ul style="list-style-type: none"> <li>a) Thermoplastic material</li> </ul> </li> <li>- Polypropylene – PP pipes <b>with a solid wall</b> and smooth interior, <math>SN \geq 8</math> kN/m<sup>2</sup>) and</li> <li>- Polyvinyl chloride – PVC pipes <b>with a solid wall</b> and smooth interior, ring stiffness <math>SN \geq 8</math> kN/m<sup>2</sup>)</li> </ul>	DIN 4262-1 BAS EN 1852-1:2010  BAS EN 1401-1
Quality of executed works	<ul style="list-style-type: none"> <li>- CCTV inspection of completed works;</li> <li>- Before the CCTV inspection, it is necessary to clean and flush the pipelines under a pressure of min. 150 bar (nozzle pressure);</li> </ul>	BAS EN 13508-1:2014 BAS EN 13508-2+A1:2012
Maintenance	<ul style="list-style-type: none"> <li>- All parts of the cross connections must be regularly maintained and accessible at all times;</li> <li>- Flushing and cleaning of the system should be performed every 3 months, or in accordance with the system maintenance instructions;</li> <li>- The quality of the pipe material must ensure stability during flushing under a pressure of min. 150 bar (nozzle pressure).</li> </ul>	System maintenance instructions, prepared by the manufacturer and delivered to the end user

Table 6. Technical requirements for the design and construction of lateral drains and overview of applicable standards

### 19.3.2. Seepage water drainage system

To ensure the evacuation of seepage water from the tunnel, a system of longitudinal filtration and water drainage is used. Seepage water drainage involves the construction of drainage

layers of appropriate thickness, including deep longitudinal drainage. When constructing the seepage water drainage system, it is necessary to use drainage and lean concrete, filter materials, geotextiles, and thermoplastic pipes of appropriate diameter. Considering that the drainage pipes for tunnel seepage water pass through the inspection chambers of the main central collector, it is necessary to provide a cleanout with a cover on the seepage water drainage pipes inside the inspection chambers. The seepage water drainage system is constructed with perforated pipes up to the entrance of the inspection chambers, and the part of the pipe that passes through the inspection chamber and on which the cleanout with a cover is planned, is constructed from pipes without perforations (solid pipe). In this way, the possible backflow of water from the main collector to the drainage collector is prevented without eliminating the possibility of system inspection.

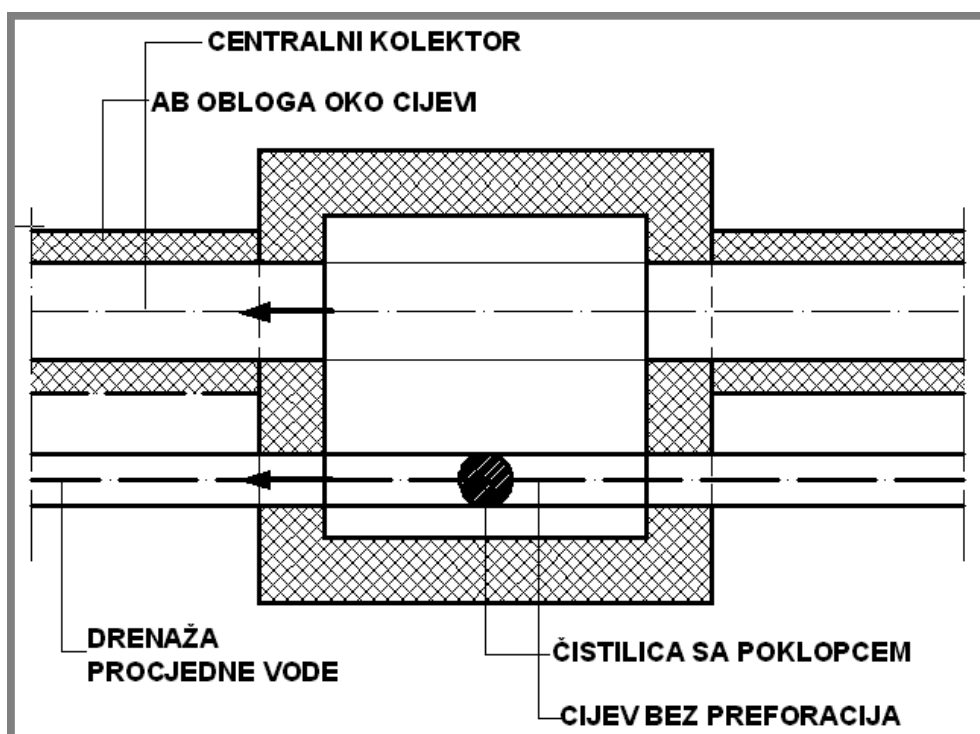


Figure 25. Detail of seepage water drainage system

The arrangement of the drainage layers should be such that, even in the event of a blockage of the longitudinal deep drainage, they allow unimpeded filtration of water outside the tunnel structure for a certain period of time.

The discharge of seepage water is carried out directly into the recipient without prior purification. In case of connection to other drainage systems, it is necessary to provide protection against backflow. The quality of the installed pipes for seepage water drainage is proven by CCTV inspection.

#### 19.3.2.1. Technical requirements for the design and construction of the seepage water drainage system

An overview of the basic technical characteristics for the seepage water drainage system is given in the following table. These must be adhered to during design and construction, all in accordance with valid regulations and standards.

SEEPAGE WATER COLLECTION PIPES		
DESCRIPTION	CHARACTERISTICS	Relevant standards/norms
Location	- Bottom elevation of the pavement structure.	
Dimensions	- The pipe diameter is determined by calculation, while it is recommended that the minimum internal pipe diameter be DN/ID 150 mm.	
Materials	- The pipes should be made <b>of material with a solid wall</b> , 220° perforations, perforation width 1.2 mm, and ring stiffness $SN \geq 8 \text{ kN/m}^2$ ; - Pipes passing through the inspection chambers of the main central collector should be made of material <b>with a solid wall without perforations</b> , ring stiffness $SN \geq 8 \text{ kN/m}^2$ with a cleaning piece and cover.	DIN 4262-1.
	Material used for pipes: - Polypropylene - PP pipes with <b>a solid wall</b> and smooth interior, Type R3, $SN \geq 8$ ); - Polyvinyl chloride - PVC pipes with <b>a solid wall</b> and smooth interior, Type C2, ring stiffness $SN \geq 8 \text{ kN/m}^2$ )	DIN 4262-1 Type R3 BAS EN 1852-1:2010 BAS EN 1401-1
Quality of executed works	- CCTV inspection of completed works; - Before the CCTV inspection, it is necessary to clean and flush the pipeline under a pressure of min. 150 bar (nozzle pressure).	BAS EN 13508-1:2014 BAS EN 13508-2+A1:2012
Maintenance	- All parts must be regularly maintained and must be accessible at all times; - Flushing and cleaning of the system should be performed every 3 months, or in accordance with the system maintenance instructions prepared by the manufacturer; - The quality of the pipe material must ensure stability during flushing under a pressure of min. 150 bar (nozzle pressure).	System maintenance instructions, prepared by the manufacturer and delivered to the end user

Table 7. Technical requirements for the design and construction of seepage water drainage systems, including an overview of applicable standards

### 19.3.3. Internal drainage system

Water from the roadway in the tunnel is collected via an open curb (continuous "slit" drainage channels). Continuous "slit" drainage channels are positioned on the lower side of the roadway, i.e., they follow the transverse slope of the roadway in the tunnel.

The internal drainage system consists of:

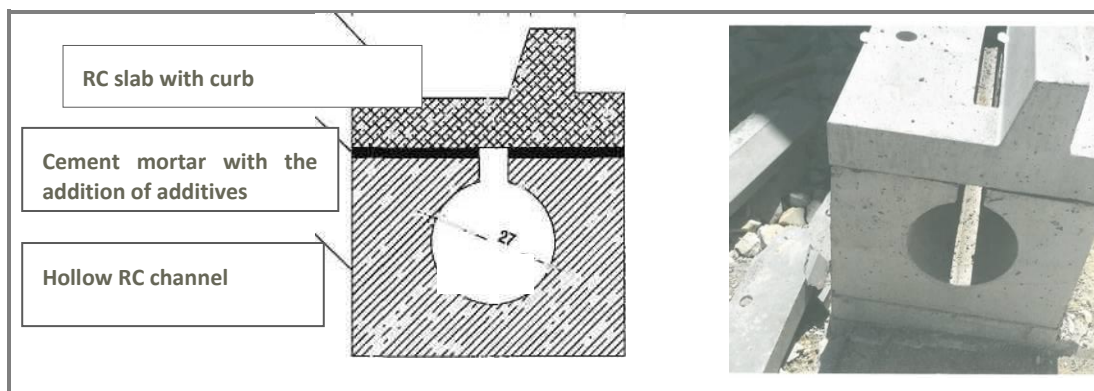
- Continuous "slit" drainage channels and
- Siphon inspection chamber with a baffle and cover;

### **Continuous "slit" drainage channels**

Continuous "slit" drainage channels can be constructed monolithically (on-site) or prefabricated. In the case of monolithic construction of continuous "slit" drainage channels, the drainage channels are constructed in two parts. The first part of the continuous "slit" channels is an RC channel of circular cross-section, and the second part is an RC slab with a curb. The installation technology of continuous "slit" channels constructed on-site is as follows:

- Installation of the reinforcement cage, which consists of Q188 reinforcement meshes and  $\Phi 16$ mm anchors;
- Installation of double-sided formwork;
- Installation of internal sliding formwork made of 12 m long steel pipe;
- Installation of C35/45 concrete with microfibers;

After a certain time from the completion of concreting the RC channel section, the sliding formwork is pulled out towards the next section. At the joint between the sections, a "groove" is left - an extension for the next section. A sealing rubber is installed in the groove, whose function is to ensure the impermeability of the joint between the two sections. The characteristics of the sealing rubber must be entirely in accordance with BAS EN 681-1:2003 (Elastomeric seals - Material requirements for pipe joint seals used in water and drainage applications). Given that in this method of execution the continuous "slit" channel consists of two connecting elements, it is necessary to ensure the stability and impermeability of the joint of the lower part of the channel and the RC slab. This joint needs to be made of sulfate-resistant cement mortar to which waterproofing additives are added. Before installing monolithic continuous "slit" drainage channels in the tunnel, it is necessary to make a test section in the length of two sections (24 m), with the installation of RC slabs with a curb, and to test the impermeability of all joints and the stability of the connected parts of the channel. It is important to emphasize that regardless of the fact that the continuous "slit" drainage channel is constructed in two parts, it is necessary to ensure the compactness and impermeability of the element as a whole. The cross-section of the RC continuous "slit" drainage channel is shown in the following figure, while the technical requirements to be adhered to during the design and installation of the channel are given in chapter 19.3.3.1 (Table 8).



**Figure 26.** Representation of the continuous "slit" drainage channel

In the case of installing prefabricated continuous "slit" channels, it is necessary to ensure the impermeability of the joint between the prefabricated elements. At the joint between two elements, a sealing compound (polyurethane mixture) is applied, which is resistant to chemical influences and achieves the impermeability of the joint between the prefabricated elements.

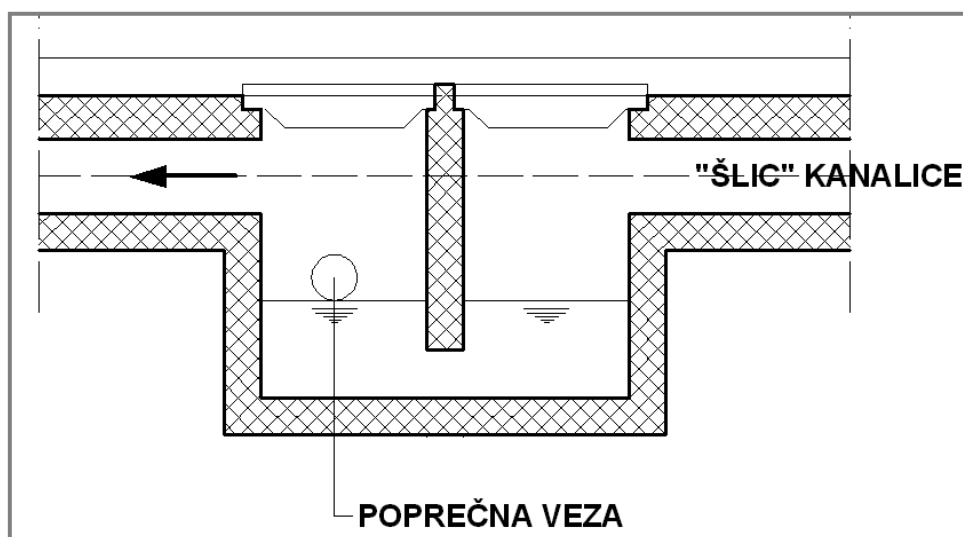
Given that the installation of prefabricated elements ("slit" drainage channels) is carried out on the invert arch, it is necessary to adequately secure the connection between the prefabricated channels and the invert arch, as well as the stability of the channels themselves. Also, when choosing the installation of prefabricated continuous "slit" channels, elements of greater lengths should be preferred in order to reduce the number of joints, which are potential weak points of the system. Before installation and adoption of the construction methodology, it is necessary to make a test section with a length of 12 m, and to check the impermeability of the joints, as well as the stability of the elements.

### **Siphon inspection manhole**

The distance between siphon inspection manholes must not exceed 65 m. Siphon inspection manholes in the system of continuous "slit" drainage channels, in addition to inspection, also serve to prevent the spread of fire along the tunnel.

The height of the cross connection in the siphon shaft must not exceed the height of the lower bearing layer (buffer layer), planned as part of the construction of the pavement structure. Bearing in mind the above, it is necessary to define the height of the cross connection and the depth of the baffle within the siphon manhole. The height difference between the water outlet elevation from the siphon manhole and the bottom of the baffle, i.e., the immersion depth of the baffle, should be a minimum of 15 cm.

The internal drainage system is dimensioned in a way that guarantees the reception of a relevant inflow of 100 (l/s) on any grid of the continuous "slit" channel. In addition to this key requirement, which primarily relates to the reception of the relevant amount of incident pollution, it is understood that the drainage system is designed and capable of unhindered reception of the relevant firefighting water amount of 20 (l/s) or polluted water during tunnel washing of the relevant 10 (l/s).



**Figure 27.** Detail of the siphon manhole with a cross connection to the central collecting collector

Only in exceptional cases can the location of the siphon manhole be flush with the inspection drainage niche. If the siphon manhole lies in the same plane as the inspection drainage niche, it is mandatory to comply with the condition that prevents the possibility of backflow in the external drainage system.

This condition defines the height difference between the inlet and outlet elevations of the cross connection from the siphon manhole:

$$K_{up} = K_{izvp} + 2 \times DN \text{ (OD)} \quad (19.3.1)19.31$$

where,

**K<sub>up</sub>** – elevation of the cross connection inlet to the siphon manhole (section: inspection niche – siphon manhole);

**K<sub>izvp</sub>** – elevation of the cross connection outlet from the siphon manhole (section: siphon manhole – inspection manhole of the main central collector).

**DN (OD)**– outer pipe diameter

By satisfying the conditions that prevent the possibility of backflow in the external drainage system, it is possible to connect the inspection niche with the siphon manhole and thus reduce the total number of cross connections in the tunnel.

#### **19.3.3.1. Technical requirements for the design and construction of the internal drainage system**

An overview of the basic technical characteristics for the tunnel internal drainage system is given in the following table. These must be adhered to during design and construction, all in accordance with applicable regulations and standards.

<b>INTERNAL DRAINAGE SYSTEM</b>		
<b>DESCRIPTION</b>	<b>CHARACTERISTICS</b>	<b>Relevant standards/norms</b>
<b>CONTINUOUS “slit” DRAINAGE CHANNELS</b>		
Location	- Edge of the roadway (on the lower side).	
Dimensions	- The clear opening diameter is determined by hydraulic calculation; - The minimum clear opening is DN/ID 200 mm, but it is necessary to perform a hydraulic calculation in order to adopt the required dimensions.	
Materials	- Micro-reinforced concrete with plastic fibers content >1.0 kg/m <sup>3</sup> according to ÖVBB guidelines for micro-reinforced concrete.; - Conditions of resistance to frost, salt, and chemically aggressive media must be met with the mandatory use of sulfate-resistant cement and the addition of microsilica; - The required concrete class is C35/45, XA3/ XD3, D <sub>max</sub> = 16 mm, F4 consistency <sup>11</sup> - Alternatively, polymer concrete with equivalent properties. The conditions are: flexural strength ≥ 20 N/mm <sup>2</sup> (mean value from 3 samples), water absorption 0 mm and PH value 2-12.	BAS EN 14889-2:2009. BAS EN 1433:2005 BAS EN 1433/A1:2010 BAS EN 1917:2007 BAS EN 1917/Cor2:2010 BAS EN 206:2014
<b>SIPHON INSPECTION CHAMBER</b>		
Location	- For every L ≤ 65.0 m' of the internal drainage system.	
Dimensions	- The dimensions of the siphon chamber must be determined based on calculations, depending on the layout of the chambers and the amount of water collected by the internal drainage system.	
Materials	- Micro-reinforced concrete with plastic fibers content >1.0 kg/m <sup>3</sup> according to ÖVBB guidelines for micro-reinforced concrete.; - Conditions for resistance to frost, salt, and chemically aggressive media must be met with the mandatory use of sulfate-resistant cement and the addition of microsilica. - The required concrete class is C35/45, XA3/ XD3, D <sub>max</sub> = 16 mm, F4 consistency <sup>11</sup> - Alternatively, polymer concrete with equivalent properties. The conditions are: flexural strength ≥ 20 N/mm <sup>2</sup> (mean value from 3 tests), water absorption 0 mm and PH value 2-12; - The cover of the siphon inspection chamber is of solid cross-section, made of ductile iron, without any openings on the cover. A grating or a cover with openings (cavities) must not be placed on the siphon inspection chamber because the siphon chamber serves to prevent the spread of fire in the tunnel.	BAS EN 1917:2007 BAS EN 1917/Cor2:2010 BAS EN 1433:2005 BAS EN 14889-2:2009  BAS EN 1433/A1:2010 BAS EN 206:2014  BAS EN 124:2002

INTERNAL DRAINAGE SYSTEM		
DESCRIPTION	CHARACTERISTICS	Relevant standards/norms
Quality of executed works	<ul style="list-style-type: none"> <li>- Before the construction of the pavement structure layers, it is necessary to test the impermeability of the system.</li> <li>- The impermeability testing of the system is performed after all connections have been made, so that the entire system is covered (connection links, slot channels, and siphon inspection chambers);</li> </ul>	BAS EN 1610:2002
	<ul style="list-style-type: none"> <li>- CCTV inspection of the completed works is done for cross connections and "slit" channels. For siphon inspection chambers, a visual inspection of the executed works is performed by the Supervising Engineer;</li> <li>- Before the CCTV and visual inspection, it is necessary to clean and flush the pipelines under pressure.</li> </ul>	BAS EN 13508-1:2014 BAS EN 13508-2+A1:2012
Maintenance	<ul style="list-style-type: none"> <li>- All parts of the internal drainage system ("slit" channels and siphon manholes) must be regularly maintained and accessible at all times;</li> <li>- Flushing and cleaning of the pressurized system should be performed every 3 months;</li> </ul>	System maintenance instructions, prepared by the manufacturer and delivered to the end user

Table 8. Technical requirements for the design and construction of internal drainage systems, including an overview of applicable standards

#### 19.3.4. Central collector

The central collector has the function of evacuating groundwater in case of malfunction of the lateral drainage system, as well as water from the roadway (including incidental liquids/pollution). Lateral drains are connected to the central collector by means of overflows in the inspection niches, and the siphon manholes of the continuous "slit" channels are connected to the central collector (at the location of the inspection manholes) by cross connections. The connection of the cross connections is realized at the location of the inspection manholes of the central collector.

The central collector should be dimensioned taking into account the amount of groundwater due to possible overflow from the external drainage system and the hydraulic parameters used in dimensioning the internal tunnel drainage system. The construction technology of the central collector, which is positioned in the middle of the traffic lane, includes the construction of a concrete base and reinforced concrete (RC) lining. The base is made of drainage (porous) concrete, in order to allow the inflow of seepage water to the drainage collector. For the construction of the RC lining around the pipe, use concrete of strength class C25/30, reinforcing meshes Q 188 and reinforcing bars (anchors)  $\Phi 16\text{mm}$

In the part of the tunnel where the concrete invert is constructed (Figure 28) the pipe of the central collector is installed by embedding anchors  $\Phi 16\text{ mm}$  into the concrete invert, onto which a horizontal reinforcing bar of the same cross-section is subsequently welded. By applying this construction method, improved structural stability of the collector is achieved, and the efficiency of drainage is increased, which is ensured by the formation of a continuous gradient

of the collector with minimal deviations in pipe slope during installation. Subsequently, a concrete bedding for the pipe is constructed up to the drainage concrete level, after which the collector pipe is mounted onto the horizontal bars. Following the installation of the central collector pipe, reinforcement meshes are installed and the concrete encasement around the pipe is cast.

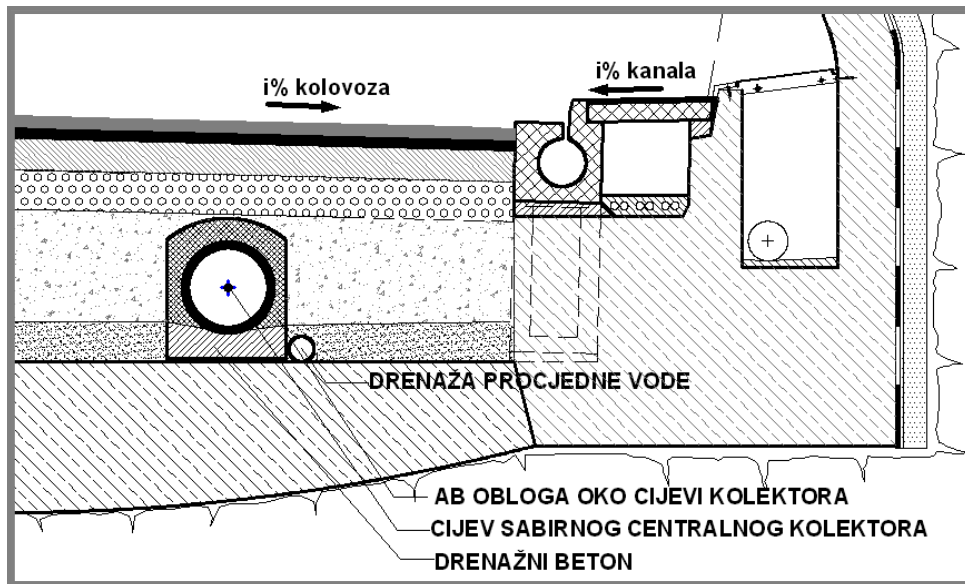


Figure 28. Detail of the central collector in the tunnel

In the part of the tunnel where the invert arch is not constructed, the central collector is constructed in such a way that backfilling or excavation of material is previously done to the lower elevation at which the collector pipe is installed. The concrete base and RC lining around the pipe are constructed in the same way as in the part of the tunnel with the invert arch.

### **Inspection (control) manholes/shafts of the central collector**

Inspection chambers of the collecting pipe are constructed at the connection points of cross connections to the central collecting pipe at a maximum distance of  $L=60$  m. The inspection chamber consists of an entrance opening and a working chamber, and can be constructed as prefabricated or monolithic. Since they are located in the roadway, they need to be constructed of concrete with a strength class of C30/37. Inspection chambers should be designed and constructed to withstand all loads they may be exposed to during the construction and exploitation of the tunnel without loss of their original purpose and damage to the environment. The structural elements of the inspection chambers (thickness of the slab, walls, etc.) are determined according to the static calculation in the design phase.

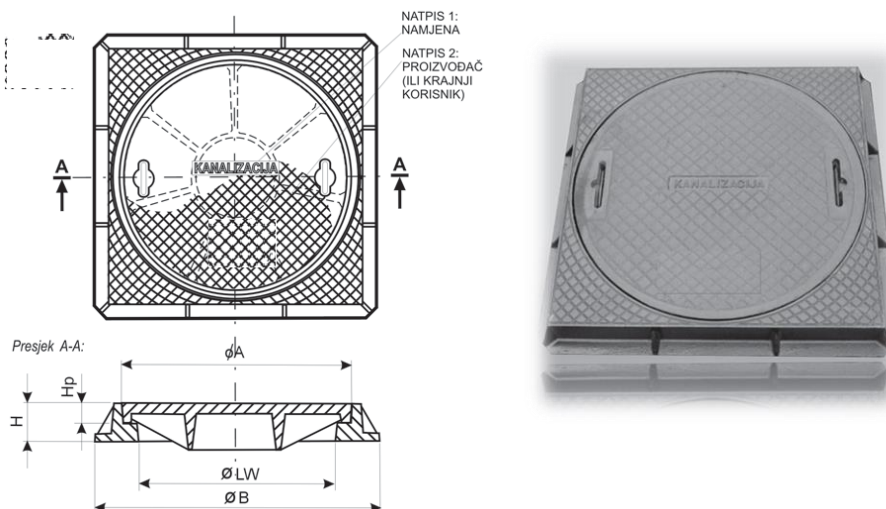
The internal dimensions or diameter of the inspection chamber depend on the pipe diameter of the central collecting pipe. The minimum internal dimension of the inspection chamber is: 100x100 cm for inspection chambers with a square cross-section or  $\Phi 100$  cm for inspection chambers with a circular cross-section.

In addition to static resistance, the inspection chambers of the central collecting pipe must meet the requirements related to impermeability and resistance to aggressive chemical effects. Inside the chamber, Inox climbing steps are installed for access by system maintenance workers. The bottom of the chamber is shaped with C30/37 class concrete in the form of a channel to direct the flow of wastewater. It is necessary to install a circular sewer cover with a square frame on the entrance opening of the inspection chamber.

The installed covers must meet the following:

- The minimum cover class must be D 400 (load capacity 400 kN);
- The cover must not have ventilation openings;
- The minimum diameter of the frame opening (clear width) is 600 mm;
- The total clearance size ( $a_1+a_2= a$ ) between the cover and the frame must be less than or equal to 9.0mm;
- The minimum insertion depth of the cover into the frame (A) must be 50 mm;
- The height of the frame for a class D 400 cover is a minimum of 100 mm. This dimension can be reduced to 75 mm, provided that:
  - the frame is located in a concrete bed of minimum C35/45 so that there is a connection between the frame and the concrete;
  - if the frame has anchors and if it is secured by them
- The contact surfaces of the frame and the cover (the surface on which the cover rests on the frame) should be mutually aligned, i.e., designed in a way that ensures a stable and quiet position of the cover;
- The frame bearing must be made in such a way that the pressure on the frame bearing under the test force does not exceed 7.5 N/mm<sup>2</sup> and that it ensures stability under working conditions;
- The surface of the cover must be flat. The maximum deviation in terms of levelling is 0.8% in relation to the clear width of the cover ( $O = 600 \text{ mm} \cdot 0.8\% = 4.8 \text{ mm}$ );
- The surface of the cover and frame should be structured. The height of the raised parts for class D 400 is 3-8 mm. The raised surface must not be less than 10% nor greater than 70% of the total surface of the cover and frame;
- The frame and cover should be tested and marked, entirely in accordance with BAS EN 124:2002.

The illustration of the frame and covers of the inspection manhole is given in the figure below.



**Figure 29.** Detail of the frame and cover of the inspection manhole

#### **19.3.4.1. Impermeability testing**

Given that impermeability is one of the basic conditions that the system must fulfil, after the pipe installation is completed, it is necessary to perform an impermeability test of the drainage system. The impermeability testing of the internal drainage system must be carried out in accordance with the BAS EN 1610:2002 standard. It is important to note that the impermeability testing of the system is performed immediately after the installation of the pipes, and before the construction of the reinforced concrete (RC) lining around the pipes, because all joints must be visible to allow for their inspection.

#### **19.3.4.2. Technical requirements for the design and construction of the main central collector**

An overview of the basic technical characteristics for the main central collector, as well as an overview of the applicable standards, is given in the following table, and they must be adhered to during the design and construction of the system, all in accordance with applicable regulations and standards.

MAIN CENTRAL COLLECTOR		
DESCRIPTION	CHARACTERISTICS	Relevant standards/norms
Location	<ul style="list-style-type: none"> <li>- Middle of the traffic overtaking lane,</li> <li>- Bottom elevation of the tunnel pavement structure.</li> </ul>	
Dimensions	<p><b>COLLECTOR:</b></p> <ul style="list-style-type: none"> <li>- Determine the pipe diameter based on hydraulic calculation. The minimum internal pipe diameter is DN/ID 300 mm;</li> </ul> <p><b>INSPECTION CHAMBERS:</b></p> <ul style="list-style-type: none"> <li>- Clear dimensions in floor plan: 100x100 cm or DN /ID 100cm;</li> <li>- Distance between inspection chambers <math>L \leq 60</math> m';</li> </ul>	
Materials	<ul style="list-style-type: none"> <li>- Materials that can be used for the collector are:</li> </ul>	
	<ul style="list-style-type: none"> <li>a) Thermoplastic materials (polyvinyl chloride - PVC or polypropylene - PP) with <b>solid wall</b> and smooth interior, <math>SN \geq 8</math> kN/m<sup>2</sup>)</li> </ul>	DIN 4262-1 TYPE C2 BAS EN 1852-1:2010
	<ul style="list-style-type: none"> <li>b) Duroplastic materials (reinforced polyester - GRP, <math>SN \geq 5000</math>)</li> </ul>	BAS EN 14364+A1:2009 and ÖNORM B5161
	<ul style="list-style-type: none"> <li>- Inspection chambers in the tunnel roadway which must be manufactured from concrete class C30/37, XA3/XD3<sup>11</sup></li> </ul>	DIN 1045-1 BAS EN 206:2014
	<ul style="list-style-type: none"> <li>- The inspection chamber cover should be manufactured from ductile iron, load bearing class min. D 400 kN, with a square frame and circular cross-section;</li> </ul>	BAS EN 124:2002
	<ul style="list-style-type: none"> <li>- Inox steps for access to the inspection chamber</li> </ul>	BAS EN 14396:2008
Quality of executed works	<ul style="list-style-type: none"> <li>- System impermeability testing. Impermeability testing includes testing of collectors and inspection manholes with all connection joints;</li> </ul>	BAS EN 1610:2002
	<ul style="list-style-type: none"> <li>- CCTV inspection of completed works;</li> <li>- Before the CCTV inspection, it is necessary to clean and flush the pipelines under a minimum pressure of 150 bar (nozzle pressure).</li> </ul>	BAS EN 13508-1:2014 BAS EN 13508-2+A1:2012
Maintenance	<ul style="list-style-type: none"> <li>- All parts of the system (pipes, inspection manholes) must be regularly maintained and must be accessible at all times;</li> <li>- Flushing and cleaning of the system should be performed every 3 months;</li> <li>- The quality of the pipe material should ensure durability during flushing under a minimum pressure of 150 bar (nozzle pressure).</li> <li>- Cleaning of the drainage system should be performed using high-pressure equipment with a minimum nozzle pressure of 150 bar, all in accordance with the system maintenance instructions prepared by the material manufacturer.</li> </ul>	System maintenance instructions, prepared by the manufacturer and delivered to the end user.

Table 9. Technical requirements for the design and construction of the central collector, including an overview of applicable standards

### 19.3.5. CCTV inspection of lateral drains and central collector

CCTV inspection, i.e., recording of the collector with a robot camera, must be performed after the completion of all works on the central collection collector, lateral drains, and leachate drainage. A detailed description of CCTV inspection is presented within Chapter 19.1.3 of this document (“CCTV inspection of the internal drainage system”).

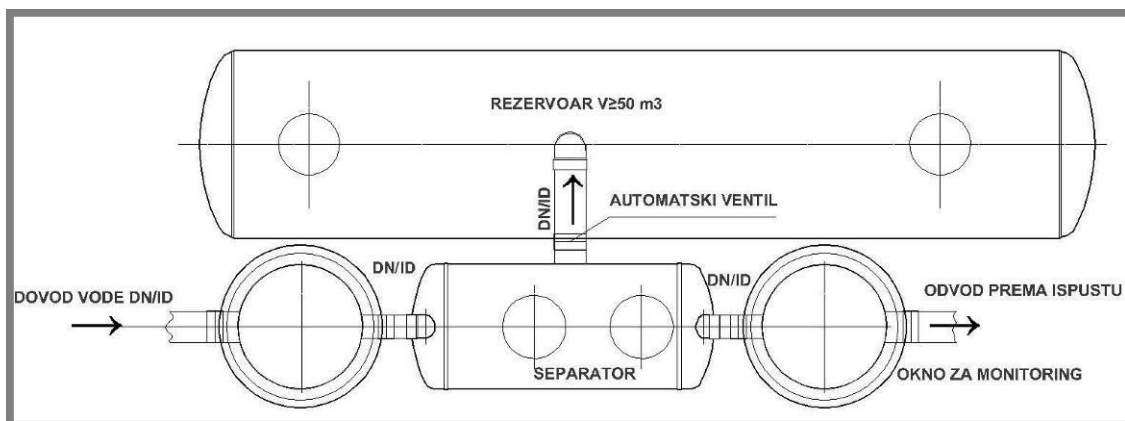
### 19.3.6. Systems for treatment of oily water from tunnels / Water protection systems

The discharge from the central collection collector must be designed in such a way as to provide for the installation of an oil and grease separator without a bypass, which has the function of purifying a smaller amount of wastewater (oily water) that enters the system (e.g., due to tunnel washing). The degree of purification of wastewater (oily water) should be designed to meet all conditions and requirements prescribed by valid legal regulations<sup>17</sup>.

In the event of an accidental situation, i.e., the occurrence of pollution that cannot be adequately treated, the total quantity of wastewater is directly diverted to a reservoir for accidental liquid retention, which is connected to the separator without a bypass (Figure 30). Diversion is carried out through automatic regulation (automatic valve) in case of increased pollution levels.

The tank space used to receive the relevant quantities of incident liquid must be 100% watertight, and fully comply with environmental requirements and regulations.

The dimensioning of the tank for receiving incident liquid should be carried out under the assumption of the maximum inflow amount in the event of incident pollution, and accordingly, it is necessary to provide an available tank space volume of at least 50 m<sup>3</sup>.



**Figure 30.** Schematic representation of the system discharge from the central collector

An overview of the technical requirements for separators and tanks for receiving incident liquid from the motorway route is presented in table 4 **Error! Reference source not found.**

<sup>17</sup> “Regulation on Conditions for the Discharge of Wastewater into Natural Receiving Bodies and Public Sewerage Systems” (“Official Gazette of the Federation of Bosnia and Herzegovina”, No. 04/12) currently governs this area.

### 19.3.7. Tunnel fire protection system (hydrant network)

In order to ensure sufficient quantities of water for fire protection in the tunnel, it is necessary to provide a water supply system for the tunnel, as well as a hydrant network inside and outside the tunnel. As presented in the chapter "Side drains", for the water supply of the tunnel, it is necessary to check the possibility of water supply by collecting groundwater from the tunnel.

If this is not possible or requires large investment costs, the water supply of the tunnel should be provided using the nearest available supply sources. It should be emphasized that when choosing a solution, the water supply should be routed via the shortest possible path to avoid long lengths of supply pipelines. In tunnels longer than 500 m', the fire protection system should have a pressurized pipeline and above-ground hydrants with a reliable water supply along the entire tunnel. Hydrants inside the tunnel must be spaced at a maximum distance of 150 m from each other, with connections facing the niche opening (towards the door). The water supply to the hydrant niche must be provided from the main hydrant pipeline, which has a minimum diameter of DN/ID 100 mm and is located in the installation channel. The hydrant network inside the tunnel must have a ring structure for a more secure water supply to the fire protection system and easier maintenance and management of the system.

Hydrants inside the tunnel are located in hydrant niches. The equipment installed alongside the hydrants in the tunnel must enable the extinguishing of class A and B fires with at least two hydrants, and with two portable fire extinguishers with a capacity of 9 and 6 kg (all in accordance with JUS Z.C2.035).

For extinguishing class "A" fires (solid materials that burn with a flame or glow), water is used in the form of a dispersed jet or mist created by a nozzle. The nozzle should have a standard flow rate of 400 l/min (7 l/s) with a range of 30 m at a pressure of 6 bar upstream of the nozzle.

For extinguishing class "B" fires (flammable liquids), foam with a 3% concentration is used. In addition, valves with a Storz coupling for filling fire trucks are an integral part of the equipment.

The fire hydrant niche should enable the following:

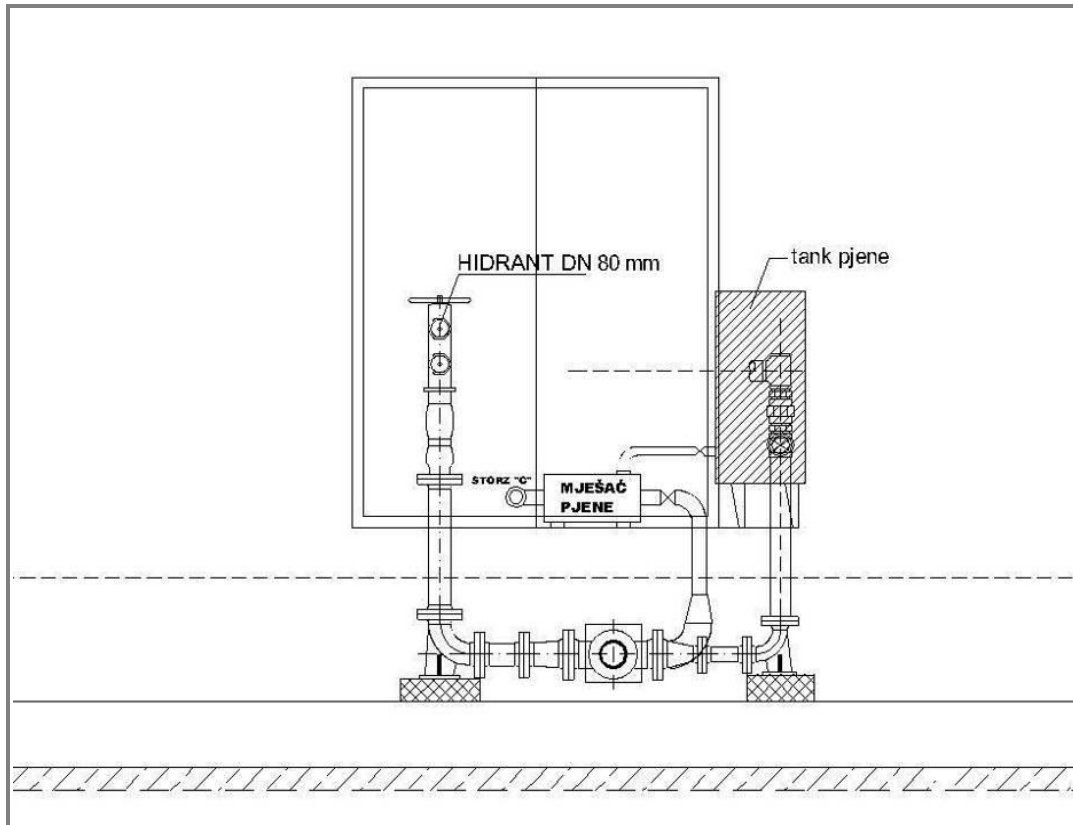
- Extinguishing fires with foam, with simultaneous filling of the tank truck;
- Simultaneous extinguishing of fires with water and foam;
- Extinguishing fires with water with simultaneous filling of the tank truck.

Inside the niche, in addition to tunnel hydrants with connections of different diameters depending on the choice of hydrant type (type A, B, and C), additional fire protection equipment is installed. This equipment includes:

- Branch with 2" valve - for foam mixing,
- Fire hose 3" (type A,B,x),
- Universal nozzle and heavy foam nozzle,
- Foam tank and foam mixing equipment,
- Other equipment (universal wrench "A-B-C", couplings, lighting fixture with transformer and switch, manual fire extinguisher).

One hydrant cabinet must be installed in each vehicle stopping niche (lay-by). It is recommended that the depth of the hydrant niche<sup>18</sup> is about 1.0 m, closed with metal fireproof doors with an opening angle of 180° and the possibility of stopping in the open position.

The following figure shows a detail of the fire protection system in the hydrant niche.



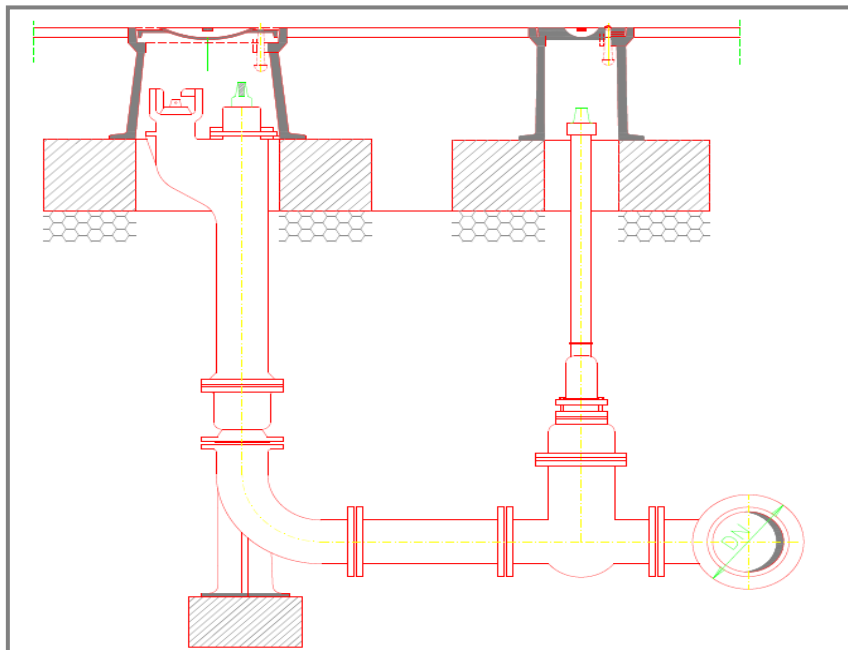
**Figure 31.** Detail of the fire protection system in the hydrant niche

Water drainage must be resolved inside the hydrant niches to prevent water penetration from the niche into the installation channel due to a possible hydrant failure or during hydrant use. Hydrants outside the tunnel must be installed immediately next to the tunnel portals (entrance and exit portals) in such a way that at least one underground hydrant is installed at the entrance portal, while one underground and one above-ground hydrant are installed at the exit portal.

The installation location of the underground hydrant must be marked in a conspicuous manner, all in accordance with the requirements and regulations specified in DIN 4066.

<sup>18</sup> In accordance with the Austrian RVS guidelines (2009)

The following figure shows a detail of the construction of an underground hydrant on the external hydrant network.



**Figure 32.** Detail of underground hydrant construction

Fittings and armatures should be made of high-quality cast iron. The hydrant network executed inside the tunnel (in the installation channel) must be protected from freezing. This condition is achieved by foreseeing the use of factory thermally pre-insulated pipe material during the design, which is installed as such on the construction site.

For tunnels whose total length does not exceed 500 m', it is necessary to provide hydrants at the entrance and exit portals, specifically in an underground design.<sup>18</sup>

#### **19.3.7.1. Technical requirements for the design of the fire protection system**

An overview of the basic technical characteristics for: elements of the fire protection system, and an overview of the applicable norms is given in the following table and must be adhered to during the design and construction of the system, all in accordance with applicable regulations and standards.

FIRE PROTECTION SYSTEM (HYDRANT NETWORK)		
DESCRIPTION	CHARACTERISTICS	Relevant standards/norms
Location	<ul style="list-style-type: none"> <li>- <i>External hydrant network</i>: at the entrance and exit portal;</li> <li>- <i>Internal hydrant network</i>: Installation channel on the opposite side in relation to the SOS niches.</li> </ul>	
Dimensions	<p><b>PIPE MATERIAL:</b></p> <ul style="list-style-type: none"> <li>- The pipe diameter is determined by calculation. The minimum internal pipe diameter is DN/ID 100 mm and NP 10 bar;</li> </ul>	C.J1.030, C.J1.1031, ISO/R 13-55, DIN 28502, DIN 28513 and BAS EN 545:2012.
Material	<p><b>PIPE MATERIAL:</b></p> <ul style="list-style-type: none"> <li>- Ductile iron with TYTON joint. External protection: zinc - aluminium minimum 400 g/m<sup>2</sup> and epoxy coating &gt;100µm. Internal protection: cement mortar;</li> </ul> <p><b>HYDRANTS; FITTINGS AND ARMATURES:</b></p> <ul style="list-style-type: none"> <li>- Ductile iron with protective epoxy layer;</li> <li>- The selected materials must be of high quality and resistant to external influences, and guarantee the sustainability of the structure and purpose of the system during the exploitation and maintenance phase.</li> </ul>	DIN 28600, ISO 2531; DIN 3476 DIN 28603; DIN 30677-2 BAS EN 545:2012
Quality of executed works	<ul style="list-style-type: none"> <li>- After completing the pipeline laying works, it is necessary to perform a system test - pressure test;</li> <li>- Before the pressure test, it is necessary to flush the pipeline,</li> <li>- Functionality test of the fire protection system;</li> </ul>	EN 805:2000 Relevant applicable legislation <sup>19</sup>
Maintenance	<ul style="list-style-type: none"> <li>- The technical soundness of the hydrant network must be continuously checked every 6 months;</li> <li>- Extraordinary inspections are mandatory just like regular ones<sup>19</sup></li> </ul>	System maintenance instructions, prepared by the manufacturer and delivered to the end user

Table 10. Technical requirements for the design and construction of fire protection systems, including an overview of applicable standards

### 19.3.7.2. Pressure testing of pipelines (EN 805:2000)

Hydrostatic pressure testing of pipelines is performed according to the standard method given in the European standard EN 805:2000. For the testing, it is necessary to install special X-pieces which will be removed upon completion of the testing.

<sup>19</sup> The regulations currently in force are: the Law on Fire Protection and Firefighting ("Official Gazette of the Federation of Bosnia and Herzegovina", No. 64/09) and the Regulation on Technical Requirements for External and Internal Fire Hydrant Networks ("Official Gazette of the Federation of Bosnia and Herzegovina", No. 87/11).

Pressure testing is carried out in 3 phases:

- Phase 1 - preliminary test
- Phase 2 - pressure drop test
- Phase 3 - main pressure test

The maximum design pressure (MDPa) at the highest point of the pipeline can be read, while the STP - System Test Pressure is defined based on the following formulas:

$$STP = MDPa \times 1,5 \quad (19.3.2)19.32$$

or

$$STP = MDPa + 500kPa \quad (19.3.3)19.33$$

The lower value obtained by calculation according to the above formulas is taken. In exceptional cases when testing shorter sections (section length up to 100 m), the value of the working (operating) pressure of the system is taken as the STP.

### **Phase 1: Preliminary test**

The pipeline is filled from the lowest point, at a rate of 3 l/sec (10.8m<sup>3</sup>/h) with parallel de-aeration of the pipeline at the highest point, as well as all connections. All valves on the line are closed after de-aeration and the pressure is raised to the STP value within 10 minutes. The pressure should be maintained in the pipeline for 30 minutes for the fast method or 24 hours for the standard method.

If there is a pressure drop of more than 0.50 bar during the specified pressure maintenance time (30 minutes or 24 hours), it means that there is a leak or damage on the pipeline. In this case, the testing is interrupted and the test should be repeated after the damage is repaired. If a pressure drop of less than 0.50 bar is recorded, the second phase of the test is initiated.

### **Phase 2: Pressure drop test**

It allows the estimation of the remaining air in the pipeline. Upon completion of Phase I of 30 minutes (or 24 h), where the pressure is maintained at the STP level, a measurable amount of water  $\Delta V$  (cm<sup>3</sup>) is released from the pipeline and the resulting pressure drop  $\Delta p$  (bar) is measured.

The allowable change in water volume in the pipeline  $\Delta V_{zul}$  (cm<sup>3</sup>) is calculated based on the following formula:

$$\Delta V_{zul} = 1,5 \times \Delta p \times L \times A \quad (19.3.3)19.3$$

where

$\Delta p$  - pressure drop (bar);

L - pipeline length (m');

A – pressure constant, characteristic for the pipe type/diameter (cm<sup>3</sup>/bar,m);

1,5 – factor for determining the allowable air share in the pipeline before the main pressure test

If the discharged amount of water from the pipeline is less than or equal to the change in water volume in the pipeline, i.e., if  $\Delta V \leq \Delta V_{zul}$  applies, the pipeline can be considered properly and sufficiently vented.

### **Phase 3: Main pressure test**

Upon completion of the pressure drop test (Phase 2), the pressure on the pressure gauge is monitored for 30 minutes, and if there is no pressure drop, the testing is successfully completed. However, if a pressure drop occurs, the test is extended for another 60 minutes. If a pressure drop of more than 30% of the STP is recorded during that 60-minute period, the test must be repeated.

In the previously presented manner (pressure test), it is possible to check the quality of the executed works on the hydrant network. However, the functionality of the entire fire protection system is tested after all works are completed, including the installation of hydrants, all in accordance with the applicable laws and regulations related to the fire protection system<sup>19</sup>.

**20. INSTRUCTION FOR DESIGN AND EXECUTION OF  
BLASTING WORKS ON MOTORWAY PROJECTS**

## **Introduction**

This instruction defines the project documentation (main and execution project) of excavation by blasting, its content, legal entities that can prepare and revise it, measures and procedures during the execution of blasting works on sections of motorways and expressways, as well as special safety measures during the execution of blasting works. The instruction is intended for designers and reviewers of the main and execution project, Contractors, and supervising engineers engaged during the construction of motorways and expressways.

The instruction was prepared in accordance with the following Laws, Decrees and Rulebooks:

- 1) Law on Mining of the Federation of Bosnia and Herzegovina.
- 2) Decree on the type, content, marking and storage, control and nostrification of investment-technical documentation ("Official Gazette of the Federation of BiH", No. 33/10)
- 3) Rulebook on technical norms for handling explosive materials and blasting in mining (Official Gazette of SFRY No: 26/88 and 63/88)
- 4) Rulebook on technical measures and occupational safety in underground mining works (Official Gazette 11/67; 35/67; 60/70; 9/71 and 5/73)
- 5) Law on Occupational Safety (Official Gazette of SR BiH No: 22/90)
- 6) Rulebook on occupational safety in construction (Official Gazette 42/68)

In case of possible conflicts between the above-mentioned Laws, Decrees and Rulebooks, the stricter requirements shall apply.

### **20.1. Project documentation**

Blasting excavation projects (main and detailed) must be prepared for all facilities and interventions on the motorway that are carried out by blasting:

- tunnel
- cuttings
- rock cuttings
- foundation and construction pits, etc.

#### **20.1.1. Main design for excavation by blasting**

As part of the preparation of the Main Design for the motorway section, in the case of excavation by blasting, the designer is obliged to also prepare the Main Design for excavation by blasting.

The Main Design for excavation by blasting should contain:

- Description of the geotechnical characteristics of the rock mass (description of the geological structure of the terrain, fracture system, etc.) that may affect the choice of explosives and blasting methods,
- Description of drilling works (general and technical characteristics of drilling blast holes)
- Selection of blasting means and equipment
- Protection measures

The main blasting design is an integral part of the investment and technical documentation for which the Federal Ministry of Physical Planning (in accordance with Article 46 of the Decree on the type, content, marking and storage, control and nostrification of investment and technical documentation) issues a building permit.

### **20.1.2. Detailed design of excavation by blasting**

Before starting the excavation works by blasting, the Contractor is obliged to provide a revised Execution design for excavation by blasting, all in accordance with Articles 48 and 70 of the Decree on the type, content, marking and storage, control and nostrification of investment-technical documentation, as well as in accordance with the Law on Mining of the Federation of Bosnia and Herzegovina.

The execution design for excavation by blasting should contain:

- Geotechnical characteristics of rock masses confirmed in the G31 mission, and the categorization of rock masses necessary for dimensioning the blasting works.
- Description of drilling works (detailed technical characteristics of drilling blast holes, drilling step lengths, etc.)
- Selection of means and equipment for blasting. (explosives, initiating means, blasting machines, equipment, etc.)
- Blasting works, namely:
  - Calculation of blasting parameters.
  - Basic parameters for determining the blasting scheme.
  - Elements of the blasting profile.
  - Charging blast holes, connecting and controlling the blast field.
  - Blasting technology
  - Blasting patterns
- Occupational safety measures.

The project is prepared and revised by an authorized company for this type of design, all in accordance with Article 72 of the Law on Mining of the FBiH.

All changes and additions during the work must first be approved by the authorized auditor for blasting works, and then by the supervising engineer.

Blasting boreholes are generally made using deep drilling rigs equipped and adapted for this type of work. Preliminary geotechnical investigations determine the physical and mechanical properties of the rock masses and the strike and dip of the layers in relation to the embankment axis, based on which the technology will be selected, i.e., the method of excavation, drilling method, borehole spacing, and the amount of explosive charge will be determined.

The arrangement of boreholes as well as the amount of explosive per blast hole should be such as to ensure the creation of the most favourable granulation of the blasted material and that the need for subsequent crushing of stone pieces is minimal.

The blasting excavation project must be designed so that the blasting works cause minimal damage to the rock mass in the slope, that the excavation works do not endanger the stability of the excavation at any stage of the work, and to ensure that during the excavation works, impacts that would cause disruption to traffic, people, and the environment are minimized.

## 20.2. Execution of works

Blasting works can be performed by a commercial company that meets the conditions from Article 16 of the Law on Mining of the FBiH. The contractor must comply with technical regulations and standards in mining, occupational safety regulations, environmental protection, conditions established in the urban permit and other regulations, provide personal protective equipment to employees, and implement regulations on the protection of people and property.

Excavation works by blasting shall be carried out in accordance with:

- 1) The Main Design of excavation by blasting
- 2) The Detailed Design of excavation by blasting
- 3) The Law on Mining of the Federation of BiH
- 4) The Rulebook on technical norms for handling explosive materials and blasting in mining. (SL. SFRJ No: 26/88 and 63/88)
- 5) The Rulebook on technical measures and occupational safety in underground mining works (SL. 11/67; 35/67; 60/70; 9/71 and 5/73)

During blasting works, the Contractor must have a trained and qualified workforce for this type of work.

With every use of explosives, it is necessary to act in accordance with the approved detailed blasting design, applicable laws and regulations for such works for the safety of the own construction site, equipment, facilities, people and the environment.

Total blasting works include:

- preparatory works,
- main blasting works
- drilling and primary blasting,
- if necessary, subsequent profile adjustment and secondary blasting.

During blasting, as with other excavation works, it is necessary to minimize negative effects such as seismic effects, noise, dust and rock mass fragments thrown by the explosion that would cause disruption to traffic, people and the environment. If such disturbances occur, the Contractor is obliged to eliminate them immediately at his own expense. Due to the negative effects caused by blasting, it is necessary before starting full-capacity works to conduct trial blasting with a smaller capacity to check the intensity of negative effects and the assumptions given in the blasting design.

Trial blasting is carried out by the Contractor upon approval of the supervisory team. The result of the trial blasting is entered into the Initial Blasting Report and verified by the supervision. Only when the theoretically obtained parameters are confirmed can full-capacity blasting be approached.

During the execution of works, it is necessary to install all required traffic and safety signalling.

In order to achieve the highest quality slope construction, it is mandatory to perform "smooth blasting" before other blasts in the excavation profile. This makes the slopes easier to arrange during final finishing, they have more regular surfaces, and the amount of loose material that needs to be cleaned from the slope is minimal. In this way, the loosening of the rock mass in the slopes is prevented, making them more stable and easier to maintain.

If the separation of the rock mass along the designed slope surface down to the grade line from the rest of the mass in the excavation core is performed, over-excavation of the excavation profile is reduced to a minimum. This effect depends on the strength of the rock mass, i.e., the strike and dip of the layers towards the embankment axis, as well as the type of stratification and fracturing of the rock mass.

The material is excavated to the designed slope inclination with the mandatory removal of loose and scattered rock parts down to the subgrade elevation, on which construction site traffic can thus take place.

If the excavated material is to be used for the production of granular stone material for making wedges at structures, as a finishing layer - embankment crowns, bearing layers of the pavement structure of access roads and ramps, aggregates for concrete and asphalt layers, it is necessary to obtain evidence of usability from an authorized body based on the results of laboratory tests.

If, based on previous tests by an authorized body, evidence of the usability of the stone material is obtained, appropriate work technology should be foreseen, and attention should be paid to excluding the mixing of clayey admixtures with the tested stone material. The use of such materials requires the consent of the supervising engineer.

#### **20.2.1. Professional staff**

Only reliable and professionally trained persons designated by the Technical Manager of the site can work with explosive materials:

- Blasters
- Assistant blasters
- Persons responsible for the storage of explosive materials

Persons responsible for working with explosive materials must be professionally trained to perform these tasks. The contractor must have a record of all persons on the site working with explosive materials. The record must contain personal data, data on professional qualifications, passed exams, a new medical certificate every year, and for blasters older than 55 at least twice a year, a testing certificate, and a record of offenses and penalties. Every year, it is mandatory to renew the knowledge of responsible persons, conduct a knowledge check, and keep a record of it. Persons who do not pass the knowledge renewal and check cannot be allowed to work with explosive materials.

The responsibility for implementing this procedure lies with the main Contractor, who appoints the project manager. The supervision is obliged to control the implementation of the mentioned procedures and compliance with laws and bylaws.

#### **20.2.2. Blasting**

Before the start of blasting, it is necessary to ensure the supply, delivery, and storage of explosives and initiating devices. The Contractor's project manager is responsible for the safety of transport and storage.

Preparation also includes notifying the public by the Contractor, especially the stakeholders who will feel the effects of the blasting. The Contractor's project manager is responsible for public notifications.

It is necessary to carry out a detailed inspection and determine the condition of all structures in the area of possible blasting impact before and after the completion of blasting. The inspection is carried out jointly by the Supervisory Team and the Contractor's representative (project manager). After the inspection, photo documentation and a record are prepared.

Blasting in the tunnel is used as a tool for cutting the rock mass, not for its complete destruction. Although blasting must be effective, the greatest attention must be paid to minimizing the destruction of the surrounding rock in the excavation walls, and achieving the most precise excavation contour possible. Efforts should be made to minimize over-profile excavations in the tunnel, as well as the unblasted part that needs to be removed later.

### **Blasting procedure**

Upon completion of the transfer of explosive materials to the work site, the securing of the blasting site begins. All persons not participating in the blasting phase are removed from the blasting site, and physical security is placed at the entrance to the blasting zone to prevent other persons from accessing the construction site.

In addition to the physical person, a warning sign "STOP BLASTING" is also placed. Before starting to fill the boreholes, the blaster must be familiar with the amount of explosives for each borehole, as well as the wiring diagram of the minefield. The blaster is obliged to prepare the cartridges according to the blasting pattern.

In the event of certain deviations during drilling, which may be caused by geological or other unforeseen conditions, the blaster can change the blasting pattern according to the given situation. The new blasting pattern is approved by the Technical Blasting Manager and the supervising engineer.

The blaster prepares and places the primer cartridges into the prepared boreholes, after which the assistants fill the boreholes with explosives. Charging can only be done by placing individual cartridges into the borehole using a wooden tamping pole. After charging, the borehole is plugged with a clay plug or some other inert material. The wiring of the mines can only be done by the blaster. When wiring, attention must be paid to making good contacts between the detonator wires. After wiring, it is necessary to measure the resistance and, in case of any deviations from the calculated resistance, find the cause and eliminate it as soon as possible.

If it is determined that everything is in order, the detonator wires are connected to the electrical cable, through which the minefield is connected to the blasting machine.

Before firing, it is necessary to check whether all workers have left the blasting site, and to warn all workers at the worksite about the blasting, so that they can take shelter in a safe place in a timely manner.

The blaster is also obliged to perform the firing of mines from a safe place, so as not to endanger himself and the firing equipment. The final check of the resistance of the detonator and the cable is performed immediately before connecting the wires to the blasting machine, in order to carry out the blasting afterwards.

After firing the mines and ventilating the worksite, the blaster is obliged to check the condition at the blasting site. Special attention should be paid to any unexploded mines, and all measures must be taken to destroy these mines according to the manufacturer's instructions. When the blaster is convinced that the situation at the blasting site, after blasting, is safe for the further continuation of works, he notifies all present at the worksite about it with a sound signal. After inspecting the worksite, the blaster is obliged to hand over the worksite to the site manager in written form on a previously defined and adopted form.

The blaster is obliged to return all unused explosive materials from the blasting site to the PS. All data on the used quantities of explosive materials must be kept accurately and must be equal to the data on the inventory status in the magazine. In the event that the blaster performs the function of a storekeeper, he must also keep records of the inventory status in the magazine. The responsibility for implementing this procedure lies with the blaster. The technical manager of the worksite is responsible for controlling the work of the blaster.

The technical manager of the construction site is obliged to check the inventory status in the magazine at a certain time interval and to confirm the correctness of the inventory with a signature in the book of received explosive materials.

The supervision is obliged to control the implementation of the mentioned procedures.

### **Transport of explosive materials**

The transport of explosive materials by public road to the worksite can only be carried out by an appropriate vehicle that meets the ADR requirements. The person transporting explosive materials by public road to the worksite must also meet the ADR requirements, as well as the co-driver.

The transport of explosive materials to the construction site is possible only with the acquisition of a special transport permit issued by the competent PS of the MUP at the request of the legal entity performing the transport. The transport of explosive materials is organized by the Contractor.

### **Receipt of explosive materials**

The technical manager of the blasting site is an engineer who manages the blasting operations and who is appointed for this by the responsible person in the legal entity responsible for carrying out the blasting operations (Contractor or subcontractor for blasting).

The receipt of explosive materials is carried out by a person authorized by the Technical Manager of the blasting site - the main blaster - who is also the handler of the handy magazine (hereinafter referred to as the PS handler), based on a requisition signed by the Technical Manager of the blasting site. In this task, he can be assisted by another person qualified for these tasks, who must be authorized by the Technical Manager of the blasting site. The main blaster keeps a logbook of received explosive materials containing all relevant data on the type and quantity of explosive materials. The logbook of received explosive materials is stored in the site documentation.

Unloading of explosive materials from the vehicle and loading them into the PS is done manually. During the receipt of explosive materials, within a radius of 20 m, no other person may be present except the PS handler, his assistant, and the vehicle crew. The handler is obliged to immediately enter the received quantity and type of explosive materials into the logbook of received explosive materials. When all the explosives are placed in the PS, the handler is obliged to lock the PS with a padlock. The control of the handy magazine and the logbook of received explosive materials is carried out by the Technical Manager of the construction site.

Supervision is mandatory to control the implementation of the mentioned procedures and compliance with laws and bylaws.

### **Storage and transport of explosive materials**

For the temporary storage of the required quantities of explosive materials, the Contractor will use auxiliary magazines at the worksite. The entire storage area will be secured with a fence. The magazine should be located in the safest place on the worksite. A maximum of up to 500 kg of explosives and 1000 detonators can be stored in the auxiliary magazines. All explosive materials must be stored in their original packaging.

Explosive materials stored in the PS are withdrawn in the following manner:

- The responsible PS manager on shift withdraws the required quantity of explosive materials
- The withdrawn quantity is recorded and entered into the logbook of received explosive materials
- Blasters take over the explosive materials and record the withdrawn quantities in the blaster's booklet.

During the transfer of explosive materials from the PS to the place of use at the worksite, vehicles must not move along the planned route and all other machines must be turned off. The transport of explosive materials from the PS to the place of use at the worksite is carried out separately for explosives and separately for detonators. Explosive materials are transported-transferred manually and in their original packaging from the PS to the place of use. Detonators can only be carried by the blaster, separately from the explosives.

The blaster is responsible for implementing the stated procedure. The control of storage and transfer of explosive materials is performed by the Technical Manager of the construction site. Supervision is mandatory to control the implementation of the mentioned procedures and compliance with laws and bylaws.

### **Records**

Blasters must keep a blasting logbook (daily card), which records the use of quantities, the used quantities of mine-explosive materials. Every used quantity must be confirmed by the Technical Manager of the site or his deputy, who is obliged to confirm the use of the stated quantities of explosive materials after each blasting.

## **20.3. Special safety measures during execution of blasting works**

### **20.3.1. Safety measures for unexploded mines**

If the blaster determines by inspecting the site that there are unexploded mines, he is obliged to record the number and position of the unexploded mine and proceed to take measures for the destruction of the unexploded mine according to the instructions of the explosive manufacturer. After identifying the unexploded mine and marking it, it is necessary to carefully remove the inert material from the borehole in order to determine the direction of the borehole. At a distance of 8 borehole diameters from the unexploded mine, a new borehole is drilled, parallel to the borehole of the unexploded mine. The new borehole is filled with explosives and initiated according to the blasting procedure. Filling with explosives, securing, and inspection are done as in the initial blasting. The responsibility for implementing this procedure lies with the blaster.

The Technical Manager of the site is responsible for controlling the work of the blaster. The supervisor is obliged to control the implementation of the stated procedures.

### **20.3.2. Safety measures against seismic effect of blasting**

Tremors caused by blasting are directly related to the amount of explosive initiated. The strength of the tremor is also affected by other factors, such as soil type, distance from the blasting site, water saturation, the method of opening the minefield, and others. Since the mentioned factors are constant, the Contractor can only influence the factor of the amount of explosive charge in the blast holes, the amount of explosive per millisecond interval.

Another important piece of data is the permissible limit of tremors caused by blasting. Since domestic norms have not been adopted, it is necessary to apply foreign norms. The Austrian norms ONORM S 9020 and the German DIN 4150 are recommended. ONORM S 9020 contains information for the rational preparation of an optimally adapted assessment of tremors caused by blasting at 4 levels. It is also necessary to perform seismic measurements on nearby buildings. The implementation of this procedure is controlled by the supervisor by entering it into the construction log.

### **20.3.3. Safety measures against scattering of materials**

Usually, at the beginning of tunnel construction and initial blasting, there is a possibility of blasted material scattering. Excessive scattering of blasted material needs to be reduced by technical corrections, namely:

- By optimizing the explosive charge of the boreholes, i.e., optimal specific consumption of explosives.
- By optimal concentration of explosives in the boreholes
- Sufficient burden and sufficient length of the clay stemming - plug.
- Covering the minefield or closing the entrance with felt.

The safety radius of scattering is approx. 100 m.

#### **20.3.4. Safety from occurrence of shock wave**

Every blasting causes an instantaneous change in air pressure in the surroundings. This phenomenon results in a shock wave. Before initiating the minefield, it is necessary to remove all employees from the endangered area zone, which is defined based on trial blasting and air blast measurements. The blaster is responsible for carrying out this procedure, and the endangered area zone is determined by the Technical Manager of the blasting site.

#### **20.3.5. Safety from the occurrence of toxic, suffocating, and thermal effects of blasting**

When blasting in a tunnel, the danger of toxic and suffocating effects is always present. Due to the high risk of toxic and suffocating effects, after each blasting, it is necessary to wait some time (approx. 20 minutes) for the dust to settle, for the gases generated by blasting to be diluted by ventilation, and for the worksite to be aired out.

It is mandatory to measure the concentrations of hazardous gases and only then perform an inspection of the worksite after blasting. All measurements of hazardous gas concentrations must be performed at prescribed intervals.

The shift supervisor and the blaster are obliged to control the ventilation of the worksite, namely:

- a) Blasters
  - At the beginning of the shift
  - During the shift, before the start of drilling minefields, before and after charging blastholes, before and after blasting, at the location from which blasting is performed
  - At the end of the shift
- b) Shift supervisor
  - During every tour, arrival, and departure from the worksite
  - During any, even the slightest, disturbance in ventilation and whenever the opportunity arises

Blasters and shift supervisors are obliged to record the results of the gas condition control in the tunnel into the appropriate registry.

#### **20.3.6. Safety from occurrence of methane ( CH<sub>4</sub> )**

Methane is a colourless gas, a compound of carbon and hydrogen with the chemical formula CH<sub>4</sub>. It is the main constituent of natural gas. Methane is lighter than air and occurs in the roof parts of tunnels, where it should be measured according to the rules. It often appears in coal seams, and is sometimes found under pressure in the rock mass in the form of "pockets". When encountering these pockets, methane outbursts occur in the form of blowers, whereby the concentration of methane in the air suddenly increases, usually above the MAQ (minimum allowable quantity).

When ignited, methane burns with a bright bluish flame, and its combustion produces carbon dioxide and water. It is insoluble in water, and in a mixture with air in the range of 5 to 15% it is highly explosive; it has the greatest explosive effect at a concentration of 9.5%. An explosive mixture of methane and air can be ignited by a spark or an open flame.

In the event of methane occurrence greater than 0.5%, the procedure is as follows:

- stop all work at the face of the worksite (where methane appeared)
- turn off the operation of all machines at the worksite
- withdraw workers from the tunnel or the contaminated area
- disconnect the power supply (at the switch outside the tunnel)
- control the operation of the fans
- prohibit entry into the tunnel or approach to the contaminated area until the arrival of inspection authorities.

In addition to the procedure described above, the Contractor is obliged to comply with positive legal regulations and bylaws in the field of occupational safety as listed below:

- 1) Law on Occupational Safety (Official Gazette of SR BiH No: 22/90)
- 2) Rulebook on occupational safety in construction (Official Gazette 42/68)
- 3) Rulebook on technical norms for handling explosive materials and blasting in mining. (Official Gazette of SFRY No: 26/88 and 63/88)
- 4) Rulebook on technical measures and occupational safety in underground mining works (Official Gazette 11/67; 35/67; 60/70; 9/71 and 5/73)
- 5) FIDIC 6.7 health and safety

Update of the Instruction Set, section for the internal drainage system performed by:

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