ЈАВНО ПРЕДУЗЕЋЕ
ПУТЕВИ СРБИЈЕ

REPUBLIC OF SERBIA

TRANSPORT REHABILITATION PROJECT

SERBIAN ROAD CONSTRUCTION SPECIFICATIONS

2. SPECIAL TECHNICAL CONDITIONS

2.5 CIVIL ENGINEERING STRUCTURES AND SUPPORT ELEMENTS

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2.5.1 CEMENT CONCRETE

2.5.1.1 Introduction

2.5.1.1.1 General

Special technical conditions for works with cement concrete include all types of cement concrete used in the construction of bridges, as well as for manufacture of semi-products These works include special-purpose works with cement concrete.

Cement concretes are placed in compliance with the manner, dimensions and quality determined in the project documentation and in these technical conditions.

2.5.1.1.2 Terminology

The terms used in these technical conditions shall have the following meanings:

Concrete (beton, Beton) is a material produced by mixing cement, coarse and fine aggregate and water, with or without the presence of mineral and/or chemical admixtures, which develops its properties by cement hydration.

Fresh concrete (sveži beton, Frischbeton) is concrete that has been fully mixed and which can still be compacted by the selected compaction method.

Hardened concrete (očvrsli beton, Festbeton) is concrete in a solid state which has reached a measurable strength.

Normal-weight concrete (beton normalne težine, Normbeton) is concrete with a volume weight when dry greater than 2 000 kg/m^3, but not exceeding 2 600 kg/m^3.

Light-weight concrete (laki beton, Leichtbeton) is concrete with a volume weight when dry no less than 800 kg/m^3 and no greater than 2 000 kg/m^3; produced by using light aggregate for all or part of the used aggregate..

Heavy weight concrete (teški beton, Schwerbeton) is concrete with a volume weight when dry greater than 2 600 kg/m^3.

High performance concrete (beton visoke čvrstoće, Hochleistungsbeton) is concrete with compressive strength class of C50/60 in case of standard or heavy-weight concrete, or LC50/55 in case of light-weight concrete.

Truck mixer (mešalica za beton) is-a special concrete mixer mounted on a self-propelled chassis capable of mixing and delivering a homogeneous concrete.

Batch (mešung, Charge) is the quantity of fresh concrete produced within one working cycle of a mixer, or the quantity prepared within one minute.

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

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

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

Water–cement ratio (vodocementni faktor, Waser-Zement wert) is the ratio of the effective water content to the effective cement content in the concrete mix.

Characteristic strength (karakteristièna čvrstoća, charakteristische Festigkeit) is the value of strength for the tested concrete quantity below which maximum 5 % of the results of all possible strength tests can be expected

Execution class (izvođačka klasa, Ausführungsklasse) is the set of requirements that determines the quality levels for execution (including casting) of the structure in full, of for an individual constituent part.

Execution specification (izvođačka specifikacija, Ausführungsspezifikation) is the documentation consisting of all the plans, technical data and requirements necessary for the execution of a specific structure, provided to the contractor by the structure designer. It contains building (and casting) specifications for the structure which supplement and detail the requirements of

the European standard for construction of concrete structures, and also refer to the national regulations that need to be observed in-situ (e.g. for concrete).

Quality plan (plan kvaliteta**,** Qualität planen) is a document setting out the procedures and appropriate means that shall be implemented, as well as who shall implement them and when, in order to meet the building (casting) requirements for a specific structure. Guidelines on the content of the quality plan can be found in SRPS ISO 9000.

2.5.1.1.3 Abbreviations used

SRCS - Serbian Road Construction Specifications

SRDM – Serbian Road Design Manual

2.5.1.1.4 Reference standards

The following standards were used in the preparation of these technical conditions:
- SRPS EN 206-1 - Concrete - Part 1: Specification, performance, production and conformity
- SRPS EN 197-1 - Cement - Part 1: Composition, specifications and conformity criteria for common cements
- SRPS EN 12620 – Aggregates for concrete
- SRPS EN 1008 Mixing water for concrete - Specification for sampling, testing and assessing the suitability of water, including water recovered from processes in the concrete industry, as mixing water for concrete
- SRPS EN 934-2 - Admixtures for concrete, mortar and grout - Test methods - Part 2: Concrete admixtures - Definitions, requirements, conformity, marking and labelling
- SRPS EN 13055-1 – Lightweight aggregates - Part 1: Lightweight aggregates for concrete, mortar and grout
- SRPS ENV 13670-1 – Execution of concrete structures - Part 1: Common.

2.5.1.1.5 Description

Works with cement concrete include the procurement of basic materials for production of the cement concrete mix (aggregate fraction mix, cement, water, chemical and mineral admixtures) production, transport and placing of the fresh cement concrete in the places and in the manner specified in the project documentation. These works include protection of the surface of the fresh concrete after placing.

Works should be executed in weather conditions free of precipitation and at air temperature (without wind) of 5℃ to 30℃. If works are executed in conditions other than the aforesaid, the specified concrete temperatures (heating, cooling) need to be ensured during production, and the appropriate protection and curing measures taken after placing.

Normal-weight cement concrete (concrete for structures on roads) shall be in compliance with the requirements of standard SRPS EN 206-1.

For special types of cement concrete, such as:
- for roads and other traffic surfaces;
- for other material (e.g. fibers) and basic materials not included in standard SRPS EN 206-1 (e.g. polymers);
- with largest aggregate grain of 4 mm or less (mortars)
- for special technologies (e.g. shotcrete);
- for disposal of liquid or gaseous waste;
- for storage pools for waste material harmful to the environment;
- for massive structures (e.g. partitions);
- dry mixtures and other;

additional and/or special requirements shall be defined in the project documentation.

According to place of mixing concrete can be:
- cement concrete mixed in-situ;
- ready-mixed concrete mixed at the concrete plant and transported to the site;
- cement concrete mixed at the concrete plant for execution of various concrete elements.

From the aspect of setting, cement concrete can be fresh, in the hardening process (early-age) and hardened concrete.

From the surface aspect cement concrete can be shaped as visible (shaped by use of formwork or in some other manner), or as wearing or protective cement concrete.

The type of cement concrete suitable for the specific use shall as a rule be defined in the project documentation and be ensured by use of the appropriate basic materials, mixing procedures and prior testing of the cement concrete.

Cement concrete for structures shall be in compliance with the requirements of standard SRPS EN 206-1.

According to the SRPS EN 206-1 standard and on the basis of various characteristics, or properties, concrete is divided into several classes - grades:

According to consistency fresh cement concrete is divided into the following classes:
- degree of slump (S1 to S5)
- degree of compaction (C0 to C3) or
- degree of flow (F1 to F6),

where the degrees of consistency are not mutually directly dependent and do not depend on the class relating to the largest aggregate grain. In such cases classification is performed according to the size of the coarsest aggregate grain in the cement concrete on the basis of which the size of the aggregate was determined in compliance with SRPS EN 12620.

Hardened cement concrete is divided into the following classes:
- strength class (C 8/10 to C 100/115 for normal-weight and heavy-weight cement concrete, or LC 8/9 to LC 80/88 for lightweight cement concretes),
- volume weight classes of cement concrete (only for lightweight cement concrete);
- degree of water permeability (V-I to V-III),
- degree of exposure to carbonation-induced corrosion (XC1 to XC4),
- degree of exposure to corrosion from chlorides other than from sea water (XD1 to XD3),
- degree of exposure to chemical attack (XA1 to XA3),
- degree of exposure to wear (XM1 to XM3),
- degree of internal resistance of cement concrete to freeze/thaw attack without de-icing salts (XF1, XF3)
- degree of resistance to freeze/thaw attack with de-icing salts (XF2, XF4).

Requirements for the properties of both fresh and hardened cement concrete are detailed in the specification for the cement concrete. The authority issuing the specification (contracting authority, designer, contractor and/or manufacturer) shall take the following into consideration when preparing the specification:
- the intended use of the fresh and hardened cement concrete;
- the curing conditions;
- the dimensions of the structure;
- the environmental actions (degree of exposure);
- the requirements regarding the visual appearance of the surface;
- the requirements regarding the protective layer;
- the limitations from the viewpoint of the use of the basic materials.

Due to the different exposures of individual structural elements of the structures on roads, additional requirements for classes and degrees of exposure need to be taken into account in designing and execution, examples of which are given in table 2.5.1.1.

Table 2.5.1.1: Example of defining the classes and degrees of exposure of cement concretes

Structural elements	Specification for cement concrete
foundations "white" (i.e. without tar coat) basin edge rims concrete carriageways	C25/30, XC2, V-I V-II, XF3, C25/30, XF4, XD3, V-II (recommended w/c<0,5) C35/45, XF4, XM3, V-II, XD3

The chloride content in the cement concrete expressed as the percentage of the chloride ions in the cement mass for the stated purpose of the cement concrete may not exceed the values listed in table 2.5.1.2.

The chloride content in the cement concrete shall be calculated in compliance with SRPS EN 206-1.

2.5.1.2 Basic materials

The basic materials for mixing cement concrete shall not contain harmful additives in quantities that could decrease the durability of the cement concrete or cause corrosion of the reinforcement steel. All the basic materials shall have properties suitable for use in cement concrete.

If the basic material has been prepared in a general context, it is not necessary suited to all the conditions and to every composition of cement concrete.

In cement concrete prepared in compliance with SRPS EN 206-1 only those basic materials that are suitable for the stated intended use may be used.

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Table 2.5.1.2: Greatest permissible chloride content in cement concrete

Composition of cement concrete	Degree of exposure	Chloride content class	Greatest Cl^- content relative to cement mass*
contains reinforcement steel or other metals excluding corrosion resistant truck mixtures	-	Cl 1.00	1%
contains reinforcement steel or other embedded metals	XD1 XD2	Cl 0.20	0.20%
	XD3	Cl 0.40	0.40%
contains prestressing steel	XD1, XD2	Cl 0.10	0.10%
	XD3	Cl 0.20	0.20%

Legend:
If type II mineral admixtures are used and taken into consideration in the concrete quantity, then the chloride content is expressed as a percentage of the mass of chloride ions relative to the total mass of cement and mineral admixtures.

2.5.1.2.1 Aggregate (mixture of fractions)

Aggregate for cement concrete mixtures can be made of natural grain (gravel or sand) or a mixture of crushed stone gravel and sand. Recycled aggregate can also be used.

Aggregate for cement concrete mixtures shall comply with the requirements of SRPS EN 206-1 standard, the specifications for cement concrete and other special requirements in the project documentation. Natural and recycled aggregates of normal-weight (grain volume weight > 2000 kg/m3) shall be in compliance with the SRPS EN 12620 standard, and lightweight aggregates with the SRPS EN 13055-1 standard.

In selecting the aggregate, grain size and other categories (e.g. flakiness**,** freeze resistance, abrasion resistance, fine particle content) the following shall be taken into consideration:

- the manner of work execution,
- the end use of the cement concrete,
- the requirements regarding the protective layer of the cement concrete,
- the dimensions of the structure,
- the environmental conditions to which the structure will be exposed,
- all the requirements for the aggregate exposed on the cement concrete surface or aggregate for machine finishing of the cement concrete surface.

The use of recycled aggregate shall be previously justified.

All-in aggregate may be used only for concretes up to class C12/15.

2.5.1.2.2 Cement

Cement is hydraulic binder, i.e. a pulverized inorganic material that forms a paste when mixed with water, which, due to reactions and hydration processes, sets and hardens, and upon hardening retains its stability.

Cement consists of various materials. The properties of the cement, and therefore the properties of the fresh and hardened cement concrete, depend on the properties of these constituent materials.

For cement concrete prepared in compliance with standard SRPS EN 206-1, cement with properties prescribed by standard SRPS EN 197-1 shall be used. In special cases, cement not in compliance with SRPS EN 206-1 can be used for mixing cement concrete, such as sulfate-resistant cement, calcium-aluminate cement, or low-heat hydration cement.

2.5.1.2.3 Water

The quality of the water used for mixing cement concrete can affect the setting time, the development of compressive strength, stability and protection of reinforcing steel from corrosion.
In assessing the quality of the water for mixing cement concrete, the purpose for which the produced cement concrete will be used shall be taken into consideration. Observing the conditions set forth in SRPS EN 1008, the following waters can be used for mixing cement concrete:
- drinking water
- water obtained from processes in the cement concrete industry,
- ground water,
- natural surface water and industrial waste water, and

Municipal waste water shall under no circumstances be suitable for mixing cement concrete.

Usability shall be justified by testing for all waters except drinking water.

2.5.1.2.4 Chemical admixtures

The following are chemical admixtures:
- plasticizers,
- superplasticizers,
- water-retaining admixtures,
- air entraining admixtures,
- set accelerators,
- hardening accelerators,
- set retarders,
- water resisting admixtures,
- admixtures for work at low temperatures.

Use of chemical and other admixtures shall be in compliance with standard SRPS EN 206-1.

The total chemical admixture content shall not exceed 50 g/kg of cement (unless otherwise specified by the admixture manufacturer).

Use of chemical admixtures in quantities less than 2 g/kg of cement is permitted only with previous uniform mixing with water used for mixing cement concrete.

If the quantity of liquid admixtures exceeds 3 l/m^3, the additional water shall be factored in when calculating the water-cement ratio,

The effect of the chemical admixtures, their mutual interrelation and interrelation with the used cement shall previously be verified by testing.
In the use of chemical admixtures the manufacturers' instructions must be complied with.

2.5.1.2.5 Mineral admixtures

A mineral admixture is a finely ground and sieved material added to cement concrete to improve certain properties of fresh or hardened cement. There are two types of inorganic admixtures:
- inert mineral admixtures (type I), and
- pozzolanic or latent hydraulic mineral admixtures (type II).

The quantities of mineral admixtures type I and II shall be verified by testing.

If a type II mineral admixture is deemed suitable, then its quantity may be factored in when calculating the cement content in the water-cement ratio. In such calculations the k-value concept described in standard SRPS EN 206-1, point 5.2.5.2.1 is applied. The usability of other procedures shall be justified by previous testing.

2.5.1.2.6 Protective agents

Liquid chemical sprayed agents can be used as protective agents for temporary surface protection of fresh and hardening cement concretes from drying and/or damage due to

precipitation, forming a uniform film on the surface of the concrete.

The following liquid protective agents can be used for more permanent protection of hardening and hardened cements from weather and chemical actions (carbonation, corrosion of reinforcing steel):
- as admixtures in the mixing of cement concrete (watery emulsions of silicone and acrylates)
- for coating the cement concrete (epoxy, acrylic and vinyl resins) and
- for coating and in-depth penetration, or impregnation of the cement concrete (e.g. water impervious materials: silicones, siloxanes, silanes, linseed oil, diluted epoxy and acrylic resins).

Linseed oil is a good way to protect hardened concrete from water and chemical actions. It can, as needed, be diluted by up to 50% with melting agents or heated, which increases its penetration capacity.
In the use of chemical admixtures the manufacturers' instructions must be complied with.

2.5.1.2.7 Polymers

For polymer-, polymerized (modified by polymers) and polymer impregnated cement concrete and mortar, polymers in the following forms can be used:
- admixtures for improving the cement concrete (polyvinyl acetate, polyvinyl propionate or butadiene-styrene) or acrylate water emulsions); or
- adhesives for cement concrete (epoxy resins with admixtures and amino hardening agents or with solvents and polyamide hardening agent).

2.5.1.3 Quality of materials

2.5.1.3.1 Aggregate

For mixing cement concrete in compliance with SRPS EN 206-1, standard aggregate is used in compliance with the provisions of SRPS EN 12620, or lightweight in compliance with SRPS EN 13055-1.

The selection of type of aggregate depends on the purpose and use of the cement concrete, as well as of:
- the manner of work execution,
- the end use of the cement concrete,
- the requirements for the protective coating of the cement concrete,
- the dimensions of the structure,
- the environmental conditions to which the structure will be exposed,
- the exposure of the surfaces and the potential machine finishing of the cement concrete surfaces.

The aggregate for cement concrete shall be in accordance with the granulometric composition, the grain shall be chemically inert, washed or dusted. Good adhesion to the cement stone shall be ensured. The use of an individual type of aggregate for the mixing of cement concrete shall be verified within the trial testing of the cement concrete. Ensuring the quality and determining compliance is performed in accordance with the 2+ system, meaning that the manufacturer conducts quality control in compliance with the provisions of the standard, and obtains a certificate of production control from the competent certification authority. On the basis of the production certificate the manufacturer issues a declaration of product conformity.

2.5.1.3.1.1 Geometrical, physical and chemical requirements

Aggregates for cement concrete shall have the properties listed in table 2.5.1.3.

Table 2.5.1.3: Required properties of aggregates for cement concrete

Property	Requested category	Testing procedure
○ Water absorption	$WA_{24}2$	SRPS EN 1097-6
○ Resistance to fragmentation according to the Los Angeles procedure	LA_{15} to LA_{30}	SRPS EN 1097-2
○ Frost-resistance (magnesium sulfate procedure)	F_1 oz. MS_{18}	SRPS EN 1367-1 SRPS EN 1367-2
○ Particle shape (Shape index)	SI_{15}	SRPS EN 933-4

2.5.1.3.1.2 Granulometric composition

The selection of granulometric composition of the aggregate for mixing cement concrete shall be adjusted to the intended use of the cement-concrete mix, and sufficient workability and compaction of the cement concrete shall be ensured.

When selecting the grain, the maximum nominal upper aggregate size in the mix:
- may not be larger than a quarter of the smallest dimension of the cement concrete element's cross-section (in case of slabs it may not be larger than a third of the slab's thickness) and
- may not be larger than 1.25 times the size of the smallest free horizontal gap between the steel bars - reinforcing.

The usability of the aggregate's granulometric composition shall be verified by prior testing of the cement-concrete mix.

The recommended grade range of the granulometric composition for cement concrete mixes is given in table 2.5.1.4 and shown in figures 2.5.1.1 to 2.5.1.3.

Table 2.5.1.4: Recommended threshold values for granulometric composition of cement concrete aggregate

Aggregate mix	Threshold curve	Sieve opening size [mm]							
		0.25	0.5	1.0	2.0	4.0	8.0	16.0	31.5
		passed through sieve [m.-%]							
0/8 mm	upper lower	11 5	27 13	42 21	57 36	74 61	100 100		
0/16 mm	upper lower	8 3	20 7	32 12	42 21	56 36	76 60	100 100	
0/32 mm	upper lower	8 2	18 5	28 8	37 14	47 23	62 38	80 62	100 100

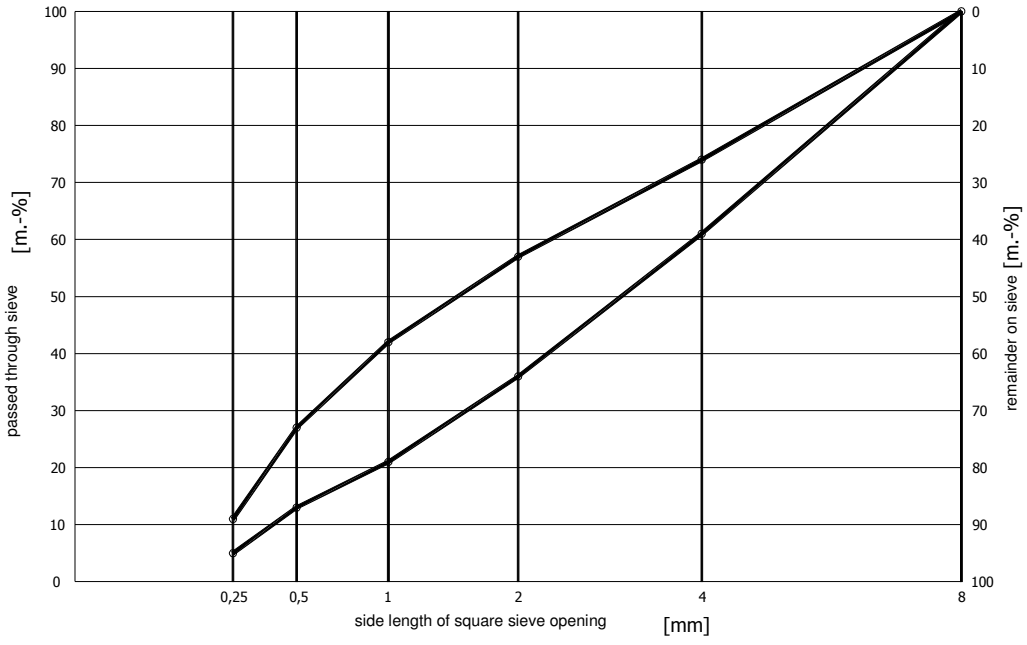

Figure 2.5.1.1: Threshold particle size distribution curve for 0/8 mm aggregate

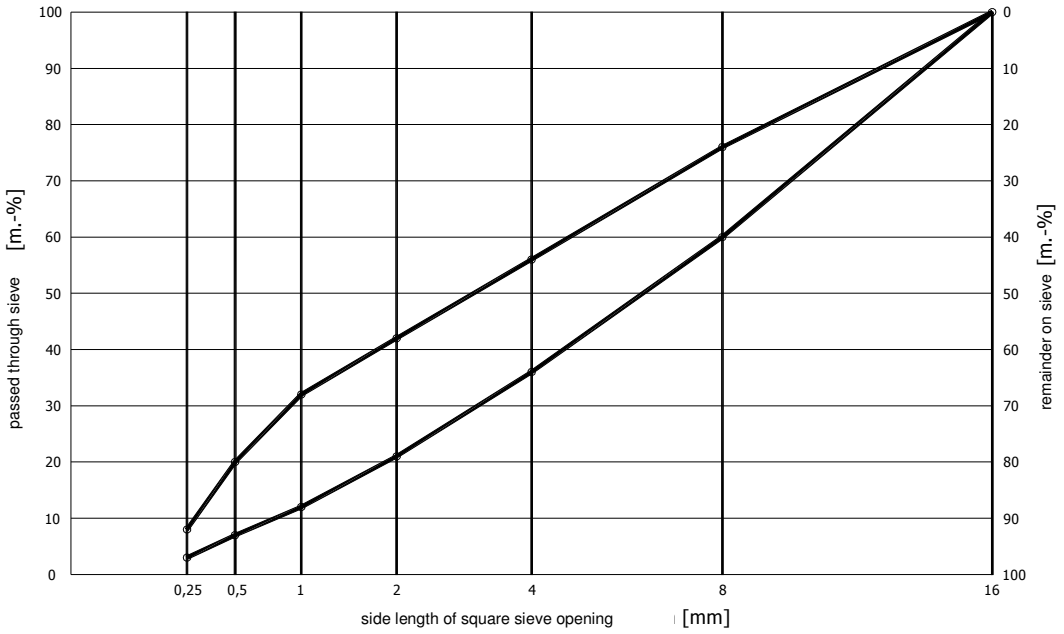

Figure 2.5.1.2: Threshold particle size distribution curve for 0/16 mm aggregate

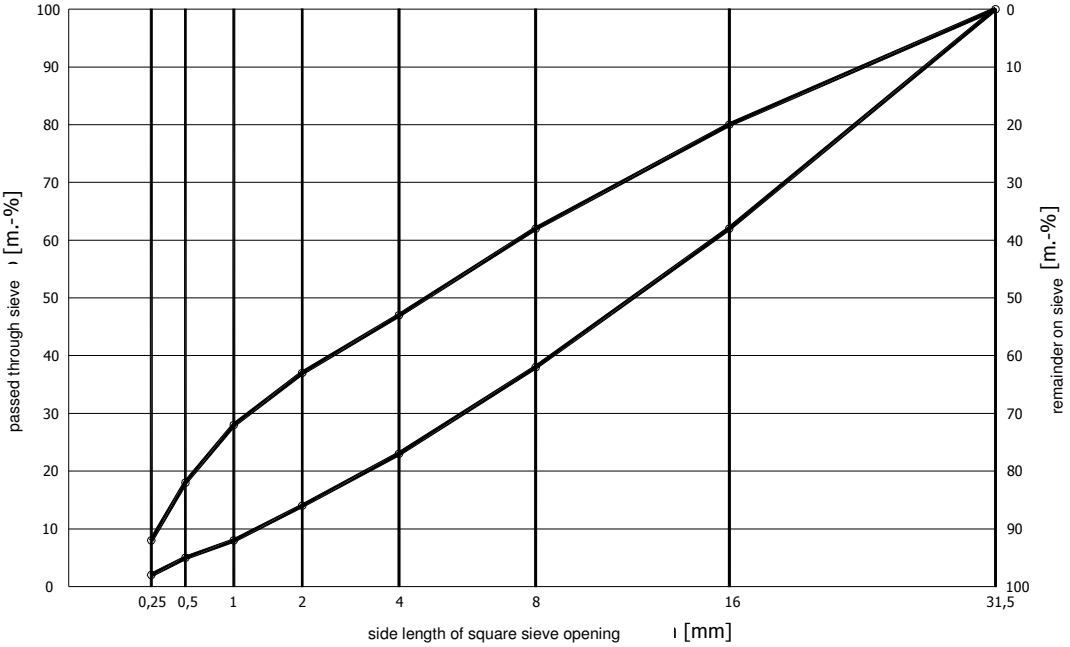

Figure 2.5.1.3: Threshold particle size distribution curve for 0/32 mm aggregate

2.5.1.3.2 Cement

For cement concrete works for structures on roads cement in compliance with SRPS EN 197-1 shall be used.

According to the content of the main ingredients SRPS EN 197-1 standard differentiates between the following:

- Portland cement clinkers;
- granulated blast furnace slag;
- microsilica;
- natural and calcined natural pozzolans;

- silicon and calcium electrofilter ash;
- burnt shale;
- limestone and
- less important ingredients (0-5%).

27 different types of cement are classified in the 5 main types:
- CEM I, Portland cement
- CEM II, Portland-composite cement
- CEM III, Blastfurnace cement
- CEM IV, Pozzolanic cement
- CEM V, Composite cement.

Cements are also classified into 6 grades depending on their compressive strength (table 2.5.1.5).

Table 2.5.1.5: Cement grades according to SRPS EN 197-1 based on compressive strength

Grade of strength*	Compressive strength [MPa]				Setting time	Volume stability (expansion)
	early strength		standard strength			
	2 days	7 days	28 days		[min]	[mm]
32.5 N 32.5 R	- ≥ 10.0	≥ 16.0 -	≥ 32.5	≤ 52.5	≥ 75	≤ 10
42.5 N 42.5 R	≥ 10.0 ≥ 20.0	- -	≥ 42.5	≤ 62.5	≥ 60	
52.5 N 52.5 R	≥ 20.0 ≥ 30.0	- -	≥ 52.5	-	≥ 45	

** N –ordinary early compressive strength; R-high early compressive strength*

When selecting cement the following shall be taken into account:
- the manner of work execution,
- the end use of the cement concrete,
- the curing conditions,
- the dimensions of the structure,
- the environmental conditions to which the structure will be exposed,
- potential alkali reactivity of aggregate with the basic materials.

To ensure unified quality of cement concrete, unified quality of cement has to be ensured.

Portland cements of different qualities and from different manufacturers may not be mixed if the appropriate quality has not been proven first.

As a rule, cement with the same properties, manufactured from the same raw materials (which is therefore of uniform quality) shall be used for multiple layers of cement concrete in the same cross section.

Verifying the quality and justifying the cement properties is performed in accordance with the 1+ system, meaning that the authorized certification authority conducts quality control in compliance with the provisions of the standard, and issues an EC certificate of conformity. On the basis of this certificate the manufacturer issues an EC declaration of product conformity.

2.5.1.3.3 Water

The required properties of water for preparing mixes and protecting cement concrete, as well as the types and frequency of testing, are defined in standard SRPS EN 1008.

Drinking water can be used for mixing cement concrete without additional justification of its compliance.

Sea water may be used only for mixing cement concrete for non-reinforced structures, while municipal waste water may not be used in the mixing of cement concrete.

2.5.1.3.4 Chemical admixtures

Generally speaking, for mixing cement concrete in compliance with SRPS EN 206-1, chemical admixtures in compliance with SRPS EN 934-2 shall be used.

The used chemical and other admixtures shall provide the required improvements of the relevant properties of the mix in the relevant state of the cement concrete (fresh, hardening, early-age and hardened cement

concrete). All of the aforementioned shall be verified by prior testing.

Verifying the quality and justifying the compliance of the chemical admixtures is performed in accordance with the 2+ system.

2.5.1.3.5 Mineral admixtures

The following mineral admixtures shall be used for mixing cement concrete in compliance with SRPS EN 206-1:
- type I mineral admixtures;
- mineral fillers, complying with SRPS EN 12620;
- pigments (SRPS EN 12878),
- type II mineral admixtures;
- electrofilter ash (SRPS EN 450), and
- microsilica (SRPS EN 13263).

The quantities of type I and type II mineral admixtures shall be verified by testing of the cement concrete.

Verifying the quality and justifying the compliance of type I mineral admixtures is performed in accordance with the 2+ system.

Verifying the quality and justifying the compliance of type II mineral admixtures is performed in accordance with the 1+ system.

2.5.1.3.6 Protective agents

The quantities of liquid chemical agents for surface protection of cement concrete are defined in the technical conditions and manufacturer's instructions for the products.

The film of the chemical agent used for temporary protection shall protect the surface of the cement concrete in the appropriate manner for no less than 7 to 14 days, depending on the speed of the cement hydration process.

The protective agent may not have an adverse effect on the cement setting speed, or on the surface and surface payer of the cement concrete, which shall be justified by prior testing.

2.5.1.4 Execution of cement concrete works

2.5.1.4.1 Deposits of materials

The contractor shall provide the engineer with a list for quantities for all the foreseen materials. For all placed cement concrete and all materials that he intends to use in preparing the cement concrete mix (cement, water, chemical and other admixtures, protective agents, adhesives), the contractor shall provide the engineer with the justifications for the use of these materials (declaration of conformity, certificates) prior to commencement of works, for verification by the engineer.

2.5.1.4.2 Depositing material

If the contractor is temporarily depositing aggregates the depositing area shall be marked, prepared in the appropriate manner and protected from precipitation as a rule.

Cement shall be stored in the appropriate silos.

If water other than from the waterworks shall be used for the mixing of cement concrete, it shall be stored in water tanks or in the manner approved by the engineer.

Chemical and other admixtures for cement concrete shall be stored according to the manufacturer's instructions.

Protective agent for curing and maintaining fresh or early-age cement concrete and polymers shall be stored according to the manufacturer's instructions.

The quantities of all material in the depositing areas shall be such that they allow for continuing production of the relevant mix of fresh cement concrete.

2.5.1.4.3 Preparing the ground and formwork

Formwork for placing fresh cement concrete shall be executed according to the size requirements and other foreseen characteristics, listed in the project documentation.

If unbound materials can be used as a blinding layer for cement concrete this has to be envisaged by the project documentation.

If this layer is water pervious, then it shall:
- be coated with the suitable impervious material (PVC foil);
- be sprayed with bitumen emulsion;
- be soaked with water.

The manner of preparing the ground shall be foreseen in the project documentation. The preparation quality shall be verified by the engineer.

The contractor may start placing the cement concrete only after the engineer has taken over the formwork and ground, or reinforcement.

The contractor shall be obligated to maintain the formwork or ground and placed reinforcement in the condition it was in at the time of takeover, for the entire period of time until the placing of the cement concrete commences. He shall be obligated to repair all damage on time and in the appropriate manner. See also SRSC chapter 2.5.3.

2.5.1.4.4 Geometrical characteristics and tolerances

The nominal values of geometric properties of concrete elements are given in the technical documentation.

The geometric properties of structural concrete elements shall be in compliance with the required minimum nominal dimensions.

The geometric tolerances for linear beams and piers are given in SRPS ENV 13670-1. See also SRSC chapter 2.5.11.3.

Regarding the specification for characteristics of the surface of placed concrete, see SRDM, chapter 9.12.8, which sets out the requirements.

2.5.1.4.5 Mixing of concrete

Fresh cement concrete must be mixed at the appropriate concrete batching plant.

Evaluation, supervision and certification of production control are conducted in the volume and frequency defined by standard SRPS EN 206-1.

The composition of the cement concrete mix shall be adapted to the manner of transportation and placing.

The mixing time and other specifics affecting the quality shall be adjusted so as to ensure a homogenous cement concrete mix.

If the works are executed at low temperatures, the cement concrete plant shall ensure the possibility of heating the aggregates and/or water to the specified temperature.

The produced fresh cement concrete mix may be stored for a short time in the appropriate silos at the concrete plant or be transported immediately to the place of placing. During this process drying, hardening, subsequent adding of excess water or subsequent heating or cooling of the fresh cement concrete mix must be prevented.

2.5.1.4.6 Producing precast elements

The precast concrete element production plant shall be equipped with the necessary machines and devices for placing fresh cement concrete, and the necessary space for maturing of the prefabricated elements. This space shall be protected from the elements (precipitation, frost, sun).

Precast elements shall be marked (production date, designations according to the project documentation, weight and placement position). Transport and placement can be conducted only when the cement concrete reaches the necessary strength. Possible damages, if any, must not affect the load-bearing capacity, durability, appearance or serviceability of the element.

2.5.1.4.7 Transporting fresh cement concrete

Placing the appropriate fresh cement concrete into the prepared formwork or on a ground, which must not be frozen, can begin only when approved by the engineer.

The appropriate vehicles, mixers or agitator trucks shall be used for transporting concrete. The fresh cement concrete must remain homogenous during transport, that is its basic properties must not change.

The number of vehicles used to transport fresh cement concrete to the site shall be suited to the conditions of uniform placement and the capacities of the manufacturing equipment, transportation distance and capacity of the placement itself.

2.5.1.4.8 Placing fresh cement concrete

2.5.1.4.8.1 General

Cement concrete should be placed as soon as possible after mixing, so as not to decrease the possibility of its placement, that is before the setting of cement begins (no more than 1.5 hours). The consistency may be corrected as needed, but in doing so the provisions of standard SRPS EN 206- and the admixture manufacturers' instructions shall be complied with.

The height of the free fall of fresh cement concrete in placement may not be more than 1.5 m, unless the measures required to prevent segregation are in place.

The height of laid layers shall be adapted to the manner and performance of the compacting devices and the capacities of the concrete mix production plant. Each layer shall be laid on the previous one during a timeframe that ensures good adhesion of both layers with recompaction that must be done along the entire thickness of both layers.

Fresh cement concrete is compacted by mechanical vibrators (pervibrators, plane vibrators, formwork vibrators), and particular care is to be taken along reinforcing bars and along the formwork work. The manner and conditions for using compaction devices for compacting the cement concrete shall be approved by the engineer.

The temperature of the fresh cement concrete during placement shall be no less than 7℃ (in exceptional cases 3℃), and no more than 25℃ (in exceptional cases 30℃). The temperature of the formwork or ground for the cement concrete shall be between 3℃ and 40℃. If the air temperature is below 5℃ or above 30℃, hardening of cement concrete in the specific conditions shall be ensured, and shall be approved by the engineer.

2.5.1.4.8.2 Construction joints

If a layer of placed cement concrete cannot be re-vibrated, then a cold joint shall be envisaged for that spot. The manner of finishing such joints shall be foreseen in the project documentation. The project documentation shall define the construction joints and the manner of their finishing in the places in which fresh concrete is laid onto already hardened concrete, and the design for placement of cement concrete shall take this into account. There should be as few construction joints as possible.

In prestressed structural elements, the construction joints of the cement concrete may not be parallel with the steel wires or rods.

The surface of the cement concrete in the area of the construction joints shall be previously prepared by the necessary procedure (washing, blast cleaning, sanding, surface setting retarder…) so as to achieve the structure of hardened concrete.

The manner of preparing the construction joint, as well as the use of setting retarders and polymer- or epoxy-based coating or mortar, executing ribs, teeth, placing steel bars for increasing the load-bearing capacity of the construction joint, shall be approved by the designer and the engineer.

2.5.1.4.8.3 Visible surfaces of cement concrete

The design documentation shall define the scope and manner of finishing the visible surfaces of the cement concrete.

The contractor shall provide the engineer, in a timely manner prior to placement of the cement concrete, with a sample of the visible surface of the cement concrete (structure, visual appearance, geometry).

The color and structure, or visual appearance, of the visible surface of the cement concrete shall be uniform. All repairs, which must be small-scale, shall be approved by the engineer.

The visible surfaces of the cement concrete may also be finished by subsequent finishing of the formwork surfaces.

2.5.1.4.8.4 Protecting and curing cement concrete

General

In order for cement concrete to reach its expected potential properties, especially in the protective layer above the reinforcement, it shall be protected and cured in the proper manner. The protection and curing procedures shall commence immediately upon placement and compacting, or surface finishing.

Placed cement concrete shall be protected:
- in the setting and hardening stage from drying, cooling, damage due to precipitation, vibration and mechanical damage;
- in the hardened stage from chemical action and mechanical damage.

Protection of cement concrete shall prevent:
- overly fast drying of the cement concrete surface due to:
  - low air humidity;
  - high air temperature;
  - high cement concrete temperature;
  - high wind speed; and
  - direct exposure to the sun;

- rinsing by rain and running water
- overly fast cooling in the first several days after placement;
- large differences between the air temperature and the temperature of the placed concrete;
- adverse consequences of low temperatures on hardening and freezing;
- harmful effects of vibrations and punching due to which cracks can occur in early-age concrete, or the decreased adhesion capacity of concrete and reinforcement.

Curing cement concrete ensures sufficient water, or moisture, in the capillaries, for the optimum cement hydration, by which the expected properties of the hardened concrete are achieved.

Excessive drying of the placed cement concrete can be prevented by the proper wet curing and/or chemical protective agents. Proper protection of cement concrete shall be ensured immediately upon completed vibration and shall be continued for no less than 7 days, or as long as necessary to reach the cement concrete to 60% of the foreseen value of compressive strength. In the use of chemical protective agents for protection of cement concrete from drying the technical conditions prescribed by the manufacturer shall be taken into consideration. The conditions for permanent protection of fresh or hardening cement concrete shall be proposed by the contractor in compliance with said technical conditions, and confirmed by the engineer.

Excessive heating, overly fast cooling and damage to large surfaces of placed fresh and hardening cement concrete can be prevented by covering the surface with fabric, plastic foil or some other appropriate material. Protection shall be continued until the cement concrete reaches 60% of the requested value of compressive strength

As the porosity of the surface of hardened cement concrete limits its durability, the surface of the concrete shall be properly protected. This is achieved by procedures that prevent penetration of water into the cement concrete. The protection or contractor's proposal for protection of cement concrete foreseen in the project documentation shall be approved by the engineer.

Curing methods

The curing procedure shall be determined before commencement of works at the site. Curing methods that can be applied independently or in mutual combinations are as follows:

- concrete remains in the formwork;
- plastic sheeting;
- wet covering;
- spraying with water;
- immersing in water,
- spraying with chemical curing agents that form an impermeable protective film.

From the viewpoint of performance of the individual methods, the concrete structure becomes more dense with wet curing, when the cement concrete is soaked with water during hardening, as compared to the method that merely prevents evaporation of water from the cement concrete. In cold weather the wet curing procedure is not permitted. Spraying warm surfaces with cold water can cause thermal stress and cracks, so the water has to be heated to the necessary temperature prior to use.

Duration of curing

The duration of the curing depends on the weather conditions and on the achieved compressive strength at the end of the curing which is expressed as the ratio of the mean strength at the end of curing to the mean strength after 28 days (table 2.5.1.6).

Table 2.5.1.6: Environmental conditions and duration of curing depending on the compressive strength of the cement concrete at the end of curing

Weather conditions		Average humidity [%]	Requested-concrete strength development
H	humid	> 80	0.1
M	medium	from 65 to 80	0.4
D	dry	from 45 to 65	0.5
VD	very dry	< 45	0.6

The criterion for duration of the curing can be:
- minimum time with regard to the weather conditions and the concrete hardening dynamics (table 2.5.1.7);
- maturity of the cement concrete, i.e. the achieved degree of hydration, expressed as the sum of the products of measured temperatures and the duration time for each temperature.

Table 2.5.1.7: Duration of curing in days

Environmental conditions during curing	Relative air humidity	Temperature of the cement concrete [°C]								
		5	10	15	5	10	15	5	10	15
	[%]	minimum duration of curing [in days]								
- no direct sun - medium sun, medium wind speed - strong sun, high wind speed	> 80	2	2	1	3	3	2	3	3	2
	> 50	4	3	2	6	4	3	8	5	4
	< 50	4	3	2	8	6	4	10	8	5
		fast			medium			slow		
		strength development of cement concrete								

2.5.1.4.8.5 Casting in cold weather

General

This chapter determines the cold weather conditions in which the hydration dynamics of the cement slows due to low temperatures, and additional measures that need to be taken in casting for protection of early-age concrete from freezing and for ensuring the conditions that enable normal development of the foreseen properties of the hardened cement concrete are taken.

Cold weather is weather when the air temperature is below 0°C at any time of day and when the average daily temperature is below +5°C for three consecutive days. The average daily temperature is the average of the highest and lowest measured temperature from midnight to midnight. The period of cold weather ends when the air temperature for three consecutive days is above 10°C and lasts for at least half a day.

A transitional period is a period when not all the requirements for cold weather have been met, but the temperatures can drop below 0°C at night.

Protection time is the required period of time during which the regulation temperature for placing cement concrete shall be maintained.

In casting we can identify the following activities: mixing, transport, placement, protection and curing of cement concrete.

Preparation prior to casting

The contractor shall present a detailed program of the procedures he intends to execute in casting during cold weather to the engineer for approval, in a time table.

Prior to casting, all the materials and/or equipment for protecting the cement concrete shall be prepared on site, as well as the equipment for regular measuring of the temperature.

On the placement location snow and ice shall previously be removed from all the surfaces on which the cement concrete is to be placed, including the reinforcing steel. Casting on frozen or frost-damaged elements is not permitted.

The ground shall be thawed to the depth to be specified by a soil mechanic. The temperature of the ground on which cement concrete is to be placed shall not be below 3°C.

The temperature of the cement concrete into which prestressing cables are injected shall not be below 5°C.

Casting shall be executed at the highest temperature during the day.

Temperature of cement concrete

Temperature at placement

The lowest permissible temperature of cement concrete for placement and protection depends on the smallest cross-section diameter, as listed in table 2.5.1.8. The temperatures from said table may not be exceeded by more than 10℃. The temperature of the grout shall not be below 5℃.

With massive cement concretes the temperature in the middle of the cross-section shall not exceed 60℃, while the surface temperature difference shall not exceed 20 K degrees.

The temperature of the fresh cement concrete shall be measured for each batch delivered to the site, prior to placement. The hardening temperature of the cement concrete shall be measured at least once a day, on the surface or at the contact with the formwork.

Table 2.5.1.8: Permissible temperatures of cement concrete depending on the cross-sectional diameter

Smallest cross-section diameter	Lowest cement concrete temperature at placement	Greatest permissible temperature drop in the first 24 hours upon removal of protection
- under 30 cm	11℃	20 K
- from 30 to 90 cm	9℃	17 K
- from 90 to 180 cm	7℃	12 K
- over 180 cm	5℃	10 K

Temperature at the end of protection

The temperature drop of the hardening cement at the end of protection may not exceed the values listed in table 2.5.1.8 during the first 24 hours.

Strength of cement concrete

Before exposing the cement concrete to frost with temperatures below 5℃, its compressive strength shall be at least 5 MPa.

Table 2.5.1.9: Minimum compressive strength of cement concrete depending on the average daily temperature

Anticipated average daily temperature after end of protection	Percentage of required characteristic compressive strength
above 0℃	50
from 0℃ to -5℃	65
from -5℃ to -10℃	85
below -10℃	95

The strength of the cement concrete prior to removal of the vertical formwork shall be sufficient to resist damage to the surface.

The strength of cement concrete at disassembly of trusses and with possible use of temporary trusses shall be determined by the designer. The strength of the cement concrete may in no case whatsoever – depending on the anticipated temperature after removal of the protection – be below the values listed in table 2.5.1.9.

Strength shall be determined on no less than three samples that are kept in the same conditions regarding protection as the placed cement concrete.

Casting

Mixing cement concrete

The aggregates in the deposit area in the concrete plant must not contain frozen lumps or ice.

The initial temperature of the cement concrete after mixing in the mixer shall be greater than the placement temperature for the value of the foreseen cooling during transport. This difference may be no greater than:
- 2 K, if the air temperature is above 1°C;
- 5 K, if the air temperature is from -1 to -10°C; and
- 8 K, if the air temperature is from -10 to -15°C.

Fresh cement concrete temperature shall in no case be over 30°C, except for steamed cement concrete.

The required initial temperature shall be achieved by heating the individual materials for cement concrete; however the following temperature values may not be exceeded:
- for water 100°C
- for aggregate 65°C
- for cement 50°C.

Before adding the cement in the mixer the temperature of the pre-mix shall be 40°C at the most.

There must be no lumps of frozen aggregate, ice or snow in the mixer. Sand may not be heated by steam.

To accelerate hydration the use of fast-setting cement, an increased amount of cement and/or a decreased amount of w/c is recommended, or the use of chemical admixtures. With cement concretes for prestressed structures, the use of chemical accelerators that contain chlorides is not permitted.

Transport and placement

Transport and placement of cement concrete shall be executed without delays, which can be achieved by good organization of work.

Curing and thermal protection

The appropriate curing procedure shall be implemented to ensure the sufficient quantity of water for hardening cement binder, while thermal protection shall ensure the required temperature for the normal hydration procedure.

Measures shall be undertaken to preventing drying of cement concrete, and continued, if in the indoor or outdoor area after removal of protection:
- the cement concrete is warmer than 15°C, the air temperature is 10°C or more;
- the air temperature is over 10°C, humidity under 40%.

Drying of cement concrete must also be prevented if the covered element or closed space is dry-heated by petroleum or gas heaters and in high wind conditions with simultaneous high temperature of the cement concrete.

Steam, wet covering, impermeable sheeting, chemical agents or water can be used for curing and prevention of drying. Curing by water is the weakest, especially if there is danger of the saturated cement concrete freezing after removal of the thermal protection. Steam or water curing shall be ended no less than 24 hours before the end of protection, enabling the cement concrete to dry off before exposure to low temperatures.

The following are suitable means of thermal protecting of placed cement concrete:
- covering exposed surfaces with insulation materials, e.g. plates of expanded polystyrene, polyurethane foam, mineral wool, cellulose fibers, straw or textile;
- covering the entire element or casting in an indoor area;
- thermal insulation of the formwork;
- steam.

During the transitional period early-age cement concrete shall be protected for at least 24 hours after casting.

In cold weather cement concrete shall be protected and cured:
- for at least 3 days, if no particular strenght is required of the element, taking minimum temperatures and permissible temperature drops into account, as listed in table 5.13, or
- until a safe strenght for the structure is achieved.

2.5.1.4.9 Quality of execution

In due time before commencement of the works the contractor shall provide the engineer with a specification of the cement concrete with all the required data according to these technical conditions.

2.5.1.4.9.1 Execution classes

Supervision and control of works shall ensure that the casting is carried out precisely in accordance with the execution specification for concrete.

Control means verifying the conformity of the properties of placed concretes that shall be used, as well as monitoring the execution of works.

The quality management requirements are prescribed by one of the following three classes, and the strictness of the requirements increases from the 1st to the 3rd class:
- 1st execution class
- 2nd execution class
- 3rd execution class

The execution class can refer to the entire structure, to the constituent parts of the structure or to specific concretes, or technologies used for the execution of works.

The execution class that needs to be employed shall be specified in the execution specification. See also table 2.5.1.14.

2.5.1.4.9.2 Initial test of mix design

In compliance with the provisions of standard SRPS EN 206-1, before using new cement concrete the contractor has to determine, by initial testing, the mix design that meets the set requirements for fresh and hardened cement concrete. The manufacturer can also justify the cement concrete mix on the basis of new test results or long-term experience. The volume of air (micropores) in the cement concrete exposed to frost and salt action (XF 4), determined by the procedure from standard SRPS EN 12350-7, shall conform to the values from table 2.5.1.10.

Table 2.5.1.10: Air content in cement concrete exposed to frost and salt action (XF 4)

Maximum nominal upper aggregate size [mm]	Air content [V.-%]
32 16 8	4 to 6 5 to 7 7 to 10

The volume of air (micropores) in the cement concrete can replace the appropriate volume of particles under 0.25 mm.

Apart from a statement on the specification for the cement concrete mix, the contractor shall also present the necessary proof of source and quality of all the material that will be used in the preparation of the initial test.

By the initial test the contractor has to prove that the foreseen granulometric composition of aggregates, cement, water, chemical and other admixtures can ensure the safe quality of cement concrete in compliance with these technical conditions.

The contractor may not commence production and placement of the cement concrete before obtaining the approval of the engineer.

2.5.1.4.9.3 Required properties

The properties of the placed cement concrete shall be in conformity with the provisions of the project documentation, standard SRPS EN 206-1 and the national supplement document.

The following criteria shall be used to determine the class of the cement concrete:
- if the available number of strength tests is n ≤ 6 from 2-4, or 5-6 consecutively taken samples:

$f_{cm} \geq f_{ck} + k_1$ (1)

$f_{cmin} \geq f_{ck} - 4$ (2)

where:
- k_1= 3 MN/m^2 – for 2-4 taken samples
- k_1= 2 MN/m^2 – for 5-6 taken samples
- f_{cm} – arithmetic mean in MN/m^2
- f_{ck} – characteristic strength in MN/m^2

- f_{cmin} – minimal value of consecutive test results in MN/m^2

- if the number of results of tested samples is 6 < n < 30, and the standard deviation σ is known on the basis of a number of previous test results (n≥35) and is not less than 4 MN/m^2, then the evaluation can be made in the following manner:

$$f_{cm} \geq f_{ck} + (1.65 - 2.58/n^{1/2})\ \sigma \quad (3)$$

$$f_{cmin} \geq f_{ck} - 4 \quad (4)$$

where:
- σ standard deviation in MN/m^2

Standard deviation is derived from no less than 35 consecutive results from tests taken during the three months prior to commencement of production. This value is taken as the estimated value for all test results:

$$\sigma = ((\sum f_{cm} - f_{ci})^2/(n-1))^{1/2} \quad (5)$$

where:

f_{ci} – individual testing value MN/m^2

f_{cm} – arithmetic mean for n samples in MN/m^2

n – the number of samples

If the number of test results is n ≥ 35 and the standard deviation is estimated on the basis of the previously obtained results, then the evaluation can be derived from equations (3) and (4) provided that σ is:

- for structures spanning over 10 m: σ≥5 MN/m^2
- for structures spanning under 10 m: σ≤3 MN/m^2

If the calculated σ is below the above given values, then the smallest possible σ should be taken, taking into account the classification of the structures and the number of test results.

Chemical admixtures added to cement concrete can change the properties only within the limits specified in the project documentation or the relevant technical regulations.

Unless the project documentation specifies otherwise, the value of the water-cement ratio for cement concrete mixes with reinforcement may be 0.70 at the most.

The consistency of the fresh cement concrete is not specified, but shall be such that the required properties of the placed fresh or hardened cement concrete can be obtained with the available means of transportation and compacting apparatus.

2.5.1.4.9.4 Initial production test and placement

The contractor shall verify and justify the specification for the cement concrete mix in production in the appropriate concrete plant, transport to the site and placement, when he obtains the approval of the engineer.

The location of the test placement shall be approved by the engineer on the agreed structure after verification of the prepared formwork, or substrate, and placement of the reinforcement steel.

In test production and placement the following shall be determined on the grounds of the examination by the contractor's internal control:
- the compliance of the deposit areas and the production plant for fresh cement concrete mixes, the compliance of the selected manner of transportation and placement equipment, all in the context of the requirements from these technical conditions;
- a sample of the mix shall be taken from the placement location for testing the characteristics of the fresh and hardened cement concrete;
- the compliance of the finishing of the visible surfaces of the cement concrete;
- the execution of joints;
- appropriate protection for the cement concrete surface; and
- levelness and height of the cement concrete.

If the contractor has previously already placed cement concrete under similar conditions and with similar means for mixing cement concrete, the results may be included as results of the initial production test and placement. This shall be decided on by the engineer.

2.5.1.4.9.5 Continuous production and placement

The engineer may approve the contractor’s execution of work on the basis of the results of prior testing. The execution approval includes the conditions for characteristics of the cement concrete mix and the conditions for conducting internal quality control foreseen by these technical conditions.

The approval for placement of the fresh cement concrete mix shall also contain special requirements for possible additional preparation of the surface, formwork or ground in the context of point 2.5.1.4.3 of these technical conditions.

Should any changes occur during production or placement of the fresh cement concrete mix, the contractor shall submit a proposal for changes to the engineer in writing.

2.5.1.4.9.6 Quality control on site

Quality control on site according to execution classes

Control in the 1st execution class is control that can be undertaken by the immediate contractor executing the works, i.e. inspection that shall be undertaken of all executed works – self-inspection.

Control in the 2nd execution class, apart from the self-inspection, also includes internal systematic and regular control by way of specified procedures within the company executing the works - internal systematic control.

For control in the 3rd class, apart from self-inspection and internal systematic control, undertaken by the contractor himself, broader control can be requested in compliance with the national regulations and/or the execution specification. This broader control can be conducted by an independent third party – independent control.

For structures in the 3rd execution class, internal systematic control shall include all the casting works relevant for the load bearing capacity and durability of the structure. This includes prior inspection of cleaning before casting, concrete, casting and curing.

If broader (or independent) control has been requested, its scope shall be at least equal to the scope determined for internal systematic control in the 2nd execution class.

For structures in the 2nd execution class, internal systematic control shall include all the casting works for significant structural elements, such as piers and beams. For other structural elements random probes shall be conducted, in a scope depending on the relevance of the structural element to the load-bearing capacity and durability.

2.5.1.4.9.7 Execution specification for concrete

Before commencing construction (casting) of any part of the structure, complete execution specifications relating to that part of the structure must exist.

The execution specifications shall include the following:
- reference to SRPS ENV 13670-1 and the national supplement if issued,
- reference to other governing national regulations and standards,
- specifications for concrete and casting the structure (concrete specification) containing information and requirements for casting the specific structure, prepared to supplement or adjust the requirements from the above mentioned documentation.
- plans and other technical documentation necessary for execution of the works.

Table 2.5.1.12 contains the control list of requirements and information to be included in the execution specification for the casting stage, as needed,

If relevant, procedures for the following shall also be defined:
- amendment of the previously agreed requirements;
-- classification, archiving and registration of the technical documents that were used in casting the concrete structure.

2.5.1.4.9.8 Quality plan

The quality plan included in the execution specification shall be available on site. The quality plan may refer to all the workds, or one comprehensive plan can have separate added plans for various stages and works that shall be executed.

2.5.1.4.9.9 Documentation in the casting record

Records shall be kept in accordance with table 2 for each execution quality class.

2.5.1.4.9.10 Internal quality control

The contractor shall present the scope of testing included in the internal quality control for placement of cement concrete, in compliance with the provisions of these technical conditions, to the engineer for approval. The minimum scope of internal quality control that must be conducted by the contractor or the authorized institution in the contractor's name is listed in table 2.5.1.11.

If during inspection of the quality of internal control the engineer finds larger deviations of results from the previous technological testing, he can increase the scope of minimum internal testing. If good results are consistently repeated, the engineer can decrease the scope of testing.

The quality of the placed cement concrete can also be determined on the basis of other recognized methods, but only in agreement with the engineer. In that case the criteria for evaluating the quality of placement shall be noted, as well as the manner and scope of conducting the testing. These criteria shall be approved by the engineer.

2.5.1.4.9.11 External quality control

The scope of testing included in external quality control that a third party conducts for the third party – an institution authorized by the Serbian accrediting body, as a rule has a ratio of 1:4 to the scope of testing included in internal control. The locations for sampling the cement concrete mix and the measurement locations for the internal and external quality control testing shall be selected at random.

Table 2.5.1.11: Minimum scope of testing included in internal quality control in placing cement concrete

Property of cement concrete	Testing frequency	Note	Testing procedure
- fresh cement concrete			
- volume weight			SRPS EN 12350-6
- temperature of fresh cement concrete		at every concrete testing in case of doubt regarding the quality of each mix	-
- consistency	at 20 m^3		SRPS EN 1235-2 to 5
- micropore content Internal freeze/thaw resistance of cement concrete (M)	at 20 m^3		SRPS EN 12350-7
- micropore content surface freeze/thaw resistance of cement concrete (MS)	at 5 m^3	each procured quantity	SRPS EN 12350-7
- hardened cement concrete			
- compressive strength	at 100 m^3	1x per day, no fewer than 3 samples for each concrete batch, or according to special provisions for each segment, vertical segment, section or structural element	SRPS EN 12390-3
- water impermeability	at 500 m^3	no fewer than 3 testings for cement concretes placed into structures from the same manufacturer in a specific section of road, procured from the same concrete plant.	SRPS EN 12390-8
- internal freeze/thaw resistance (M)	at 2000 m^3		SRPS CEN/TR 15177 (SRPS U.M1.016)
- surface freeze/thaw resistance (MS)	at 1000 m^3	no fewer than 3 testings for cement concretes placed into structures from the same manufacturer in a specific section of road, procured from the same concrete plant.	SRPS CEN/TS 12390-9 (SRPS U.M1.055)
- shrinkage (90 days) - creep - static modulus of elasticity	once per structure	cement concrete for prestressed superstructures and walls over 100 m long	SRPS U.M1.029 SRPS U.M1.027 SRPS U.M1.025

Table 2.5.1.12: Control list of information in the execution specification for casting

Chapter	Text
1 Scope and area of use	List all the special requirements of relevance for an individual structure
	List all the special requirements for lightweight concrete, other materials or special technologies, if necessary
	List all the requirements for concrete elements used as plant in construction
2 Reference to other standards	Add all governing national standards or regulations applicable on site
3 Definitions	Define the datum line for setting out the elements or structure being cast
4 Managing the execution of works	All the necessary technical information shall be set forth in detain in the execution specification
	List requirements relating to staff qualifications
	National regulations to be observed
	Include procedure for change of execution specification
	Requirements on classification of documents
	List whether a quality plan is required
	List the scope of special documentation, if required
	List the execution class and specify who is in charge of control
	List the provisions relating to control/inspection staff
	List all additional requirements regarding the manner of quality management, if necessary
	Select controls and testing at takeover of products with no CE markings or third party certificate
	Verify whether the scope of said controls/inspections is appropriate. If not, set additional requirements.
	List the manner of rectifying possible non-conformities if necessary

5 Casting	Verify whether all the required properties of the concrete are prescribed in compliance with SRPS EN 206-1 and the national standards or regulations applicable on the casting site
	List the smallest upper size of sieve D for concrete
	List whether a casting plan is required
	List whether test casting is required
	List whether a thicker layer of protection is necessary
	List whether sampling is required
	If shotcrete is used, the execution specification shall be in compliance with SRPS EN 14487-2
	If slip form is used, the details shall be compatible with the equipment
	If casting under water is required, the details shall be compatible with the casting method
	List whether early-age concrete should be protected from aggressive substances
	List the curing class to be implemented
	List possible special requirements for curing
	List whether special measures for decreasing the possibility of onset of cracks due to thermal shrinkage are required
	List possible requirements for surface finishing, if any
6 Geometric tolerances	Specify whether 2nd tolerance class is applicable
	Specify applicable special tolerances and elements
	Specify tolerances for cross-sections to be cast under water
	Specify requirements for surface of bearings with full plate contact
	Possible requirements regarding combination of structural tolerances and structural deformations
	List requirements for secondary lines

Table 2.5.1.13: Types of controls/inspections and documentation

Item/subject-matter	1st execution class	2nd execution class	3rd execution class
Type of control/ inspection	Visual inspection and random measurements	Visual inspection and systematic, as well as routine measurements of important parts	Visual inspection Detailed inspection of all the parts of relevance for the load-bearing capacity and durability of the structure
Inspecting authority	Self-inspection	Self-inspection Inspection in compliance with the construction procedures Possible additional requirements from the execution specification	Self-inspection Inspection in compliance with the construction procedures Additional requirements from the execution specification for constructing the structure
Scope	All works	Apart from self-inspection, systematic routine inspection of works shall also be conducted	Apart from self-inspection, systematic regular inspection of works shall also be conducted
Inspection report	Not required	Required	
Geometry of structure as executed to date	Not required	In compliance with execution specification	

Table 2.5.1.14 – Recommendations for determining execution class

Criterion for determining execution class	1st execution class	2nd execution class	3rd execution class
Type of structure	Simplest structures on roads	Bridges spanning up to 15 m Simpler structures on roads	Bridges spanning over 15 m Traffic infrastructure structures
Structural elements	Beams and slabs spanning up to 10 m Usual walls and piers Simple strip footings and isolated foundation	Beams and slabs spanning over 10 m Slim walls and piers Demanding shallow and deep foundations Vaults and arches	Extremely demanding shallow and deep foundations Arches spanning over 10 m

Criterion for determining execution class	1st execution class	2nd execution class	3rd execution class
		spanning up to 10 m Simpler prestressed elements	Prestressed elements
Building technology	Casting on site	Casting on site Building with precast products and elements	Casting on site Building with precast products and elements with special tolerances
Concrete strength class	Up to and including C25/30	All	All
Exposure classes	X0, XC1, XC2, (XF1, XA1, XM1)	All	All
Reinforcement	Reinforcing steel	Reinforcing steel and prestressing steel	Reinforcing steel and prestressing steel

2.5.1.4.9.12 Assessment of in-situ compressive strength of placed cement concrete

The procedure is intended for assessment of in-situ the compressive strength of the placed cement concrete in structures if samples were not taken for any reason or if the obtained test results were negative.
1
Assessment of in-situ for samples taken from the structure shall be conducted in compliance with SRPS EN 13791. The sample shall consist of no less than 3 cylinders, 100 mm in diameter and length.

If there are fewer than 15 samples, the obtained results can be evaluated by two procedures. If it is determined that the results obtained from samples taken from the structure are lower due to limited hydration of the cement concrete in the structure, the results may be corrected by correction factor γ = 1/0.85 (concrete curing coefficient).

Example:
$f_{ck,is,cube} = f_{cm,is} - 1.48\ S$ or (6)
$f_{ck,is,cube} = f_{cmin,is} + 4$
(7)

where:
- $f_{ck,is,cube}$ – characteristic strength of cube taken on site in MN/m^2
- S – standard deviation for n samples in MN/m^2; when $S<2\ MN/m^2$, S is taken to be $S=2\ MN/m^2$
- $F_{cmi,is}$ – arithmetic mean for strength for cylinders in MN/m^2
- F_{cmin} – lowest value of results for cylinders in MN/m^2

Example:
$f_{ck,is,cube} = f_{cm,is} - k$ or (8)
$f_{ck,is,cube} = f_{cmin} + 4$
(9)

where:
n – the number of samples
$k = 4\ MN/m^2$ for n = 10-14
$k = 5\ MN/m^2$ for n = 7 - 9
$k = 6\ MN/m^2$ for n = 3 - 6

2.5.1.4.9.13 Assessment of in-situ resistance to penetration of water under pressure

The procedure is intended for verifying the resistance of cement concrete to penetration of water under pressure if samples were not taken for any reason or if the obtained test results were negative

Assessment of in-situ of the resistance of cement concrete to penetration of water under pressure for samples taken from the structure shall be conducted in compliance

with SRPS EN 12390-8. The sample shall consist of 3 cylinders taken from the structure, each 150 mm in diameter and length

Permissible depth of water penetration in compliance with SRPS EN 12390-8 shall be:
V-I average 50 mm, maximum 65 mm,
V-II average 30 mm, maximum 40 mm,
V-III average 20 mm, maximum 25 mm.

2.5.1.4.9.14 Assessment of in-situ internal resistance of cement concrete to freeze/thaw attack with de-icing salts

The procedure is intended for assessment of in-situ of the resistance of cement concrete to freeze/thaw attack with de-icing salts if samples were not taken for any reason or if the obtained test results were negative.

The test sample consists of three cylinders 150 mm in diameter and 100 mm long.
Measurement for loss of mass should be conducted after 7±1, 14±1, 28±1, 42±1 and 56 freeze-thaw cycles.

Permissible loss of mass is specified in standard SRPS EN 12390-9,

2.5.1.4.9.15 Assessment of in-situ internal resistance of cement concrete to freeze/thaw attack

The procedure is intended for verification of the internal resistance of cement concrete to freeze/thaw attack if samples were not taken for any reason or if the obtained test results were negative.

Assessment of in-situ resistance of cement concrete to freeze/thaw attack on samples taken from the structure shall be conducted in compliance with standard SRPS CEN/TR 15177. The test sample consists of three cylinders 100 mm in diameter and 300 mm long

The dynamic modulus of elasticity is measured on the samples at every 7±1, 14±1, 28±1, 42±1 and 56 freeze-thaw cycles and compared to the results of the reference measurements conducted on saturated samples.

Permissible decrease of modulus of elasticity is 25%.

If the decrease of modulus of elasticity is less than or equal to 25% (average of three samples), the interior of the cement concrete can be characterized as resistant to freeze-thaw attacks.

2.5.1.4.10 Measurement and taking over the works

2.5.1.4.10.1 Measurement of the works

The executed works are measured in compliance with the general technical conditions and calculated in cubic meters.

All quantities shall be measured in the actual executed volume and according to the type of works executed within the quantities from the project documentation.

2.5.1.4.10.2 Taking over of works

The engineer shall take over the placed cement concrete in compliance with the quality requirements from these technical conditions and with the general technical conditions. All discovered deficiencies as compared to these requests shall be rectified by the contractor before continuing the works. If he should fail to do so, deductions shall be calculated for non-compliant quality of the executed works

2.5.1.4.11 Works calculation.

2.5.1.4.11.1 General

The executed works shall be calculated In accordance with the general technical conditions.

The quantities determined and taken over in accordance with the general technical conditions shall be calculated at the agreed unit prices.

The agreed unit price shall include all costs and activities necessary for completion of the works. The contractor shall not be entitled to seed additional payments.

2.5.1.4.11.2 Deductions due to non-compliant quality of the cement concrete

Quality of materials

Due to the required compliant quality of material for cement concrete, in the calculation of works there are no deductions for quality of material.

Quality of execution

Placed cement concrete shall be calculated:

- in the quantity specified in accordance with point 2.5.1.4.10.1 of these technical requirements
- according to the agreed unit prices,
- in compliance with the provisions of agreed general technical conditions.

In case of deficiencies in the quality of the placed cement concrete, the engineer may activate the provision of financial deductions.

The following bases shall be taken into account when evaluating the non-compliant quality of executed works and calculation of the deductions:

Insufficient compressive strength

Financial deductions shall be calculated according to the following formula:

$$FO = \frac{O}{100} \cdot K \cdot C \cdot PD \qquad (€)$$

where:
O – deviation from the threshold value, calculated according to the following equation:

$$O = \frac{f_{ck} - f_{ckd}}{f_{ck}} \cdot 100 \quad (\%)$$

f_{ck} prescribed (characteristic) compressive strength (MN/m^2)
f_{ckd} achieved (determined) characteristic compressive strength (MN/m^2)
K coefficient of impact on serviceability
C agreed unit price (€/m^3)
PD volume of deficiencies in executed works (m^3).

Determining the financial deduction for each individual non-compliant result of compressive strength testing of cement concrete shall be based on the basic required (threshold) values and the specified ultimate limit values $f_{cksm.}$

Example:

f_{ck} = 37 MN/m^2
f_{ckd} = 35.2 MN/m^2
f_{cksm} = 33.3 MN/m^2
K = 3
C = 100 €/m^3
PD = 50 m^3:

$$FO1 = \frac{37,0 - 35,2}{37,0} \cdot 3 \cdot 100 \cdot 50 = 750 \ €$$

FO = 750 €

Insufficient tensile strength at bending

Financial deductions shall be calculated according to the following formula:

$$FO = \frac{O}{100} \cdot K \cdot C \cdot PD \ (€)$$

where:
O – deviation from the threshold value, calculated according to the following equation:

$$O = \frac{f_{fk} - f_{fkd}}{f_{fk}} \cdot 100 \ (\%)$$

f_{fk}-prescribed (characteristic) tensile strength at bending,
f_{fkd}-achieved (characteristic) tensile strength at bending.

Determining the financial deduction for each individual non-compliant result of testing of tensile strength at bending of cement concrete shall be based on the basic required (threshold) values and the specified ultimate limit values $f_{cksm.}$

Example:

f_{fk} = 5 MN/m^2
f_{fksm} = 4 MN/m^2
f_{fkd} = 4.4 MN/m^2
K = 5
C = 100 €/m^3
PD = 150 m^3

$$FO1 = \frac{5,0 - 4,4}{5,0} \cdot 5 \cdot 100 \cdot 150 = 9.000 \ €$$

Insufficient internal resistance to freeze/thaw attack

Financial deductions shall be calculated according to the following formula:

$$FO = \frac{O}{100} \cdot K \cdot C \cdot PD \ (€)$$

where:
O – deviation from the threshold value, calculated according to the following equation:

$$O = \frac{0,75 - ZO_d}{0,75} \cdot 100 \ (\%)$$

where the ultimate limit value is zo_{sm} = 0.65

ZO_d - actual achieved ratio between E_{din} concrete samples exposed to the required number of cycles and E_{din} concrete samples not exposed to the freeze / thaw cycles
K - coefficient of impact on serviceability = 1
C - agreed unit price (€/m^3)

PD - volume of deficiencies in executed works (m^3)

Example:

ZO_d = 0.70,
K = 1,
C = 100 €/m^3
PD = 150 m^3

$$FO = \frac{0,75 - 0,70}{0,75} \cdot 1 \cdot 100 \cdot 150 = 1050 \ €$$

Insufficient surface resistance to freeze/thaw attack with de-icing salts

Financial deductions shall be calculated according to the following formula:

$$FO = \frac{O}{100} \cdot K \cdot C \cdot PD \quad \text{(KM)}$$

where:

O – deviation from the threshold value, calculated according to the following equation:

$$O = \frac{m_d - m_m}{m_m} \cdot 100 \quad (\%)$$

m_{sm} – ultimate limit value = 0.40 mg/mm^2 for XF4
m_m – permitted value for loss of mass during required testing cycle = 0.20 mmg/mm^2 for XF4
m_d - achieved (determined) value for loss of concrete mass during required freeze cycles (mg/mm^2)
K - coefficient of impact on serviceability
C - agreed unit price (€/m^3)
PD - volume of deficiencies in executed works (m^3)

For each overstepping $m_d > m_n$ protection of the surface of the cement concrete shall be executed.

Example:

m_d = 0.30 mg/mm^2
m_m = 0.20 mg/mm^2
K = 0.3
C = 100 €/m^3
PD = 150 m^3

$$FO = \frac{0,30 - 0,20}{0,2} \cdot 0,3 \cdot 100 \cdot 150 = 2.250 \ €$$

Insufficient water impermeability

Financial deductions shall be calculated according to the following formula:

$$FO = \frac{O}{100} \cdot K \cdot C \cdot PD \ (€)$$

where:

O – deviation from the threshold value, calculated according to the following equation:

$$O = \frac{e_{max.d} - e_{max.m}}{e_{max.m}} \cdot 100 \ (\%)$$

$e_{max.sm}$ – ultimate limit value for greatest depth of water penetration = $e_{max.m}$ + 2 cm
$e_{max.m}$ – permissible value for greatest depth of water penetration (cm)
$e_{max.d}$ - achieved (determined) value for greatest depth of water penetration (cm)
K coefficient of impact on serviceability = 0.3
C - agreed unit price (€/m^3)
PD - volume of deficiencies in executed works (m^3)

For each overstepping $e_{max.d} > e_{max.m}$ protection of the surface of the cement concrete shall be executed.

Example:

$e_{max.d}$ = 4.0 cm
$e_{max.m}$ = 3.0 cm
K = 0.3
C = 100 €/m^3
PD = 150 m^3

$$FO = \frac{4,0 - 3,0}{3,0} \cdot 0,3 \cdot 100 \cdot 150 = 1.485 \ €$$

Insufficient thickness of protective layer

Financial deductions shall be calculated according to the following formula

$$FO = f \cdot C \cdot PD \ (€)$$

where:

f - deduction coefficient dependent on O

$$O = \frac{h_n - h_{dop} - h_d}{h_n} \cdot 100 \ (\%)$$

h_n - planned thickness of protective layer (cm)
h_{dop} – permissible thickness deviation = 0.5 cm
h_d - achieved (determined) thickness of protective layer (cm)

The value of coefficient f shall be determined on the basis of table 2.5.1.15

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Table 2.5.1.5: Deficiency coefficients depending on deviation of the protective layer thickness from planned

O (%)	0.5	1	2	3	4	5	6	7	8	9	10
f	0.03	0.05	0.10	0.15	0.19	0.23	0.27	0.31	0.35	0.39	0.42

Financial deduction shall be determined for each individual protective layer thickness result based on the specified threshold/limit values.

Example:

h_n = 24 cm
h_d = 22.5 cm
C = 100 €/m^3
PD = 110 m^3

$$O = \frac{24{,}0 - 0{,}5 - 22{,}5}{24} \cdot 100 = 4{,}2\%$$

f = 0.20 (from table 2.5.1.15)

$$FO = 0{,}20 \cdot 100 \cdot 110 = 2.200 \quad €$$

Excessive unevenness

If individual unevenness on the protective layer of the cement concrete exceeds the threshold value, the financial deduction shall be calculated according to the following formula:

$$FO = \sum O_i^2 \cdot š \cdot K \cdot C$$

where:

$\sum O_i^2$ - sum of squares of unevenness deviations

š – width of the traffic lane in the place of measurement, including the border lane (m)

Example:

O_1 = 2 mm O_1^2 = 4
O_2 = 1 mm O_2^2 = 1
O_3 = 2 mm O_3^2 = 4
ΣO_i^2 = 9

K = 0,3
C = 100 €/m^3
š = 4.25 m

$$FO = 9 \cdot 0{,}3 \cdot 100 \cdot 4{,}25 = 1.147{,}50 \quad €$$

Unfulfilled requirements for visible concrete

Requirements for visible cement concrete

In evaluating the non-compliant quality of visible cement concrete the requirements for unevenness and surface cavities are taken into consideration.
In measuring unevenness the following deviations are permitted:

- under a 4.0 m measuring strip the permitted deviation is OD_m = 20 mm
- under a 2.5 m measuring strip the permitted deviation is OD_m = 16 mm.

In determining the surface cavities only pores with diameters ≥ 1 mm and ≤ 15 mm are taken into consideration. The permissible percentage of surface of such pores (on a measuring surface ≥ 50 x 50 cm) is 0.3%.

Calculation of deductions

Financial deductions shall be calculated according to the following formula:

$$FO = \left(\frac{O_R}{100} \cdot K_R \cdot PD_R + \frac{O_{PP}}{100} \cdot K_{PP} \cdot PD_{PP} \right) \cdot C$$

(€)

where:

O_R - deviation from the threshold value, calculated according to the following equation:

$$O_R = \frac{OD_d - OD_m}{OD_m} \cdot 100 \quad (\%)$$

OD_{sm} – ultimate limit value = OD_m + 4 mm
OD_m – permissible value of unevenness deviation relative to length of measuring strip (mm)
OD_d - achieved (determined) value of deviation (mm)
K_R - coefficient of impact on serviceability = 0.1
C - agreed unit price (€/m^3)
PD_R- volume of deficiencies in executed works - unevenness (m^3)

O_{PP} – deviation from the threshold value, calculated according to the following equation:

$$O_{PP} = \frac{PP_d - 0{,}3}{0{,}3} \cdot 100 \quad (\%)$$

PP_{sm} – ultimate limit value for percentage of surface pores (on measuring surface ≥ 50 x 50 cm) = 0.4%
PP_d - achieved (determined) value for percentage of surface pores (on measuring surface ≥ 50 x 50 cm) (%)
K_{PP} - coefficient of impact of surface pores on serviceability = 0.3
C - agreed unit price (€/m^3)
PD_{PP} - volume of deficiencies in executed works – surface pores (m^3)

Example:

OD_d = 22 mm
OD_m = 20 mm
K_R = 0.1
PD_R = 750 m^3
PP_d = 0.35%
PP_m = 0.30%
K_{PP} = 0.3
PD_{PP} = 1200 m^3
C = 100 €/m^3

$$FO = \left(\frac{22-20}{20} \cdot 0{,}1 \cdot 750 + \frac{0{,}35-0{,}30}{0{,}30} \cdot 0{,}3 \cdot 1200 \right) \cdot 100 = 6.750.....EUR$$

2.5.2 REINFORCEMENT STEEL

2.5.2.1 General

Reinforcement steel takes on its intended role only if prepared and placed properly and in compliance with the specified conditions and relevant design plans. This rule applies equally to both the simplest and the most demanding reinforcement works.

2.5.2.1.1 Description

Steel works constitute classic reinforcement of concrete structures, and include the following:
- leveling;
- cutting;
- bending steel wires, bars or meshes;
- assembly and ;
- placing to the prepared formwork.

When using steel for prestressing concrete structures, not all the said stages of works are necessarily required.

There are three types of reinforcement with steel:
- simple: single reinforcing across one field for slabs and plates, reinforcing for foundations, walls and ordinary pillars;
- medium demanding: single reinforcing across one field, reinforcing for continuous foundations and beams, arched walls and beams. ordinary frames and demanding pillars;
- demanding: double reinforcing across several fields for beams and slabs, reinforcing for skew frames and shells.

Conditions for injecting reinforcement steel for reinforcing prestressed structures are detailed in section 2.2.5.7 of these technical conditions.

2.5.2.2 Basic materials

The basic steel materials used for reinforcing structures in road building are as follows:
- smooth and ribbed steel;
- steel meshes;
- welded steel meshes;
- wires, bars and strands for prestressing;
- protective sheaths for prestressed steel strand cables;
- arches for tunnels; and
- anchors for tunnels (SN, IBO).

2.5.2.2.1 Reinforcing concrete structures

The following can be used for reinforcing concrete structures:
- smooth and ribbed steel wire (∅ ≤ 12 mm) and bars (∅ > 12 mm) with round cross-section and
- steel meshes (welded from wires or from stretched metal).

Smooth wires of soft steel of S235 and S275 quality have the following official diameters: 5, 6, 8, 10 and 12 mm.

Smooth bars of soft steel of S275 quality have the following official diameters: 14, 16, 18, 20, 22, 25, 28, 32 and 36 mm.

Ribbed wires and bars of high-quality hard steel of B500 B or C quality with transverse ribs with variable cross sections are used

with the following official diameters: 6, 8, 10, 12, 14, 16, 19, 22, 25, 28, 32, 36 and 40 mm.

Drawn steel wires for meshes with longitudinal and bi-directional load-bearing capacity have the following official diameters: 4.0, 4.2, 4.6, 5.0, 5.5, 6.0, 6.5, 7.0, 8.0, 8.5, 9.0, 10.0 and 12.0 mm.

2.5.2.2.2 Steel for prestressed concrete structures

For prestressed concrete structures only the following can be used for prestressing:
- smooth and profiled steel wire with round cross section;
- smooth and ribbed steel bars with round cross section
- steel strands (from smooth wires).

Steel wires, bars and strands for prestressing must be made of alloyed or unalloyed hot-rolled carbon steel.

The official diameters of the wires and bars used for prestressed concrete structures are as follows:
- smooth wire: 2.5, 3, 5, 7, 8, 10 and 12 mm
- profiled wire: 4, 5 and 7 mm
- smooth and ribbed bars: 14, 16, 20, 25, 28, 32, 36 and 40 mm
- steel strands from:
  - one or two smooth wires: diameter of each individual wire 2 to 4 mm,
  - seven smooth wires: nominal strand diameter 6, 4; 7, 9; 9.3; 11.0; 12.5 and 15.2 mm.

The appropriate devices for anchoring the prestressing steel shall also be required for prestressed structures.

2.5.2.2.3 Building underground and retaining structures in cohesionless materials

When building underground and retaining structures in cohesionless materials, the following can be used for strengthening the structure:
- steel anchors and nails;
- steel forepoling bars;
- steel arches; and
- steel formwork – tunnel panels.

During works the contractor can also use other materials for strengthening the structure (e.g. carbon fiber plates, glass fiber anchors), if it has previously been verified that these materials meet the requirements from the viewpoint of structure safety and durability and if their use is approved by the engineer.

2.5.2.2.4 Quality of materials

The quality of steel for reinforcing concrete structures, for prestressed concrete structures and for strengthening in building structures in cohesionless materials shall meet all the specified requirements.

The manufacturer shall be responsible for certification of the conformity of the steel or other material, while the internal control of the contractor executing the construction works and the external control of the client shall be responsible for the takeover.

2.5.2.2.4.1 Steel for reinforcing concrete

For reinforcing concrete in road structures, steel that conforms to the requirements of the standards listed in table 2.5.2.1 can be used.

Table 2.5.2.1: Types of reinforcement steel and technical regulations

Type of steel	Technical regulations
- smooth and ribbed	SRPS EN 10080, DIN 488,
- steel meshes;	SRPS EN 10080, DIN 488,
- welded steel bars	SRPS EN ISO 17660, SRPS EN 10080, DIN 488,

2.5.2.2.4.2 Steel for prestressing concrete

For prestressing concrete structures and anchoring retaining structures, anchoring in tunnels, and constructing other structures on roads, steel that conforms to the requirements of the standards listed in table 2.5.2.2 can be used.

Table 2.5.2.2: Types of prestressing steel and technical regulations

Type of steel	Technical regulations
- wires, bars strands for prestressing	SRPS EN 10138
- protective sheaths for prestressed steel strand cables	SRPS EN 523

2.5.2.2.4.3 Supporting tunnel vaults

For supporting tunnel vaults and building other underground structures on roads, steel that conforms to the requirements of the standards listed in table 2.5.2.3 can be used.

Table 2.5.2.3: Types of steel for supporting tunnel vaults and technical regulations

Type of steel	Technical regulations
- tunnel arches	DIN 21544, DIN 21545, SRPS EN 10025, NTS*
- tunnel anchors (SN, IBO)	Technical approval

Legend:

* NTS - national technical approval

2.5.2.2.4.4 Takeover of steel construction products

The internal control of the contractor executing the construction works and the external control of the client shall be responsible for the takeover of steel construction products.

The minimum scope of type of testing for individual types of products is specified in table 2.5.2.4.

Table 2.5.2.4: Minimum frequency of internal and external control testing at takeover of steel construction products

Type of steel	Mechanical properties	Chemical analysis	Frequency of internal control	Frequency of external control	Other control/inspection
smooth steel	Re, Rm, A10 (Agt), bending, return bending		1 testing / 20 tons	1 testing / 80 tons	
ribbed steel	Re, Rm, A10 (Agt), bending, return bending	C, Mn, Si, P, S, N, Cekv	1 testing / 20 tons	1 testing / 80 tons	
steel meshes	Rp0,2, Rm, Agt, bending, shear force	C, Mn, Si, P, S, N	1 testing / 20 tons	1 testing / 80 tons	
welded steel bars, smooth and ribbed	Rm, bending	C, Mn, Si, P, S, N	2 × testing for tensile strength / 150 welds 2 × testing for bending / 150 welds	2 × testing for tensile strength / 600 welds 2 × testing for bending / 600 welds	
wires, bars and strands for prestressing	Rp0,2, Rm, E, Agt Relaxation of steel *		1 testing / coil	- if all the final products for the structure are from one batch (up to 40 tons) 3 testings - if all the final products for the structure are from several batches at least 2 testing / 2 batches	- visual inspection of the surface (must be without flaws and corrosion damage) - coils must be protected from damage, contamination and corrosion
protective sheaths for prestressed steel strand cables	verification of dimensions	C, Mn, Si, P, S, N	1 sample / structure		
tunnel arches	Rp0,2, Rm, A5, toughness	C, Mn, Si, P, S, N	1 testing / 30 tons	1 testing / 120 tons	
tunnel anchors	- anchor as a whole Fm, bar ReH, Rm, A10 bar, connector, base plate and nut Brinell hardness, metallographic testing (as needed – e.g. in case of cast iron elements)	C, Mn, Si, P, S, N (for the bar, connector, base plate and nut separately)	1 testing / 200 pieces	1 testing / 800 pieces	* conducted in the certification stage

2.5.2.2.5 Method of execution

Bending the steel for reinforcing and prestressing concrete structures is usually detailed in the relevant design plans.

2.5.2.2.5.1 Forming - bending

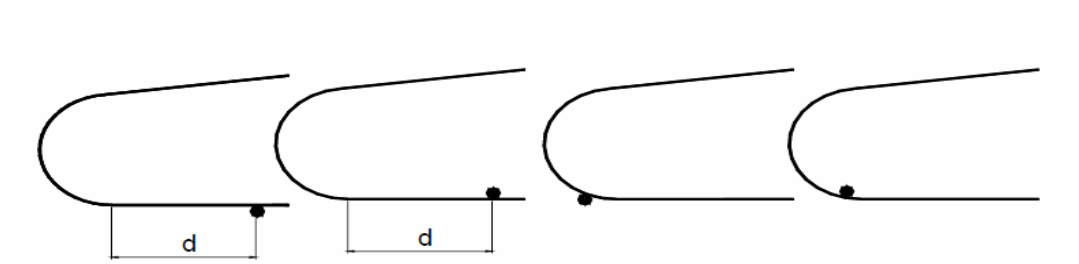
The smallest mandrel diameters for bending and executing hooks are listed in tables 2.5.2.5 and 2.5.2.6 for different types of wires, bars and welded steel meshes.

Table 2.5.2.5: The smallest mandrel diameters for bending and executing hooks for reinforcement bars

Reinforcement	Hooks, bends, loops		Bent bars		
	Bar diameter		Thinnest concrete cover, perpendicular to the plane of the curve		
	<20 mm	≥20 mm	>100 mm and >7Ø	>50 mm and >3Ø	≤50 mm and >3Ø
Smooth S 220	2.5 Ø	5 Ø	10 Ø	10 Ø	15 Ø
Ribbed B400, B500	4 Ø	7 Ø	10 Ø	15 Ø	20 Ø

Table 2.5.2.6: Smallest mandrel diameters for welded reinforcement and meshes

Smallest diameter of bending	
Welds outside the bend	Welds inside the bend



for d<4 Ø: smallest diameter of bending 20 Ø
for d≥4 Ø: table 2.5.2.5 applies

Standard hooks at the ends of smooth bars are semicircular (180°), and at the ends of stirrups are (135°). At the ends of ribbed steel wires and bars the hooks are by standard perpendicular (90°).

2.5.2.2.5.2 Positioning

The positioning of steel for reinforcing and prestressing concrete is detailed in the project documentation.

The horizontal or vertical spacing between parallel wires or bars:

- may not be less than 3 cm;
- must be at least equal to the diameter (thickness) of the bar;
- may not be less than 80% of the size of the largest grain in the cement concrete mix;
- must enable access of the appropriate device for compacting cement concrete.

If necessary wires or bars (no more than four) can be arranged in bundles without spacing between them. The diameter of the bundle

cannot exceed 44 mm. If the necessary conditions for efficient bonding and anchoring of steel wires and bars are provided, then bundles with larger diameters may be used. Such positioning shall be approved by the engineer.

2.5.2.2.5.3 Joints

Joints of steel wires, bars and meshes for reinforcement can be executed:
- with overlap;
- with overlap and hooks;
- by electric butt welding;
- welded crossbars.

The length of the joints with overlap is determined depending on the diameter of the wires or bars and the adhesion conditions, but may not be less than 20 cm.

The quality of wire or rod joints by welding shall be verified by previous testing.

The employed joining method must ensure the regulation safety.

Joining strands for prestressing concrete structures and concrete anchors for strengthening in building tunnels is not permitted as a rule, regardless of the fact that they are injected.

Joining steel arches, forepoling bars and formwork panels must be detailed in the project documentation. If this has not been done, the decision shall be made by the engineer.

2.5.2.2.5.4 Anchoring

Steel wires and bars can be anchored by:
- straight extensions;
- hooks;
- loops; and
- welded crossbars.

Reinforcement meshes are anchored without hooks, unless used for stirrups.

In preparing the project, the regulation conditions for anchoring of all the steel elements to be used for reinforcement shall be taken into consideration. The conditions for anchoring shall be listed in the project documentation.

If the contractor wishes to execute anchorage by a method not listed in the project documentation, he shall prove by testing that the safety factor for the anchorage is 1.8. Such a manner of anchoring may be employed only after approval by the engineer.

2.5.2.2.5.5 Prestressing

Prestressing of structures and individual elements shall be executed in compliance with the requirements from the technical documentation.

Prestressing may be executed only after the cement concrete has achieved the strength under stress foreseen by the project documentation.

The order of stressing the steel wires, bars or strands and the value of the stress forces shall comply with the values for stress forces set forth in the project documentation at all times. The prestressing record shall list the measured force and the stretch of the steel wire, bar or strand, as well as the stresses determined by direct measurement (if foreseen in the project documentation). See also SRSC chapter 2.5.4.

2.5.2.2.5.6 Protection cover

Steel reinforcement wires, bars and meshes are generally exposed to the actions of aggressive surroundings. These actions necessitate suitable thickness of the cement concrete protective cover, which shall be no less than 3.5 cm, or protective coating, if the steel wires, bars or meshes are outside of the concrete cross section.

The cement concrete cover over steel bars may not be thinner than the diameter of the sheaf of bars. If a cover thicker than 5 cm is required, this cover shall be reinforced by an additional thin steel mesh that shall be at least 2 cm from the outer surface of the cement concrete.

The necessary spacing between the steel wires, bars or reinforcement meshes and the formwork shall be ensured by the appropriate spacers, which must be permanent and ensure the stable position of the placed reinforcement.

The thickness of the cover is ensured by spacers such as e.g. point spacers as shown in figure 2.5.2.1, or linear spacers, made of fiber concrete, all in compliance with standard BS 7973-1:2001. With its form the point fiber concrete spacer ensures cover thickness of 4.5 cm and 3.5 cm, depending on the placement position. It has a hole ∅ 2.5 mm in the middle, for tying the spacer to the reinforcement.

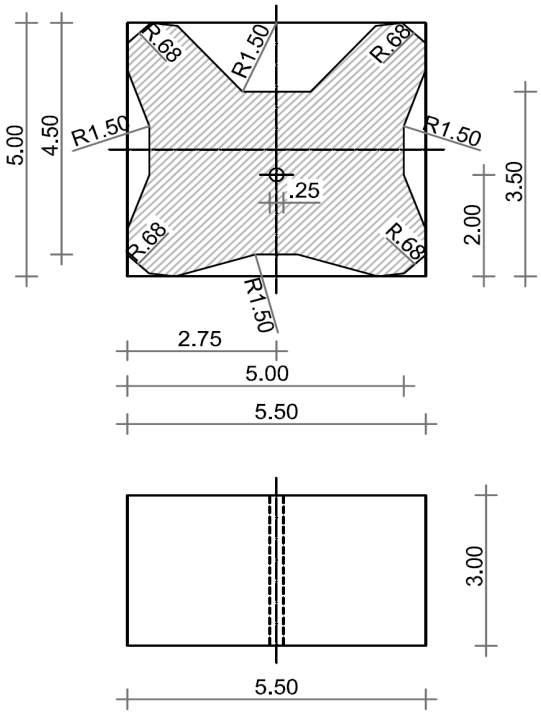


Figure 2.5.2.1: Spacer for proper distribution of the cover

Spacers are manufactured from high grade micro concrete with compressive strength no less than 50 MPa. Spacers are positioned according to figure 2.5.2.2. The distance between the spacers is 50 d in both directions (d = thickness of reinforcement bar closest to the formwork), and may not exceed 50 cm.

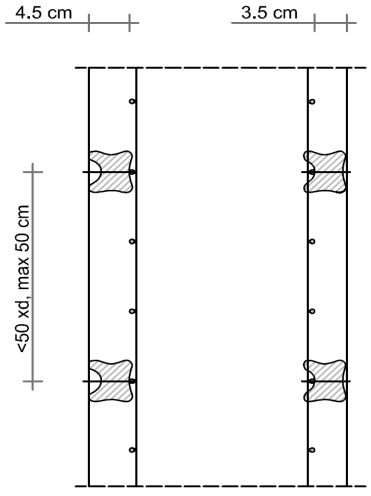


Figure 2.5.2.2: Method of placing spacers

A spacer is properly affixed with wire to the bar closest to the formwork so that it ensures stability of the reinforcement and the desired thickness of the cover.

The necessary cover thickness for the grout for steel strands for prestressing concrete structures and for steel anchors and nails for strengthening shall be defined in the project documentation.

The project documentation shall also specify the type of sheaths for protecting the steel wires, bars and prestressing sheaths in contact with the cement concrete during the execution of works.

2.5.2.2.6 Quality of execution

The contractor shall provide the engineer, in due time before commencing the execution of works, with a technological elaboration containing all the necessary proof of origin and quality for all the steel elements foreseen for reinforcement according to the project documentation or these technical conditions.

All the steel elements for reinforcement and strengthening shall be built in according to the solutions from the project documentation and the requirements from these technical conditions.

2.5.2.2.7 Verification of quality of execution

Before the placement of cement concrete and grout mass commences, the engineer shall verify the quality of forming (bending) and the method of positioning, joining, anchoring and protecting the steel elements for reinforcement according to the requirements of the project documentation and these technical conditions. The surface of the placed steel reinforcement elements must be clean. Only partial surface rust is permitted.

Steel bars shall be affixed in a manner that ensures their stability against movement or additional bending.

All deficiencies shall be rectified by the contractor before commencement or continuation of works.

The scope of internal and external control of the steel reinforcement and strengthening elements shall be adapted to the specific conditions of use and the conditions of the relevant regulations.

The internal control shall verify all the specified properties of:

- steel wires, bars and strands at every 20 tons of steel of the same dimensions and origin by 5 tested samples;
- steel reinforcement meshes at every 1% of the number of supplied meshes by the appropriate number of samples for individual testing;
- steel ribs arches, forepoling bars and formwork panels at every 20 tons of steel by three testing samples.

The proposed testing program for internal quality control for each structure shall be verified by the engineer.

The scope of testing by external quality control shall be determined by the engineer in a ratio of 1:4 to the internal control testing.

Assessment of conformity shall be conducted by a third party – institute, the duties of which shall depend on the specific type of reinforcement of strengthening.

Certification of internal production control, product certification and issuing certificates of conformity may be conducted only by a legal entity which is accredited for conducting the works of certification according to the standard SRPS EN 45011 with the Accrediting body of Serbia.

2.5.2.2.8 Measurement and taking over the works

The executed works shall be measured in compliance with the procedure from the general technical conditions and calculated in the appropriate units of measure.

All quantities shall be measured in the actual executed volume and according to the type of works executed within the quantities from the project documentation.

Built-in reinforcement and strengthening steel shall be taken over by the engineer in accordance with the requirements and quality from these technical conditions and with the general technical conditions. All determined deficiencies as compared to said requirements shall be rectified by the contractor before continuation of works.

2.5.2.2.9 Works calculation.

2.5.2.2.9.1 General

The executed works shall be calculated according to the procedure from the general technical conditions.

The quantities determined and taken over under point 2.5.2.2.8 shall be calculated according to the agreed unit prices.

The agreed unit price shall include all costs and activities necessary for full completion of the works. The contractor shall not be entitled to seek additional payments.

In exceptional cases reinforcement steel may be included in the unit price for a cubic meter of cement concrete. Such calculation method shall be approved by the engineer.

2.5.2.2.9.2 Deductions due to non-compliant quality

If the built-in reinforcement steel is of the specified or appropriate quality, in the calculation of works there are no deductions for quality.

If the contractor builds in reinforcement and strengthening steel that does not comply with the requirements under point 2.5.2.2.4 of these technical conditions, the manner of calculation shall be decided on by the engineer. The engineer shall be entitled to refuse takeover of the entire executed works.

If the contractor fails to ensure the required quality of works in compliance with point 2.5.2.2.6 of these technical conditions, the manner of calculation shall be decided on by the engineer.

2.5.3 FORMWORK

2.5.3.1 Support elements

2.5.3.1.1 Description

Scaffolds and formworks, as well as their supports and bases, must be designed and constructed so that they are:
- Able to withstand any unforeseen influence to which they may be subjected during the construction process,
- Strong enough to guarantee achieving of prescribed structural tolerances and harmonize structural element integrity.

Form, function, appearance and durability of the permanent concrete structure should not be undermined or corrupted by use of scaffolds, formwork and auxiliary supports, or by their removal.

Bearing structures and formwork must meet SRPS ENV 13670-1 standards or there must be a proof of their adequacy for the intended use.

Scaffolds and formworks that meet European standards for systems of temporary devices (SRPS EN 12812, SRPS EN 12813 and SRPS EN 12811-1)° meet the requirements of these specifications.

2.5.3.1.2 Basic materials

All materials can be used if their use meets the structural requirements provided in SRPS ENV 13670-1 standard. Material must meet applicable standards for the product, i.e. if there are none, material can be used if properties of the material are taken into account.

2.5.3.1.3 Quality of materials

Quality of all used materials must meet the requirements from the project documentation or corresponding records of the contractor (formwork design plans).

Adequacy of chosen materials and processes must be proven by static calculation and previous installation of the part of scaffolds.

2.5.3.1.4 Method of Execution

2.5.3.1.4.1 Design and installation of bearing structure

If execution specification requires method description, adopted project parameters should be specified, i.e. project execution class and scaffolds assembly and dismantling procedure should be described and this also includes auxiliary supports. Description should specify requirements for handling, installation, extension, loading, dismantling, lowering and disassembly.

Scaffolds design must take into account deformations before and after casting in order to prevent harmful cracks in early age concrete.

Regarding the scaffolds basis, elastic deformation of concrete during subsequent loading should not be overlooked.

If the final permanent structure design requires supporting of the part of structure, while the furthest parts of the support structure that also include embankments are incomplete, such requirements should be specified in the execution specification.

2.5.3.1.4.2 Removal of bearing structure

Bearing structure, temporary supports and formwork should not be removed until the concrete achieves necessary strength in order to:
- Prevent damage to the surface that can occur during lining,
- Prevent transfer of impacts that in this phase affect concrete element,
- Prevent deformations that are greater than permitted which are set out by this standard or in the execution specification,
- Prevent damages caused by climatic influences.

Removal of formwork should be done so that in the process, structure is not exposed to impacts and stress, with purpose of avoiding damages to permanent structure.

Scaffolds should be unloaded in sequence which guarantees that other elements of the scaffolds or any permanent support structure should not be overloaded in the process. During unloading and disassembly, stability of building structure and formwork should be preserved.

Regarding the use of auxiliary and/or re-installed supports, description of procedure or execution specification should contain detailed removal schedule.

2.5.3.1.5 Verification of quality of execution

Quality of all materials used must meet the requirements specified in project documentation or corresponding records of the contractor (formwork design plans).

Completed work is taken over by the technologist - formwork designer, before being taken over by the competent engineer at the construction site. Observed condition is entered into control sheet and construction journal.

2.5.3.1.6 Measurement and taking over the works

2.5.3.1.6.1 Measurement of the works

Completed work should be measured in accordance with the SRCS, Section 1.3 of Technical conditions and calculated in proper measuring units.

All quantities must measure actually completed volume and type of work specified in the priced bill of quantities of the project documentation.

2.5.3.1.6.2 Taking over of works

Completed work on scaffolds should be taken over by the engineer according to quality requirements provided in these technical requirements and in Section SRCS 1.3. The contractor is obliged to eliminate all deficiencies identified in relation to these requirements.

2.5.3.1.7 Works calculation

2.5.3.1.7.1 General

Completed work should be calculated in accordance with SRCS Section 1.3 of Technical Conditions.

Quantities should be calculated according to unit prices in the contract.

Unit prices in the contract must include all services required for completion of works. Contractor does not have the right to consequently require additional payments.

2.5.3.1.7.2 Deductions due to non-compliant quality

Quality of materials

There are no deductions for the quality of material in the works calculation in case of adequate quality of materials used for works on the scaffolds.

If contractor applies material that does not meet requirements of these technical conditions, the engineer will decide on the method of calculation.

Quality of execution

If contractor does not guarantee required quality of construction work, the engineer will decide on method of calculation.

2.5.3.2 Formwork boards

2.5.3.2.1 Description

Formwork made of boards is different from formwork made of panels. Wooden panels require completely smooth surface without any hems. It is preferred that on a particular structural element (e.g. superstructure, abutments and piers) only one type of formwork is applied. Typical dimensions of panels are 50/200/2.5 cm. Joints between panels should be such that the panels do not tilt over each other.

On formwork made of boards, dimensions of all boards must be identical. Formwork boards should be of the same form and size. The same material that was used for formwork should be used for making angles and outer edges. Direction of installation must be the same for all elements of the formwork, either if it is made of panels or boards. All corners should be cut out. Please also see SRDM, Section 9.12.8.

2.5.3.2.2 Basic materials

All materials can be used if their usage meets structural requirements provided in SRPS ENV 13670-1 standard.

Material must meet applicable standards for the product, i.e. if there are none, material can be used only if its properties are taken into account.

2.5.3.2.2.1 Multilayered connected plywood

Composition and conditions for specific types of plywood are set out in SRPS EN 636 standards. It should be noted that outer protective layers could be UV unstable (e.g. polyphenols) and therefore adequacy of observed surface must be examined, particularly in relation to differences in colour shades and stains on the concrete surface.

2.5.3.2.2.2 Multilayered plywood coated with special layer

Composition of this panel type is improved by an outer protective layer made of durable materials (e.g. polypropylene), which makes it resistant to weather conditions and suitable for reusing as panel formwork.

2.5.3.2.3 Method of execution

2.5.3.2.3.1 Design and installation of formwork

If execution specification requires method description, it should also contain supporting, assembly and disassembly procedures. It should specify requirements for handling, installation, extension, loading, dismantling, lowering and disassembly.

Formwork must hold cement concrete in required form until it becomes sufficiently hard.

Formwork and connections between panels or boards must be tight enough to prevent loss of fine parts.

Formwork that can absorb significant quantities of water from the cement concrete or facilitate its evaporation should be adequately processed in order to reduce water drain from the cement concrete unless this was its intended use.

Formwork's interior surface should be clean. If execution specification requires that cement concrete surfaces made with formworks should be visible, surface must be processed so that desired surface finish can be achieved.

If final permanent structure design requires special processing of the surface, it should be specified in the execution specification.

Formwork must not exceed limits of elastic deformation during subsequent stressing.

If slip formwork is used, system design should take into account properties of formwork material and envisage everything that is necessary for mastering the building geometry.

2.5.3.2.3.2 Embedded elements and components built in the formwork

Temporarily embedded elements for formwork fastening, such as wedges, pipes and similar objects that will be cast and embedded as components:

- Must be sufficiently strongly fastened to remain in desired position during casting,
- Must be properly protected from corrosion,
- Must be sufficiently hard and strong in order to keep the shape during casting,
- Must be covered with prescribed concrete protective layer unless the surface is not treated,
- Must not cause irreversible impact on the structure,
- Must not adversely react with the cement concrete, reinforcement and steel for prestressing,
- Must not leave stains on the treated surface that was prescribed,
- Must not deteriorate functionality and durability of structural elements,
- Must not prevent proper incorporation and hardening of fresh concrete.

Recesses and cavities that are used for temporary structures should be filled and treated with material that has the same properties as surrounding concrete, except if function of elements is such that they can remain exposed or if it is specified otherwise.

2.5.3.2.4 Verification of quality of execution

Quality of all materials used must meet the requirements specified in project documentation or corresponding records of the contractor (formwork design plans).

2.5.3.2.5 Measurement and taking over the works

2.5.3.2.5.1 Measurement of the works

Completed work should be measured in accordance with the SRCS, provision 1.3 of Technical Conditions and calculated in proper measuring units.

All quantities must measure actually completed volume and type of work specified in the priced bill of quantities of the project documentation.

2.5.3.2.5.2 Taking over of works

Completed work on the structure should be taken over by the engineer according to quality requirements provided in these technical requirements and SRCS 1.3 provisions. The contractor is obliged to eliminate all deficiencies identified in relation to these requirements.

2.5.3.2.6 Works calculation

2.5.3.2.6.1 General

Completed work should be calculated in accordance with SRCS, Section 1.3 of Technical Conditions.

Quantities should be calculated according to unit prices in the contract.

Unit prices in the contract must include all services required for completion of works. Contractor does not have the right to consequently require additional payments.

2.5.3.2.7 Deductions due to non-compliant quality

2.5.3.2.7.1 Quality of Materials

There are no deductions for the quality of material in the works calculation in case that material of adequate quality was applied in works on the scaffolds.

If contractor applies material that does not meet requirements of these technical conditions, the engineer will decide on the method of calculation.

2.5.3.2.7.2 Quality of execution

If contractor does not guarantee required quality of construction work, the engineer will decide on the method of calculation.

2.5.4 PRESTRESSING

2.5.4.1 Introduction

2.5.4.1.1 Description

These technical conditions include general requirements for production of concrete structures in the prestressing phase.

It is assumed that all special requests that are important for casting of a particular structure will be stated in the execution specification.

Requirements apply to building structures made of prestressed concrete, particularly:
- Structures connected to pre-tensioned cables,
- Structures connected to post-tensioned cables,
- Structures unconnected to post-tensioned cables within or outside the cross section.

2.5.4.1.2 Reference standards

Existing technical conditions include EN standards. The latest versions are the most relevant for application:
- SRPS ENV 13670-1 – Execution of concrete structures - Part 1: General
- EN 1990, Eurocode - Basis of structural design.
- EN 1992-1-1, Eurocode 2: Design of concrete structures - Part 1-1: General rules and rules for buildings.
- CWA 14646:2003 – Requirements for the installation of post-tensioning kits for prestressing of structures and qualification of the specialist company and its personnel
- ETAG 013- Guideline for European technical approval of post-tensioning kits for prestressing of structures
- SRPS EN 10138-1- Steel for the prestressing of concrete - Part 1: General requirements
- SRPS EN 10080 – Steel for the reinforcement of concrete – Weldable reinforcing steel – General
- SRPS EN 10025 – Hot-rolled products of structural steel – Technical delivery conditions for non-alloy structural steels
- SRPS EN 523 - Steel strip sheaths for prestressing tendons – Terminology, requirements, quality control
- SRPS EN 10255 - Non-alloy steel tubes suitable for welding and threading– Technical delivery conditions
- SRPS EN 446 - Grout for prestressing tendons – Grouting procedures
- SRPS EN 934-4 - Admixtures for concrete, mortar and grout - Part 4: Admixtures for grout for prestressing tendons - Definitions, requirements, conformity, marking and labelling
- SRPS EN 10204 – Metallic products - Types of inspection documents
- SRCS 2.5.2 – Reinforcement steel
- SRCS 2.5.11.3 – Geometric tolerances for concrete structures

2.5.4.1.3 Terminology

Anchorage (anker) is a mechanical device that usually consists of several components, designed to retain stress in a tensioned element-cable and to transfer loads to the structure.

Coupling (spojnica) is a device that connects adjacent parts of cables.

Deviator (devijator) is a structural element through which external cables pass and transfer loads to the structure.

Filling material (materijal za punjenje) is a material used to completely fill the space around tensioning elements in the duct, in order to provide protection from corrosion and/or connection with the structure. Cement filling is often called mortar or grout.

Cables (kablovi) are a single or a set of tensioning elements used for prestressing of the structure, including necessary protection and anchors.

Execution specification (specifikacija za izradu) is a document which consists of all plans, technical information and conditions required for the execution of a particular design. It includes specification for constructing structures that supplements and further defines requirements of the European standards and it also refers to national regulations that must be taken into account.

2.5.4.1.4 Abbreviations used

SRCS – Serbian Road Construction Specifications

SRDM – Serbian Road Design Manual

ETAG – European Technical Approval Guideline

ETA - European Technical Approval

2.5.4.2 Requirements

2.5.4.2.1 Prestressing materials

2.5.4.2.1.1 Systems for post-tensioning

Systems for post-tensioning must have European Technical Approval (ETA) and must comply with requirements set out in the execution specification.

All parts of the system for post-tensioning must be compatible and must come from the same prestressing system. Guidelines with requirements for post-tensioned cables are given in European Technical Approval Guideline ETAG 013.

2.5.4.2.1.2 Protective sheaths

Protective sheaths that are made of steel strips must comply with SRPS EN 523.

Protective sheaths made of materials other than steel, must comply with European Technical Approval for prestressing system used.

2.5.4.2.1.3 Tensioning elements

Prestressing steel (wires, bundles, bars) must comply with SRPS EN 10138 and other requirements provided in the execution specification.

Materials for prestressing other than steel must comply with requirements provided in the execution specification. Please also see SRCS 2.5.2.

2.5.4.2.1.4 Elements of anchors and related accessories

Prestressing system anchor must have components that are specified in European Technical Approval (ETA). Please see SRCS 2.5.2.

2.5.4.2.1.5 Cable supports

Cable supports must not adversely affect steel and concrete and must be sufficiently rigid in order to provide stable fixation of cables in required position during casting and they also must not damage protective sheaths.

Distances between supports must ensure compliance of protective sheaths with required lines and heights.

2.5.4.2.1.6 Cement grout

Grout for filling of ducts and anchors must comply with SRPS EN 447 / SRPS EN 446.

2.5.4.2.1.7 Grease, wax and other products

Grease or wax for filling of ducts and anchors of unsupported cables must comply with requirements of the European Technical Approval (ETA).

2.5.4.3 Test methods

2.5.4.3.1 Testing of materials – components of the prestressing system

Actual physical properties of tested components (mechanical, chemical, metallurgical, geometrical, etc. as relevant) are determined and documented and must comply with ETA specifications. For all types of tests please also see ETAG013.

2.5.4.3.2 Testing of prestressing systems

Testing of prestressing systems must be documented with a report that includes the following:

- Statement signed by the laboratory or body that performed testing or witnessed that tests were performed in accordance with ETAG013.
- Certificates for all relevant materials confirming the compliance to corresponding specifications. Actual properties of components (mechanical, chemical, metallurgical, geometric, etc. as relevant) at the time of testing and for the materials from which they were produced. This particularly includes tightening elements, anchor components, ducts, fillings, reinforcement and concrete,
- Equipment certificates and device calibration certificates (every 6 months),
- Descriptions and drawings of samples in actual dimensions,
- Descriptions and drawings of measuring equipment with calibration certificates,
- Detailed descriptions of testing procedures,
- Records for all measurements and observations,
- Photographs of samples before, during and after the tests,
- Test date and location,
- Full names of persons responsible for testing and their signature,

- All tests for obtaining of ETA recorded in the report with remarks whether test was successful or not.

2.5.4.4 Compliance control

System of compliance certification that was set out by the European Commission and the mandate 98/456/EC is the 1+ system with additional testing of samples, described in Council Directive (89/106/EEC), Annex III, and it specifies:

- Tasks for the manufacturer: internal production control. Further testing of samples taken at the factory by the manufacturer in accordance with prescribed test plan,
- Tasks for the Institute: Initial typical product testing and initial examination of factory and factory production control, continuous monitoring, assessment and approval of internal production control and additional sample tests.

2.5.4.4.1 Internal production control

Manufacturer is performing a continuous internal control of production. All the elements, requirements and regulations adopted by the manufacturer must be systematically documented in a manner and form of written procedures. This control system ensures that the prestressing system is in compliance with European Technical Approval (ETA).

Internal production control is set out by the test plan that addresses the following aspects:

- Production,
- Distribution and delivery on the site.

Control system must comply with SRPS EN ISO 9001 standard.

2.5.4.4.2 Internal control on the site

Contractor must have a certified quality system according to SRPS EN ISO 9001, taking into account the requirements of the SRPS ENV 13670-1 standards for the construction of concrete structures, the section on prestressing.

Sampling plan and test plan for the strands and other parts of the concrete prestressing system must be prepared and applied to all properties that are controlled. This is decided by the engineer.

2.5.4.4.3 Compliance assessment

Assessment of compliance must be performed by the third party - Institute where tasks depend on the specific type of prestressing system.

Certification of internal production control, product certification and issuance of the Certificate of Conformity may be conducted only by a legal entity which is accredited for conducting the works of certification according to the standard SRPS EN 45011 with the Accrediting body of Serbia.

2.5.4.4.4 Measures in the event of non-compliance

If the control detects non-compliance, adequate response is required to ensure that structure is able to respond as planned.

The following aspects should be analyzed in the following order:

- Consequences of non-compliance on the future execution of works and achieving the purpose set out in the project,
- Measures required in order to provide element's acceptability,
- Whether element that cannot be fixed should be rejected or replaced.

If the execution specification requires elimination of non-conformity, it should be done in accordance with the procedure set out in the execution specification or an agreement on this issue should be reached.

2.5.4.4.5 Execution classes

Supervision and control of the works must ensure that cable prestressing is done in accordance with the execution specification for prestressing (prestressing plan).

In relation to this, control includes examination of compliance of properties for the prestressing system embedded parts that will be used, as well as control of the execution of works.

Requirements for quality management are set out by:

- 2nd execution class or
- 3rd execution class.

Execution class (Table 2.5.4.2) may refer to the structure as a whole, the components of structure or specific technology of prestressing applied in the execution of works.

Execution class that should be applied must be specified in the execution specification. Please see Table 2.5.4.3.

2.5.4.4.6 Control of prestressing per execution class

The control in 2nd execution class, apart from self-control must also include internal systematic and routine control through specified and established procedures in the company that executes the works - internal systematic control.

The control in the 3rd execution class, apart from self-control and internal systematic control performed by the contractor may also require a wider control in accordance with the state regulations and/or execution specification. This more complete control can be performed by other company - independent control – Institute (third party – please also see Section 2.5.4.4.3).

2.5.4.5 Technical documentation

2.5.4.5.1 Technical documentation upon delivery

In order to perform compliance assessment in the construction phase and control the quality of works, it is necessary to collect at the delivery from manufacturer detailed information about technical documentation. This information includes:
- ETA approvals for specifically chosen prestressing system,
- Other relevant information (results of manufacturer's internal control for the specific delivery of material).

This information is required so that delivered products would comply with ETA and their properties would remain unchanged during transport and delivery to the site.

Provisions related to specified test plan for the prestressing system are also provided in ETAG 013.

2.5.4.5.2 Execution specification (prestressing plan)

Before the beginning of construction works, a complete execution specification is required.

Execution specification should include the following items:
- Reference to SRPS ENV 13670-1,
- Reference to other relevant state regulations and standards,
- Prestressing specification (prestressing plan) that contains information and requirements for prestressing of particular element and is made in order to supplement or adapt requirements from the above mentioned documents,
- Plans and other technical documents required for execution of works.

Table 2.5.4.1 contains a checklist of requirements and information to be included, as necessary, in the prestressing phase execution specification.

If relevant, procedures should be specified for:
- Change of previously agreed requirements,
- Distribution, archiving and registration of technical documents that were used during prestressing of concrete structure.

2.5.4.5.3 Prestressed cables

Prestressing plan must include:
- Specific sequence of tensioning,
- Pressure in the press and appropriate force in the press that needs to be achieved,
- Minimum and maximum allowed stress in the cables and their seating in the anchor,
- Required strength of concrete when the prestressing force is released.

2.5.4.5.4 Post-tensioned connected cables

Prestressing plan must include:
- Planned prestressing system,
- Type and class of prestressing steel,
- Number of bars, wires or bundles in each cable,
- Required firmness of concrete during prestressing,
- Consecutive sequence of cable prestressing and requirements for cable prestressing in phases,
- Design prestressing force and force in the press, as well as elongation of cables,
- Anticipated seating at anchors,
- Required partial or full release of supporting scaffolds.

2.5.4.5.5 Quality plan

Quality plan, which is part of the execution specification, must be available on the construction site. Quality plan may apply either to all works or one plan can contain separate plans for individual phases and works that need to be done.

2.5.4.5.6 Documentation of prestressing records

Records should be made according to Table 2.5.4.2, for particular execution quality class, and especially for:
- Verification of the required firmness of prestressing concrete,
- Type of press used,
- Measured force in the press and elongation of the cable in every phase of prestressing,
- The observed seating,
- Any serious deviation from the design force of prestressing or elongation,
- Release of the support scaffolds, if required.

2.5.4.6 Execution of prestressing

2.5.4.6.1 Installation of cables

Cables should be assembled, installed and fixed in accordance with the European Technical Approval (ETA) and as set out in the execution specification, so that the line of their spreading should be smooth, without any hanging parts and bends, and within permitted tolerances (please see SRCS Section 2.5.7.3).

The type and class of prestressing steel and documentation on origin of all components should be recorded in the inspection report documentation.

Welding of prestressing steel or anchors is not permitted. Autogenic cutting or welding of steel in vicinity of prestressing steel is not permitted, except under conditions stated in the execution specification. Welding of local reinforcement in the area of anchors, anchor plates and spot welding is not permitted, except under conditions stated in the execution specification.

All joints in protective sheaths, anchors and couplings must be sealed watertight.

Twisting and interlacing of bundles during assembling and installation should be prevented.

2.5.4.6.2 Tensioning

Tensioning must be performed in accordance with the prestressing plan prepared and approved by an engineer. Force (pressure on the manometer) and elongation should be recorded in documentation of the inspection reports. The greatest force for each system is set out in ETA.

Written instructions for prestressing must be available on the construction site.

Anchors on the prestressing side and on the anchor side should be shown in the drawings. Equipment for prestressing that complies with European Technical Approval (ETA) for specific system of prestressing should be chosen.

At the construction site before the prestressing, all relevant reports on calibration of devices for measuring of force (not older than 6 months) should be available.

Entry and/or transfer of the prestressing force to the structure is permitted only if strength of concrete is equal to or greater than the minimal compressive strength specified in the execution specification. For the particular prestressing system, a minimal required compressive strength of concrete which allows full tensioning of cables is indicated in ETA.

Results from the prestressing program and compliance or non-compliance with requirements should be noted in the inspection report.

2.5.4.6.3 Measures of protection against corrosion, freezing, damage

Written instructions for preparation and execution of measures for protection against corrosion, freezing and mechanical damages should be made.

To prevent penetration of water or excessive moisture in the cable sheaths, installation time must be limited, in the period between prestressing and grouting to:
- Up to 12 weeks between the production of cables and grouting,
- Up to 4 weeks in the formwork before the casting,
- Approximately 2 weeks in the prestressed form during severe exposure / in severe environment, before protective measures are implemented. In mild exposure / in mild environments, this deadline may be extended to 4 weeks,
- If the above mentioned period between prestressing and protection of filling material is exceeded, during this time a temporary protection should be implemented by an approved method.

Proper protective measures include the use of approved, water soluble oils or blowing dry air through protective sheaths in appropriate intervals.

Equipment for filling of cable sheaths with filling material must comply with SRPS EN 446 and the type that is permitted by European Technical Approval (ETAG013) should be chosen.

Results for the control and compliance with protection requirements should be noted in the inspection report.

Areas of anchors and protective covers must be protected just as well as cables.

If permanent protection cannot be implemented in time after installation and prestressing of cables, temporary protective measures should be applied (please see SRPS EN 446).

2.5.4.6.4 Filling with cement grout

The process of mixing (dosage, w/c, ratios, procedure, time) must comply with SRPS EN 446 and SRPS EN 447.

Filling with the cement grout must be carried out in accordance with SRPS EN 446. If filling after prestressing cannot be completed in time, it is necessary to implement temporary measures of protection that will not harm steel and/or filling compound. It is necessary to check whether reduction of adhesion due to temporary measures of protection is acceptable for the structure design.

2.5.4.6.5 Filling with grease

Injection of grease or wax must run continuously and evenly.

Volume of injected mass must be comparable with theoretical volume of cavity in the cable. Change of volume due to temperature should be taken into account.

After final injection, the accidental loss of grease or wax from the cable sheath should be prevented by sealing under pressure.

Materials, fittings and equipment must comply with temperature range required for injection of grease or wax. For work at higher temperatures, a special security measures might be required.

2.5.4.6.6 Sealing

After filling, sealing of the anchors must be completed and this provides protection from corrosion, and is equal to protection of cables (e.g. corresponding thickness of dense concrete with low permeability or the cover or combined measures).

Area of the anchor should be protected from saturation.

All plugs and openings for inlet and outlet of grout must be properly sealed and protected.

Table 2.5.4.1: Checklist of information in the execution specification for prestressing

Chapter	Text
1 Scope and area of use	List all the special requirements of relevance for the particular prestressed structure
2 Reference to other standards	Add all governing national standards or regulations applicable on site
3 Management the execution of works	All the necessary technical information shall be set forth in detail in the execution specification
	List requirements relating to staff qualifications
	National regulations to be observed

Chapter	Text
	Include procedure for change of execution specification
	Requirements on classification of documents
	List whether a quality plan is required
	List the scope of special documentation, if required
	List the execution class and specify who is in charge of control
	List the provisions relating to control/inspection staff
	List all additional requirements regarding the manner of quality management, if necessary
	Select controls and testing at takeover of products with no CE markings or third party certificate
	Verify whether the scope of said controls/inspections is appropriate. If not, set additional requirements.
	List the manner of rectifying possible non-conformities if necessary
4 Prestressing	Requirements for installation of cables for post-tensioning and for ability of staff to perform installation
	Requirements related to system of post-tensioning
	Provisions on steel for prestressing and replacement materials
	Indicate whether alternative materials are permitted instead of steel for prestressing. If so, indicate type and quality.
	Description of cable supports
	Provisions on assembly of prestressing cables
	Indicate whether welding of local reinforcement in the area of anchors and anchor plates and spot welding of perforated plates is permitted
	Requirements related to minimal compressive strength of concrete at the time of entry and/or transfer of prestressing force to the structure
	Required measures if it is not possible to reach exact elongation of pre-tensioned cables
	Required measures if it is not possible to reach exact elongation of post-tensioned cables

Table 2.5.4.2: Type of control and documentation

Item/Subject	2nd execution class	3rd execution class
Type of control/ inspection	Visual inspection and systematic, as well as regular measurements of important parts	Visual inspection Detailed inspection of all the parts of relevance for the load-bearing capacity and durability of the structure
Inspecting authority	Self-inspection Inspection in compliance with the construction procedures Possible additional requirements from the execution specification	Self-inspection Inspection in compliance with the construction procedures Additional requirements from the execution specification for constructing the structure
Scope	Apart from self-inspection, systematic regular inspection of works shall also be conducted	Apart from self-inspection, systematic regular inspection of works shall also be conducted
Inspection report	Required	Required

Table 2.5.4.3 – Recommendation for determination of execution class

Criterion for determining execution class	2nd execution class	3rd execution class
Type of structure	Bridges with span of up to 15 m Ordinary structures on the roads	Bridges with span of over 15 m Traffic infrastructure facilities
Structural elements	Ordinary prestressed elements	Prestressed elements
Reinforcement	Regular steel and prestressing steel	Regular steel and prestressing steel

2.5.5 BEARINGS

2.5.5.1 Introduction

2.5.5.1.1 Description

The main purpose of the technical conditions is to list the requirements for installation of certain types of bearings and different manners of supporting, and to indicate regular inspection and maintenance of bearings.

The technical conditions for installation of bearings are intended for beam bridges. See more on designing bearings in SRDM, chapter 9.12.5.

2.5.5.1.2 Reference standards

The technical conditions are based on EN 1337 -1-11, European standards for bearings, of which the ones relevant to installation are as follows:

- EN 1337-3: Structural bearings - Part 3: Elastomeric bearings
- EN 1337-5: Structural bearings - Part 5: Pot bearings
- EN 1337-7: Structural bearings - Part 7: Spherical and cylindrical PTFE bearings
- EN 1337-9: Structural bearings - Part 9: Protection
- EN 1337-10: Structural bearings – Part 10: Inspection and maintenance
- EN 1337-11: Structural bearings - Part 11: Transport, storage and installation
- RIZ-ING, Richtzeichnungen für Ingenieurbauten, Germany
- ZTV-ING - Zusätzliche Technische Vertragsbedingungen und Richtlinien für Ingenieurbauten
- ÖNORM B 4021 - Brückenlagerausstattung - Anforderungen, Herstellung und Produktionskontrolle
- SRDM, Chapter 9.12.5 - Bearings

2.5.5.1.3 Terminology

Bearing (ležište) is a structural element allowing transfer of selected forces from the superstructure to the substructure.

Reinforced elastomeric bearing (armirano elastomerno ležište) is made of rubber (polychloroprene with at least 60% of elastomer) reinforced with steel plates. It allows displacements (rotation and translation) by deformation of the elastomer.

Pot bearing (lončasto ležište) consists of a steel lower part in the form of an elastomer-filled pot and an upper part in the form of a piston. It can be sliding or fixed.

Spherical bearing (sferno ili kalotno ležište) is a bearing composed of steel concave and convex elements that allow rotation of the point of contact by rolling on one another. It can be sliding or fixed.

Sliding bearing (klizno ležište) is a bearing that allows relative movements between connected elements by sliding: it is a bearing that allows two surfaces to slide, and can be a sliding bearing combined with a pot bearing or elastomeric bearing or with a sliding or fixed spherical bearing.

Moving capacity of bearing (pokretljivost ležišta) is the capability of a bearing to allow relative translations or rotations of the superstructure.

Anchoring (ankerisanje) is a safety measure (joint between the bearing and the structure) that allows taking force at the bearing level if the sliding friction is insufficient due to small tension values that do not exceed the minimum values.

Base concrete (kvadar – postolje ležišta) is the part of a concrete structure onto which a bearing is installed

2.5.5.1.4 Abbreviations used

PTFE- polytetrafluoroethylene

ETA – European technical approval, consent, evaluation

SRDM – Serbian Road Design Manual

2.5.5.2 Taking over, installation, maintenance and replacement of bearings

Quality supporting is ensured by installing certified, undamaged and quality bearings, maintaining, and, if needed, replacing the bearings.

When no special instructions provided by the bearing manufacturer, contractor, engineer or transporter exist, the instructions in these specifications shall be taken into account. In any case, original documentation shall be requested from the manufacturer or supplier.

Transport, storage and installation can be conducted only be qualified workers.

Measurements on the bearing can be taken only be a bearings expert, usually certified to install bearings.

The site shall have a bearing installation plan, the necessary certificates, permits, special instructions, bearing measuring equipment and equipment for measuring structural and air temperature, and also keep a record of bearings.

2.5.5.2.1 Taking over the bearings

When taking over the bearing the following should be verified:

- certificates for the basic materials according to SRPS EN 10024 (types 3.1 and 3.2, particularly for PTFE, silicone grease and the austenitic steel plate for the sliding part), certificate of conformity (EC certificate) for the entire bearing according to EN 1337 or ETA approval, certificate of factory production control for the bearing (in some cases, for special bearings perhaps national technical permits or approvals as well);
- whether the external parts are undamaged. particularly regarding protection from corrosion: bearing plates with damaged anti-corrosion protection or with already present products of corrosion may not be installed, but first have to undergo repeating of the anti-corrosion protection, all in compliance with the design requirements;
- cleanliness of the bearing (option – dust protection for sliding surfaces);
- compliance with the bearing design (whether the additional equipment of the bearing is in compliance with RiZ-ING, Lag details or ÖNORM B 4021);
- bearing designations according to EN 1337; according to type (CE designation, and Ü according to ZTV-ING or ÖNORM B 4021 as needed);
- bearing dimensions
- size and direction of the previous placement (see certificate of factory production control and markings on the upper plate of the bearing, figure 2.5.5.4).

2.5.5.2.2 Installation

Particular attention needs to be paid to the placement of the bearings in order to prevent damage to the bearing and the structure and ensure proper functioning.

Installation shall be conducted in compliance with the design or special instructions in the presence of a representative of the bearing manufacturer.

The following should be verified before grouting:

- whether the installed bearing is identical to the design bearing;
- the direction of the bearing (X, and Y axis) (see orientation on upper plate of bearing);
- whether the bearing is horizontal (verification by leveling instrument in three points, reliability 0.6 ‰, figure 2.5.5.12);
- size and direction of the previous placement (see orientation on upper plate of bearing);
- whether possible special instructions from the manufacturer need to be taken into account regarding the installation of the bearing;
- mortar for grouting (composition, properties, method of grouting – see table 2.5.5.1).

If a (special) bearing needs to be inclined, the inclination shall be specially marked in the design or installation design plan, and must be verified prior to casting.

Otherwise the bearings must always be horizontal.

Bearings shall be fixed by assembly devices (figure 2.5.5.1) in order to remain in the proper position after casting. The use of wooden wedges is not permitted,

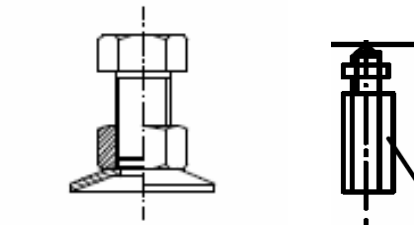


Figure 2.5.5.1 – Plates – bolts under the bearing

All additional elements used for assembly purposes (figure 2.5.5.2) shall be removed before the bearing takes over its function.

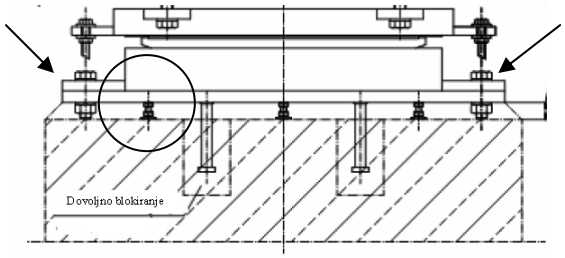


Figure 2.5.5.2 – Bearing assembly joints

Welding and flame cutting may be performed only with the consent of the bearing manufacturer so as not to cause undesirable thermal load. Bolting is preferred over welding. This is particularly true of steel and composite structures.

The inclination of the bearing plane may deviate from the design inclination by 5 ‰, unless otherwise specified in the design.

The grout (cement mortar or epoxy) for the lower plate of the bearing shall comply with the following technical condition requirements - specifications (table 2.5.5.1):

Table 2.5.5.1: Grout specification

Property	Cement grout	Epoxy grout
Compressive strength	≥ 25 MPa after 12 h	≥ 17.5 MPa after 8 h
	≥ 40 MPa after 24 h	≥ 56 MPa after 12 h
	≥ 55 MPa after 28 d	≥ 85 MPA after 24 h
	no drop in strength after 25 d and 90 d	≥ 98 MPa after 7 d
Shrinkage	≤ 2 ‰	≤ 2 ‰
Expansion	≥ 0.1 %	0%
Highest layer of grout	50 mm	30 mm
Temperature range	+ 5 ^{o}C to + 35 ^{o}C	+ 8 ^{o}C to + 30 ^{o}C
Freeze and salt resistance	yes	yes

If the sliding friction is not sufficient due to lower values of stresses below minimum, the bearing requires anchoring as well. This is decided on by the structure designer. In doing so the designer shall take into account the fact that the anchor length in the concrete may not be less than 95 mm, and that reinforcement that prevents tearing of the concrete be used (figure 2.5.5.8). Anchors shall be no less than 20 mm below this reinforcement.

In installing the bearing (figure 2.5.5.9) the formwork shall be sealed in such a manner as to prevent contamination of the bearing with laitance or concrete. If this should occur nevertheless, the concrete shall be removed immediately, before hardening. This is particularly important for the austenitic sliding surface of the bearing, as the polished surface could suffer damage which would cause fast wear of the pad (PTFE).

When the formwork is removed, the bearing shall be inspected. If damages to the anti-corrosion protection are found, the protection shall be renewed immediately with a compatible anti-corrosion coating. It would be optimal for the manufacturer of the bearing to supply a small quantity of anti-corrosion coating with the bearing, to repair minor damage.

After installation another inspection shall be conducted, measuring the levelness, sliding and tilting slots (see figures 2.5.5.5 to 2.5.5.7). This determines possible changes that can occur during installation, particularly regarding the position of the bearing or external damages.

Records should be kept of the inspection of the bearing before and after installation, which shall be signed by the contractor executing the construction works, the representative of the bearing manufacturer and the engineer. The form for making records is provided in table 2.5.5.2.

2.5.5.2.3 Maintenance

Maintenance of the bearings includes main, regular and detailed inspections, occasional inspections and control testings, cleaning, renewing anti-corrosion protection, coating and replacement of the PTFE pad, removing structural defects that could harm the bearing (humidity, etc.).

Main inspection of the bearings is carries out every 6 years and comprises visual inspection with measurement of the following:
- assessing the condition of the joints of the bearing with the superstructure and substructure (cracks in the joint; relative movements; damaged concrete in the upper or lower base concrete; cracks in the upper or lower base concrete);
- assessing the condition of the sliding surface (dirt – dust, residual laitance; scratches – individual, numerous; cracks – individual, numerous; residuals in the sliding slot);
- assessing the condition of the bolted joints with the spanning or support structure (bolted joint fixed, loose; part of bolting material missing – bolt head, etc.);
- assessing the condition of the anti-corrosion protection (cracks, scratches, peeling, loss of paint);
- measuring unusual relative movements of individual parts of the bearing (movement of the elastomeric bearing relative to the base or individual parts of the deformable sliding bearing; movements of the bearing relative to the base);
- measuring the distance between the sliding and tilting slot;
- reading movements on the scale;
- assessing the condition of the protective strip in the rocking slot (slipped out; cracked; weather damaged; mechanically damaged).

Routine inspections shall be carried out every 2-3 years. Bearings shall be inspected only visually.

An inspection detailed in scope is carried out the same as the main inspection, but only before reconstruction of the structure.

Maintenance of the bearings shall be detailed in the structure maintenance design.

The following individual measures shall be foreseen:
- working measures are not necessary;
- additional measurements and long-term observation are necessary; the results and working measures to be recorded in the report;
- minor repairs are necessary;
- repair or replacement is necessary; these results and working measures to be recorded in the report;
- detailed inspection.

In order to prevent unauthorized persons from accessing the bearings, as well as dirt from bird droppings or dust, the structure around the bearing can be closed. Care should be taken to keep the protection easily removable, particularly during bearing inspections (figure 2.5.5.10).

2.5.5.2.4 Replacement of bearings

The bearing design shall specify the conditions that ensure proper functioning of the bearing. If suspicion arises during a routine inspection that these conditions are not met (occurrence of damage, wear), such bearing must be replaced. Whether replacement is required shall first be verified by a control testing.

When replacing a bearing due to wear the entire structure shall be taken into consideration, as a re-distribution of reaction forces could otherwise occur which is inevitable in case of a change in the rigidity of a bearing. The largest permissible lifting of the structure shall not exceed 10 mm.

Replacement of worn bearings should be carried out on the entire structure, and if that is not necessary then all the bearings on the sale lateral axis of support shall be replaced.

During reconstructions possible changes to the structural static system shall be taken into account. In such cases new bearings shall be foreseen. Details and positioning of jacks are shown in figure 2.5.5.11.

2.5.5.2.5 Bearing record

Records shall be kept on the taking over, installation and condition at the very beginning of use of a bearing. The form making records is provided in table 2.5.5.2. Zero measurement of the bearing shall also be carried out.

2.5.5.3 Bearing certification and control

Certification, production control and acceptance of bearings on site are carried out:

- according to the EN 1337 standard for individual standard bearings;
- according to ETA approval for individual special types of bearings;
- or additionally for special equipment for bearings according to the national system specified in the agreement (e.g. according to the Austrian technical compliance with ÖNORM B 4021 or the German technical compliance type Z-16.7-nnn and details according to RiZ-ING).

2.5.5.3.1 EC certificates and declarations of conformity

Input material shall be in compliance with the quality control requirements according to standard “EN 10204 – Metallic products – Types of inspection documents“. Especially singled out are materials for sliding elements, such as the Teflon pad (PTFE), silicone grease in holes, plates and austenitic steel as a sliding plate. These materials require certificates type 3.1 and 3.2, issued by an authorized institution.

Certification of bearings is carried out according to system 1 quality control

When delivering the bearings to the site the manufacturer shall be obligated, apart from the aforementioned documentation, to also supply a declaration of conformity for each type of bearing according to the EC certificate.

2.5.5.3.2 Documentation

The authorized institution (from the country of the manufacturer) shall issue information on commencement of inspection of the product and production at the plant, for the purpose of issuing an EC certificate in compliance with EN 1337 or ETA approval. The institution shall previously confer with the manufacturer regarding the findings. The information is public and confidential (deposited with the authorized institution). The documentation also includes the individual workshop drawings, specification lists, quality control plans.

Evaluation of conformity for installation of the bearings on site can also be carried out by a third party – an institute whose duties depend on the specific type of bearing.

The issuance of a certificate of conformity may be conducted only by a legal entity which is accredited for conducting the works of certification according to the standard SRPS EN 45011 with the Accrediting body of Serbia.

2.5.5.3.3 CE mark and accompanying document

Information on conducted inspection is provided by the CE mark on the label on the bearing – figure 2.5.5.3 (certificate number, number of the authorized institution, type of standard EN 1337 or ETA, year of initial inspection, name of manufacturer). The documentation also comprises the accompanying list. The documentation contains no note of the significant properties of the product, except for the temperature range of action, type of sliding elements and type of internal seal.

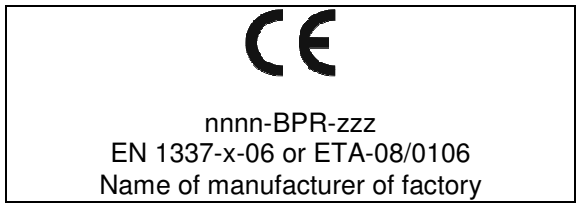
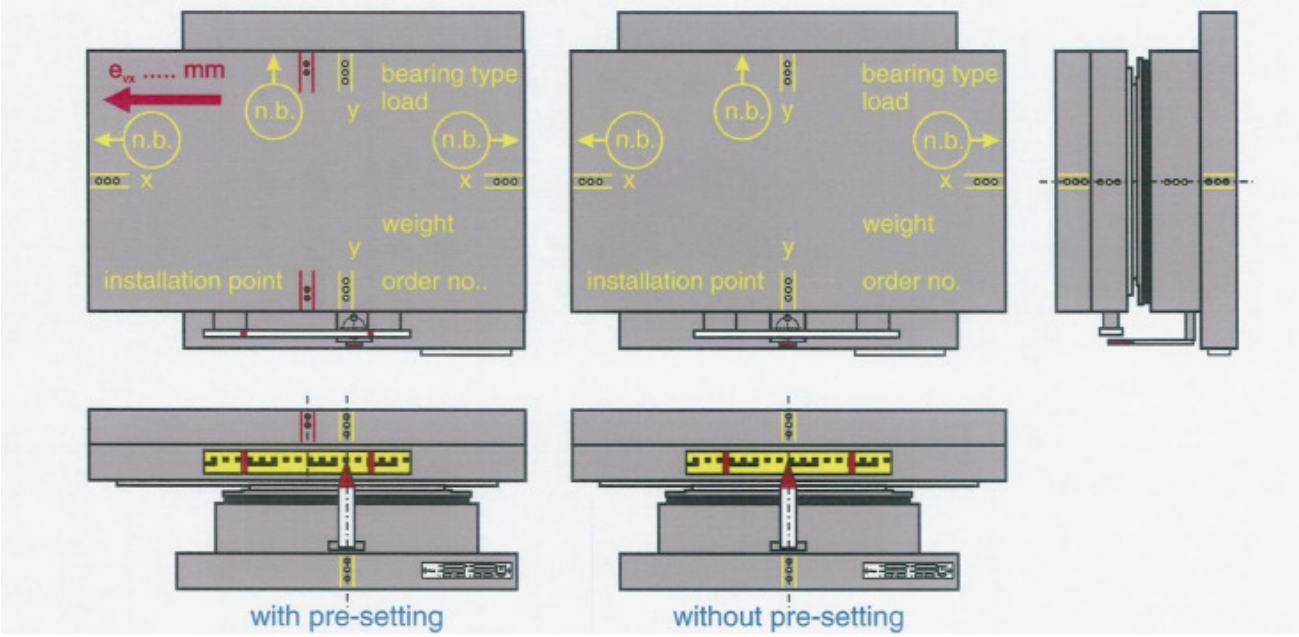
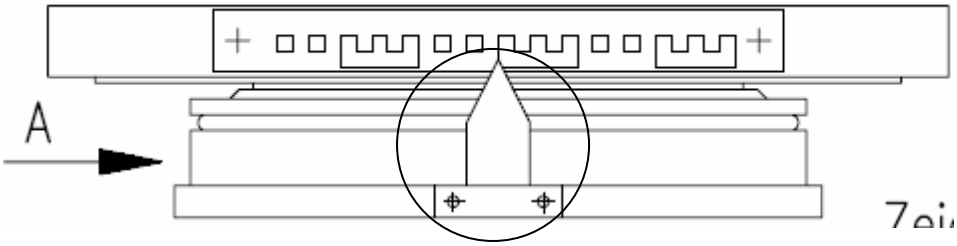


Figure 2.5.5.3 CE mark on bearing according to EN 1337





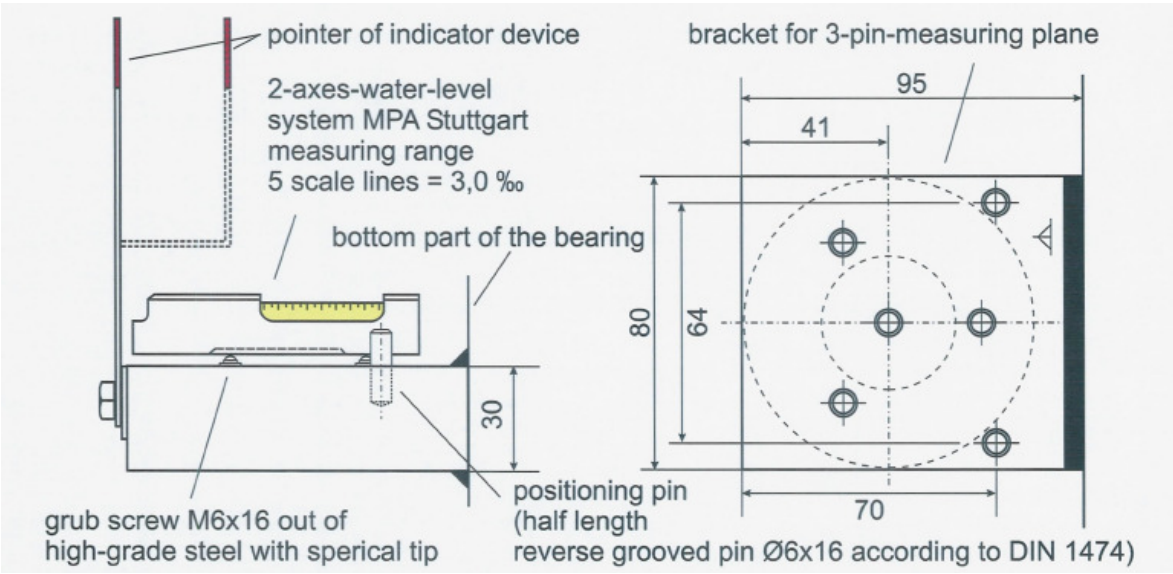
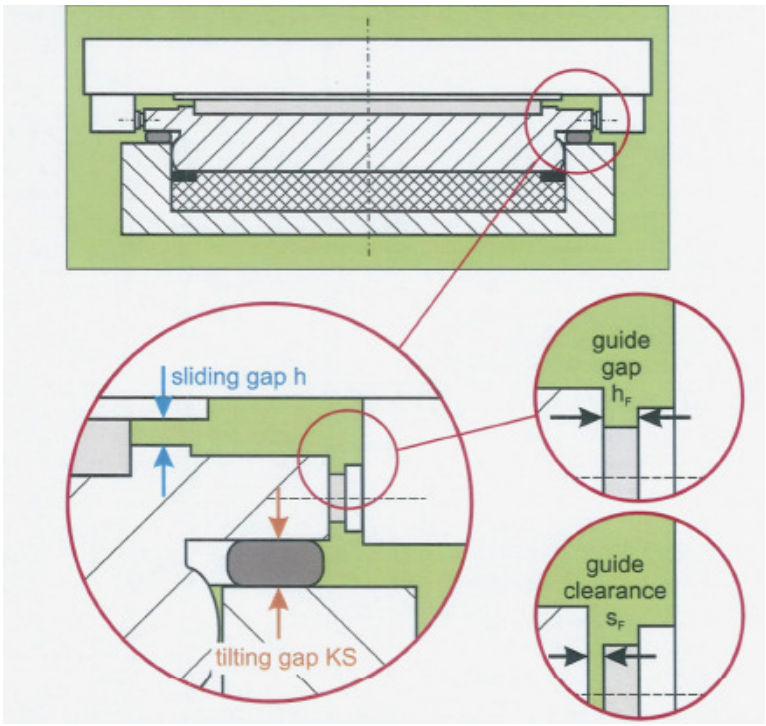
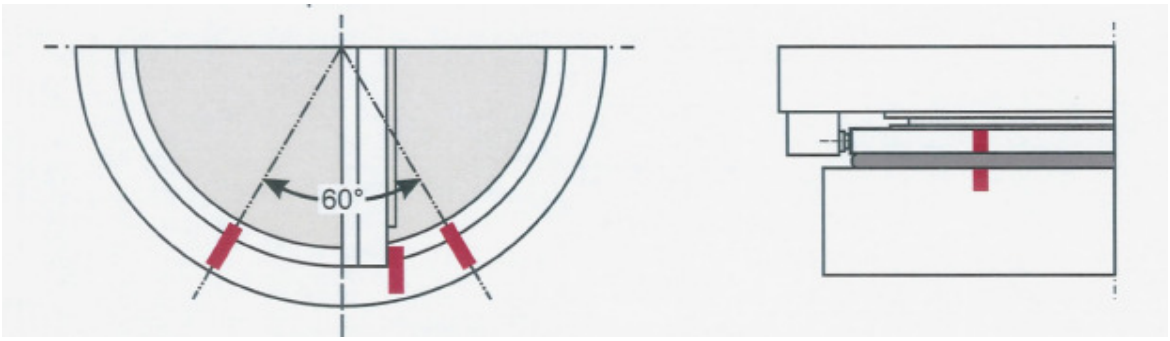
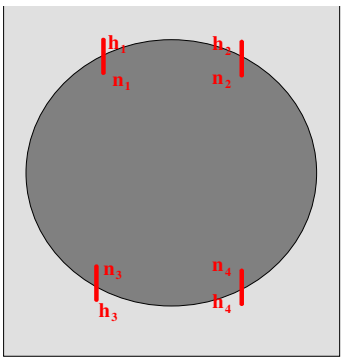


Figure 2.5.5.4 – Mark on upper plate of bearing and measuring instruments for bearing equipment according to ZTV-ING

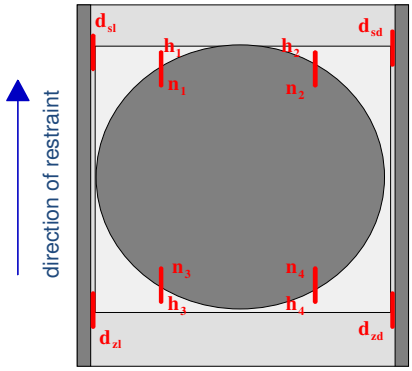




pot bearing movable in all directions



longitudinally guided pot bearing



LEGEND

h_i - height of sliding slot
d_i - lateral sliding slots
n_i - tilting slot

Figure 2.5.5.5 – Measuring points for sliding pot bearing

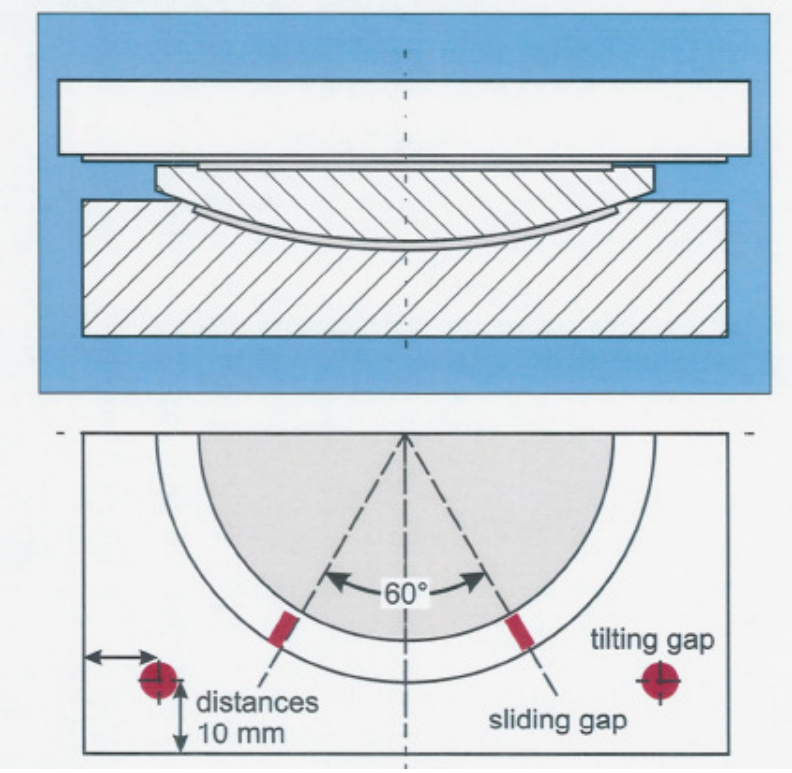


Figure 2.5.5.6 – Measuring points for sliding spherical bearing

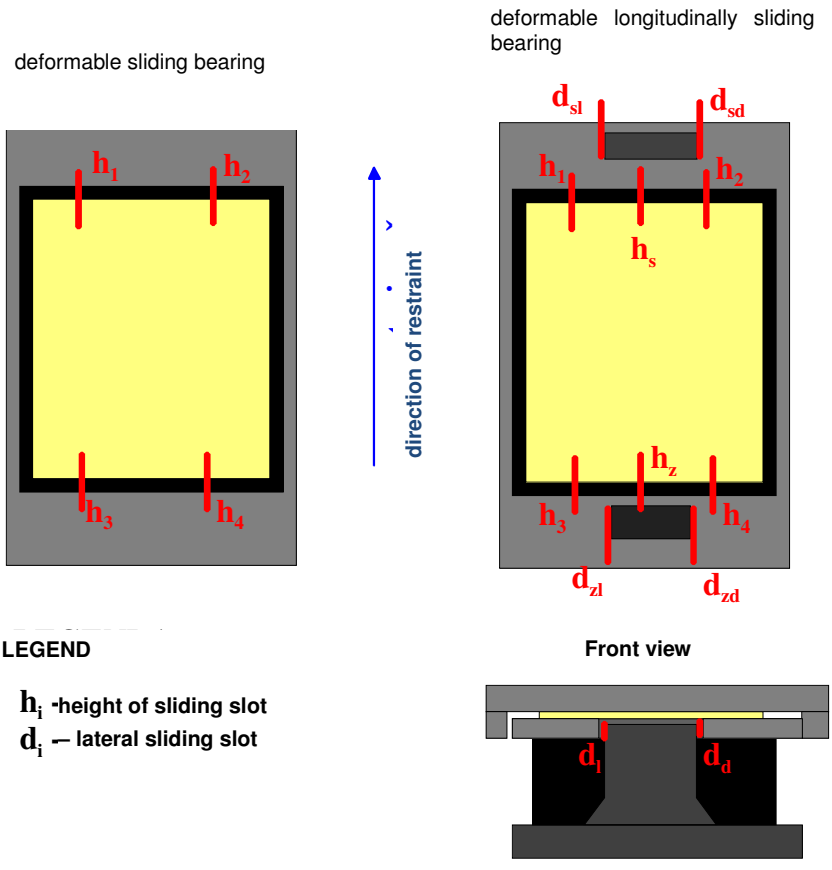
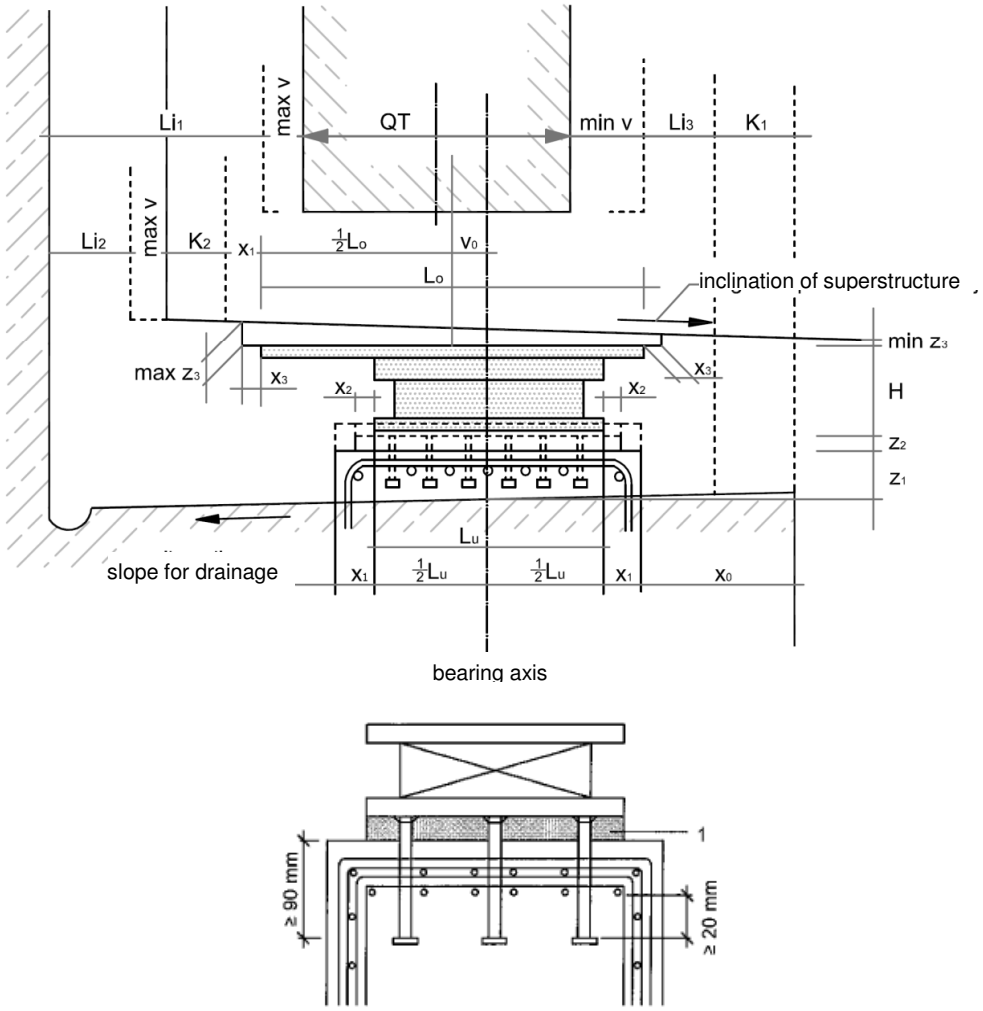


Figure 2.5.5.7 – Measuring points for sliding elastomeric bearing



Legend:

L_o	Length of bearing upper plate
L_d	Length of bearing lower plate
H	Height of installation of bearing
QT	Width of cross beam
K_1	Width of endmost abutment wall in front of cross beam
K_2	Non-bearing concrete and structures (e.g. anchor cover)
V_0	Pre-setting – centering of bearings
min v	Addition k v_0 expected minimum
max v	and maximum movement
Li_1 do Li_3	Required dimensions for ensuring possible inspection, maintenance and safety of action
$X_{0,1,2,3}$	Required horizontal displacement of bearing block, plate and leveling grout
$Z_{1,2,3}$	Required height of bearing block and leveling grout

Figure 2.5.5.8 Schematic of inter-dependence of structure and bearing dimensions and anchoring conditions

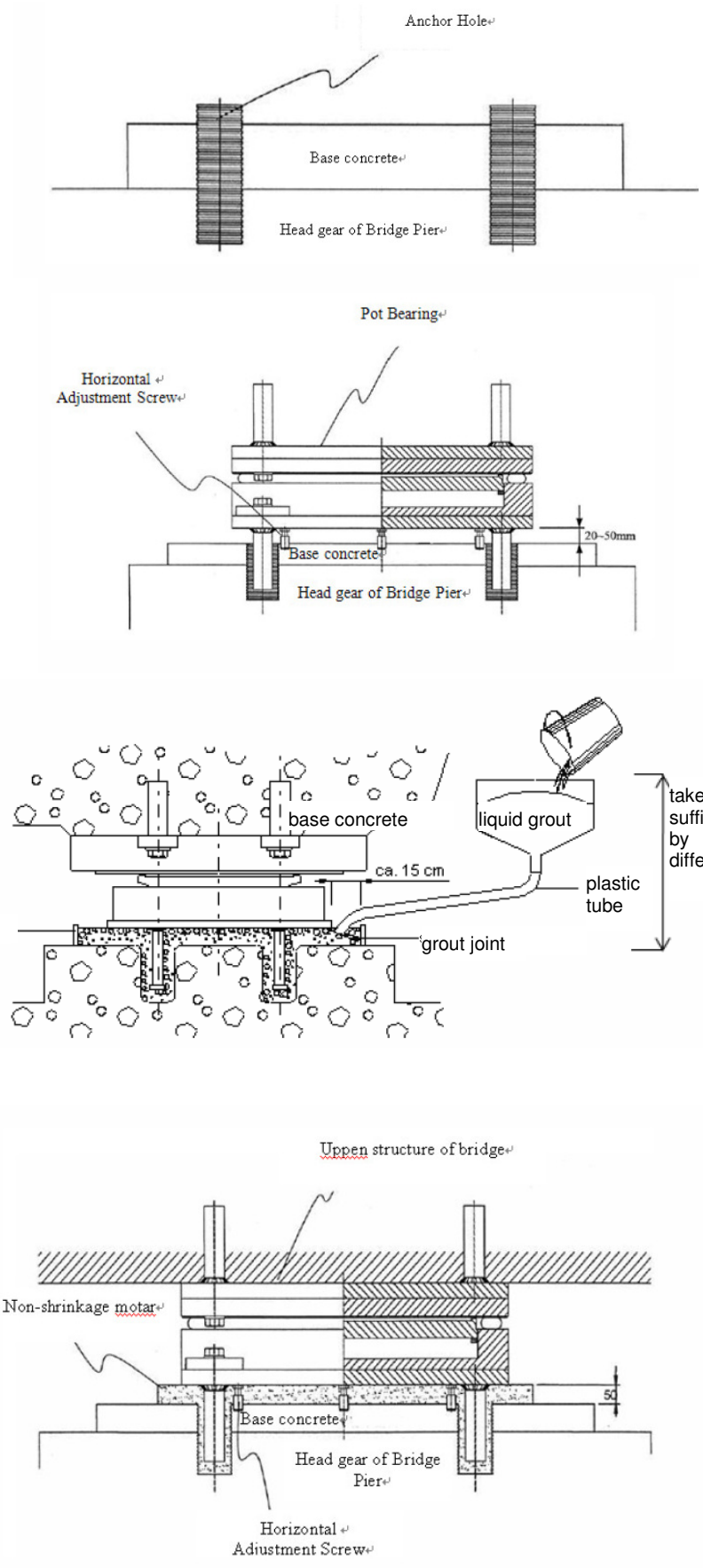
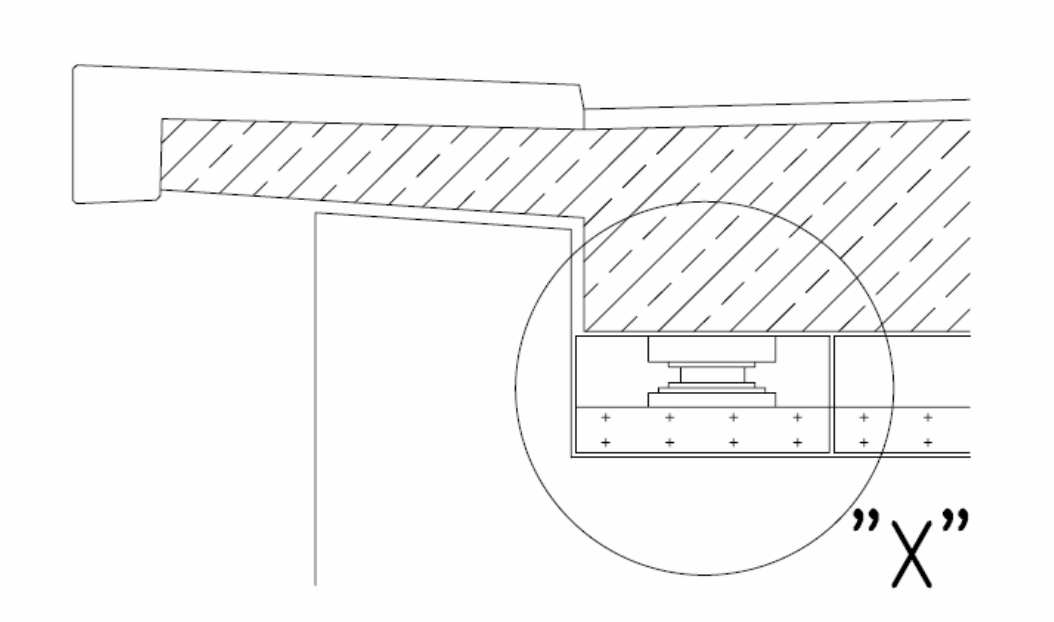


Figure 2.5.5.9 – Installation stages for bearing with anchors



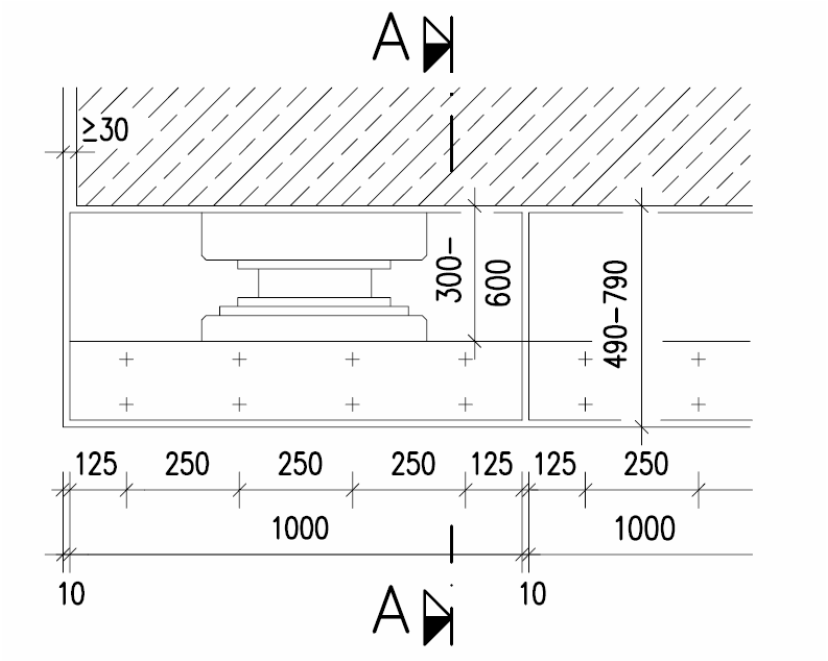
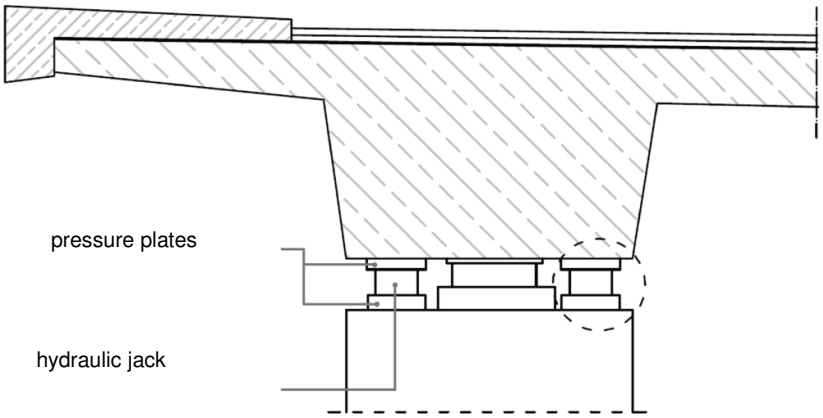
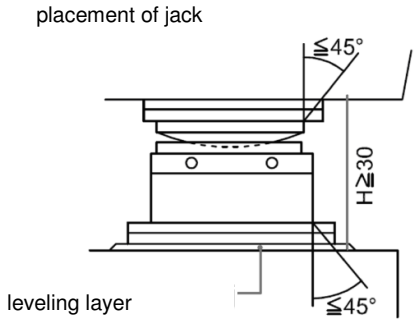
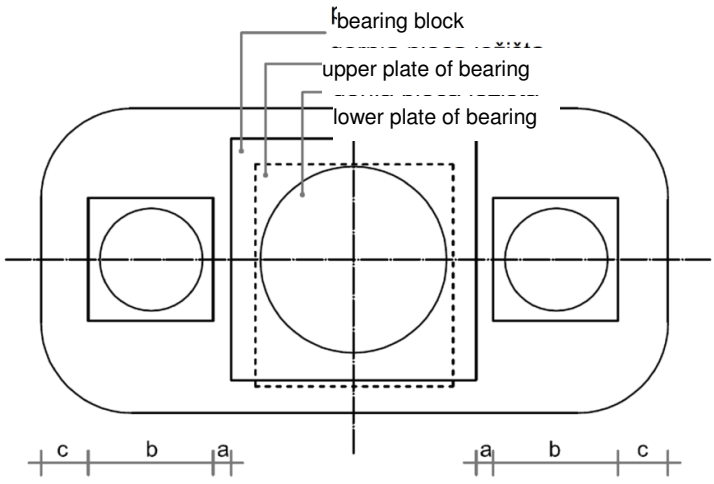


Figure 2.5.5.10 Protection of bearings with Plexiglas







a) distance between base concrete or bearing plate and pressure plate ≥ 5 cm
b) width of pressure plate
c) distance between pressure plate and edge of concrete structure (up or down ≥ 12 cm)

Figure 2.5.5.11 Requirements for placing hydraulic jacks for bearing replacement

Table 2.5.5.2: Bearing record

Road:		Section:	km:
Structure (designation, position):			
Method of construction:			
Design plan of bearing no.:		Type of bearing according to approval, or EN 1337-1:	
Bearing manufacturer /order number:			
EC certificate or ETA approval no:		Validity of approval:	
Client:		Accepting party:	Engineer:
	Stage	Description	Record
1	inspection/control of taking over and installation of bearings	installation location (abutment no/position)	
2		raising of superstructure in mm	
3		type of bearing	
4		vertical force F_z in kN	
5		horizontal force F_x / F_y in kN	
6		design movement (from fixed point) in mm $\pm e_x$/ $\pm e_y$	
7		design rotation in mm $\pm \delta_x$/ δ_y	
8		pre-setting in mm $+e_x$/ $+e_y$	
9		drawing/control certificate no	
10		delivery/installation date	
11		properly placed, supported and covered	
12		mark on bearing	
13		indicator of movement on bearing	
14		cleanliness and anti-corrosion protection	
15		fixing structure blocked	
16		cleanliness of contact surface	
17		thickness of layer (grout) in mm up/down	
18		deviation from horizontal in mm/m longitudinally/laterally	
19		direction and size of previous extension in mm	
20	placement of grout	date / time	
21		structure/air temperature in ^oC	
22		type of grout / quality certificate	
23		method of grout placement	
24		curing	
25	use of bearing	date / time	
26		superstructure released	
27		bearing blockage released and removed	
28		cleanliness and anti-corrosion protection	
29	zero measurement	date / time	
30		structure/air temperature in ^oC	
31		measurement of sliding slot max/min in mm	
32		movement (from fixed point) in mm $\pm e_x$/ $\pm e_y$	
33		measurement of tilting slot mx/min in mm	
34		measurement of bearing levelness x/y (mm/m)	

2.5.6 EXPANSION JOINTS

2.5.6.1 Introduction

Expansion joint bridges the space for free movement between the superstructure and substructure or between two parts of the superstructure on the bridge.

Only those expansion joints that provide water tightness with controlled drainage are installed.

Expansion joints must meet the following requirements:
- Water tightness and controlled drainage,
- Ability to adapt and take in expected movements,
- Ability to adapt and resistance to influence of unexpected loading,
- Resistance to influence of corrosion and abrasion,
- Must not make noise when vehicles are crossing it,
- Must have a long service life,
- Must provide simple control, maintenance, repair and replacement.

2.5.6.1.1 Description

The main purpose of technical conditions is to assist in decision-making before the procurement of expansion joint and provide technical conditions for proper installation and use.

2.5.6.1.2 Reference standards

The subject technical conditions include international standards and other technical regulations. The latest version is the most relevant for application.

- ETAG032-Part 1-8: Guideline for European technical approval of expansion joints for road bridges,
- TL/TP-FÜ, Technische Lieferbedingungen und Prüfvorschriften für wasserdichte Fahrbahnübergänge in Lamellenbauweise und Fingerübergänge mit Entwässerung von Straßen -und Wegbrücken, Germany,
- RIZ-ING, Richtzeichnungen für Ingenieurbauten, Germany,
- RVS 15.04.51: Bridges- Equipment of Bridges– Expansion Joints, (Brücken – Brückeausrüstung- Übergangskonstruktionen), Austria
- RVS 15.04.52: Bridges- Equipment of Bridges– Expansion Joints, (Brücken – Brückeausrüstung - Schalltechnische Beurteilung von Fahrbahnübergängen);
- DIN Fachbericht 100-101, Germany
- DIN 1076 - Engineering structures in connection with roads - inspection and test, Germany,
- Joints de chaussée des ponts routes, guide technique, Bagneux, SETRA, juillet 1986, France,
- Le control des traveaux de joints de chaussée et de trottoirs sur ovrages neufs et en réparation, guide technique, LCPG, juin 2006, France.

2.5.6.1.3 Terminology

Asphalt expansion joint (asfaltna dilatacija) is a term for the wide assortment of flexible bitumen expansion joints with the extensible part made of a mixture for which the term “asphalt” has become familiar.

Bitumen expansion joint (bitumenska dilatacija) is a narrower term for a flexible expansion joint whose extensible part is made of a mixture of polymerized bitumen with elastomer and stone-filler.

Bitumen sealing (bitumenska masa za zalivanje) is a polymerized bitumen mass used for the sealing of joints of asphalt layers with the expansion joint elements.

Drainage pipe (cev za procednu vodu) is a specially shaped pipe for draining the water that passes through the asphalt layers by the expansion joint.

Trench (dilatacioni otvor) is the width of the space between structural elements that is bridged by the expansion joint.

Expansion joint (dilatacija) bridges the free movement space (gap) between the superstructure and the abutment, or between two segments of the bridge superstructure.

Plug joint (dilatacija jednostavne izrade) is an element installed into the joint between the bridge carriageway and the connecting road carriageway (usually on minor bridges and to lower category roads).

Dilatation of structure (dilatiranje konstrukcije) is a wider term for structural discontinuities enabling mutually independent movement of separated structural parts.

Elastomer (elastomer) is a wider term for the synthetic rubber with required physical and chemical properties. Chloroprene rubber is used in bridge construction.

Finger, cantilever (češalj) is a constituent part of an expansion joint, shaped as a comb or a saw where two elements extending one into another ensure the continuity of the expansion joint surface.

Walkway (hodnik za pešake) in broader sense is a part of the bridge carriageway intended for pedestrians and cyclists, usually raised above the carriageway.

Steel profile (čelični profil) in expansion joints is a specially profiled steel beam on which a rubber seal is pressed in or screwed on.

Steel anchor (čelični anker) is a loop from round steel, a specially shaped element made of steel sheet, or a cylindrically shaped element, embedded in structural concrete, creating a rigid connection between the expansion joint and the bridge structure.

Moving ability (pomeranje dilatacije) is a common term for all possible movement vectors in the expansion joint axis, including rotation.

Expansion joint due to temperature (temperaturna dilatacija) is an expression for the contracting or the extending of structural elements due to their temperature change.

2.5.6.1.4 Abbreviations used

ÜBE 1 – mark for expansion joint drawing with one opening, according to German guidelines RIZ-ING

PU – polyurethane

PVC – polychloride

PFTE – polytetrafluoroethylene

ETAG – European Technical Approval Guideline

ETA – European Technical Approval

SRDM – Serbian Road Design Manual

2.5.6.2 Taking over, installation, maintenance and replacement of expansion joints

2.5.6.2.1 Taking over expansion joints from manufacturers

Expansion joint is taken over by responsible head of construction works. If necessary, it is possible to hire appropriate professional institution to perform the takeover. During the taking over, at the construction site it is necessary to check dimensions, settings of expansion joints (usually set to +10 °C), quality of material and corrosion protection. Established facts should be compared with the design and all observations should be entered into records (Table 2.5.6.4). Additionally, it is necessary to check the contents of required technical documentation, certificates, guarantees and instructions (Table 2.5.6.3).

Provisions in relation to the following must be defined in the instructions:
- Storage,
- Transportation,
- Installation,
- Maintenance, and
- Replacement.

Takeover procedure is performed on the basis of the relevant control list.

At the takeover, validity of expansion joint is confirmed in writing at the appropriate place within the single records that covers all phases from before the installation to technical taking over (Table 2.5.6.4).

If the measuring shows that temperature of the structure is higher than expected, expansion joint should be readjusted - closed. If temperature is lower than expected, expansion joint should be expanded. This procedure must always be performed by the manufacturer of the expansion joint, as it has required tools. Dimensions for adjustment of expansion joint openness at specific temperature should be provided in the table on the workshop drawing.

2.5.6.2.2 Installation of expansion joints

Expansion joint must be installed by qualified contractor according to designer's instructions and potentially in the presence of the manufacturer, but only after checking of expansion joint and parts of the structure into which it is to be built-in.

During examination a check list must be used.

If expansion joints are complex, installation is controlled by the commission composed of responsible representative of the Employer, responsible head of works, responsible designer, manufacturer's representative, and if necessary a representative of authorized institution for the control of materials and

structures. Fulfilment of requirements for installation is confirmed within single records, presented in Table 2.5.6.4.

If the contractor does not have adequately trained staff, then contractor must hire trained workers or a certified instructor.

Below are the most important general guidelines, and besides them, the specific requirements stated in the design and installation instructions provided by the manufacturer must also be taken into account.

2.5.6.2.2.1 General instructions for installation

Expansion joint is always lifted with transport crane. Expansion joint is fixed in the position with clamps, while temporary auxiliary supports should be cut.

After installation of expansion joint in prepared construction opening, it is necessary to determine whether the steel reinforcement matches the loops of expansion joint anchors. Any deviation must be approved by the designer and site engineer.

If the expansion (opening) is adjusted on the site, it is necessary to make sure that plates are set parallel and not in a sloping position, which would be incorrect. Some expansion joints have embedded markers on their steel parts that allow control of parallel placement.

Cross and longitudinal fall can usually be seen in the design plan of formwork for installation of expansion joint. The surveyor precisely determines the location of installation.

Crane's winch can be used for fine-tuning of the expansion joint.

After adjustment of the expansion joint, anchors are welded onto steel reinforcement of the structure.

2.5.6.2.2.2 Examples of errors during construction

If the width of the gap during adjustment is wrong, the following errors might appear later, e.g. sealing strip in the gap is too tight, the gap is too wide and dangerous for motorcycles, water passes through the gap and reaches the substructure.

Conversely, if the gap is too narrow, then the expansion joint or its functioning can be endangered.

If the adjustment of the cross fall and longitudinal fall is incorrect, there is possibility of pedestrians tipping over on the walkway and falling to the ground.

If the expansion joint is not in the right place or is not of the proper type, it should be immediately transferred and replaced with a new one. This is obviously a long and expensive task.

2.5.6.2.2.3 Installation of asphalt expansion joints and elastomer fillers

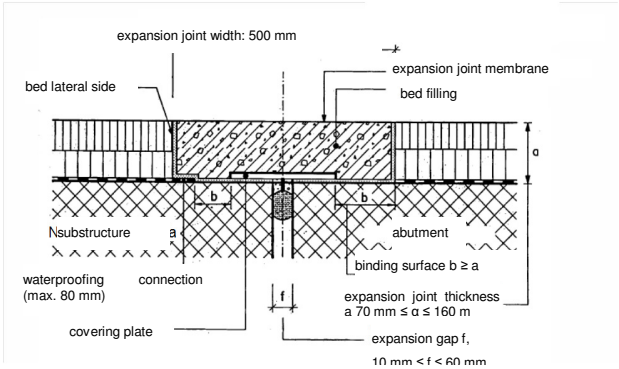


Figure 2.6.5.1: Asphalt expansion joint - Type 1 according to ETAG 032-3

Expansion joint is installed as late as possible in relation to other works, as this provides less stretching of expansion joint moving parts.

After placement of layers of asphalt pavement, a joint recess must be prepared for installation of expansion joints. Dimensions of the joint recess should be adjusted to match manufacturer's data. Lateral sides of the joint recess should be notched with hand tools deep enough to reach the waterproofing layer.

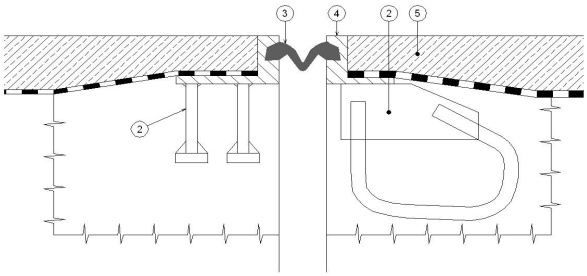
Joint recess should be cleaned, possible damages on the concrete surface should be repaired, and seal made of foam rubber should be installed in the expansion joint gap. After this an adhesive layer made of elastic polymer bitumen is applied and hot dip galvanized steel strip, which bridges the expansion joint gap, is installed. Strips are fixed with a bolt. This is followed by placement of filling and covering with a wearing layer made of polymer bitumen.

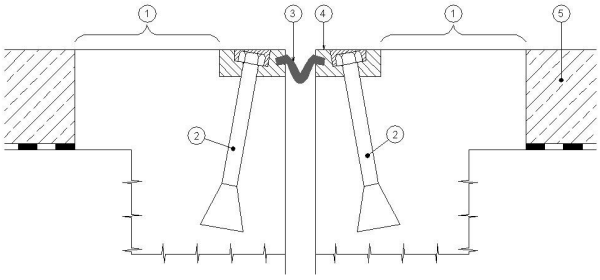
For all mentioned procedures contractor must provide certificate on conditions and procedures of installation, and for the quality of built-in materials.

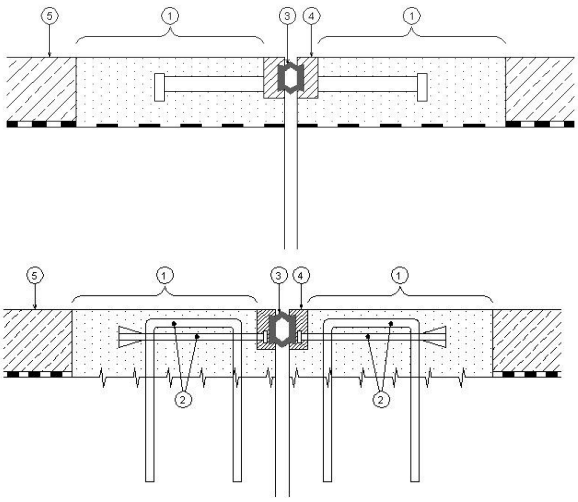
Other requirements for asphalt expansion joints:

- Width of expansion joint,
- Tolerances during execution,
- Careful execution of details,
- Temperature of built-in materials,
- Temperature during installation - in the summer,
- Putting into operation.

2.5.6.2.2.4 Installation of nosing expansion joints







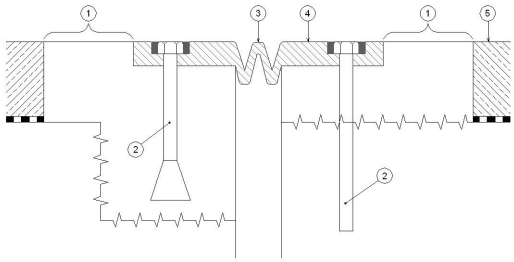


Figure 2.5.6.2: Nosing expansion joints (types according to ETAG032-4)

After transporting to the site, expansion joints must be stored so that they are protected from dirt and damage.

Installation should be performed as late as possible, especially in the structures that have a longer period of deformation development (rheology of concrete, consolidation of foundation soil).

Before the installation, geometry of the groove (dimensions, height levels), and the connecting reinforcement in the groove must be checked, and possible repairs and cleaning must be completed.

All edges should be processed on the steel structures and joints should be prepared for welding.

The size of already appearing long-term deformations of the structure and average temperature should be measured. Based on these data, manufacturer should install the expansion joint opening, i.e. adjust the size of the blockout.

During installation all measurements should be accompanied with proper surveyor control.

Delivered expansion joint is placed in the groove and anchors are welded onto connecting reinforcement (usually every fifth). First, the anchors are welded on one side, and then on the other side of the expansion joint. This way expansion joint is connected and bound with the structure, and therefore expansion joint should be immediately relieved from previously installed blockout elements.

Analogous procedure is carried out on expansion joints that are anchored with bolts.

If the structure of the bridge is made of steel, then the anchoring profile is first welded onto the superstructure; afterwards, anchors are welded onto the abutment, after which all

blockout elements must be removed. The same procedure applies to the expansion joint located between two parts of the bridge superstructure.

After fixation, all dimensions and altitude points should be checked in order to ensure complete evenness after the installation of asphalt concrete layers (prescribed depth 3-5 mm) in relation to the upper surface of the carriageway.

After all the tests, casting is performed with concrete that is prepared according to specific technological design (please see Section 2.5.6.2.2.7).

2.5.6.2.2.5 Installation of rubber mat expansion joints

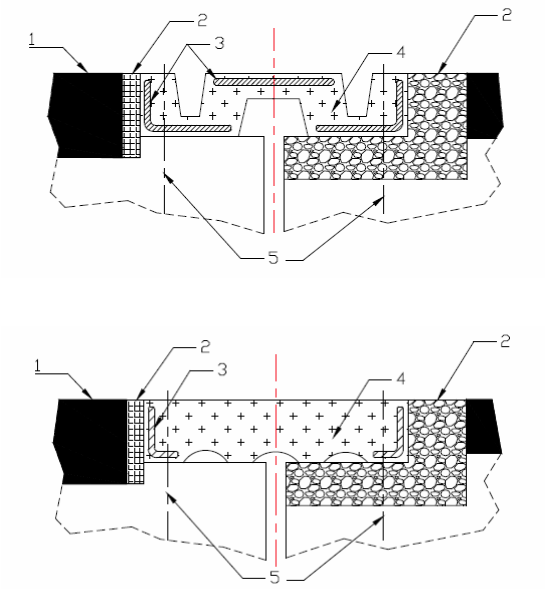


Figure 2.5.6.3: Rubber mat expansion joint for small movements (types according to ETAG032-5)

First a flat notch or a haunch should be formed on the concrete deck in order to place a joint with a rubber base and transition strip.

In the design phase it is important to place the reinforcement so that position of anchor bolts on the expansion joint should be avoided.

In order to achieve smooth traffic flow over the expansion joint, the wearing layer should be machine-installed in continuity above the construction joint and subsequently removed immediately before the installation of expansion joint.

Removal of the surface layer above the joint on the deck is facilitated by the position of protection against adhesion to the plywood whose width is a bit less than the combined width of the joint and transition strips before installation of the surface layer.

At the time of installation, depending on the average temperature of the concrete deck, it may be necessary to perform pre-compression or pre-stretching of the rubber mat expansion joint to adjust it to the relative position of the bridge deck joint.

Width of joint installation can be determined by graphic means, illustrated in the example titled *Guidelines for adjustment of temperature*, for each manufacturer separately. Once the width of installation of rubber module and new centre holes for the bolts are determined, joint module can be adjusted accordingly.

Surface layer can then be cropped and removed so that dimensions are equivalent to width of installation of the joint and two transition strips.

Exposed concrete should then be shaped and final layer of the bedding should be adjusted with polymer-modified screed thick about 20 mm, while preserving the depth of the notch.

Modules of expansion joint centred above the deck expansion joint can then be used as matrices for guiding holes to determine the final position of bolt openings, or previously prepared matrices should be used.

The final openings should be drilled and bolts should be placed with chemical anchors. Every expansion joint can then be placed into position by bolting to the fillets of the base sealer. Then the simply connected washers are located, which are supplied with each unit and the assembly is attached to the base.

Then the remaining modules should be located and fixed in the same way, where the sealing agent is applied first to the tongue and groove joint at the fitting places, in order to provide sufficient degree of water resistance.

Fixing nuts should be tightened to the extent specified for each model, and transition strips from polyureid resins should be placed at the level of the wearing layer, but slightly elevated (3 mm) compared to the top of the expansion joint module.

After final checking of the torque on fixation nuts, bolt openings should be filled with seal for openings in order to protect screws from corrosion.

Waterproofing

For improved water resistance, it is necessary to install second-degree membrane (gutter) that should be fixed with epoxy adhesive to the surface of the levelling screed in the full width of the rubber base before application of the sealing bedding. Notch depth should be adjusted by +3 mm.

Additional materials and accessories

Materials:
- Bolts - please see manufacturer's chart *Description of recommended diameters of chemical anchors and type of membrane for waterproof use*.
- Seal - one component durable putties (e.g. polysulfide) for the bedding and sealing of all modules. It can be used for the bolt opening for purpose of filling the bolt openings.
- Polymer-modified mortar for the level screed that can be used with level screeds or beddings.
- Polyureid resin for formation of transition strips between wearing surfaces of the road and joint module.

Equipment:
- Tools for extrusion/decompression for the adjustment and preparation of the joint module, in order to match the deviations in temperature / joint at the time of installation - Figure 2.5.6.4,
- Rotating hammer drill,
- Forced concrete mixers,
- G gun,
- Torque spanner,
  Equipment for hydraulic impression.

Figure 2.5.6.4: Adjusting rubber mat expansion joint with a retractable mechanism for extrusion/compression

2.5.6.2.2.6 Installation of modular expansion joints

Basically, there is not much difference among modular metal expansion joints with rubber seals of different type and from different manufacturers. With regards to installation, some types can be problematic as their outer metal boxes for protection of control mechanisms are of various widths and lengths (Figures 2.5.6.5 to 2.5.6.7).

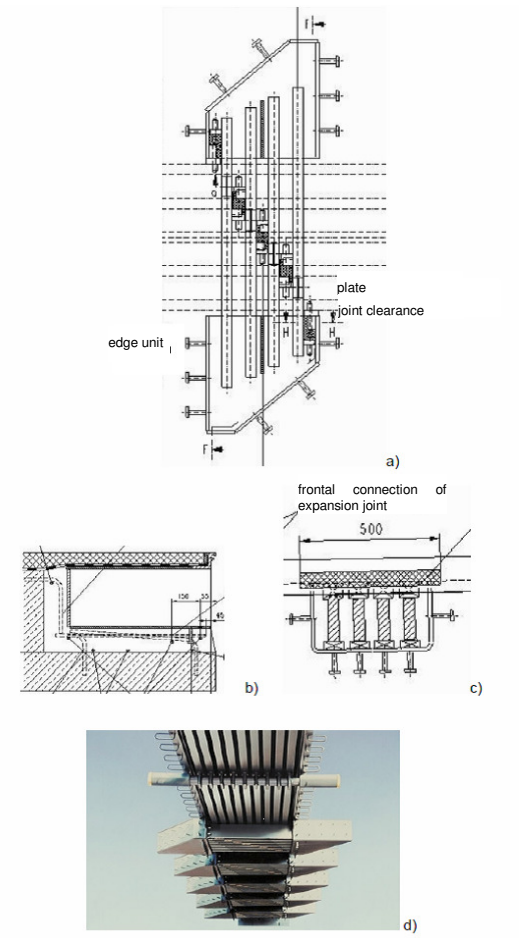


Figure 2.5.6.5: Modular expansion joint with movable mechanism within one cross beam - Manufacturer 1

Width of the box with the increased number of plates is up to 500 mm, as each plate requires one cross beam. Possible causes of damage may vary; one of them is certainly flawed installation of expansion joints, or improper grouting of metal parts with concrete.

Another problem are steel edge profiles. They usually have edge profile 80 mm wide, and it can be increased up to 150 mm (according to ÜBE-1). In such cases,

ventilation holes with Ø 20 mm and 25 cm spacing are required.

Otherwise porous areas appear below the edge profile and premature damage to edge asphalt occurs.

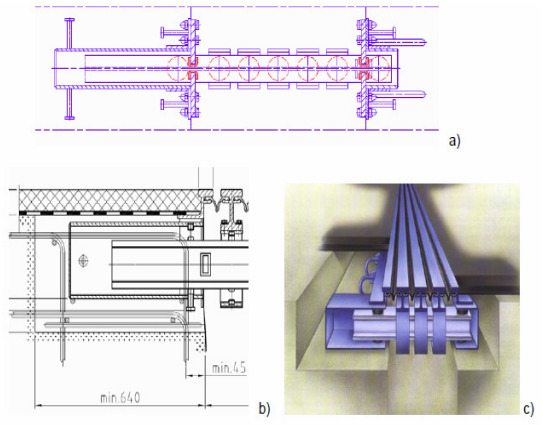


Figure 2.5.6.6: Modular expansion joint with movable mechanism within one cross beam - Manufacturer 2

Modular expansion joints with kinematic mechanism (hinge) can come very close to each other, especially in the centre of the expansion joint. An example of such modular hinged expansion joint is shown in Figure 2.5.6.7.

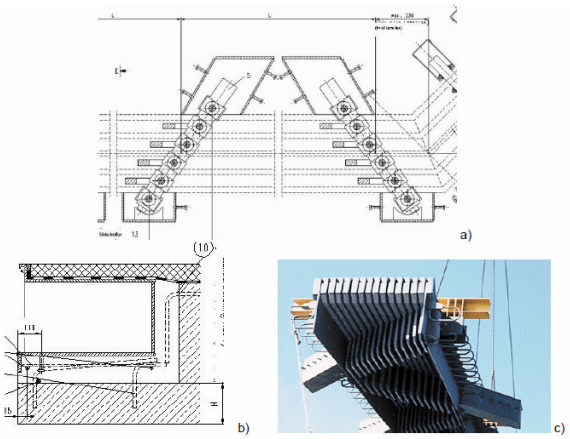


Figure 2.5.6.7: Modular expansion joint with kinematic mechanism (hinge)

After the concrete specification is provided in the concrete mix design (please see Section *Installation with Concrete*), expansion joint is prepared for installation. First the sealing of all openings of the expansion joint steel contacts and openings below the formwork in the construction openings must be completed, in order to avoid leaking of cement mortar or even concrete. Particularly sensitive areas are around the boxes, or in the boxes where bearings for cross beams are located. Self-adhesive PVC strips can be used for sealing of contacts, and PU foam that swells is required for sealing of openings.

Sometimes the formwork sheets below expansion joints are only 1.5 mm thick. In this case it is necessary to provide additional support for boards and beams, as the concrete will move apart the sheets during casting. After checking that the contacts are free from defects, it is possible to start with the casting.

In addition to known principles regarding the start of casting (not in the rain, cold or hot weather), it is necessary to provide proper compaction devices (usually the injection vibrators with 40 mm cross section or in the case of reinforcement placed at greater distances up to 57 mm, as well as the chain). Speed is of particular importance, i.e. number of entries-exits of the vibrator from the concrete, and especially in aerated concrete. If there is a risk that air bubbles did not come out under the wide boxes or that they were accrued under the roof or in the corners, the steel chain should be used to scrape the bottom side of the box or e.g. the vibrator should be placed again under the surface of the edge profile and the aeration opening should be observed too see if the air bubbles are still coming out. If bubbles are still coming out, additional compaction of concrete is necessary. After the casting is completed, the concrete must be aligned with the height of the upper surface. As the grouting procedure is sometimes lengthy and demanding, the consistency during casting later pays back plentifully. Practice has shown that expansion joints usually fail primarily due to poorly grouted areas. Therefore the control mechanism, i.e. expansion joint as a whole comes into resonance, bearings, slip hinges and bolts start to fall out, steel welds or profiles crack, and asphalt on the carriageway starts to crack and fall off. Service life of the expansion joint is greatly reduced in such way.

2.5.6.2.2.7 Installation of cantilever expansion joints

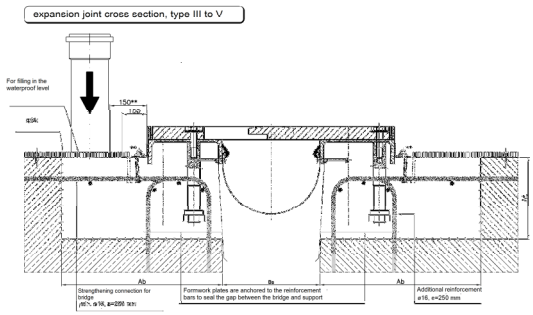


Figure 2.5.6.8 Cantilever expansion joints - principle of installation with a funnel

When using a highly quality standard or self-compacting concrete the formwork can easily be filled with a funnel made of PVC pipe that should be previously fixed on the formwork. Similarly, pouring can be done with concrete pump or separately using only the concrete mixer.

The maximum distance between individual pipe fillings is 6 m. The formwork should be well sealed with polyurethane foam or equivalent material.

Casting is done from the bottom to top (to the level of insulation) and along the entire width in a single stroke.

Concrete is aerated at the highest point, through holes in the marginal area. The level of pipe charging must be several centimetres above the highest point of the expansion joint in order to ensure complete filling with the concrete.

Upon completion of grouting, pipes remain in place until the concrete hardens. Formwork can be removed after the concrete hardens.

2.5.6.2.2.8 Specification of the concrete used for the installation of expansion joints

Before specifying properties of the concrete for installation of expansion joints within the concrete mix design, the following should be noted: whether the expansion joint is within the motorway alignment or on turning/access point (e.g. with the over bridge, as this affects the fact whether the toughness of concrete should be increased); and whether the expansion joint on the structure is in the cross/longitudinal fall greater than 3% (self-compacting or regularly treated concrete that transfers a certain fall). Only after this a more detailed specification can be provided. The next parameter is the speed of concrete hardening and moisture content at placing of waterproofing layer, especially for reconstructions that usually last shorter, or less than a month. And the last but not the least, the degree of reinforcement in the construction opening around the expansion joint (depending on the size of the largest grain of the mineral aggregate).

Example 1 of the concrete specification: Structure within the motorway alignment

C 35/45, S4, D_{max}=16 mm,
XF3, XF4, XD3, low shrinkage (0.40 mm/m)

Here self-compacting concrete may be used, since the slopes of the structure are small. As the expansion joint is on the structure with very heavy traffic, in addition to conventional reinforcement it is necessary to provide steel microfibers to ensure that cracks do not appear within the concrete microstructure due to fatigue. Since self-compacting concrete is used with a high amount of fine particles, certain degree of tightening should be provided. This can be achieved by using the expansion cement or expansion admixtures. Concrete aeration is obligatory, in accordance with requirements of SRPS EN 206-1.

Example 2 of the concrete specification: Structure within the motorway alignment

C 35/45, S3, D_{max}=16 mm, XF3, XF4, XD3

For large structure slopes, a slightly denser concrete with lower consistency is more appropriate. Since the expansion joint is on the structure with a very heavy traffic, the required toughness of the concrete should be provided. Because of the thick reinforcement, it is recommended to use grains of size up to 16 mm. Concrete aeration is necessary, in obligatory, in accordance with requirements of SRPS EN 206-1.

Example 3 of the concrete specification: Structure on the turning / access point

C 30/37, S4, D_{max}=16 mm, XF3, XF2 XD3

Self-compacting concrete may be used here, since the slopes of the structure are small. As the expansion joint is on the structure with a lighter traffic, conventional reinforcement is

sufficient. Class of concrete hardness can be lower, but not less than C30/37. Since the content of fine particles is smaller, hardening is usually not problematic. Due to use of self-compacting concrete, value of D_{max}=16 mm is preserved. Concrete aeration is recommended.

Example 4 of the concrete specification: Structure on the turning / access point

C 30/37, S3, D_{max}=31.5 mm, XF3, XF2, XD3

For large structure slopes, a slightly denser concrete with lower consistency is more appropriate. Due to normally distributed reinforcement, it is recommended to use grains of size up to 32 mm. Concrete aeration is recommended.

During reconstruction of expansion joints the increase of strength with time is of particular importance. Therefore, it is necessary to specify:

- Cement with rapid hardening (CEM I 42.5 or 52.5, CEM II 42.5 R),
- Hyperplastifier,
- Rock dust, fly ash or silica fume,
- W/c less than 0.43,
- Decrease of consistency over time - after 60 minutes not less than one degree: from S4 to S3, from S3 to S2,
- Compressive strength after 1 day is greater than 30 MPa (average for 3 results).

2.5.6.2.2.9 Installation of Waterproofing with the expansion joint

Prior to installation of waterproofing layer it is necessary to remove laitance from the concrete surface with water under high pressure, sandblasting, brushing, etc. The waterproofing layer should be carefully glued to the expansion joint profile, which must be primed. The remaining gap is sealed with bitumen filling together with gap that was formed in the protective layer of the waterproofing. Alternatively, protective layer can be attached to expansion joint with the bitumen sealing strip. The procedure is determined by technical conditions for the final waterproofing of the vertical boundary surface. Particular attention should be paid to all joints of boundary surfaces with surfaces on the expansion joint (Figure 2.5.6.9).

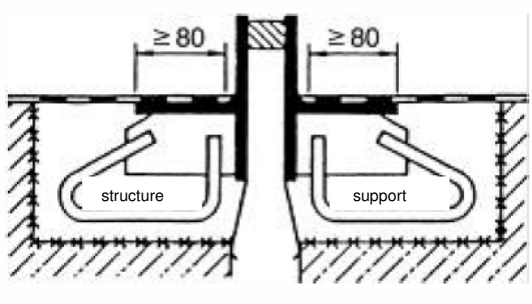


Figure 2.5.6.9: Connection of waterproofing on the steel edge area of the expansion joint

2.5.6.2.2.10 Installation of the wearing layer next to the expansion joint

Wearing layer along the expansion joint should be carefully installed. Solid elements of the expansion joint prevent rolling and compacting of asphalt-concrete next to the expansion joint, which causes cracking of the wearing layer next to the expansion joint.

Quality compression is achieved by covering the solid elements with the board of proper width before the rolling – installation of templates. After rolling, board is removed and rolling is continued, which additionally compresses the wearing layer (roller does not press the expansion joint). Thickness of the board (pad) is chosen so that the expansion joint remains 3-5 mm below the surface of the carriageway after completion of rolling. This allows compacting of the wearing layer under the strain from car wheels, and expansion joint is prevented from the impact of the plough during snow removal.

In special cases, in the transitional zone of the asphalt before and after the expansion joint it is possible to make special ribs from epoxy concrete in the form of fish bones. Please see more about this in the Austrian Guidelines RVS 15.04.51.

2.5.6.2.3 Inspection and maintenance of expansion joints

Procedure of inspection and maintenance is set out by the manufacturer, as well as the technical approval (e.g. ETA or national) for particular type of the expansion joint. Upon technical taking over the contractor must provide the manager of the structure with instructions (Table 2.5.6.3), which are an integral part of the expansion joint technical documentation. Manager of the structure must enter the procedure in the protocol (technical instructions), whereby it appoints a

responsible person that takes care of the control and maintenance. If maintenance works require restrictions in traffic, then works should be carried out as agreed with appropriate services that regulate traffic.

Maintenance service examines the expansion joint twice a year. During examination of the expansion joint, structural elements of the structure in which the expansion joint is installed must also be examined.

2.5.6.2.4 Repair of expansion joints

Before repair it is necessary to thoroughly examine the expansion joint. This should be done in two steps:
- First, the surface condition is examined,
- Then situation in the expansion joint is examined. This requires list of components of the expansion joint.

Surface condition inspection should include:
- Overall condition of the expansion gaps and especially in case of several connecting plates of the modular expansion joints,
- Sealing strips in the gaps - openings,
- Corrosion of steel parts (especially in the closed space of the panel),
- Condition of seal between the expansion joint and the road surface,
- Whether the expansion joint profile edge is askew or not,
- The height of the expansion joint,
- All anchoring bolts.

When verifying the condition in the interior, the following should be ascertained:
- Whether there are any places where the water penetrates,
- All expansion joint parts are in their positions,
- All expansion joint parts are in good condition,
- Individual elements allow necessary movements,
- All components are without any damages,
- Whether the steel boxes (for modular expansion joints) are resistant to corrosion and grouted with concrete,
- Cleanliness.

Based on the analysis of expansion joint condition, repair plan should be made. There are small and major repairs of expansion joints. In small repairs, spare parts are replaced, such as elastomer springs, rubber rings, plastic disks and the like. Replacement of these parts, above or below the expansion joint, is performed with special tools, and only by the manufacturer. The lifespan of the spare parts is shown in Tables 2.5.6.1 and 2.5.6.2.

Table 2.5.6.1: Lifespan of components - definition according to ETAG032

Category		Required lifespan
A	Not replaceable	Same as for the expansion joint composition
B	Replaceable, with greater traffic disturbance	At least half of the expansion joint lifespan, but not less than 10 years
C	Replaceable, with smaller traffic disturbance	Not less than 10 years

Table 2.5.6.2: List of components for modular expansion joints - lifespan according to ETAG032-8

Components	Required lifespan
Plates between expansion joints	B
Steel edge profile	A
Cross beam	B
Pantograph (cross beam)	B
Transversal box	A
Rubber seal - profile - strip	C
Fixed or sliding bearing with PTFE	C
Prestressed element	C
Elements of the control mechanism	C
Anchor loop	A
Elements against the noise (plates)	B

Examples of repairs:

Example 1 – Repair or elastomer rubber strip

If the sealing rubber elastomer strip is punctured or cut at certain places, it should not be immediately replaced with a new one. Manufacturer may insert a section at the place of damage and vulcanize the entire strip.

Example 2 – Repair of the longitudinal steel plate

Repair of a transversally fractured longitudinal steel plate is similar to repair of the sealing strip; it is completed by partial replacement of damaged sections. First a transversal cutting and removal of the fractured section of the plate is done, and then the replacement part is inserted and connection is transversally welded. Welds should be ground and coated with paint.

Example 3 – Repair of cross (lateral) beams below the plates

Repair of fractured steel beam is more demanding. The old part has to be removed and replaced with a new one; afterwards, it is necessary to assemble and weld two halves at the site.

Example 4 – Repair of transversal boxes

It is possible to repair fractured steel boxes. Usually the bearing disks fall out due to lack of concrete grouted below the bottom of the box. Repair is divided into at least five phases. First, all bearings from solid polyamide and elastomer springs have to be removed from the box. Then the concrete should be removed from below the box (as deep as possible, and at least reaching the half of the box). The following step is to install the new, additional steel sheet onto the bottom of the box (with anchors), which is welded onto existing parts of the bottom. Finally, formwork is installed and casting below the opening of the box is performed.

After hardening of the concrete, springs and bearings for lateral beams are re-installed.

2.5.6.2.5 Replacement of expansion joints

Replacement of expansion joints is done through a procedure which is identical to described procedure for installation of new expansion joints, or on the basis of technical documentation for execution.
During replacement the specifics of the described procedure need to be taken into account. Particular attention should be paid to procedure of removal of expansion joint, which can destructively affect the structure. It is recommended to remove the concrete with a robot and water under high pressure (more than 2,000 bars).

Replacement of expansion joints is often carried out without interruption of traffic, which requires implementation in phases. In such cases expansion joint has pre-fabricated joints.

2.5.6.2.6 Certification and inspection of expansion joints

Taking over and inspection of expansion joints is performed:
- In accordance with ETA technical approval, in accordance with ETAG032, 1-8 for particular type of the expansion joint,
- Or in the previous period according to national system specified in the agreement (e.g. according to Austrian technical approval in accordance with RVS 15.04.51 or according to German technical approval in accordance with TL/TP FÜ, ZTV-BEL-FÜ or according to French technical approval N° F AT J0 and the like).

2.5.6.2.6.1 Certification according to ETA technical approval

Input materials must be in accordance with the requirements for quality control according to standard *SRPS EN 10204 - Metallic products - Types of inspection documents*.
Details on internal control of the manufacturer for modular expansion joints are given in tables 2.5.6.3 and 2.5.6.5.

Documentation

Authorized institution (from manufacturer's country) provides information about the start of examination of the product and production at the factory for the purpose of issuance of ETA approval. It previously consults with the manufacturer about the results. Information is public and confidential (deposited with the authorized institution). Documentation also includes specific workshop drawings, specification lists, control plans and quality control plans.

CE mark and accompanying document

Information on conducted inspection is provided by the CE mark on the label – Figure 2.5.6.8 (certificate number, number of the authorized institution, year of initial inspection, ETA number and ETAG number). The documentation also comprises the

accompanying list with production date and batch number of the product. The documentation contains no note of the significant properties of the product.

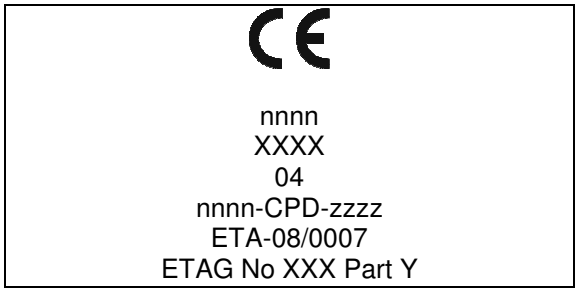


Figure 2.5.6.8: CE mark for expansion joints according to ETAG032-1

2.5.6.2.6.2 Certification in accordance with the national technical approval

Certification of compliance with national technical approval is done similarly as for the European technical approval. It is based on the control of independent certification authority - institution (third party) that issues technical approval to the manufacturer. Relations between the manufacturer and the independent institute are governed by written agreement (Contract of Surveillance). For example in Germany, in accordance with DIN 18200 standard, control of the independent institute is performed at least twice a year and it includes random checks. Certification body issues inspection report.

In Germany BASt regularly keeps records on valid technical permits that are available on the Internet at:
http://www.bast.de/.

Austria has the similar case. BMVIT keeps records on issued technical approvals:
http://www.bmvit.gv.at/verkehr/strasse/technik/bautechnik/uebergangskonstruktionen/index.html

In France, SETRA is the responsible authority. List of technical approvals for expansion joints can be found at: *http://www.setra.developpement-durable.gouv.fr/Avis-techniques-en-cours-de.html*.

The final assessment of conformity of installed expansion joints can be performed at the site by a third party - the Institute.

The issuance of a Certificate of Conformity may be conducted only by a legal entity which is accredited for conducting the works of certification according to the standard SRPS EN 45011 with the Accrediting body of Serbia.

Table 2.5.6.5: Required minimal scope of instructions issued by expansion joint manufacturer according to ETAG032-1

The suggested format of instructions for installation:
Installation instruction should have the format shown in the following list and if possible should contain brief and clear information required for installation. Information and specific values that do not require basic examination should be indicated.
Installation instructions should contain the title page with the following information:
* Title: Installation instructions (exact title / name of expansion joint system)
* Installation instructions

Contents
1. Data
1.1 Description of the system
1.3 Scope of application
- Limitations of application (e.g. maximum slope, weather conditions, etc.)
2. Components (tabular list in all cases)
2.1 Delivery form
- Material, chemical type
- In colour
- Package size
- Storage requirements
2.2 Marking in accordance with regulation on hazardous substances
With instructions for disposal of liquid and solid waste residue, including residual solid (hazardous) material (waste codes as given in Appendix C of Waste TA)
2.3 Composition of tanking and the joint filling mixture
- Bonding materials
- Quantity of bonding material
- Distribution of aggregate grain sizes
- Type and source of the aggregate
- Other material components by type and quantity
- Special properties (if applicable)
2.4 Other components of the expansion joint kit
- Type of plate
- Thickness of plate in function of width of expansion joint opening
- Strip width
- Type of fixing
- Type of seal
- Miscellaneous
2.5 Materials used for coating of surfaces
- Material for binders (if used)
- Gritting material, particles, distribution
- Miscellaneous
Installation

3.1 General
- Measures of safety at work. This is required according to European regulations.
3.2 Description of operations
3.2.1 Making of expansion joint recess
- In the existing carriageway
- In case of construction or carriageway reconstruction
- Connecting with waterproofing layer
3.2.2 Preparation of support areas and/or support wall below the expansion joint opening
- The process of preparation (instructions for grit blasting material, if necessary)
- Cleaning, drying and preheating of expansion joint opening
- Cleaning of surroundings after preparation of the surface
3.2.3 Previous preparation of concrete deck by sealing, repair or waterproofing
- Description of previous preparation work
- Compatibility of work with technical instructions
- Description of application and mixing of components

- Processing of requirements (minimum and maximum temperatures for materials and support, maximum moisture content, dew point temperature, the amount of moisture on the support)
- Minimum and maximum waiting period before re-coating in the function of temperature range (10 °, 20 °, 30 ° C)

3.2.4 Sealing of structural gap
- Caulking and sealing materials
- Procedure for sealing of openings
- Description
- Plate placement
- Plate fixation
- Miscellaneous

3.2.5 Joint recess tanking
- Work process
- Desired thickness of layers / applied quantities
- Material temperature (Rmin / Tmax)
- Supports temperature (Tmin / Tmax)
- Waiting periods before installation of the joint recess filling
- Special points concerning concrete joint recess wall
- Miscellaneous

3.2.6 Filling of joint recess
- Weather conditions
- Installation process for individual carriageway lanes / layers
- Composition / mixing proportions
- Mixing (type and duration)
- Pre-heating of stone chippings (type and duration)
- Temperature of binding material (temperature for preparation and installation)
- Holding time for binder material in agitation boiler
- Temperature of stone chippings (temperature of preparation and installation)
- Temperatures of support area (Tmin / Tmax)
- Compaction
- Minimal and maximal waiting period before installation of subsequent layers and final processing
- Desired thickness of layers / applied quantities per square meter
- Production of expansion joint sections in a day
- Miscellaneous

3.2.7 Surface dressing
- Gritting time
- Application of surface dressing
- Quantity of surface dressing
- Compacting of surface dressing
- Waiting period before exposure to traffic
- Miscellaneous

Appendix
- Additional information for security / work safety
- Diagrams
- Miscellaneous
- Description of work should be such that it includes depth of surfacing,-weather conditions, gap width, deck and asphalt conditions.

Table 2.5.6.4: Sample record for the expansion joint

Structure (road section, mark, position):			
Client (Employer):			
Accepting party:			
Name of expansion joint manufacturer, purchase order number:			
Number of expansion joint technical approval, issued by:			
Validity of approval:			
Contractor, responsible head of construction:			
Number of the design for expansion joint execution and installation:			
Engineer, site engineer:			
No.	Stage	Description	Entry
1	Basic data about the expansion joint	Place of installation (support no., axis)	
2		Expansion joint type	
3		Capacity of movement vertically to the expansion joint axis	
4		Movement for 1 ℃	
5	Delivery of expansion joint to the site	Date of take over from the manufacturer	
6		Date of the delivery to the site	
7		Mark on the expansion joint	
8		Expansion joint delivered in functional condition (Yes/No)	
9		Proper condition of all steel and blockout elements	
10		Condition of anticorrosion protection of steel parts	
11		Proper condition of rubber seal - strip	
12		Expansion joint properly stored, supported, protected	
13	Before installation	Proper size of expansion joint recess, niche for installation	
14		Cleanliness and preparation of contact surfaces	
15		Proper condition of anchoring reinforcement	
16		Proper condition of holes for anchoring bolts	
17		Number of technological design for installation	
18		Number of geodetic report on measurement of geometry	
19	During installation	Date / hour	
20		Temperature of the superstructure in ^{o} C	
21		Width of expansion joint gap	
22		Proper geometry of tightening	
23		Proper resistance to tightening	
24		Removal of expansion joint blockout elements	
25		Anticorrosion protection, seal, cleanliness before casting	
26		Mark and number of samples of installed material	
27	Exploitation	Date / hour	
28		Temperature of the superstructure in ^{o} C	
29		Width of expansion joint gap	
30		Anticorrosion protection, seal, deck sheets	

Contractor: Expansion joint manufacturer: Engineer:

Date:

Table 2.5.6.5: Procedure and conformity evaluation (example for modular expansion joint-ETAG032-8)

Procedure	Subject	Standard/Specification	Requirements	Supervision Frequency
Measurements and visual procedure	Main dimensions of expansion joint (parts) with possible lifting in relation to cross-section of the structure (including kerb, walkway, gullies...)	-		
	Regulation of the width of opening	-	Please see workshop drawings	On the entire cross-section, at 3 m length
	Control mechanism		Please see workshop drawings	100 %
	Cross beams, plates, edge profiles - examination of dimensions		Please see workshop drawings	100 %
	Cross beams - placement		Please see workshop drawings	100 %
	Condition of prestressed elements		Please see workshop drawings	10 %
	Bolt torque		Please see workshop drawings	10 %
	Evenness		Please see workshop drawings	
Measurements and visual procedure	Anti-corrosion protection Surface properties (roughness, cleanliness) Dew point, paint drying time, thickness of each layer or the entire coating	Manufacturer's specification in accordance with EN 12944	Dry film thickness, according to workshop drawing	According to program, according to EN 12944-7, at every 2 m on the cross-section; for small areas – 20% for inspection
	Dominantly dynamically loaded welds,	EN ISO 3834, confirmed welding	EN ISO 3834-2 Please see workshop	-

	work procedure description, dimensions control, errors	procedure	drawings	
	Dominantly statically loaded welds, dimensions control			
	Not loaded welds, dimensions control	-	Please see workshop drawings	-
	Subject	Standard/Specification	Requirements	Supervision Frequency
	Connections of sinus plates with plates Weld connections Bolt connections	Please see dynamically loaded welds. Please see manufacturer's requirements	Please see dynamically loaded welds. Please see manufacturer's requirements	Please see dynamically loaded welds 100 %
Visual examination	Rubber seal Installation and tightening Injuries	-	Please see workshop drawings/specifications	-
	Secondary welds errors	-		-
	Butt weld preparation of centre beams and edge beams	-		
	Marks, including CE	-		-
	Label tables (order no., structure, axis, mass, adjustment)	-		-
	Sliding elements, condition (roughness, cleanliness, grease)	-		-
	Bearings, adjustment, tightening, control mechanism	-		-

2.5.7 STRUCTURES

2.5.7.1 Precast concrete elements

2.5.7.1.1 Introduction

Industrialization of construction, and assembly of precast elements as its element, especially in construction of superstructures and bridge equipment elements, is achieved primarily through design of proper technical solutions, and then with application and mastering of contemporary technology, proper preparation, planning and organizing of assembly process.

Modern technical solutions of precast bridge structures must be followed by proper technology and organization of work. During design and construction of precast structures it is necessary to define production of elements and assembly processes that will ensure required results in relation to deadlines, costs and quality.

2.5.7.1.1.1 Description

Technical requirements for precast elements are component of construction specifications and refer to relevant specifications related to concrete-related standards and concrete structures design.

Assessment of compliance in these technical requirements refers to final precast elements that are available in the market and includes equipment, materials, production process and appearance of final products.

2.5.7.1.1.2 Reference standards

Existing technical requirements include EN standards. The latest versions are always the most relevant ones.

- SRPS EN 13369 – Common rules for precast concrete products
- SRPS EN 13225 – Precast concrete products - Linear structural elements
- SRPS EN 206-1 - Concrete - Part 1: Specification, performance, production and conformity
- SRPS ENV 13670-1 – Execution of concrete structures - Part 1: Common

2.5.7.1.1.3 Terminology

Precast concrete element (prefabrikovani montažni betonski element) is an element made of concrete in accordance with precast concrete element standards or specific standards for a product. The product is a result of industrial process that is subject to factory production control system and there is a possibility for sorting before delivery.

Finished concrete product (finalni (gotov) proizvod) is a precast concrete product that is available in the market or is delivered to the site.

Structural precast product (konstrukcioni prefabrikovani proizvod) is a precast concrete product which according to its function, mechanical resistance and/or stability of construction work corresponds to structure in which it is installed.

Light-weight non-structural element (lagani nekonstrukcijski element) is a precast concrete product for which there are no legal requirements on mechanical resistance in situ.

2.5.7.1.1.4 Abbreviations used

SRDM – Serbian Road Design Manual

2.5.7.1.2 Requirements

2.5.7.1.2.1 Material requirements

Only materials certified for use should be applied.

Benefits of a particular material can be determined on the basis of European standard referring to use of materials in concrete or concrete products, and in absence of European standard, ISO standards can be used under the same conditions.

Requirements for Basic Materials for Concrete Production

SRPS EN 206-1 standard is applied, along with provisions from the Annex and/or national Annex to SRPS EN 206-1.

Recycled crushed concrete aggregate

Recycled crushed concrete aggregate that is added to and mixed with other aggregates must not adversely influence bonding and curing of concrete and it also must not adversely affect durability of concrete products at the end of their use.

Reinforcement steel

Reinforcement steel must meet requirements of EN 1992-1-1 standard (Eurocode 2).

Prestressing steel

Prestressing steel must meet the requirements of EN 1992-1-1 standard (Eurocode 2).

Included machine parts and joints

Included machine parts and joints must:
- Be resistant to design forces,
- Have required ductility,
- Keep these properties during entire lifetime of the concrete product.

2.5.7.1.2.2 Production requirements

Concrete production requirements

Composition of concrete, cement and aggregate type, admixtures and additives use, chloride and air content and concrete temperature most comply with SRPS EN 206-1 standard.

SRPS EN 206-1 standard should be used in concrete specification.

Additional regulations given in the national annex to SRPS EN 206-1 should also be taken into account.

Concrete installation and compaction

During installation concrete should be compacted so that quantity of caught or remaining air should not be significant in order to avoid segregation. It should also be taken care that reinforcement is properly installed in the element.

Curing and protection (protection from drying out)

During drying and curing concrete must be protected from loss of strength that is consequence of cracking caused by temperature and shrinking. All surfaces of the fresh cast concrete must be protected by at least one of the methods specified in Table 2 of SRPS EN 13369 standard. If this cannot be done, additional tests of final products or other methods should be used to prove that products has not lost strength and there are no surface cracks although protection was not used.

Protection is applied until standard strength is achieved at the end of care period, which is expressed through curing degree or numeric values specified in Table 1 of SRPS EN 13369 standard. For bridge elements whose expected lifespan is longer than 50 years or for specific local climate zones, other values and conditions in project documentation may apply.

Hardened concrete requirements

Strength classes

Concrete compressive strength class is determined on the basis of the following criteria:
- Product's mechanical resistance is confirmed and proved in initial type test and routine test of this property during factory production control for final products,
- Strength class is not a relevant parameter that indicates durability of the final product.

2.5.7.1.2.3 Final product requirements

Geometric properties and tolerances

Nominal values of final product's geometric properties are specified in technical documentation.

Geometric properties of concrete structural products must comply with required minimal nominal dimensions.

Geometric tolerances for linear beams and piers are specified in SRPS EN 13225 standard. For example, for the T-beam of superstructure please see Figure 2.5.7.11 and Table 2.5.7.1.1.

Surface properties

The holes resulting from air caught with the formwork are cavities whose depth is less than 3 mm and greatest dimensions in the surface plane are between 5 and 15 mm. If the maximum value is greater than 15 mm or depth is greater than 3 mm, this should be considered as a hole. Staines whose dimension is below 3 mm should be neglected.

Number of holes caused by air is the number of pores that can be counted on the 1 m^2 surface. Maximum number of holes caused by air is defined as average value of three counting of holes caused by air - number is counted in the frame with dimensions 1 x 1 m. If dimensions of an element are less than 1 m, then frame should be formed from the greatest possible length in one direction and corresponding length that would give surface

area of 1 m^2 in another direction. Frame should be placed in way that is best for counting the number of holes resulting from air. Observed areas for counting should not be overlapping.

In relation to final product surface specification, SRPS EN 13369, Appendix J, should be mentioned, as it provides recommended values. Also, SRDM Section 9.12.8 requirements should be taken into account.

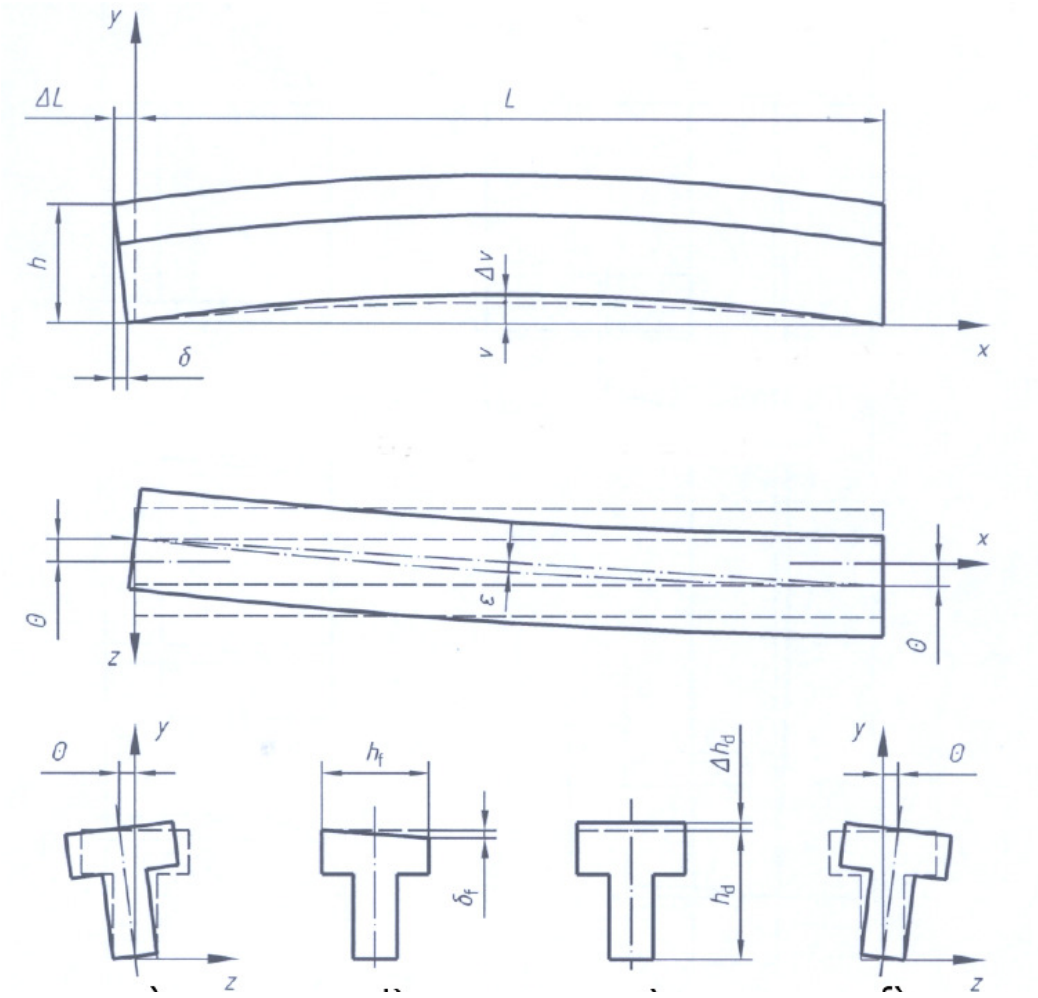


Figure 2.5.7.1.1: Beam tolerances

Table 2.5.7.1.1: Beam tolerance values

Measuring	Permitted deviation	Values
Angle Θ from the vertical plane of the middle slab	+- Θ	L/700
Camber v in the vertical plane	+- Δ v	L/700

Mechanical resistance

All relevant properties of supporting concrete support, in the limit state, are considered to satisfy required leading capacity and usability.

Mechanical resistance should be checked by computational method combined with a test or only with a test.

Resistance to fire

Fire resistance must be provided if there is legal requirement of this property in situ.

Durability

Basic materials for concrete making must be chosen so that cured concrete during designed lifespan is sufficiently resistant to different degradation mechanisms:

- Resistance to carbonisation (XC mark according to SRPS EN 206-1 standard),
- Resistance to chlorides (XD, XS),
- Resistance to freezing and thawing (XF),
- Resistance to chemical impact (XA).

Resistance of steel to corrosion is achieved by following the principles of EN 1992-1-1 standard (Eurocode 2). Consequences of these principles are proper protective concrete layers for concrete products of different exploitation classes and use with expected lifespan of 50 years. Proposed values for concrete products designed with a shorter lifespan (30 years) are specified separately. Other values that must be applied in situ are specified at the national level in the appendix to the execution of work standards.

Other requirements

Concrete product must be designed and produced so that it can be handled safely, without harmful effects on the product itself. Restrictions related to handling and storage during transport and in situ are specified by the manufacturer.

Manufacturer controls the weight of elements and specifies the weight if designer is different from the manufacturer.

2.5.7.1.3 Test methods

2.5.7.1.3.1 Concrete testing

Concrete strength must be examined on samples from moulds or cores or cubes extracted from the final product in accordance with the relevant specifications stated in SRPS EN 12390, Part: 1-3 and SRPS EN 12504-1 standards.

Regarding other tests, please see SRPS EN 13369 standard.

2.5.7.1.3.2 Dimensions and surface properties measurement

Dimension measuring methods for different elements and surface properties measuring methods are specified in SRPS EN 13369, Appendix J.

2.5.7.1.4 Compliance control

Concrete product compliance with relevant standard requirements and specific or specified values (levels or classes) for product properties, must be confirmed:

- By the initial testing, and when necessary also with the static calculation,
- By production control, including examination of products.

2.5.7.1.4.1 Compliance assessment

Compliance can be assessed by the third party - Institute, whose tasks will depend on the specific product type.

Internal production control certification, product certification and issuance of the Certificate of Conformity may be conducted only by a legal entity which is accredited for conducting the works of certification according to the standard SRPS EN 45011 with the Accrediting body of Serbia.

In this case it includes the following tasks:

- Initial inspection of the factory and control of factory production,
- Continued monitoring, assessment and approval of internal production control (along with supervision of material, production process and final products measuring and examination),
- Monitoring, assessment and approval of initial type product testing,
- Additional testing of samples taking at the factory or eventually on the site.

Concrete product compliance with relevant standard requirements can be assessed at the location of elements takeover (takeover assessment).

If compliance is assessed, takeover assessment is unnecessary.

2.5.7.1.4.2 Initial type test

Purpose of initial type test is to demonstrate whether a final product, product property or relevant production process meets the conditions and requirements.

Initial type test or the following tests consist of subjecting the representative final product samples and/or samples to relevant tests and/or static calculations in order to prove properties of the element or production process aspects.

All data that allow identification of product or line of products subjected to initial type test, all data which represent relevant monitoring parameters, and results of type testing, must be recorded in written form.

2.5.7.1.4.3 Internal production control

Manufacturer must have certified system of quality according to SRPS EN ISO 9001, including requirements of SRPS EN 13369 standard for the assembly elements.

Tasks, responsibilities and authorization of internal production control staff must be documented, maintained and implemented.

The manufacturer is obliged to establish, document, implement and maintain internal production control and to ensure that products placed on the market or the construction site comply with the aforementioned values and technical documentation requirements.

The manufacturer should identify relevant properties of the factory and/or production process. Also, the manufacturer defines criteria, plan and production processes that directly affect conformity of the products.

It is necessary to inspect and test equipment, raw materials, other input materials, production process and finished elements or products. The subject, criteria, method and frequency of inspection and testing are determined through inspection schemes. Frequency of tests and inspections, as well as methods that are not listed in the standard, are defined so as to ensure continuous compliance of the products.

Sampling and testing plans for finished products must be prepared and implemented to all properties that are being controlled (including the label – tag).

2.5.7.1.5 Marking with label

Each manufactured unit must be marked in order to ensure:
- Identification of the manufacturer,
- Identification of production location,
- Number of the standard,
- Identification of unit codes when necessary (e.g. when adhering to declared properties of the unit and other relevant product data in accordance with the technical documentation or data on the production process).
- Production date,
- Net weight of the unit, where necessary,
- Other installation information (e.g. location and orientation), where necessary.

In addition to these data, label marking or accompanying documentation provide the following information:
- Product identity (description according to standard and/or trade name),
- Technical documentation, when possible.

2.5.7.1.6 Technical Documentation

2.5.7.1.6.1 Documentation on Product Delivery

Technical product documentation shall be available at the moment of delivery, which complies with selected method of declaration, and:
- ensures monitoring of design assumptions, methods, results and details of structures and elements, including information on dimensions, tolerances, arrangement of reinforcement, concrete protective layer, etc.
- ensures observation of national regulations at the site of use,
- provides instructions for safe transport, handling and storing,
- gives specifications for erection of elements, and
- provides additional information regarding element labels.

2.5.7.1.6.2 Design of technology and erection organization

Constructional production is mainly carried out on the site, regardless of applied construction method. Although prefabricated elements may be produced in a plant and transported to the site, the final formation of structure is executed under conditions on the site. Sites differ from one another by type of structure and design solution, as well as by specific conditions of the location.

When drafting the design of technology, organization and erection, it is necessary to first provide numerous data and information:
- technical documentation for civil engineering structure (bridges),
- tender and contractual documentation of the site,
- field conditions of the site,
- source and price of materials,
- solution for external transport.

On the basis of defined technical documentation and parallel to the drafting of structure design, the design of technology and dynamics of construction for prefabricated elements and structure (more often a superstructure of a bridge) is being elaborated.

Designing of construction technologies includes a number of stages, among which most important are:
- selection of work methods,
- definition and description of work processes,
- required capacities of processes,
- selection of machinery, and
- static and dynamic plans for materials, labour force and machinery.

The structure of the design of construction organization is given in Figure 2:5.7.1.2.

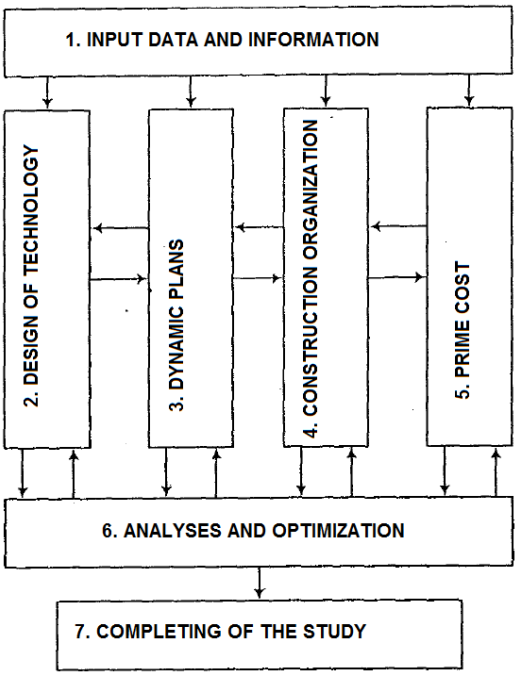


Figure 2.5.7.1.2 – The structure of design of technology, organization and erection

2.5.7.1.7 Execution of works and construction management

2.5.7.1.7.1 Management of structure erection and construction

Management of erection – construction on the site includes collection of data about work process and actions – effects, which is conducted after these data have been processed and analyzed.

During the construction of prefabricated structures, attention should be given to following phases of the process:
- plan and control of deadline for the construction of prefabricated elements, with the management of required materials stock,
- quality control of elements,
- plan and control of elements transport to the site,
- control of correctness of cranes and auxiliary means,
- management of the elements erection process,
- plan and control of the deadline for erection and construction,
- plan and control of erection and construction costs.

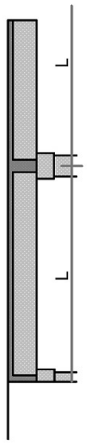
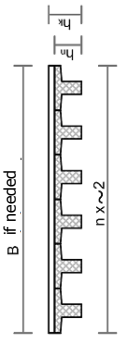
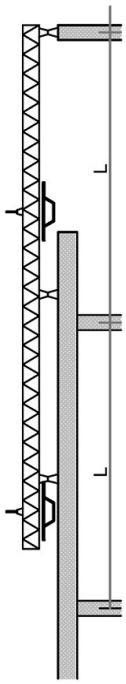
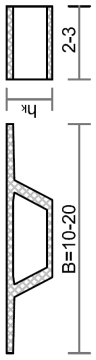
2.5.7.1.7.2 Selection of elements construction method for concrete bridge structures

To select a possible method for the erection of elements for concrete bridge structures, it is necessary to know the characteristics of bridge structure, as well as all the limitations and conditions for construction of such a bridge.

Defining uniform elaboration of technological procedures for all elements is very difficult due to variety and specificity of certain elements that are generated during construction, and due to probability of occurrence of new elements. Therefore, when elaborating technological procedures for the erection of elements, it is necessary to adhere to basic principles, and then to work out in detail technological erection procedure for every given element of the observed structure. Table 2.5.7.1.2 shows two cases of erection technology of the superstructure made of prefabricated elements – T-beams and beams of box section.

More detailed information about technology of construction by means of prefabricated elements for superstructures, may be found in SRDM, Chapter 9.11.

Table 2.5.7.1.2: Examples of construction technology for prefabricated bridge superstructure

Modern technologies of superstructures construction of bridges with beam and frame systems		LONGITUDINAL DIAGRAM OF THE BRIDGE	DIAGRAM OF CROSS-SECTION	Span l (m)
Technology for prefabricated-monolithic (composite) construction of superstructure for bridges	Superstructure constructed by prefabricated T-beams, composite with monol. reinforced concrete slab			5 – 25 5 – 200
Technology for prefabricated construction of superstructures	Superstructure constructed by prefabricated reinforced concrete segments			30 – 120 ➤ 500

2.5.7.2 Composite structures

2.5.7.2.1 Introduction

2.5.7.2.1.1 Description

These technical conditions prescribe requirements for composite structures made of steel and concrete (hereinafter: composite structure), Figure 2.5.7.21, and primarily requirements for execution, usability, betterment, as well as other requirements regarding composite structure and building products intended for building in the composite structure.

2.5.7.2.1.2 Reference standards

Composite structures shall meet all the requirements of these technical conditions, and the requirements of special technical regulations, which regulate the fulfilment of essential requirements for the structure.

These technical conditions contain EN standards and other valid documents. The latest edition shall always be applied.

- SRPS ENV 13670-1 – Execution of concrete structures – Part 1: Common
- EN 1090-1 – Execution of steel structures and aluminium structures – Part 1: Requirements for conformity assessment of structural components
- EN 1090-2 - Execution of steel structures and aluminium structures – Part 2: Technical requirements for steel structures
- SRCS – chapter: 2.5.5 Bearings
- SRCS – chapter: 2.5.1 Cement concrete
- SRCS – Chapter 2.5.2 Reinforcement steel
- SRCS – Chapter 2.5.7.4 Metal structures

2.5.7.2.1.3 Terminology

There are no significant terms used in this part of technical conditions.

2.5.7.2.1.4 Abbreviations used

SRCS – Serbian Road Construction Specifications

SRDM – Serbian Road Design Manual

2.5.7.2.2 Requirements

2.5.7.2.2.1 Material requirements

Only materials approved for intended use shall be applied.

Determination of certain material's suitability may be executed on the basis of European standard relating to use of materials in concrete or concrete products, or for steel structure, while in the absence of European standards, ISO standards may be applied under the same conditions.

Requirements for basic materials to be used in concrete

SRPS EN 206-1 standard, as well as the provisions of annex and/or national addition to SRPS EN 206-1 standard, shall be applied. See also SRCS, Chapter 2.5.1.

Reinforcement steel

Reinforcement steel shall meet the requirements of EN 1992-1-1 standard (Eurocode 2). See also SRCS, Chapter 2.5.2.

Prestressing steel

Prestressing steel shall meet the requirements of EN 1992-1-1 standard (Eurocode 2). See also SRSC, Chapter 2.5.2.

Steel products for bearing structure

Steel for superstructure (warm and cold rolled steel profiles, plates, strips, bars, wires, cast steel) shall fulfil the regulations for steel structures. Technical characteristics of structural steel products shall be stated in the design of composite structure, or in technical specifications for that product. See also SRCS, 2.5.7.4.

Composition means steel-concrete

Composition means are cylindrical dowels with a head. All properties of composition means steel-concrete are defined in SRPS EN ISO 13918 standard.

Products used for protection of composite structure's steel parts from corrosion

Technical characteristics of products used for protection of composite structure's steel parts from corrosion shall be stated in the design of composite structure, or in technical specifications for that product. See also SRCS, 2.5.7.4.

Mechanical connecting elements

Technical properties of mechanical connecting elements, as integral parts of composite structure, shall be stated in the

design of composite structure. See also SRCS, 2.5.7.4.

Additional welding materials

Technical properties of additional materials for welding of steel parts, which make the basic integral part of the composite structure, shall be stated in the design of composite structure. See also SRCS, 2.5.7.4.

Tensile elements of high strength

Technical properties of tensile elements of high strength, as integral parts of composite structure, shall be stated in the design of composite structure. See also SRCS, 2.5.7.4.

Structural bearings

Technical properties of structural bearings, as integral parts of composite structure, shall be stated in the design of composite structure. See also SRCS, 2.5.5.

2.5.7.2.2.2 Requirements for execution

The composite structure shall be executed so that, besides technical properties prescribed by these technical conditions, other requirements prescribed by technical solution and conditions for construction given in design are being met, and that preservation of these properties and serviceability of the structure during its service life are ensured.

2.5.7.2.2.3 Requirements regarding placing of concrete into the element

Concrete composition, cement and aggregate type, employment of admixtures and additives, as well as the content of chloride, air, and concrete temperature, shall comply with SRPS EN 206-1 standard.

For the specification of concrete and placing, SRPS ENV 13670-1 standard shall be applied.

Additional provisions are given in SRCS 2.51.

Concrete installation and compaction

Upon installation, concrete shall be compacted so that there is no significant quantity of captured or remaining air, and that segregation is avoided. Furthermore, attention should be given to proper placing of reinforcement into the composite slab. Casting is more thoroughly presented in SRCS 2.5.1.

Curing and protection (protection from drying out)

During drying and hardening, concrete shall be protected in a way that prevents strength loss due to cracking caused by temperature and shrinking. For more details on this, see SRCS 2.5.1.

Hardened concrete requirements

Hardened concrete requirements are given in specifications for concrete structure execution according to SRPS ENV 13670-1.

2.5.7.2.2.4 Sequence of concrete structure construction

The sequence of concrete slab installation is usually defined in the design of construction, and is subject to steel structure loading.

There are three methods for casting in segments (Figure 2.5.7.2.2):
- method 1: continuous casting in one direction
- method 2: continuous casting in one direction but regions at internal supports are casted in a second step after the concrete in mid-span regions is effective
- method 3: span by span, but in opposite direction than in method 2.

Casting of cross beams is executed simultaneously with casting of deck in bridges of small spans, while in those with greater spans, the deck is first cast, and then cross beams above the supports (Figure 2.5.7.2.3).

2.5.7.2.2.5 Compliance control

Requirements for composite structure execution are defined by program of quality control and assurance, which is the integral part of the detailed composite structure design, as given in Table 2.5.7.2.1.

Upon takeover of finished products manufactured off site, contractor shall find whether:
- the delivered product is marked in compliance with special regulation, and whether documentation data match the data given in marking of the delivered construction product,
- the construction product is delivered with technical instructions for building-in and use,
- properties, including expiry date of a construction product, and data relevant for its building-in, use and effect to composite

structure characteristics and durability, are in compliance with properties and data required by detailed design.

2.5.7.2.2.6 Compliance assessment

The composite structure is considered to have by design set properties and to be serviceable if:
- construction products are built in the composite structure in the prescribed manner, and have the declaration and assessment of compliance, or evidence of usability,
- construction conditions and other circumstances that may influence technical properties of composite structure were in conformity with design requirements,
- there is evidence of composite structure's bearing capacity and serviceability, obtained through testing under test loads, when they are prescribed as obligatory or required by design,
- there are prescribed records and/or documentation of above mentioned inspections.

If it is established that composite structure does not have technical properties required by design, subsequent verification shall be conducted.

If it is verified that achieved technical properties of composite structure do not meet the prescribed requirements, then the design of composite structure rehabilitation should be prepared.

2.5.7.2.2.7 Internal control during steel structure erection

The manufacturer shall have the verified system of quality in compliance with SRPS EN ISO 9001, including the requirements of SRPS EN 1090 standard regarding construction of steel structures.

Tasks, responsibilities and authorities of internal production control employees shall be documented, maintained and applied.

The steel structure manufacturer (usually a machinery company) is obliged to establish, document, apply and maintain the internal production control, and to ensure that structure elements delivered to the site comply with standard requirements and with values stated in requirements of technical documentation.

The manufacturer should identify the relevant characteristics of facilities and/or production process. In addition, manufacturer shall define the criteria and plan, as well as the production processes which directly affect conformity of the product.

Inspection and testing of equipment, raw materials, other input materials, production processes, and finished elements and products, are conducted. The subject, criteria, method and frequency of inspections and tests are determined by inspection schemes. Frequency of tests and inspections, and methods not stated in the standard, are defined so as to ensure the permanent conformity of the product.

Sampling plan and tests plan of finished products shall be prepared and applied for all properties that are being controlled.

2.5.7.2.3 Technical documentation

2.5.7.2.3.1 Documentation upon steel structure delivery from a factory

Technical product documentation shall be available at the moment of delivery, which complies with selected work method (welding, joining with bolts), and:
- ensures monitoring of design assumptions, methods, results and details of structures and elements, including information, such as dimensions, tolerances, etc.
- provides instructions for safe transport, handling, storing,
- gives specifications for erection of elements, and
- provides additional information.

2.5.7.2.3.2 Design of technology and erection organization

While steel structure is mainly produced in a factory, it is joined at the site, regardless of the construction method applied. Although steel elements are being produced in a factory and brought to the site, the final formation of structure is executed under conditions on the site; and sites differ from one another by type of structure and design solution, as well as by specific conditions of the location.

When drafting the design of technology, organization and erection, it is necessary to first collect numerous data and information:
- technical documentation for civil engineering structure (bridges),

- tender and contractual documentation of the site,
- field conditions of the site,
- joining method (welding procedures are very important in welding),
- solution for external and internal transport.

On the basis of defined technical documentation and parallel to the drafting of structure design, the design of technology and construction dynamics for steel structure (more often only for a superstructure of a bridge) is being elaborated.

Designing of construction technologies includes a number of stages, among which most important are:

- selection of work methods,
- definition and description of work processes,
- required capacities of processes,
- selection of machinery,
- static and dynamic plans for materials, labour force and machinery.

2.5.7.2.4 Execution of works and construction management

2.5.7.2.4.1 Methods of scaffold and formwork installation

The scaffold and formwork carriage is moving above the superstructure

See Figure 2.5.7.2.4.

The scaffold and formwork carriage is moving under the superstructure

See Figures 2.7.2.5 and 2.7.2.6.

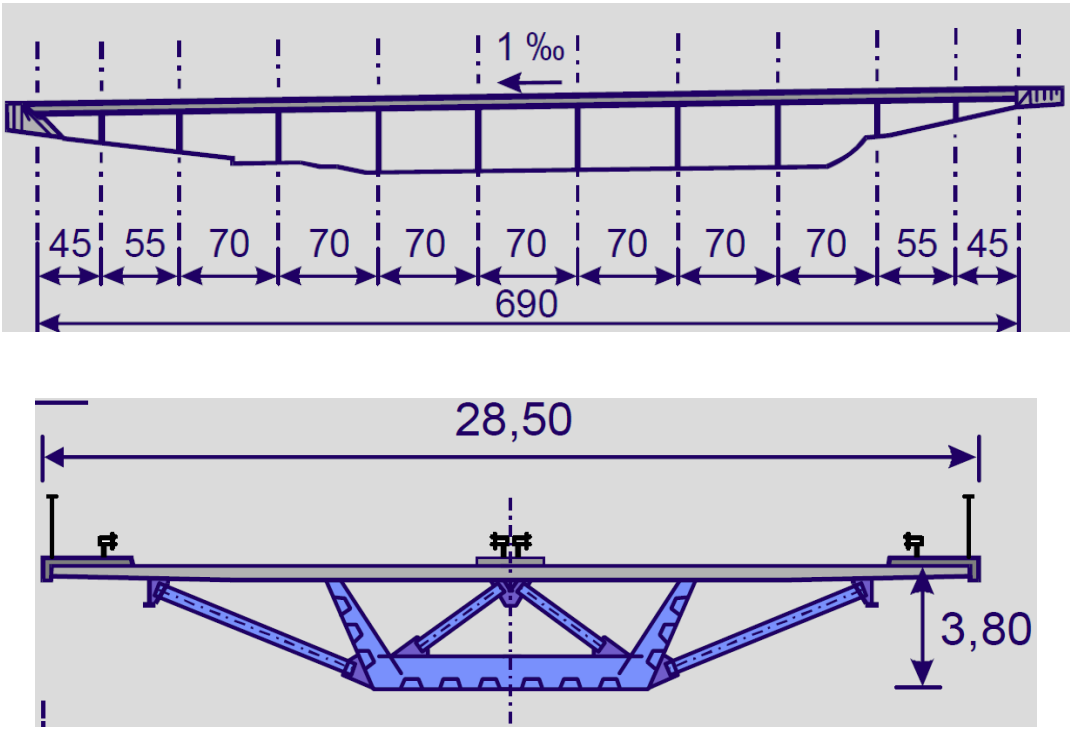


Figure 2.5.7.2.1: An example of composite viaduct in the shape of a box, and sequence of casting executed on it

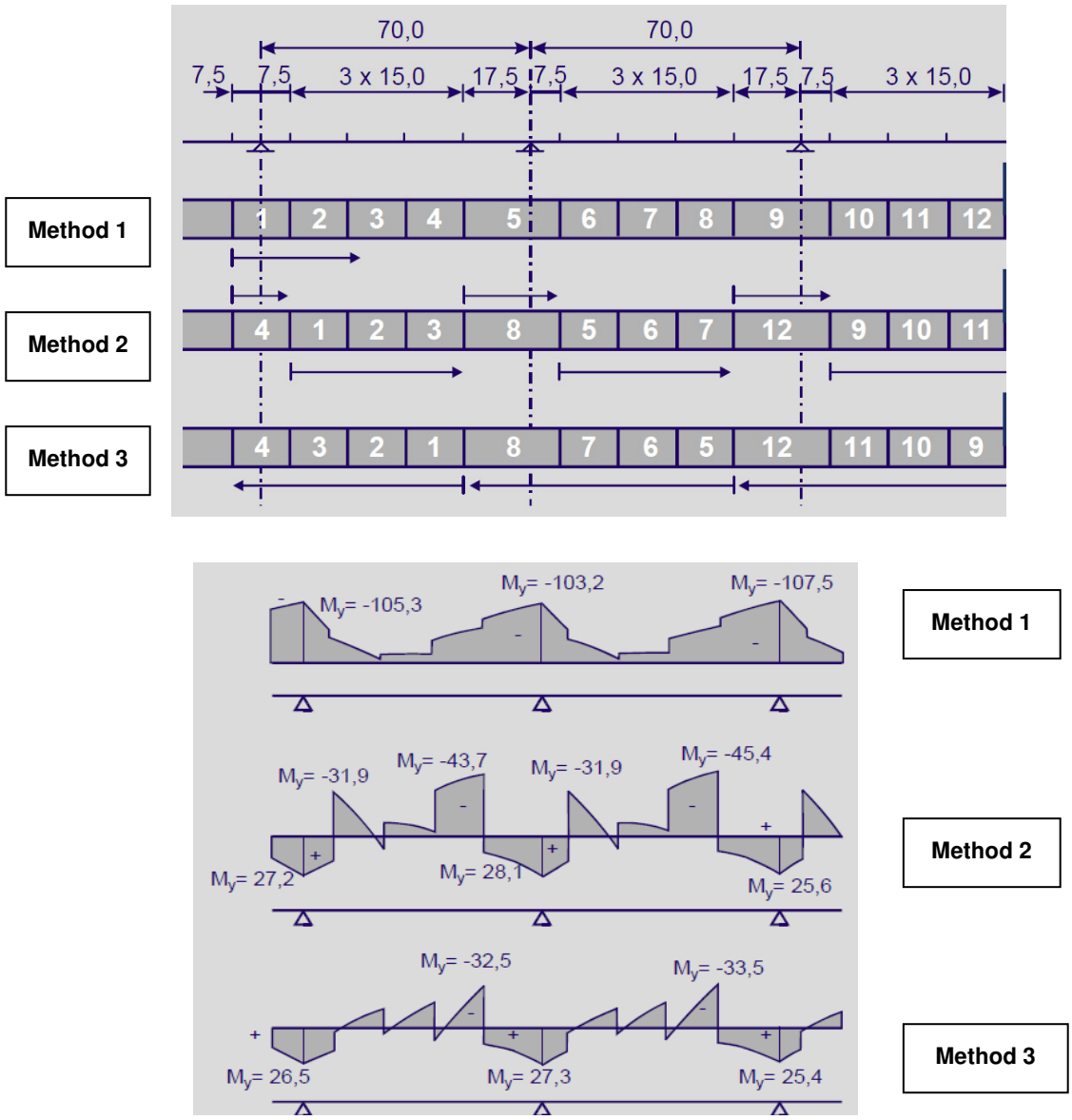


Figure 2.5.7.2.2: Possible casting sequences and bending moments – methods 1, 2, 3

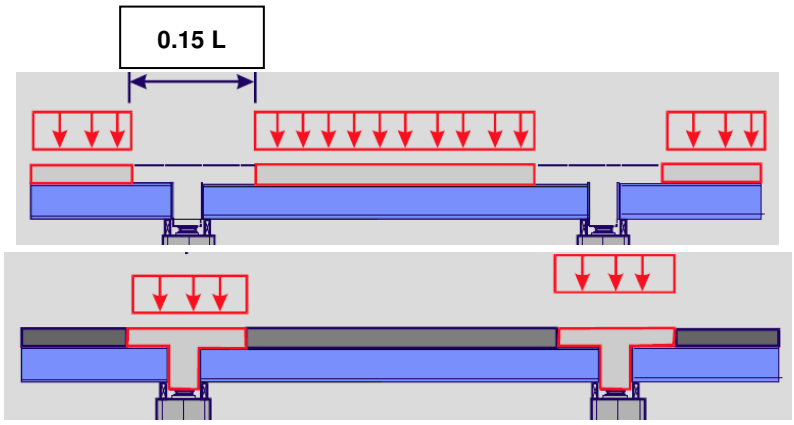


Figure 2.5.7.2.3: Sequence of casting of a slab and cross beam

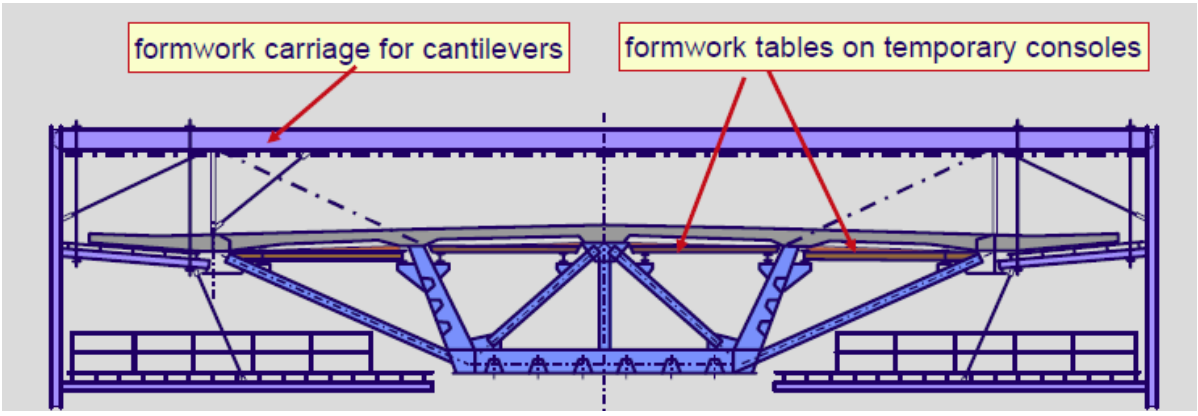


Figure 2.5.7.2.4: Scaffold erection above the composite structure, by means of formwork carriage

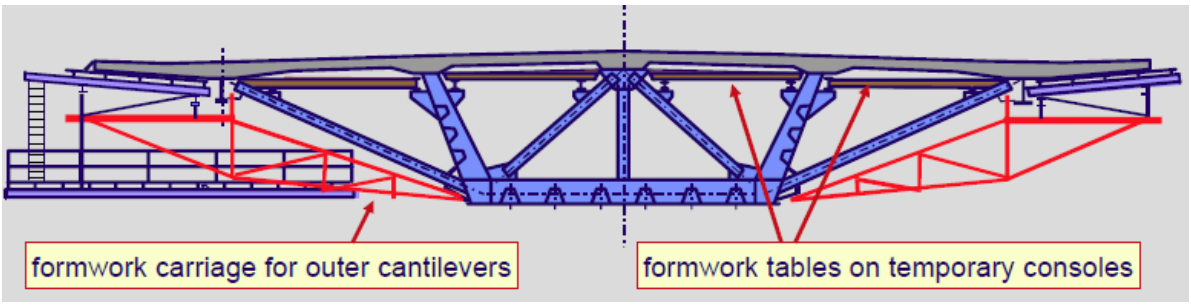


Figure 2.5.7.2.5: Scaffold erection under the composite structure, by means of formwork carriage – box section

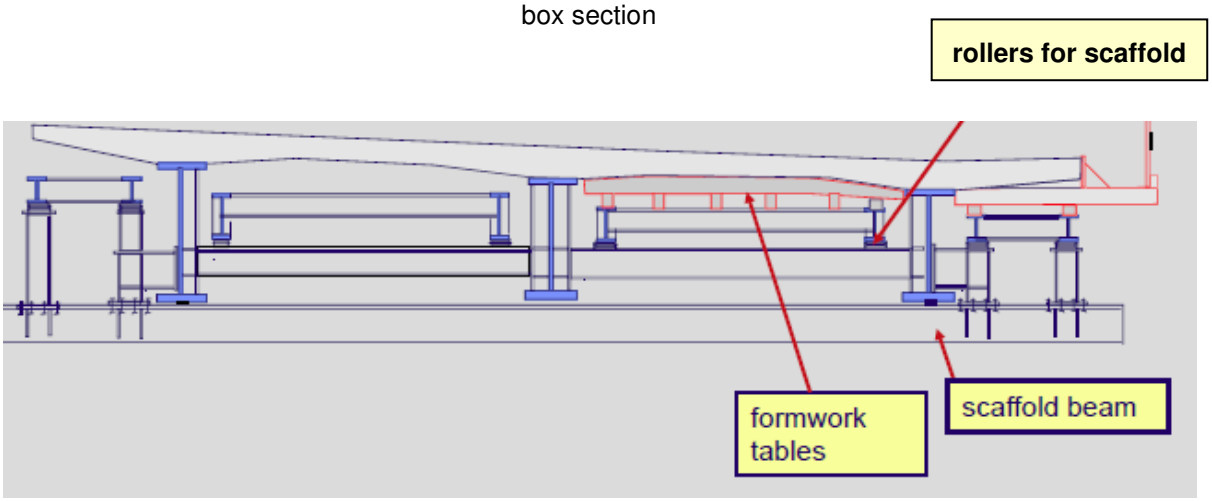


Figure 2.5.7.2.6: Scaffold erection under the composite structure, by means of formwork carriage – cross section and beams

2.5.7.2.4.2 Superstructure reconstruction – replacement of concrete deck

Replacement in separated structures

In principal, larger viaducts should be separated from each other for each direction of traffic. This is very important in case of reconstruction, when traffic is diverted to one of the structures, while the works on the other are being executed. The deck is the most sensitive component of the superstructure. Especially due to the fact that traffic load and vehicle axles pressures increase during its service life. Therefore, the concrete deck is considered to be subjected to greater wear compared to steel structure, which requires frequent replacements of the deck.

Replacement in merged structures

In case of joint structures for both directions of traffic, the traffic flow should be facilitated in both directions, on one half of the bridge, while the other is being renewed. In such a case, the existing concrete deck is being demolished by water jet method under high pressure, and is then replaced with a new deck. During this procedure, additional stresses are being introduced into the superstructure, which should already be specified in designing and constructing stage. There are at least three methods of deck reconstruction. The selection of a method is determined by the span of structure in the longitudinal direction. The first method (A) is suitable for structure with spans up to 50 m, while the other two (B, C) are appropriate for spans greater than 100 m. See also Figure 2.5.6.2.7.

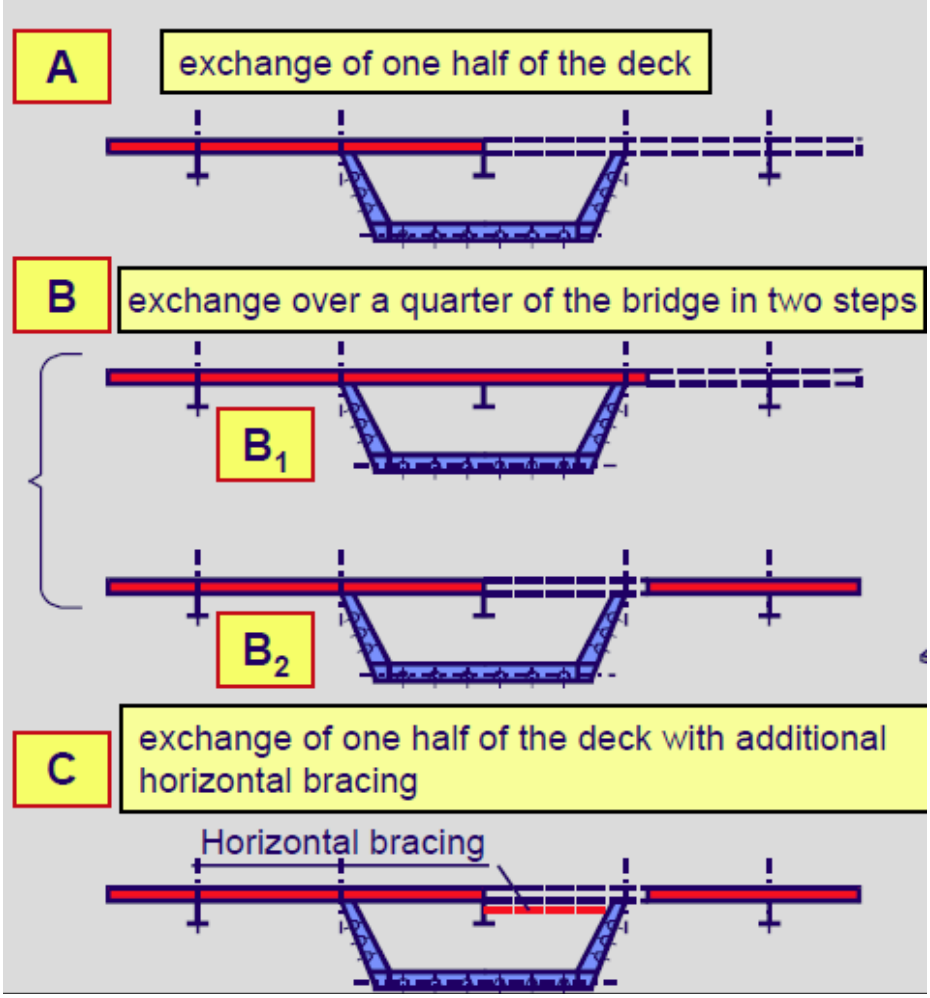


Figure 2.5.7.2.7: Sequence of deck replacement in composite structure

Table 2.5.7.2.1: Testing and inspection program for a steel structure of a bridge composite part

	Steel structures (superstructure)	Control method	Scope
1	Control prior to production of steel structure in a workshop		
	a) examination of documentation and control program	Structure	1/structure
	b) inspection of supplied materials and equipment		
	– acceptance of steel sheet from the manufacturer	acceptance	1/structure
	– control of the sheet and profile according to SRPS EN 10025	testing	4/structure
	– tensile testing according to SRPS EN 10002-1	testing	4/structure
	– toughness according to Charpy SRPS EN 10045-1	testing	4/structure
	– chemical analysis according to ASTM 415	analysis	4/structure
	– layers control	testing	4/structure
	– metal sheet , round and strip steel SRPS EN 10025, SRPS EN 10204, 3.1	certificates	4/structure
	– additional welding materials EN 756, EN 760, EN 440, EN 499, EN 10204-2.2	acceptance	1/segment
	c) inspection of welding contractor qualifications DIN 18800-7		
	– welding procedures test (PQR, WPAR) EN 288-3	acceptance	1/segment
	– inspection of welder's certificates according to SRPS EN 287-1	acceptance	1/segment
	– list of welding procedures (WPS) EN 288-2	acceptance	1/segment
	– composition EN 287-1	acceptance	1/segment
	– inspection of internal controls of welding equipment	acceptance	1/segment
	– inspection of internal control of the contractor for non-destructive testing (inspection of internal control record and documents of qualifications)	acceptance	1/segment
2	Control during the production of steel structure in a workshop		
	a) inspection of cut steel and position designations DIN EN ISO 9013	acceptance	1/segment
	b) monitoring of input materials (series)	acceptance	1/segment
	c) welding EN 5817, class B/C – drawings (visual inspection of welds)	acceptance	1/segment
	d) supervision of welding EN 719	acceptance	1/segment
	e) inspection of welding preparation and welding process (according to WPS)	acceptance	1/segment
	f) Inspection of results of non-destructive inspection of welds		

	– visual inspection – VT according to EN 970	acceptance	1/segment
	– inspection by penetration method – PT. EN 571, EN 1289	acceptance	1/segment
	– magnetic particles MT (frontal welds of standing parts and upper band, longitudinal partly welded K-welds, standing part and upper band, frontal welds of cross reinforcements, angular welds), EN 1290, EN 1291,	acceptance	1/segment
	– magnetic particles MT (frontal combined welds of longitudinal enforcements, welds of connecting metal sheets) EN 1290, 1291,	acceptance	1/segment
	– ultrasound UT (frontal welds of standing parts and band – cross) EN 1714, EN 1712	acceptance	1/segment
	– ultrasound UT (frontal cross reinforcement) EN 1290, 1291	acceptance	1/segment
	– radiography RT (crossing points of lower band frontal welds) EN 1435, EN 12517	acceptance	1/segment
	g) Execution of test non-destructive inspection of welds	acceptance	
	– Ultrasound UT (frontal welds of a standing part and band – cross) EN 1714, EN 1712	weld	2/structure
	– Ultrasound UT (frontal welds of cross reinforcements) EN 1290, 1291	weld	2/structure
	– visual inspection VT EN 970, according to drawings	weld	2/structure
	– inspection by penetration method PT - EN 571, EN 1289	weld	2/structure
	– dowels inspection	segment	2/segment
	h) segment preliminary composition according to a drawing – inspection of initial segments geodetic data (positions inspections in compliance with documentation) EN ISO 13920	acceptance	1/structure
	i) control geodetic measurements	acceptance	2/structure
	j) inspection of keeping of the journal ACP	acceptance	1/segment
	k) execution of inspection of surface preparation and coating application	acceptance	1/segment
	– inspection of quality of sandblasted surfaces EN ISO 12994-7, (SIS 055900, EN 8504)	acceptance	1/segment
	– conditions control during the coating execution (instructions provided by manufacturer)	acceptance	1/segment
	– coatings for protection from corrosion (inspection of manufacturer's certificates – documentation)	acceptance	1/segment
	– thickness control of wet and dry film of a coating ISO 2804	acceptance	1/segment
	– coating adhesion control EN ISO 2409	acceptance	1/segment
	– control and assessment of execution of referential slab for the protection from corrosion	acceptance	2/structure
	m) inspection of markings, packaging, storage and shipping	acceptance	1/segment

3	Control prior to in situ erection of steel structure		
	a) additional welding materials EN 756, EN760, EN440, EN 499, EN 10204-2.2	acceptance	1/segment
	b) inspection of welding contractor qualifications DIN 18800-7	acceptance	1/segment
	– welding procedure test (PQR, WPAR) EN 288-3	acceptance	1/segment
	– inspection of welder's certificates according to EN 287-1	acceptance	1/segment
	– list of welding procedures (WPS) EN 288-2	acceptance	1/segment
	– composition EN 287-1	acceptance	1/segment
	– inspection of internal controls of welding equipment	acceptance	1/segment
	– inspection of internal control of the contractor for non-destructive tests (inspection of internal control record and documents of qualifications)	acceptance	1/segment
	c) takeover of executed construction works (piers, supports)	acceptance	1/structure
	d) inspection of prepared erecting works	acceptance	1/structure
	f) welding EN 5817, class B – drawings	acceptance	1/segment
	g) supervision of welding EN 719	acceptance	1/segment
	h) inspection of welding preparation and welding process (according to WPS)	acceptance	1/segment
	i) Inspection of results of non-destructive inspection of welds		
	– visual inspection – VT (erection welds) EN 970	acceptance	1/segment
	– inspection by penetration method PT, (erection welds) EN 571, EN 1289	acceptance	1/segment
	– magnetic particles MT (erection welds), EN 1290, EN1291	acceptance	1/segment
	– Ultrasound UT (erection welds) EN 1714, EN 1712	acceptance	1/segment
	– radiography RT (erection welds) EN 1435, EN 12517	acceptance	1/segment
	j) Testing execution of non-destructive inspection of welds	acceptance	
	– ultrasound UT (erection welds) EN 1714, EN 1712	acceptance	1/segment
	– ultrasound UT (erection welds) EN 1290, 1291	acceptance	1/segment
	– visual VT (erection welds) EN 970,	acceptance	1/segment
	– inspection by penetration method PT (erection welds) EN 571, EN 1289	acceptance	1/segment
	– radiography RT (erection welds) EN 1435, EN 12517	acceptance	1/segment
	k) control of structure's finished parts (joints)	acceptance	1/segment
	l) control geodetic measurements of a camber	acceptance	2/structure
	m) inspection of keeping of the journal ACP	acceptance	1/segment

	n) execution of inspection of surfaces preparation and coating application	acceptance	
	– inspection of quality of sandblasted surfaces EN ISO 12994-7, (SIS 055900, EN 8504)	acceptance	1/segment
	– conditions control during the coating application (instructions provided by manufacturer)	acceptance	1/segment
	– coatings for protection from corrosion (inspection of manufacturer's certificates – documentation)	acceptance	1/segment
	– thickness control of wet and dry film of a coating ISO 2804	acceptance	1/segment
	– coating adhesion control EN ISO 2409	acceptance	1/segment
	– control and assessment of execution of referential surface for the protection from corrosion	acceptance	1/segment
4	Reports on the quality of executed works		
	a) Inspections during construction of structure in a workshop	report	1
	b) Inspections during in situ erection of the construction	report	1
	c) Final reports	report	1

2.5.7.3 Geometric tolerances for concrete structures

2.5.7.3.1 Introduction

2.5.7.3.1.1 Subject of technical conditions

Technical conditions for geometric tolerances of monolithic and prefabricated structural elements are part of the construction specifications, and refer to relevant specifications of associated standards for the construction of concrete structures.

2.5.7.3.1.2 Reference standards

Geometric tolerances of road concrete structures and elements are based on existing regulations and new standards:
- SRPS ENV 13670-1: Execution of concrete structures
- SRPS EN 13369: Common rules for precast concrete products
- EN 1990, Eurocode – Basis of structural design.
- EN 1992-1-1, Eurocode 2: Design of concrete structures – Part 1-1: General rules and rules for buildings
- SRCS – Chapter 2.5.7: Casting
- SRCS – Chapter 2.5.7.1: Precast concrete elements

2.5.7.3.1.3 Terminology

Tolerance (tolerancija) is the difference between the upper limit of the value and lower limit of the value (see also ISO 1803). Although tolerance is an absolute value without any sign, it is usually expressed as the "sum ± of permitted deviations", so that tolerance value is indicated.

Product tolerances (proizvodne tolerancije) are defined in product standards.

Assembling tolerances (montažne tolerancije) are geometric tolerances relating to position, verticality, horizontality or other characteristic of precast concrete structure.

Constructive tolerances (građevinske tolerancije) are geometric tolerances which representing the combination of product tolerances, assembling tolerances and tolerances of construction at the site.

Normal tolerances (normalne tolerancije) are the basic limits of the geometric deviations, which are to insure that structure: meets design assumptions and fulfils other functional requirements of a building. In these technical conditions, normal tolerances of 1st class tolerances are applicable.

Special tolerances (posebne tolerancije) are other tolerances, except normal tolerances.

2.5.7.3.1.4 Abbreviations used

SRCS – Serbian Road Construction Specifications

SRDM – Serbian Road Design Manual

2.5.7.3.2 Requirements

2.5.7.3.2.1 General

Finished concrete structure shall be within maximum permitted deviation so as to prevent adverse effects on:
- mechanical resistance and stability during temporary conditions and in the condition of serviceability,
- behaviour from the aspect of serviceability during the use of a building,
- possibilities of placement during erection of the structure and its non-bearing integral components.

Geometric deviations, characteristic for the structures of building construction, may also be applied for engineering buildings – bridges, or may be supplemented in the execution specification. Numerous values are given for the structural tolerances that affect the safety of structure. For geometric tolerances, there are two classes of structural tolerances specified. Unless otherwise stipulated in the execution specification, the 1st tolerance class is applicable.

1st tolerance class means normal tolerances. Tolerances given for the 1st tolerance class ensure design assumption of EN 1992 and required safety level, which is related to partial factors, which are given in EN 1992-1-1, Item 2.4.2.4. These tolerances are deemed to be essential for the mechanical resistance and stability of structures, and for the fulfilment of requirements.

Values of permitted geometric deviations from the aspect of behaviour during the use and placement possibilities may be given in execution specification according to SRSP ENV 13670-1. Unless otherwise prescribed, tolerances, given in Tables 2.5.7.3.1 to 2.5.7.3.6 of these technical conditions, are applicable.

All requirements regarding special tolerances should be defined in the execution

specification, and for that purpose following information should be given:
- supplements to permitted deviations, given in this specification,
- subsequent deviation types to be controlled, together with defined parameters and permitted values,
- whether given special tolerances relate to all associated elements, or to special elements, which are to be determined,
- whether the “frame principle“ should be applied, and the extent of permitted deviation.

Application of “frame principle” requires all points of the structure to be within the frame of prescribed theoretical position, whose marginal area spreads in any direction and which matches the prescribed deviation. When using the “frame principle“, recommended value is ± 20 mm.

Tolerances for surfaces between the elements, where forces should be transferred through the bearings, which are entirely in contact with the surface, are not defined in these specifications. Requirements for such surfaces should be given in execution specification.

Tolerances for elements installed under water level are not given in these technical conditions.

When a geometric deviation is contained in another requirement, the stricter tolerance should be applied.

Requirements of these technical conditions relate to finished structure. If elements are contained in a structure, inter-inspection of such elements shall be subordinated to the final inspection of finished structure.

Requirements for combination of structural tolerances and structural deformations are not contained in these technical conditions. Unless otherwise prescribed by the execution specification, permitted deviations, regarding condition prior to deformations caused by loads and weather dependent effects, are applicable.

2.5.7.3.2.2 Reference system

Tolerances of the position in layout plane relate to secondary lines in a plane.

Tolerances of the position along the height relate to secondary height points, e.g. to transferred reference height point.

Requirements for secondary lines should be given in the execution specification.

Instructions for marking (setting out) of secondary lines are given in ISO 4463-1.

2.5.7.3.2.3 Foundations

Supports in the bearing soil may be foundations directly in the ground, pile caps, etc. Recommended values for centre of support positions in the bearing ground are given in Table 2.5.7.3.1.

Foundations in the ground may be directly cast or produced of precast concrete elements. Requirements for tolerances of deep foundation, such as piles, bentonite walls, diaphragms, special anchoring, etc., are not covered by these specifications.

2.5.7.3.2.4 Piers and walls

Values of permitted structural deviations for piers are given in Table 2.5.7.3.2. Instructions on permitted deviations of piers and walls positions, measured relative to secondary lines, are given in Table 2.5.7.3.2.

2.5.7.3.2.5 Beams and slabs

Deviations given for direction and height position of beams and slabs are also applicable for other horizontal and inclined structural elements.

Values of permitted structural deviations for beams and slabs are given in Table 2.5.7.3.3. Tolerances of seating lengths of precast beams and slabs are not given in these specifications; they should be defined in the erection specification, or in the technical information on precast product.

2.5.7.3.2.6 Sections

Dimensions of a cross-section, thickness of a coating layer and position of usual prestressing reinforcement, shall not deviate from nominal values to greater extent than shown in Table 2.5.7.3.4. Given deviation values are not applicable for precast products. They should be in conformity with the corresponding product standard. Compliance with requirements regarding coating layer thickness should be assessed on the occasion of every single reading, unless static approach is permitted by regulations which apply to the site.

2.5.7.3.2.7 Surface and the evenness of edges

Recommended values of deviations for the surfaces and evenness are given in Table 2.5.7.3.5.

2.5.7.3.2.8 Tolerances for openings and embedded elements

Recommended values of deviations for the openings and embedded elements are given in Table 2.5.7.3.6.

2.5.7.3.3 Compliance control

Conditions for execution and control of geometric tolerances for the concrete structure are defined by program of control and quality assurance, which is the integral part of structure design specification.

Upon taking over of geometric tolerances of finished products produced outside the site, the contractor shall determine geometric tolerances also according to SRSC, Chapter 2.5.7.1.

2.5.7.3.3.1 Compliance assessment

It is deemed that geometric tolerances of concrete structure are in compliance with measures specified by design, and that structure is serviceable if:
– construction products are installed into the concrete structure in the prescribed manner, and have the declaration and assessment of compliance, or evidence of serviceability,
– construction conditions and other circumstances that may have impact on geometric properties of concrete structure were in compliance with design requirements,
- there are evidence of concrete structure's bearing capacity and serviceability, obtained through testing under test loads, when it is prescribed as obligatory, or required by design,
- there are prescribed records and/or documentation of above mentioned inspections.

If it is established that concrete structure does not have geometric properties required by design, subsequent verification shall be conducted.
If it is verified that achieved geometric properties of concrete structure do not meet the prescribed requirements, then the design of concrete structure reconstruction should be prepared.

2.5.7.3.3.2 Internal control of geometric tolerances during structure construction

Contractor must have a certified quality system according to SRPS EN ISO 9001, taking into account the requirements of SRPS ENV 13670-1 standard for the construction of concrete structures.

Tasks, responsibilities and authorities of internal production control employees shall be documented, maintained and applied.

The contractor for the concrete structure is obliged to establish, document, apply and maintain the internal construction control and to ensure that precast elements, or elements poured into the structure formwork at the site, fulfil the standard requirements, and that these are in compliance with aforementioned values and requirements specified by technical documentation.

Inspection and testing (usually executed by surveyor) are performed on finished elements or structures. The subject, criteria, methods and frequency of inspection and testing are determined by inspection schemes. Frequency of tests and inspections, and of methods not stated in the standard SRPS ENV 13670-1, are defined so as to ensure the permanent compliance of the element.

Recording plan of geodetic points for finished elements and structure components shall be prepared and applied for all properties that are being controlled.

2.5.7.3.4 Technical documentation

2.5.7.3.4.1 Documentation upon precast concrete structures delivery from a factory

Technical product documentation shall be available on the site at the moment of delivery of these elements, according to specification of SRPS EN 13369.

2.5.7.3.4.2 Documentation upon in-situ construction of concrete structures

During the structure construction, technical documentation shall be available at the site, according to SRPS ENV 13670-1.

Table 2.5.7.3.1 – Geometric tolerances for foundations

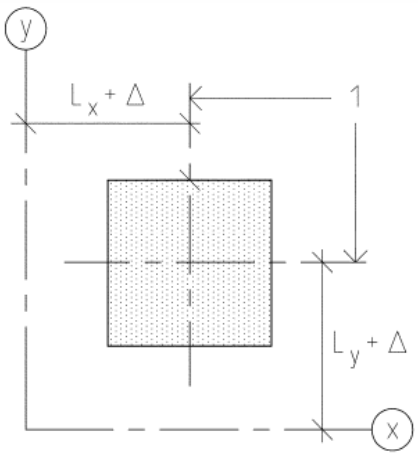
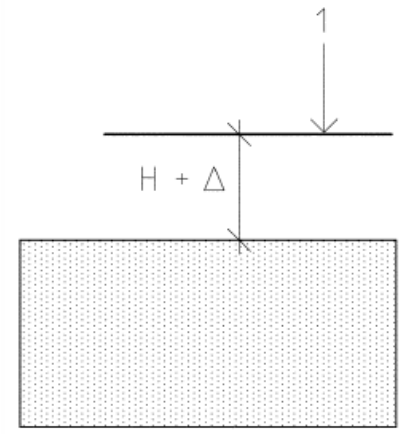
No.	Deviation type	Description	Permitted deviation Δ Tolerance class 1
a	Horizontal section  1 Centre of support y Secondary line in direction y x Secondary line in direction x	Layout position of the bearing soil support relative to secondary lines	± 25 mm
b	Vertical section  1 Secondary plane H expected distance	Position of the bearing soil support relative to the secondary plane	± 20 mm

Table 2.5.7.3.2 – Geometric tolerances for piers

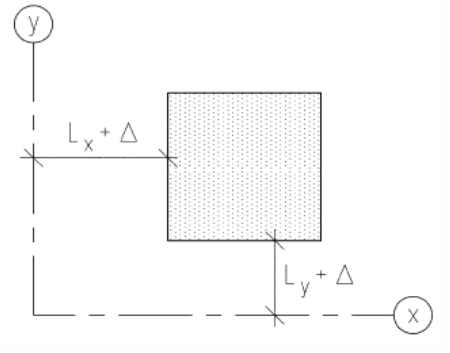
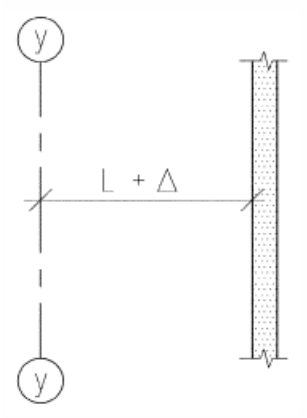
No.	Deviation type	Description	Permitted deviation Δ Tolerance class 1
a	Secondary line  Secondary line	Layout position of a pier relative to secondary lines	± 25 mm
b	Secondary line  	Layout position of a wall relative to a secondary line	± 25 mm
c	 	Daylight distance between adjacent piers or walls	± 25 mm [a)] or ± L/600 as large as possible, but not larger than 60 mm
	[a)] NOTE: In case of beams which support the precast elements, more precise values of required supporting (seating) lengths may be needed.		

Table 2.5.7.3.2 – Geometric tolerances for piers – continued

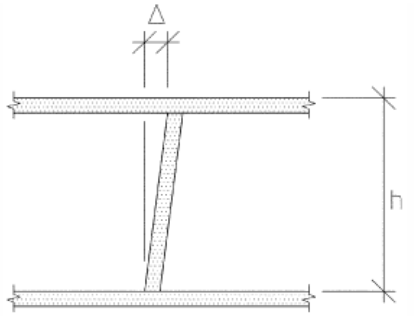
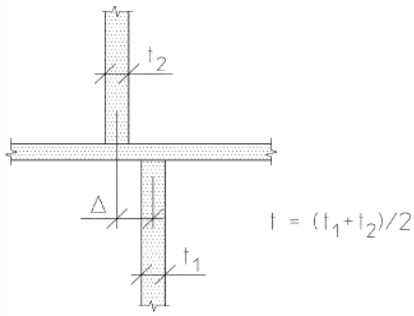
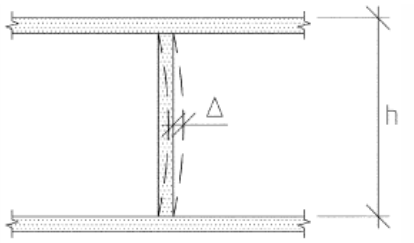
No.	Deviation type	Description	Permitted deviation Δ Tolerance class 1
		Inclination of a pier or wall h = daylight height	h/300 or 15 mm whichever is larger
		Deviation between mid-points	t/30 or 15 mm whichever is larger, but maximum 30 mm
		Pier curvature between levels of adjacent floors	h/300 or 15 mm whichever is larger

Table 2.5.7.3.3 – Geometric tolerances for beams and slabs

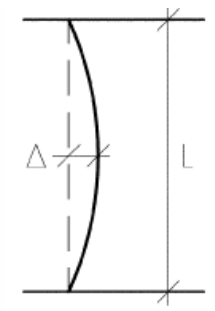
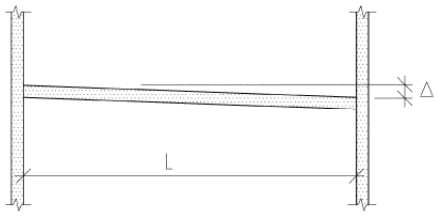
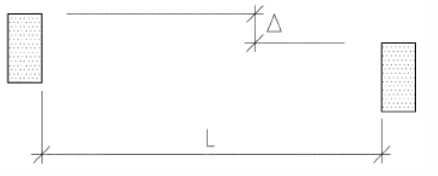
No.	Deviation type	Description	Permitted deviation Δ Tolerance class 1
a		Horizontal evenness of a beam	± 20mm or ± L/600 whichever is larger
b		Distance between adjacent beams, measured in points that match each other	± 20 [a)] mm or ± L/600 whichever is larger, but maximum 40 mm
c		Inclination of a beam or slab	± (10 + L/500)mm
d		Height position of adjacent beams, measured in points that match each other	± (10 + L/500)mm
	[a)] NOTE: In case of beams which support the precast elements, more precise values of required supporting lengths may be needed.		

Table 2.5.7.3.3 – Geometric tolerances for beams and slabs – continued

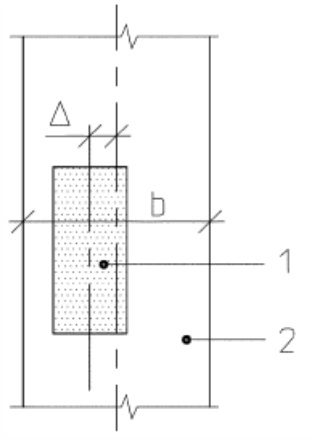
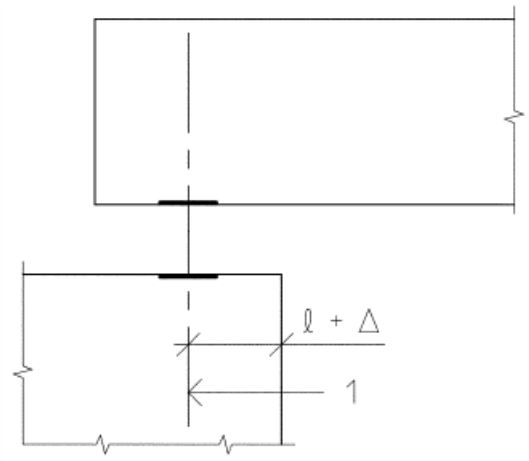
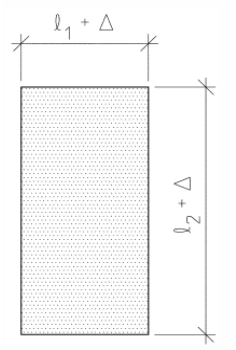
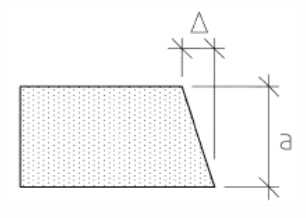
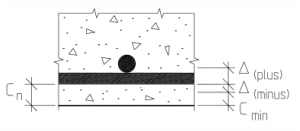
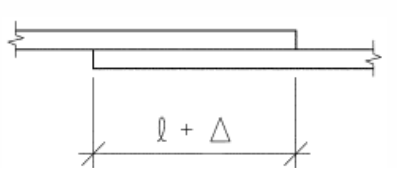
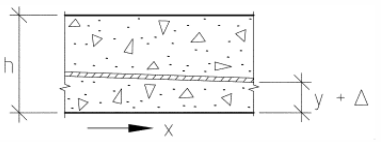
No.	Deviation type	Description	Permitted deviation Δ Tolerance class 1
	 1 beam 2 pier	Position of a beam attachment to a pier, measured relative to the beam b = beam dimensions in the same direction as Δ	± b/30 or ± 20 mm whichever is larger
	 1 Actual bearing axis on a support	Position of the bearing's axis if structural bearings are being used l = expected distance from the edge	± l/20 or ± 15 mm whichever is larger

Table 2.5.7.3.4 – Geometric tolerances for sections

No.	Deviation type	Description	Permitted deviation Δ	
			Tolerance class 1	Tolerance class 2
a	Dimensions of the section  	l = length of cross-section dimension Applicable for beams, slabs and piers For $l_1 < 150$ mm $l_1 = 400$ mm $l_1 \geq 2500$ mm Intermediate values are determined by linear interpolation	 ± 10 mm ± 15 mm ± 30 mm	 ± 5 mm ± 10 mm ± 30 mm
	NOTE 1: If required, positive deviations for foundations should be given in the execution specification. For negative deviations, above stated values apply.			
	Rectangularity of cross-section  	a = length of cross-section dimension	0.04 a or 10 mm whichever is larger, but not greater than 40 mm Positive or negative deviation	
b	Position of plain reinforcement Cross-section  c_{min}= required minimum thickness of the coating layer c_n = nominal thickness of the coating layer = $c_{min} + /\Delta_{(minus)}/$ c = actual thickness of the coating layer Δ = permitted deviation from c_n h = height of cross-section	h ≤ 150 mm h = 400 mm h ≥ 2500 mm Intermediate values are determined by linear interpolation	± 10 mm ± 15 mm ± 20 mm	± 5 mm ± 10 mm ± 20 mm
		$\Delta_{(minus)}$	Δc_{dev} a)	Δc_{dev} a)

No.	Deviation type	Description	Permitted deviation Δ	
			Tolerance class 1	Tolerance class 2
	Requirement: $c_n + \Delta_{(plus)} > c > c_n - \Delta_{(minus)}$ [a] Δc_{dev} may be found in the national supplement to SIST EN 1992-1-1. Unless otherwise prescribed, Δc_{dev} = 10 mm. It may be defined in the execution documentation whether static approach is allowed, which permits the thickness of coating layer to be in a certain percentage under the value of cmin. NOTE: Permitted positive deviation of coating layer thickness for the foundations and concrete elements used in foundations may be increased for 15 mm. Negative deviations given remain applicable.			
c	Lap-joints 	l = lap length	- 0.06 l	
d	Position of prestressing reinforcement Longitudinal section 	For h ≤ 200 mm For h > 200 mm Coating layer, measured to the cable	± 0.03 h ± 0.03 h or ± 30 mm whichever is smaller - 15 mm	

a) The values given apply to thickness- and transverse direction. For transverse direction *h* is the width of the element. For tendons in slabs larger deviations than ±30 mm may be permitted if necessary to avoid small openings, ducts, chases and inserts. The tendon profile of such deviations shall be smooth

b).Permitted minus-deviation Δc_{dev} as for ordinary reinforcement, see case b.

Table 2.5.7.3.5 – Geometric tolerances for surfaces and edges

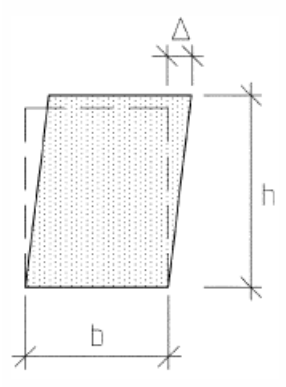
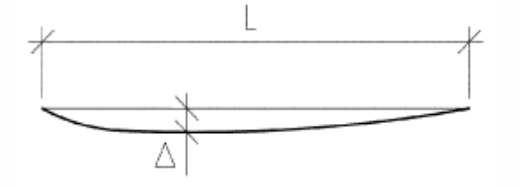
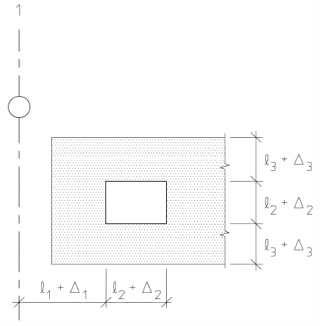
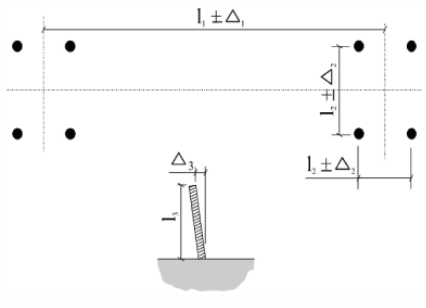
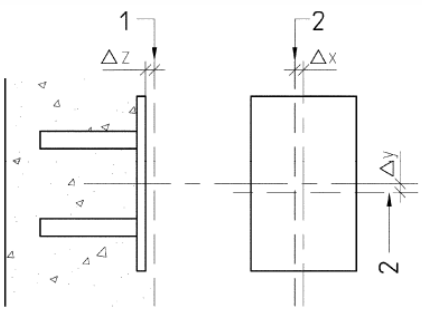
No.	Deviation type	Description	Permitted deviation Δ Tolerance class
a	Evenness Moulded or smoothed surface along the entire length locally Not moulded surface along the entire length locally 	 L = 2.0 m L = 0.2 m L = 2.0 m L = 0.2 m	 9 mm 4 mm 15 mm 6 mm
b	Skewness of cross-section 		h/25 or b/25 whichever is larger, but maximum 30 mm Positive or negative deivation
c	Edge straightness 	For lengths < ± 1 m For lengths > 1 m	8 mm 8 mm/1 m, but maximum 20 mm

Table 2.5.7.6 – Geometric tolerances for openings and embedded objects

No.	Deviation type	Description	Permitted deviation Δ Tolerance class 1
a	Blockout and recesses  1 Secondary line	Δ_1, Δ_2, Δ_3	± 25 mm Unless otherwise defined by exectuion specification
b	Anchoring bolts and similar embedded objects in foundations  l_1 = distance between groups of anchoring bolts l_2 = distance between anchoring bolts l_3 = height (clear part) of the anchoring bolt	Positioning of the bolt and of the gruop of anchoring bolts Internal distance between anchoring bolts of a group Inclination of clear part of anchoring bolt	$\Delta_1 = \pm$ 10 mm $\Delta_2 = \pm$ 3 mm $\Delta_3 = \pm$ 25 mm; -5 mm Δ_s = 5 mm or $l_3/200$ whichever is larger Unless otherwise defined in execution specification
c	Anchoring plate and similar embedded objects 	Deviation in layout Deviation along the height	Δ_x, Δ_y = 20 mm $\Delta_z = \pm$ 10 mm Unless otherwise defined by the execution specification

2.5.7.4 Metal structures

2.5.7.4.1 Introduction

2.5.7.4.1.1 Description

These technical conditions shall be applied when executing metal – steel structures.

2.5.7.4.1.2 Reference standards

Besides these technical conditions, the following shall be also adhered to:
- standards EN 1993, EN 1994, EN 1090, as well as the corresponding national supplements, and – if not replaced with SRPS EN – SRPS – standard series ISO.

In addition, for marking of steel the following are applicable:
- SRPS EN 10020, and SRPS EN 10027-1 and -2.
- EN 1090-2 Execution of steel bearing structures
- EN 1993 EUROCODE 3: Dimensioning and design of steel structures
- EN 1994 EUROCODE 4: Dimensioning and design of composite steel and concrete structures
- SRPS EN 10020 Definitions for steel classification
- SRPS EN 10025 Hot-rolled structural steel products, technical delivery conditions
- SRPS EN 10027 Steel designation systems
  Part 1: Short names, main symbols
  Part 2: Numeric system
- SRPS EN 10204 Metallic products, Types of inspection documents
- SRPS EN 10083 Steels for quenching and tempering.:
  Part 1: General technical delivery conditions
  Part 2: Technical delivery conditions for non alloy steels
- SRPS EN ISO 5817 Welding. Fusion-welded joints in steel, nickel, titanium and their alloys (beam welding excluded). Quality levels for imperfections
- SRPS EN ISO 6520 Welding and allied processes - Classification of geometric imperfections in metallic materials - Part 1: Fusion welding
- SRPS EN ISO 9692 Welding and allied processes: recommendations for joint preparation
- SRPS EN ISO 1461 Hot dip galvanized coatings on fabricated iron and steel articles - specifications and test methods
- EN ISO 14713 – Protection against corrosion of iron and steel in structures – Zinc and aluminium coatings – Guidelines

2.5.7.4.1.3 Terminology

There are no significant terms used in this part of technical conditions.

2.5.7.4.1.4 Abbreviations used

SRCS – Serbian Road Construction Specifications

SRDM – Serbia Road Design Manual

2.5.7.4.2 Requirements

Quality of all used materials, bolts, wedges and additional welding materials shall be verified with testing certificate in accordance with SRPS EN 10204. The quality of subordinated structural parts and binders can be verified only by industrial certificate 2.2, while for all other materials the certificate of testing upon takeover 3.1 shall be submitted.

2.5.7.4.2.1 Requirements for the structural steel

Steels stated in standard EN 1993-1-1, Chapter 3, may be used as structural steels, and for bridges those stated in standard EN 1993-2, Chapter 3, with observance of standard EN 1993-1-1-10 (fracture toughness). Technical conditions of delivery from corresponding standards (SRPS EN 10025) are also applicable.

2.5.7.4.2.2 Steel castings and- steels for quenching and tempering

For steel castings standard SRPS EN 10293 applies, while standard SRPS EN 10083 is applicable for steels for quenching and tempering.

2.5.7.4.2.3 Approved structural parts

For structural parts, for which the permit has been issued (including European permit: European technical approval ETA), provisions stated in it apply (ETAG = European Technical Approval Guideline).

2.5.7.4.2.4 Tendon

For tendons of strands, sheaves of strands and ropes, and for wire sheaves, quality requirements of EN 1993-1-11 apply, as well

as the provisions in relation to permit, or related provisions of tender documentation.

2.5.7.4.2.5 Fasteners

Standard EN 1993-1-8 is applicable for all of them, while for joined wedges standard EN 1994 additionally applies. Bolts of the system HV shall be used for prestressed bolts, in accordance with SRPS EN 14399.

Welding wires and accessories shall comply with regulations of EN 1090-2, or norms cited in EN 1090-2, Item 2.1.3, or Item 5.5.

Quality levels for imperfections according to EN 1090-2 shall comply with SRPS EN ISO 5817.

The quality of materials used in binding agents shall be stated by the manufacturer.

2.5.7.4.2.6 Products used for protection against corrosion of metal structure's steel parts

Technical characteristics of products used for protection of metal structure's steel parts from corrosion shall be stated in the design of metal structure, or in technical specifications for that product.

2.5.7.4.2.7 Additional welding materials

Technical properties of additional materials used for welding of steel parts, which make the basic integral parts of the composite structure, shall be stated in the design of metal structure.

2.5.7.4.2.8 Requirements for execution

Client keeps the right to assess the erection plant with regard to capacity and feasibility (spatial conditions, capacity of cranes, materials management, etc.). The erection works and ordering of materials may start only after the client has given the written approval of the erection plant.

Welding works may be performed only by plants whose welding qualifications have been verified according to SRPS EN ISO 3834-1. The evidence shall be recorded in testing logbook according to SRPS EN ISO 3834-1.

Provisions regarding execution should be followed in compliance with standards EN 1090-1 and EN 1090-2.

Plant plans shall be prepared by contractor, while structural parts shall be produced in accordance with approved site plans. Preparation of plant plans shall be performed in accordance with standard SRPS ISO 5261.

For measuring tolerances, standard EN 1090-2 applies. If special provisions are not given in standard EN 1090-2, the standard EN 1992-2, Appendix C, applies. For measuring tolerances exceeding the aforementioned, standard SRPS EN ISO 13920, with classes B and F, shall be applied.

Execution class (EXC 1 - 4)

According to standard EN 1090-2, Appendix B, there are following execution classes:

- EXC 4: for road bridges,
- EXC 3: e.g. for pedestrian and bicycle bridges, signs above roads,
- EXC 2: e.g. for bus stops, noise protection walls
- EXC 1: not applicable.

According to EN 1090-2, for EXC 4 applies assessment group B+. Requirements for group B+ include assessment groups B according to SRPS EN ISO 5817, as well as the additional requirements in compliance with EN 1090-2.

2.5.7.4.2.9 Execution of connections with bolts

For the execution of connections with bolts, EN 1090-2 is applicable. Tensile moments, as well as the instructions for erection (e.g. storage of bolt sets and use of lubricants) of prestressed bolts, shall be applied according to manufacturer's instructions.

Bolts with hardness class 12.9 shall not be used for sliding rigid connections.

Sliding rigid prestressed connections with bolts, as a replacement for removed rivets, may be taken into account only if their value of friction in unfinished surfaces, according to EN 1993-1-8, Item 3.9, is classified into category D, provided that flawless finishing of friction surfaces is not feasible, or if bigger bolts are being used.

2.5.7.4.2.10 Execution of joints by welding

For execution of joints by welding, standards SRPS EN ISO 3834-1, SRPS EN ISO 6520, SRPS EN ISO 5817, EN 1090-2 and EN 1993-1-8 apply. When preparing welds,

standard SRPS EN ISO 9692 should be adhered to.

Welded joints of bearing structural elements may be executed only by plants whose qualifications, according to standard SRPS EN ISO 3834-1, correspond to quality class 1. Sites with quality class 2 may only execute joints by welding on subordinated structural elements.

At the request, the testing certificate of welders should be submitted according to standard SRPS EN 287-1.

All angular welds shall be properly executed as continuous welds. If, due to erection-technical reasons, continuous welds are required, the regulations should be followed in accordance with EN 1090-2, Item 4.3.2.2. Continuously welded blunt angle welds are not permitted.

Joints and notches shall be welded with tight welds (except on jointing surfaces connected by bolts).

Due to technical reasons of anti-corrosion protection, all welds shall be of smooth surface.

In case of possible unevenness, pores, burnt cut, drops, sharp edge, tops, remains of slag, welding stain, crack, crater, etc.; they should be cured by appropriate subsequent treatment (e.g. by grinding).

2.5.7.4.2.11 Execution of connections with rivets

Execution of connections with rivets may be performed only by plants which can provide evidence of their expert knowledge and sufficient experience.

2.5.7.4.2.12 Execution of wedges with heads

As a rule, wedges with heads, without a thread, should be used. If in special cases threads are necessary, this shall be stated in documentation.

2.5.7.4.3 Compliance control

Conditions for execution of metal structure are defined by program of control and quality assurance, which is the integral part of metal structure detailed design.

2.5.7.4.3.1 Compliance assessment

The metal structure is considered to have by design set properties and to be serviceable if:
– products are built in the metal structure in the prescribed manner, and have the declaration and assessment of compliance, or evidence of usability,
– construction conditions and other circumstances that may influence technical properties of metal structure were in conformity with design requirements,
- there are evidence of metal structure's bearing capacity and serviceability, obtained through testing under test loads, when it is prescribed as obligatory, or required by design,
- there are prescribed records and/or documentation of above mentioned inspections.

If it is established that metal structure does not have technical properties required by design, subsequent verification shall be conducted.

If it is verified that achieved technical properties of metal structure do not meet the prescribed requirements, then the design of metal structure reconstruction should be prepared.

2.5.7.4.3.2 Internal control during metal structure erection

Manufacturer must have a certified quality system according to SRPS EN ISO 9001, taking into account the requirements of EN 1090 standard for the construction of steel structures.

Tasks, responsibilities and authorities of internal production control employees shall be documented, maintained and applied.

The metal structure manufacturer (usually a machinery company) is obliged to establish, document, apply and maintain the internal production control, and to ensure that structure elements delivered to the site comply with standard requirements and with values stated in requirements of technical documentation.

The manufacturer should identify the relevant characteristics of facilities and/or production process. Also, the manufacturer defines criteria and plan of production processes that directly affect the conformity of the products.

Inspection and testing are performed on equipment, raw materials, other input materials, production processes, and on finished elements or structures. The subject, criteria, methods and frequency of inspection and testing are determined by inspection schemes. Frequency of tests and inspections, and methods not stated in the standard, are defined so as to ensure the permanent conformity of the product.

Sampling plan and tests plan of finished products shall be prepared and applied for all characteristics that are being controlled.

2.5.7.4.3.3 Taking over of metal structure

Metal constructions are taken over by representative of the client, in the presence of representative of the contractor. According to progression of works, partial taking-over may be executed as well.

Upon taking over, protocols of all preliminary tests of suitability and controls. In the plant and during erection works, the representative of client shall have the access to all structural works. Contractor shall provide required measuring devices.

Taking over results shall be recorded in writing.

2.5.7.4.3.4 Measuring the metal structure

As a rule, measures are controlled in the plant. Important measures of structural parts shall be compared to measures stated in plans, when main beam is provisionally placed as a whole, or eventually in parts when lengths are greater than 40 m.

Supervision of measures is executed by inspection plan of measures, as well as by inspection sheets of measures, and by comparison of target and actual measures.

Control measures shall be placed so as to enable that their measurement, if possible, is executed without application of additional devices: without hooking to profile axis, but to edges, not to existing sections, e.g. at the area of welding radiuses, without sliding sections, etc.

If lifting of the bearing structure is required, the structure should be laid without loading. The form of lifting should be defined, and measures shall be protocolled.

The geometry of all permanent loads shall be measured (dead weight and expected loads), which should be documented in the corresponding protocol.

2.5.7.4.3.5 Supervision of erection

Structural supplements, which are executed at the site, as well as the building connections, shall be inspected during the process of erection.

2.5.7.4.4 Technical documentation

2.5.7.4.4.1 Documentation upon metal structure delivery from workshop

Unless otherwise required in tender documentation, proofs of quality (joints testing inspection of materials certificates, etc.) should, as a rule, be issued by internal control authority at the production plant of the manufacturer, or by the accredited inspection authority in case of periodic internal controls.

Client is entitled to be present at the time of inspection or to perform it separately. Contractor shall notify the client that he is ready for inspection in due time.

Results of internal quality control, and all the standardized test results, shall be documented in protocols and submitted to the client, together with:
- certificate of testing upon taking over 3.1. according to SRPS EN 10204,
- material certificate 2.2 according to SRPS EN 1024 regarding quality of materials,
- certificates and documentation of testing,
- radiographs,
- protocols of other indisputable method of materials control,
- certificates of annealing,
- measuring protocols,
- welding instructions,
- protocols of deviations.

Upon completing the investment plan, joint summary shall be delivered, with declaration on results. Tests and documentation shall comply with EN 1090.

2.5.7.4.4.2 Evidence of structural steel quality

Unless otherwise required in tender documentation, the procedure in compliance with execution class according to EN 1090-2 shall be applied. As a rule, for executed materials certificates the following certificates in accordance with SRPS EN 10204 shall be submitted:

For structural parts, which are exposed to traffic loads according to plans, testing and inspection certificates 3.1 should be submitted. For structures not exposed to traffic loadings, the materials test report 2.2 in accordance with SRPS EN 10204 may be submitted.

Origin of materials for EXC3 and EXC4 shall be evidenced, which means that materials certificates shall be classified into items of materials according to the plant plan.

2.5.7.4.4.3 Evidence of steel castings quality

Unless otherwise specified by tender documentation, evidence of steel castings quality shall be in compliance with EN 10293.

Unless otherwise defined by tender documentation, evidence of steels for quenching and tempering quality shall be in compliance with EN 10083.

2.5.7.4.4.4 Evidence of non-standardized steels quality

If submittal of certificates of test and taking over of materials is not possible, the evidence of quality shall be issued by the authority of internal or external control.

2.5.7.4.4.5 Evidence of welding electrodes quality

Evidence of quality of used welding materials shall be in accordance with norms and technical delivery conditions for the employed product (see Table 5 in EN 1090-2).

2.5.7.4.4.6 Testing of joints

Joints should be assessed for eventual faults according to EN 1090-2 and EN ISO 5817. Tests (VT/PT/MT/UT/RT) shall be executed in accordance with corresponding EN norms, and test results shall be given in protocols of joints testing.

Within the frame of quality management system, the execution plant shall be assessed by independent inspection authority, or it shall be provided that tests are performed by an inspection authority accredited for certification according to the standard SRPS EN 45011 with the Accreditation Body of Serbia.

Contractor shall document number and locations of tests in the test list, which shall be delivered to the client together with protocols of all tests.

2.5.7.4.4.7 Tendons test

The tendon test depends upon type and intended use of cables. Required tests should be executed in compliance with tender documentation and EN 1993-1-11.

2.5.7.4.4.8 Additional test

Client may order tests that exceed the defined volume of testing (e.g. additional joints tests). Client is entitled to order additional tests directly from inspection authority.

2.5.7.4.5 Execution of works and construction management

2.5.7.4.5.1 Preparation of erection

Since metal structures erection represents just one segment of the complex process of structures construction, the design of construction organization shall be provided.

The design of erection organization, or of technology of erection, is presented in the form of descriptions, drawings, tables, schemes, diagrams. It is always implemented together with design bases, workshop drawings and specification lists. When drafting the design of erection technology, specific conditions should be taken into account, such as technical-technological equipment of the contractor for erection works, and positioning of the site.

Preparation works for the metal structure erection conclude with protocol takeover of foundations or piers (for example, roof constructions of motorway toll stations) or, in the case of a bridge, of piers (steel structure).

Taking over is executed on the basis of geodetic recording of foundations and supports position, and of their height position. Besides geodetic measurement, the thorough visual inspection of foundations and supports shall be conducted. The erections works may start only after these procedures have been completed.

2.5.7.4.5.2 Erection of the structure – the example for steel bridge (structure with box section)

The erection at the site starts, for example, from piers to the abutments on both sides, parallel to the fixed segment, which is the last to be installed. To bring parts of a segment into the design position, the temporary pylon is usually used during erection. Welding

starts with longitudinal welds on the orthotropic plate. Then joints on cross beams are welded. All welds are executed from middle of the bridge to the ends. After these welds, the cross joints on the back of main beams – upstream and downstream – are being welded. This is followed by welding of vertical joints on cross beams. The same order is applied for welding of the next segment, and then cross joints between orthotropic plate and lower slices of main beams are being welded. After that, welding inspection is performed according to plan of inspection and installation of fitting elements of trough-shaped supports and “L” profiles. After welding of above stated elements has been completed, the rest of unfinished welds made in workshop are being welded, at lengths of 300–400 m. This order applies also to the other bridge segments.

Same principles are applicable for welding of temporary aids, used in welding, as for the structure. Welding is executed by certified welders, by using the appropriate and dry electrodes. Such aids should be made of corresponding low alloyed steel of guaranteed welding capacity. After welding has been completed, these aids shall be removed by gas cutting and subsequent grinding, when special care shall be given to preventing damage of welded surfaces.