

INTEGRAL CONCRETE BRIDGES

SUMMARY:

Integral bridges are concrete bridges consisting of a frame structure without any expansion joints and bearings. The integral bridges are constructed monolithically, and the dimensions of structural load bearing elements are more abundant. Damages to such bridges are less intensive due to elimination of the main sources of damages, i.e. discontinuity areas, expansion joints, and bearing zones. The maintenance costs are lower, and the traffic is safer. Frame structures contain system reserves in both load distribution and static actions.

A bridge design in accordance with rules and codes is not a sufficient guaranty for a good and durable bridge. A correct conception is required taking into consideration experiences of practice and information gained from bridge maintenance and management.

The paper includes the following chapters: introduction, delusions in the field of prefabricated structures, damages to concrete bridges, beam and frame concrete bridges, concepts of integral bridges, constructive details of integral bridges, and analysis of integral bridges.

1. INTRODUCTION

On the actual roads there are numerous bridges of small and medium spans, which essentially affect the construction time and costs. Individual solving of such bridges according to subjective inclinations and the level of both knowledge and experience of design engineers is a history. The construction economy, time and technology require that groups of bridges are designed and constructed as a whole.

The field of activity is to search for optimum bearing structures where maximum possible resistance and durability of a bridge as an utilizable structure can be achieved by proper amount of both material and work. Such a task which seems to be simple is complex and functionally conditioned.

In the bridge construction, prestressing of reinforced concrete has been developing in the filed of beam systems of bearing structures. This is completely understandable as both bending and tension are such states of stress, which do not correspond to the natural properties of the concrete as construction material.

The prestressing has been developing in two directions: in the direction of mastering large span bridges, which had been out of reach for the reinforced concrete, and in the direction of development of construction technologies.

From among static systems, a beam on two supports spanning between 15 and 50 m, as well as continuous and frame systems of bearing structures are mostly used.

As the development and the application of unified steel falsework and other equipment for cast-in-situ concreting had fallen behind, the reinforced concrete lost its competitiveness in view of the prefabricated element construction even in structures where it is objectively advantageous.

Uncritical acceptance of all the advantages and innovations that had arisen with prestressing of the reinforced concrete, led to the decrease of both bearing capacity and durability ob structures, as well as to significant costs related to the rehabilitation of endangered bridge bearing structures.

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A delusion that reinforced concrete structures need not be maintained, as though durable materials are in question, has also been transferred to bearing structures made of prestressed reinforced concrete. Such a wrong opinion has been emphasized for a long time as basic advantage in comparison with other construction materials.

Visible damages to bearing structures of bridges and frequent failures and destructions have drawn attention of professional publicity to inspection of constructed bridges, to gathering and selecting relevant information, as well as to creating informational systems on executed bridges. Now, bridge designers have opportunity to participate in bridge inspections and to use the gained information efficiently. In such a way it is possible to have influence on the change of present situation as well as of progress and innovations.

2. DELUSIONS IN THE FIELD OF PREFABRICATED STRUCTURES

Structures made of prefabricated (precast) reinforced concrete elements are positively advantageous in the construction of industrial, public, and residential buildings, provided that they are based on verified and adequate constructive and technological solutions. The construction method based on prefabricated elements has certain advantages in the field of bridges as well, however some potential risks can be encountered if both exploitation and climatic conditions are not taken into account.

A load bearing structure made of prestressed reinforced concrete can be assessed as successful if an optimum amount of material, work, and construction time has been achieved.

On the basis of continuous monitoring of bridge behaviour during the service life, of detailed professional inspections during the preparation of appropriate bridge informational systems, as well as of published comprehensions, certain common features can be summarized, and useful ideas to eliminate deficiencies noticed and to improve constructive solutions of bridge bearing structures can be provided. All the schemes of bridge load bearing structures made of prefabricated prestressed reinforced concrete elements contain longitudinal joints between precast girders (Fig. 1). A monolithic structure created only by cross connections above the bridge supports is insufficient to ensure a collective work of all structural members during the bridge service life.



Fig. 1

After longer service and fatigue of the longitudinal hinge connection, such solutions may lead to longitudinal cracks through which the water can seep. So the way is clear for destruction of the load bearing structure. The thickness of the upper slab amounting to 15 cm is insufficient to ensure safety against punching due to vehicle wheel impact, particularly in conditions of uneven and damaged carriageways.

The design of bridge cross sections, where the upper chord is in the plane of the carriageway slab (Fig. 2), has resulted as a consequence of the aspiration for reduced concrete quantities, which particularly applies to the cast-in-situ concrete. Longitudinal construction joints are potential places of water penetration, damages, and destruction. The small width of connecting slabs does not provide conditions for a good execution and does not ensure a monolithic cross section.

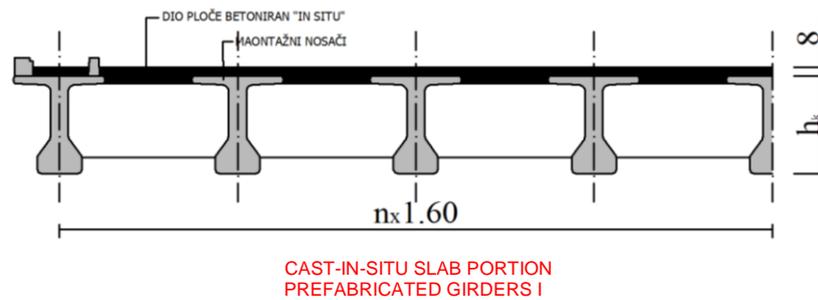


Fig. 2

Attempts to execute the reinforced concrete carriageway slab above the main prefabricated girders as a prefabricated slab have not ensured the bridge durability, especially in severe climatic conditions as well as on roads with high traffic intensity. Already after 10 years, detailed reconstructions were indispensable, which has led to administrative interdiction of such solutions.

A monolithic effect, i.e. co-acting of prefabricated girders within the bearing structure cross section, as well as the bridge durability, can be ensured by designing such cross sections (Fig. 3) where the carriageway slab is cast in situ above the upper chord of already erected main girders, thus forming a unified composite cross section. Concreting of the slab is simple, since no falsework is required. A possibility of use for oblique and curved bridges, as well as of neutralizing geometrical errors is enabled.

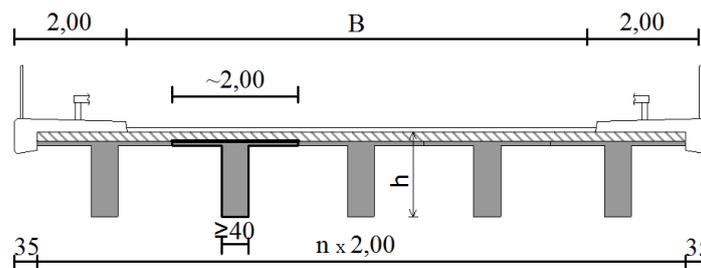


Fig. 3

The majority of bridges made of precast prestressed reinforced concrete girders, executed both abroad and in homeland, have a transverse discontinuity above the piers. The joints above the piers have resulted from the indulgence to the fabrication and erection technology (Fig. 4).

The simplest erection and construction method is to place the main girders onto final bearings, either movable or fixed. By casting carriageway cross girders above the bridge supports, a transverse stiffness of the prefabricated load bearing structure is achieved. The space between the main girder ends is bridged by means of expansion joints in case of movable bearings or by means of cantilever voids with a hinge in the middle in case of fixed bearings (Fig. 4).

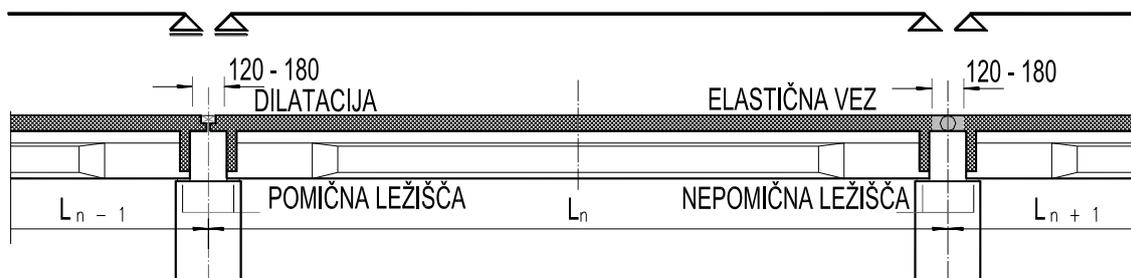


Fig. 4: Prefabricated discontinuous load bearing structure
 DILATACIJA=EXPANSION JOINT; ELASTIČNA VEZ=ELASTIC JOINT; POMIČNA LEŽIŠĆA=MOVABLE BEARINGS; NEPOMIČNA LEŽIŠĆA=FIXED BEARINGS

3. DAMAGES TO CONCRETE BRIDGES

Damages to concrete bridges can result from the following factors:

- structural deficiencies of bridge load bearing structure and equipment,
- corrosion of both reinforcement and tendons,
- aggressive action of chemical compounds (chloride and other aggressiveness of environment),
- damages due to low temperatures (freezing),
- processes within the reinforced concrete structure,
- prevented displacements,
- mechanical actions - damages,
- occurrence of cracks in concrete structures.

Structural deficiencies of bridge load bearing structures and equipment are consequence of the following:

- bridge structure design in view of its arrangement and static scheme,
- false solutions of constructive details,
- incorrect solutions of bridge equipment (bearings, expansion joints, waterproofing, asphalt carriageway, barriers, dewatering),
- unsuitably selected construction methods, precast or semi-precast construction with discontinuities and joints on the carriageway slab,
- adequate choice and poor quality of materials,
- absence of permanent protection and maintenance of bridges.

Fig. 5 shows damages to a discontinuous superstructure made of prefabricated girders with both transverse and longitudinal actual and construction joints.



Fig. 5

Construction of discontinuous bridges and viaducts of prefabricated girders, which are not composite with the reinforced slab, and without cast-in-situ cross girders is no more permitted in the majority of the EU countries.

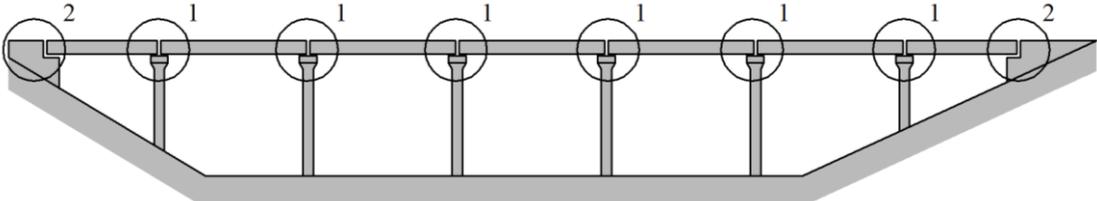
Other causes of damages to concrete bridges will not be discussed hereinafter, as this is not within the topic of the present paper.

4. BEAM AND FRAME BRIDGES

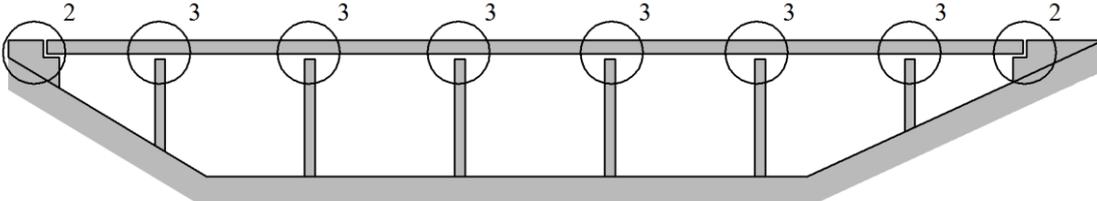
From among five known load bearing systems (beam, frame, arched, suspension, and cable stayed), beam bridges are most frequently constructed. The majority of all the executed bridges belong to concrete beam bridges.

The span length, total length, cross section design, method of supporting, and transfer of actions from the superstructure to supports, as well as the construction technology have been changing during more than 100 years of concrete bridge development.

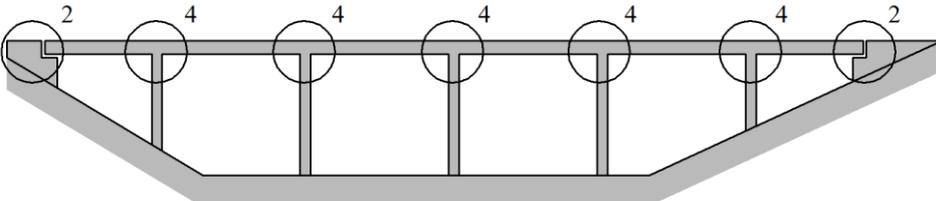
In Fig. 6, four characteristic schemes of concrete beam and frame bridges are shown. The scheme in Fig. 6a) is a discontinuous bridge with transverse discontinuities and double bearings and expansion joint above the piers. The superstructures are composed of precast girders, predominantly of a T-section, and of spans between 10 and 40 m (50 m). In the period from 1960 and 2000 a great number of such bridges were built in homeland and abroad (Fig. 7).



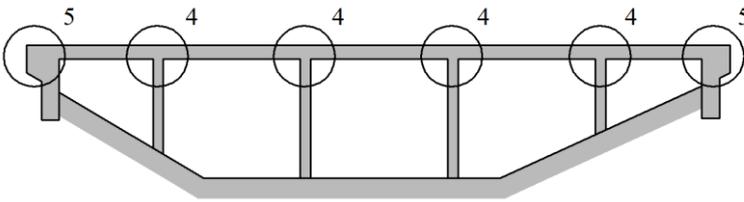
a) Scheme of a discontinuous bridge



b) Scheme of a continuous bridge



c) Scheme of a quasi-integral bridge



d) Scheme of an integral bridge

1. Transverse discontinuities - simple beams with bearings and expansion joints
2. Bearings and expansion joints above abutments
3. Continuous superstructures with bearings above piers
4. Stiff frame connection between the superstructure and piers
5. Stiff connection of elastic modified abutments

Fig. 6: Scheme of beam and frame concrete bridges



Fig. 7

Significant damages to prefabricated bridges and high rehabilitation costs amounting to 50-60% of the value of a new bridge, directed already after 20-25 years of exploitation the development of bridge construction towards the monolithic execution of bridge and viaduct superstructures (Fig. 6b).

The technology of construction of bridge superstructures of spans between 20 and 50 m and of lengths between 200 and 1,000 m by incremental launching of 15-25 m long segments prefabricated on a fill, allows a rapid and economical execution of bridges and viaducts having bearings on all the piers and abutments, and expansion joints only at the abutments (Fig. 8).



Fig. 8

Bridges, viaducts, and overpasses of smaller lengths, i.e. of 150 m (200 m), and of spans between 15 and 35 m, are constructed as quasi-integral structures (Fig. 6c), with a stiff connection at piers, and with bearings and expansion joints at abutments. Unified steel falseworks can either be fixed underneath the entire structure, or movable, when the superstructure is executed span-by-span (Fig. 9).



Fig. 9

Overpasses and bridges of a length up to 90 m are designed as integral structures (Fig. 6d) without any bearing and expansion joints. A monolithic structure is cast on a fixed steel falsework. In case of longer structures, abutments and fills have to be modified in order to achieve their sufficient elasticity. If a superstructure is curved, the integral structure can also be adopted for greater lengths (Fig. 10).



Fig. 10

5. CONCEPTS OF INTEGRAL BRIDGES

Integral bridges are concrete frame structures without any expansion joints and bearings. Integral bridges are constructed monolithically, and the dimensions of load bearing structural elements are more abundant. Damages to such bridges are less intensive due to elimination of the main sources of damages, i.e. discontinuity areas, expansion joints, and bearing zones. The maintenance costs are lower, and the traffic is safer. Frame structures contain system reserves in both load distribution and static actions.

Dimensional disproportions shall be avoided in the integral bridge design, as the concentration of stresses and cracks is avoided in this way. For bridge structural elements, which are prone to more rapid deterioration, their ability of being replaced shall be ensured. A bridge design in accordance with rules and codes is not a sufficient guaranty for a good and durable bridge. A correct conception is required taking into consideration experiences of practice and information gained from bridge maintenance and management.

Integral frame bridges are not recommended for oblique structures where the angle of obliqueness is less than 30° , neither for frame structures of greater length with low and stiff piers. The interaction bridge - foundation ground is very important component of both deformational and load bearing behaviour of an integral structure, therefore cooperation between the bridge designer and soil mechanics specialist is indispensable when determining realistic soil mechanical parameters.

Integral bridges are advantageous due to:

- lower construction costs;
- lower maintenance and repair costs, since such bridges do not contain elements, which would require intensive maintenance. Bearings and expansion joints on bridges increase the construction costs, and, which is even more important, the maintenance costs; they also cause traffic risks and jams. Therefore, they shall only be used when this is inevitable. Penetration of water from the carriageway in expansion joint and bearing zones are the most frequent causes of damages and decay of concrete. The replacement of expansion joints and bearings is often very complicated and expensive, particularly on motorways with dense traffic;
- simpler and faster construction, as there are no bearing and expansion joints, which require rigorous installation tolerances with a precise sequence of working operations;
- higher level of service;
- permanent and from maintenance independent prevention of direct access of salts to structural elements located under the carriageway;
- diminishing of hazard of differential settlements and buckling of piers;
- taking negative reactions from the superstructure;
- shorter lateral spans enable the execution of larger central span in structures consisting of three spans;
- higher reserves in the load bearing capacity due to possible redistributions of actions in the ultimate limit state.

The magnitude of parasite actions depends to a great extent on the structural geometry, on the ratio of the superstructure stiffness to the pier stiffness, as well as on the foundation ground stiffness. It is essential to employ a realistic modelling of the stiffness of both structure and foundation ground, thus actual loads are taken into account by the design model. If a small value is assumed for the foundation ground stiffness, secondary forces and moments resulting from temperature changes and prestressing will be underestimated. Therefore, for integral bridges, the calculation of secondary forces and moments shall be carried out separately, where lower and upper limits of the soil characteristics are taken into consideration.

Static systems of integral concrete bridges are frame structures having one, two, or more spans as shown in Fig. 11.

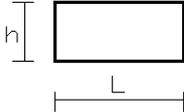
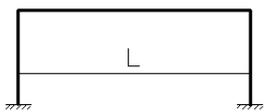
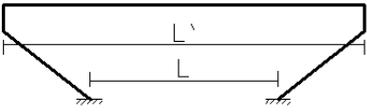
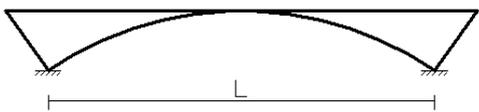
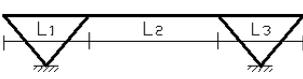
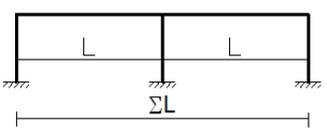
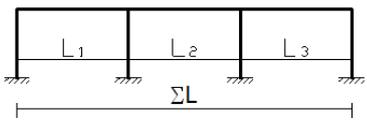
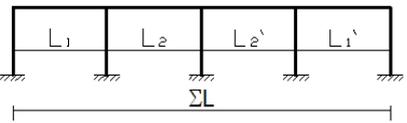
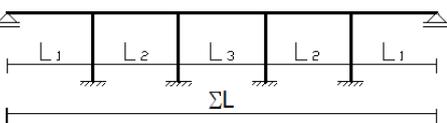
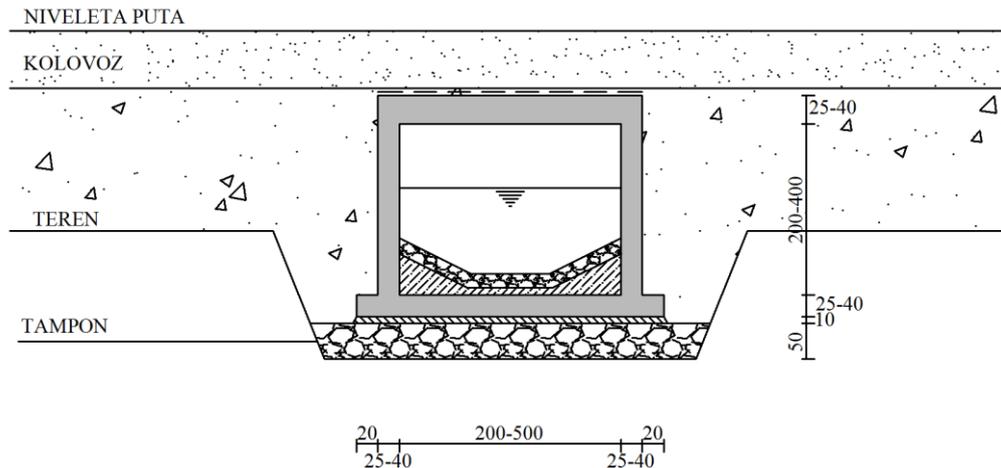
STATIČKI SISTEM	NAZIV STATIČKOG SISTEMA OBJEKTA	RASPONI	
		ARMIRANI BETON	PREDNAP.AR. BETON
1 	zatvoreni okvir	2 - 5 (8)	/
2 	otvoreni okvir	5 - 25	20 - 60
3 	otvoreni okvir sa kosim stubovima	15 - 30	30 - 70
4 	integrirani lučni okvir	35 - 50	35 - 70
5 	okvir sa tri raspona i kosim stubovima	20 - 30	30 - 70
6 	okvir sa dva raspona	15 - 25	20 - 40
7 	okvir sa tri raspona	15 - 25	20 - 40
8 	okvir sa četiri raspona	15 - 25	20 - 40
9 	okvir sa više raspona	15 - 25	20 - 40

Fig. 11: Static systems of integral concrete bridges

STATIC SYSTEM, DESIGNATION OF STRUCTURAL STATIC SYSTEM, SPANS, REINFORCED CONCRETE, PRESTRESSED REINFORCED CONCRETE, 1=CLOSED FRAME; 2=OPEN FRAME, 3=OPEN FRAME WITH

INCLINED PIERS; 4=INTEGRATED ARCH FRAME, 5=THREE-SPAN FRAME WITH INCLINED PIERS, 6=TWO-SPAN FRAME, 7=THREE-SPAN FRAME, 8=FOUR-SPAN FRAME, 9=MULTI-SPAN FRAME

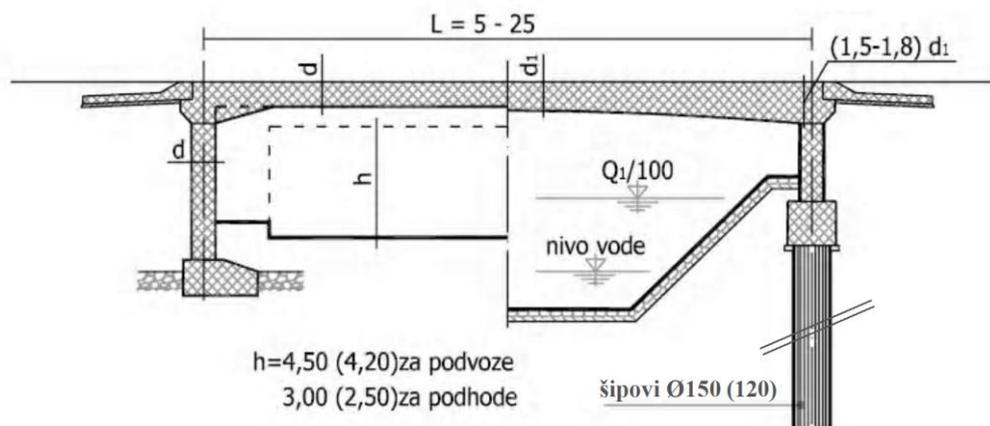
A closed reinforced concrete frame of 2-5 (8) m span and 2-4 m height can be used for water culverts or pedestrian and vehicle underpasses under another road or railway. The structure is economical and simple for both construction and maintenance. It is recommended to execute the culverts and underpasses under the pavement structure in order not to interrupt the traffic-dynamical and visual continuity of the road (Fig. 12).



NIVELETA PUTA=ROAD VERTICAL ALIGNMENT; KOLOVOZ =PAVEMENT, TEREN=GROUND, TAMPON=TAMPON

Fig. 12

An integral frame reinforced concrete structure is economical for the construction and a simple solution for underpasses and bridges of spans between 8 and 25 m, founded directly or on bored piles of diameter 120 (150) cm. For spans up to 15 m, the superstructure is flat, i.e. without any voutes. For larger spans, however, voutes or variable depth with parabolic intradoses is recommended (Fig. 13).



šipovi=piles; za podvoze=for vehicle underpasses; za podhode=for pedestrian underpasses; nivo vode=water level

Fig. 13

For overpasses and bridges of 20-50 (60) m span, prestressed reinforced concrete monolithic structures are designed, founded directly or on bored piles.

In Fig. 14 a scheme of a prestressed reinforced concrete frame structure of a motorway overpass of 30-50 m span is shown. A characteristic feature is the widening on the top of the piers, which is required

to avoid the collision between the frame reinforcement and the anchorage zone of the deck tendons. The details of such widening are presented in the next chapter.

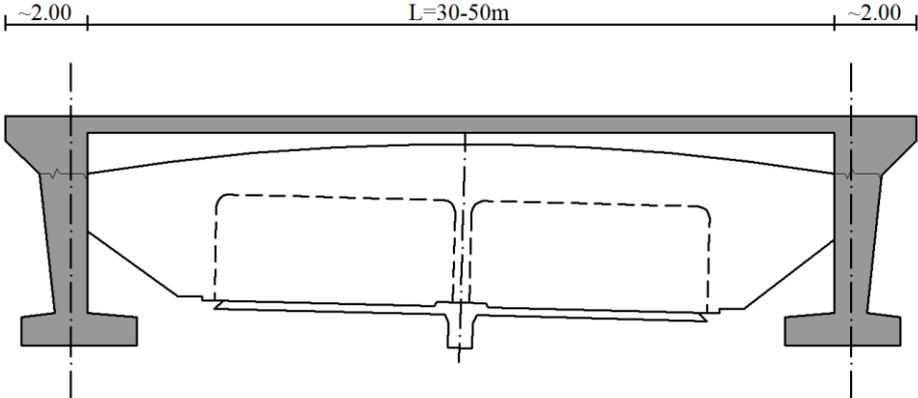


Fig. 14

A characteristic example of an overpass running across a future highway, which is designed as a frame integral prestressed reinforced concrete monolithic structure of 30 m span with a parabolic intrados, is shown in Fig. 15.



Fig. 15

Integral concrete structures can also be designed for arch bridges of spans of 35-70 m, where the foundation conditions are considered as favourable (Fig. 16).

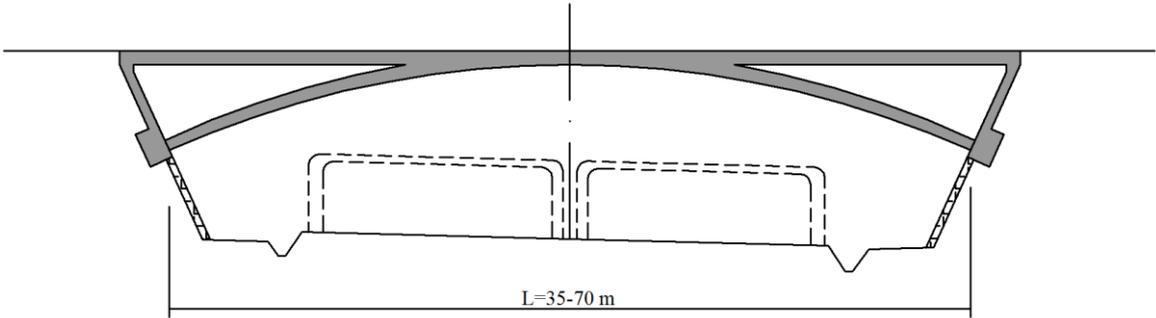


Fig. 16

An overpass, running across a motorway in a deep rock cut, is designed as an integral reinforced concrete structure of 50 m span, where massive abutments are replaced by inclined concrete walls (Fig. 17).



Fig. 17

Motorway overpasses with two, three, or four spans can be designed as reinforced concrete or prestressed reinforced concrete structures of a total length less than 80 (90) m. The length of an integral structure also depends on the foundation method and constructive modifications of the abutments (Fig. 10 and Fig. 18).

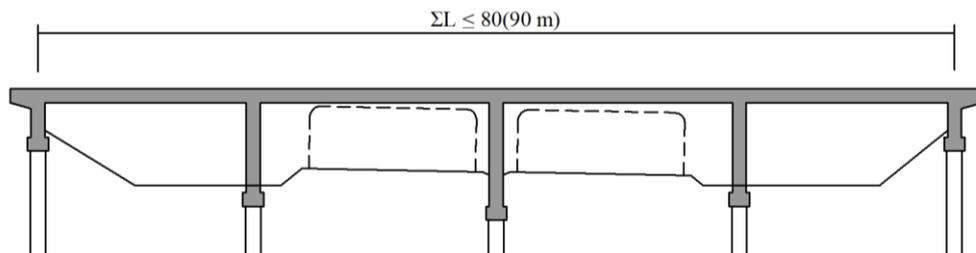


Fig. 18

The recommended cross sections of reinforced concrete and prestressed reinforced concrete bridges for all the nine static systems indicated in Fig. 11 are shown in Fig. 20. A solid slab, a slab girder, and a double-web T-beam are simple for both construction and reinforcing. In prestressed cross sections there is sufficiently width for the tendons, which do not change their horizontal position. The construction depth of the cross section is less than 1/20. The cantilever dimensions depend on the thickness of the slab or the slab girder. The cantilever size shall be harmonized with the position of the dewatering gullies to avoid their encroachment into the load bearing section.

Slab girders for construction depths more than 1.00 m with vertical and inclined lateral sides allow thinner piers on the less loaded plane. A double-web T-beam is a good solution for bridges measuring more than 12 m in width, and for oblique bridges, as the effects of obliqueness are diminished.

Integral bridges can also be constructed from precast T-girders of a wide and thin upper flange, and of a web of constant width of 40 cm or more. The girders are prestressed with bonded prestressed tendons, or with post-tensioned tendons. Above the prefabricated girders a slab of minimum thickness of 20 cm is cast. Such a slab is composite with prefabricated girders by means of dowels. By foreseeing cross girders above the abutments and piers, which are cast simultaneously with the slab above the girders, a stiff connection and an integral structure is achieved.

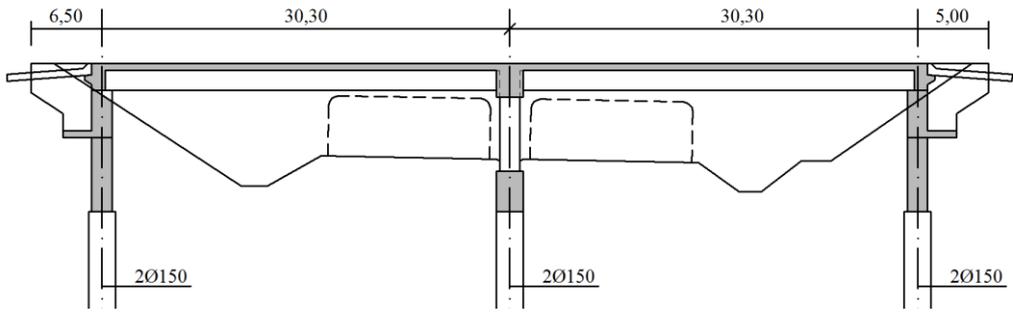


Fig. 19

TIP PRESJEKA	SKICA POPREČAOG PRESJEKA	KONSTRUKTIVNA VISINA "h"
PUNA PLOČA BEZ KONZOLA		40-80
PUNA PLOČA SA KONZOLAMA		80 - 100
PLOČASTI NOSAČ		100 - 140
TRAPEZNI PLOČASTI NOSAČ		100 - 150
REBRATA PLOČA		120 - 160
MONTAŽNI T NOSAČI SPREGNUTI SA MONOLITNOM AB PLOČOM		50 - 150

Fig. 20: Recommended cross sections of superstructures of concrete integral bridges

Tip presjeka=cross section type; skica poprečnog presjeka= cross section sketch; konstruktivna visina=construction depth; puna ploča bez konzola=solid slab without cantilevers; pločasti nosač=slab girder;

trapezni pločasti nosač=trapezoidal slab girder; rebrasta ploča=double-webbed T-beam; montažni T nosači spregnuti sa monolitnom AB pločom = prefabricated T-girders composite with monolithic reinforced concrete slab

As curved integral bridges react more favourably to the effects of temperature and concrete shrinkage in comparison with straight bridges, they can be executed in greater lengths. Bridges curved in plan have a horizontal deformation, so that they are less affected by the secondary forces due to the temperature change and concrete creep and shrinkage. The change of the length of curved bridges occurs on the entire bridge length, except at the abutments. Structures made of high-performance concrete are less sensitive to forces resulting from the concrete creep and shrinkage, so integral structures of greater lengths can be designed. The transition from the bridge to the road body requires special solutions for longer integral bridges. Such solutions will be discussed in the following chapter.

For the Sunniberg Bridge in Switzerland, Prof. Menn has designed a curved integral structure of 526 m length, with high and elastic piers, which is a record length of integral bridges so far.

According to the British Highway Agency Standards, bridges of a length up to 60 m shall be designed as integral bridges without any bearing and expansion joints.

In Slovenia, technical specifications for integral bridges are under preparation.

For bridges measuring 40 - 90 m in length, flexible abutments shall be designed, which can be achieved by uniting the bored pile foundations and the abutment with shorter cantilever wing walls, as well by adequate execution of the fill (modified backfills). In the next chapter, the design of elastic abutments and interventions to allow deformations of integral structures will be discussed.

An omission of monolithic connection between the abutments and superstructure is only justified, where secondary forces and moments due to the mobilized earth pressure and a very stiff foundation are hardly mastered and controlled. Where only piers are monolithically connected with the superstructure, a quasi-integral bridge is in question (Fig. 6d).

6. CONSTRUCTIVE SOLUTIONS OF INTEGRAL BRIDGES

Road culverts, underpasses, and minor bridges measuring up to 15 m in length, are designed as reinforced concrete frame integral structures. Culverts and underpasses of openings up to 5 (8) m are closed frames, while for openings (lengths) above 5 (8) m they are designed as open frames. For the transition from the bridge structure to the road body no additional measures are required. The completed structure is backfilled with stony material, which shall be compacted to Proctor degree of 95-98%. Fills (backfills) behind the walls shall be executed in layers, symmetrically on both sides, in order not to provoke additional stresses and deformations of the frame structure. The transition from an integral reinforced concrete bridge to the road body without a transition slab is shown in Fig. 21.

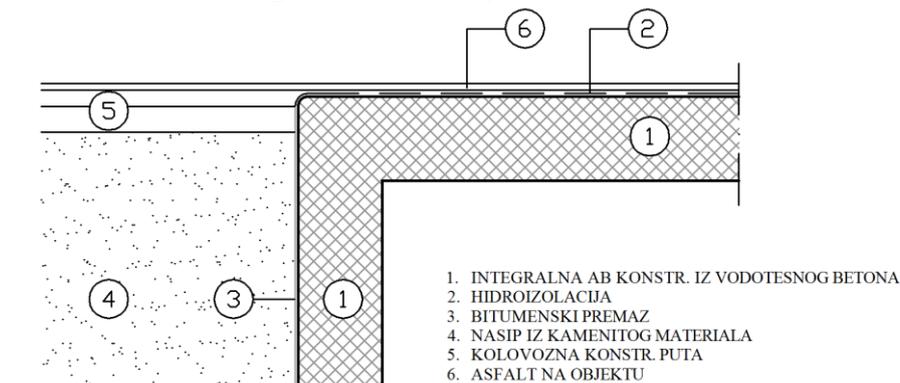


Fig. 21

1=integral RC structure made of waterproof concrete; 2=waterproofing; 3=bituminous coating; 4=fill of stony material; 5=road pavement; 6=asphalt

Culverts and underpasses of an opening up to 8 m should preferably be lowered into the fill, so that the road pavement can run over these structures continuously.

On motorways, however, transition slabs are required for such structures. The function of the transition slabs is neutralise possible settlements at the structure. Deformations of structures not exceeding 15 m in length do not cause cracks in the asphalt course.

Appropriate reinforcing of frame corners is required, which shall be harmonized with the position of construction joints (Fig. 22).

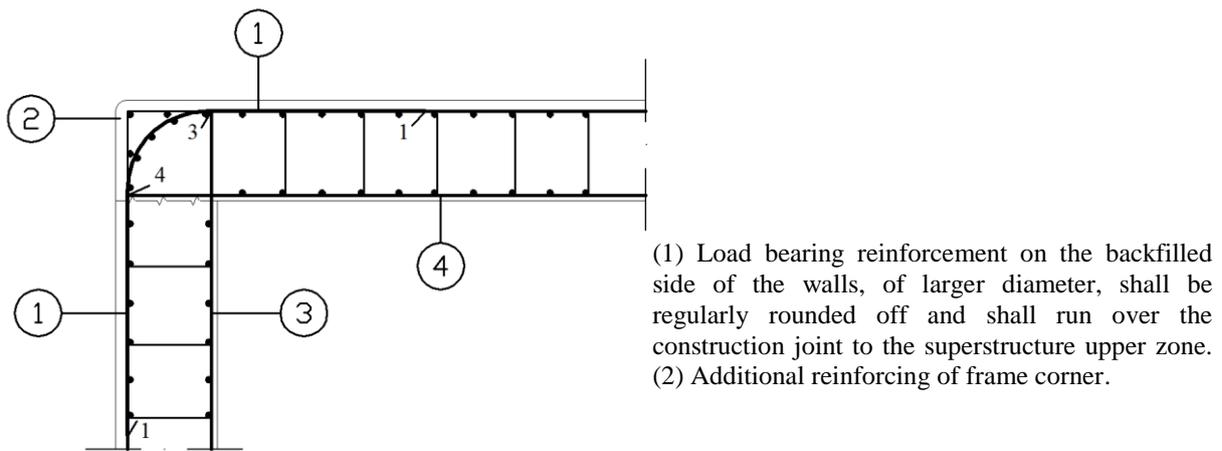


Fig. 22

Road bridges and underpasses measuring up to 35 m in length are designed as reinforced concrete or prestressed reinforced concrete integral frame structures of one or two spans. Additional measures are required for the transition from the structure to the road body.

A fill constructed of stony materials shall be carried out as modified reinforced fill, using polymer meshes of low extensibility, e.g. aramide. When laying the reinforcing meshes, attention shall be paid to their proper tightening. In this way, the meshes will be able to take tensile forces immediately. In addition, such meshes reduce the fill pressure on the structure.

For structures on roads of lower ranking, where no transition slabs are foreseen, reinforced concrete supporting beams of 80/100 cross section shall be executed in the width of the structure/fill. On the top of the contact between the supporting beam and the structure, a 2 cm wide joint shall be foreseen, which must be filled up with an asphalt putty of permanent elasticity (Fig. 23).

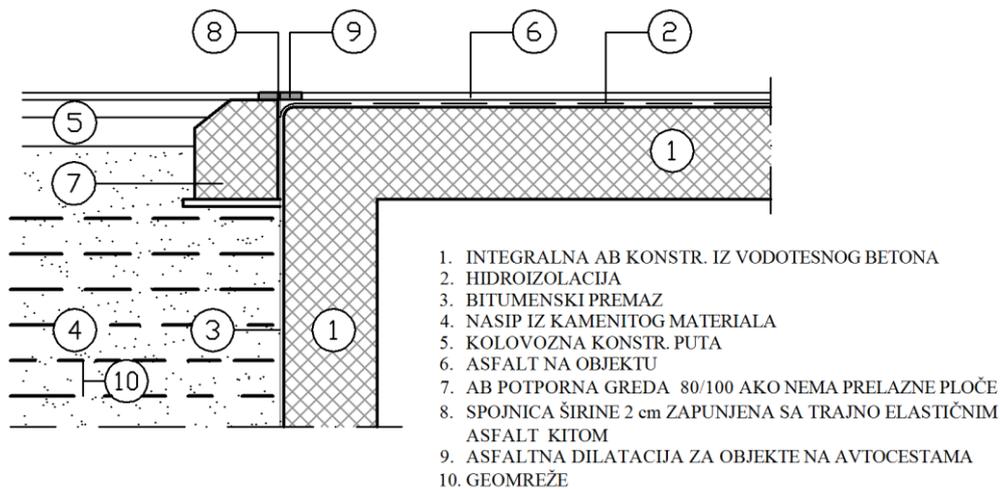


Fig. 23

1=integral RC structure made of waterproof concrete; 2=waterproofing; 3=bituminous coating; 4=fill made of stony material; 5=road pavement; 6=asphalt; 7=RC supporting beam 80/100, where no transition slab is foreseen; 8=joint of 2 cm width filled up with asphalt putty of permanent elasticity; 9=asphalt expansion joint for motorway bridges; 10=polymer meshes

For bridges on main road and motorways, the transition from the structure to the road fill is carried out by means of a transition slab. In this case a 50 cm wide and 8 cm thick asphalt expansion joint is foreseen.

For bridges of up to 60 (90) m length, having a transition slab, additional solutions are required on the fill and in the transition slab supporting zone.

The fill shall be reinforced with polymer meshes. Between the fill and the walls (abutments) of an integral structure, a 10-30 cm thick polystyrene layer shall be inserted, which allows structural deformations (Fig. 23).

Polymer reinforcing meshes reduce earth pressures on abutments, while the polystyrene enables deformations. Possible settlements of the ground behind the abutments can be neutralised by suitable transition slab, which is supported by the structure via neoprene bearings.

Several studies on the design of flexible abutments and interaction between the ground and an integral structure have been made (5), (8), (11).

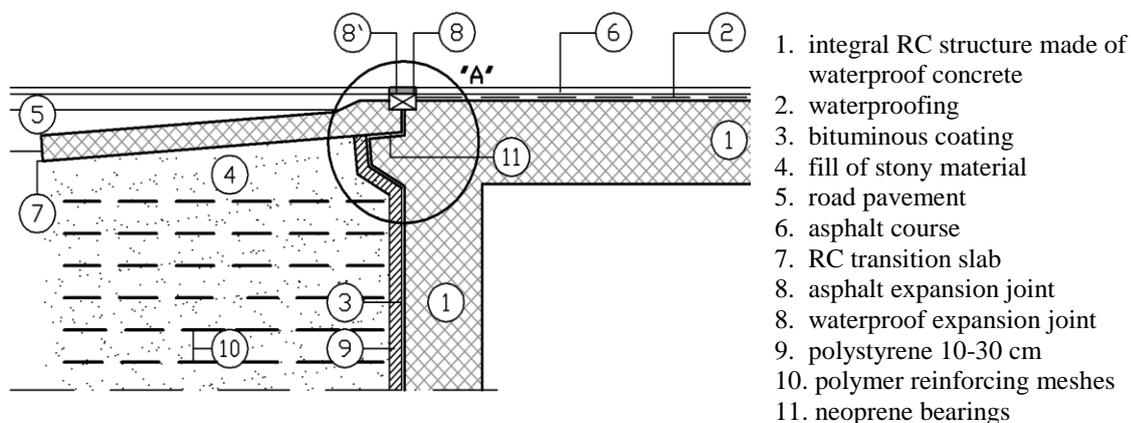
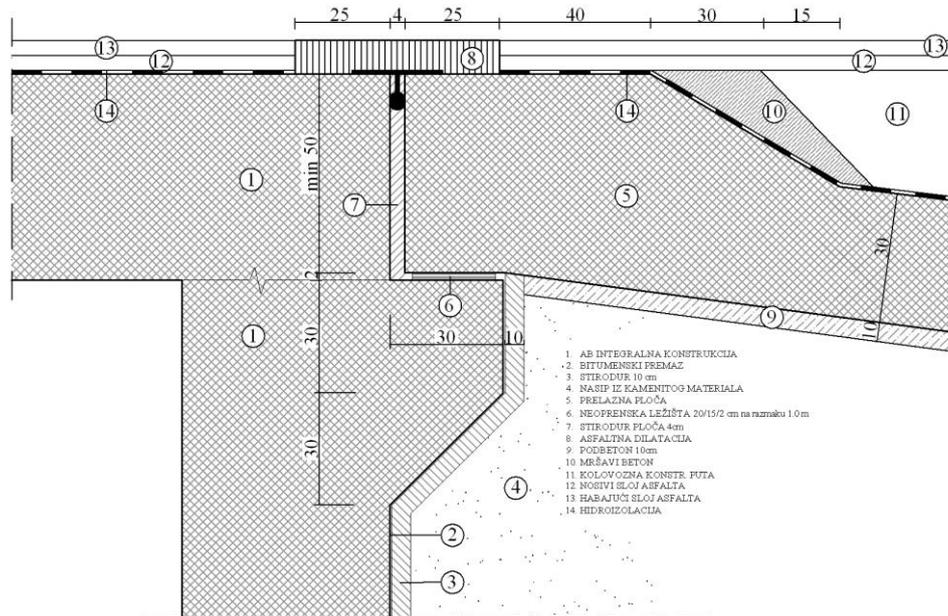


Fig. 24

The detail „A“ of the transition slab supporting zone is shown in Fig. 25. The transition slab rests on the abutment cantilever part via neoprene bearings of dimensions 20/15/2 cm spaced at 1.0 m. The void between the bearings and at the front of the transition slab shall be lined with polystyrene of appropriate thickness. Above the top of the transition slab and of the superstructure end, and asphalt expansion joint of 55/10 cm is foreseen for structures of up to 60 m length and a waterproof steel or rubber expansion joint for structures of 60 - 90 m length respectively.



1=RC integral structure, 2=bituminous coating, 3=polystyrene 10 cm, fill of stony material, 5=transition slab, 6=neoprene bearings 20/15/2 spaced at 1.0 m, 7=polystyrene panel 4 cm, 8=asphalt expansion joint, 9=concrete underlay, 10=lean concrete, 11=road pavement, 12=asphalt bearing course, 13=asphalt wearing course, 14=waterproofing

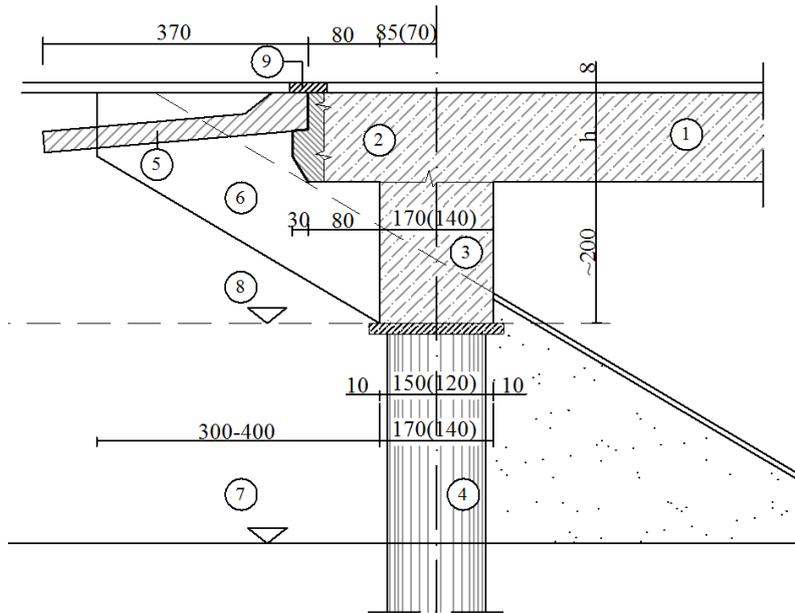
Fig. 25

Elastic abutments through which a fill is formed and which comply with the nature of integral structures for overpasses and other structures shall be designed in accordance with the instructions shown in Fig. 26.

Bored piles of diameter 120 or 150 cm are executed from a fill constructed approximately 3.0 m below the road vertical alignment. Above the piles, a beam measuring 1.40 m or 1.70 m in width shall be cast up to the construction joint at the contact with the superstructure. The beam shall be reinforced as shown in Fig. 26.

The superstructure is extended by 80 (80 + 30) cm. In this way, a collision between the reinforcement and the tendons heads is avoided. The outer reinforcement from the beam shall be extended and bound with the upper reinforcement of the superstructure. After the tendons have been tensioned, the front surface of the extension and the transition slab support are cast.

For such abutment design it is not indispensable to reinforce the fill with meshes, as the ground pressures are significantly smaller due to a lowered fill. In case of directly founded abutments, a less stiff structure without wing walls or with shorter cantilevered walls shall be designed. Reinforcing of the fill by means of polymer meshes and the polystyrene layers shall be executed according to the detail shown in Fig. 24.



1. Prestressed RC superstructure
2. Superstructure extension
3. Beam above piles
4. RC piles of ϕ 150 (ϕ 120)
5. Transition slab
6. Cantilevered wing walls
7. Ground level
8. Level of fill for pile execution
9. Asphalt expansion joint/polystyrene 10-30 cm

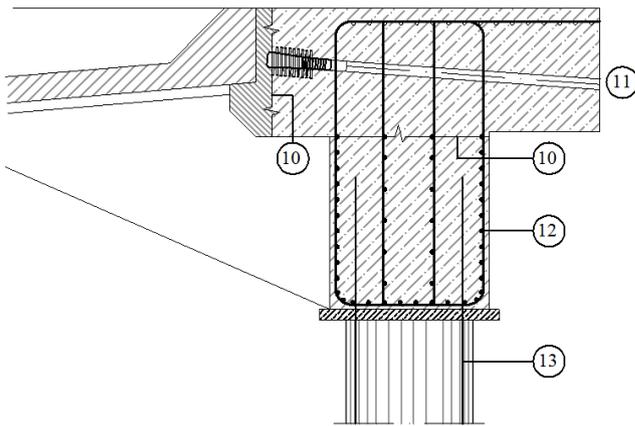
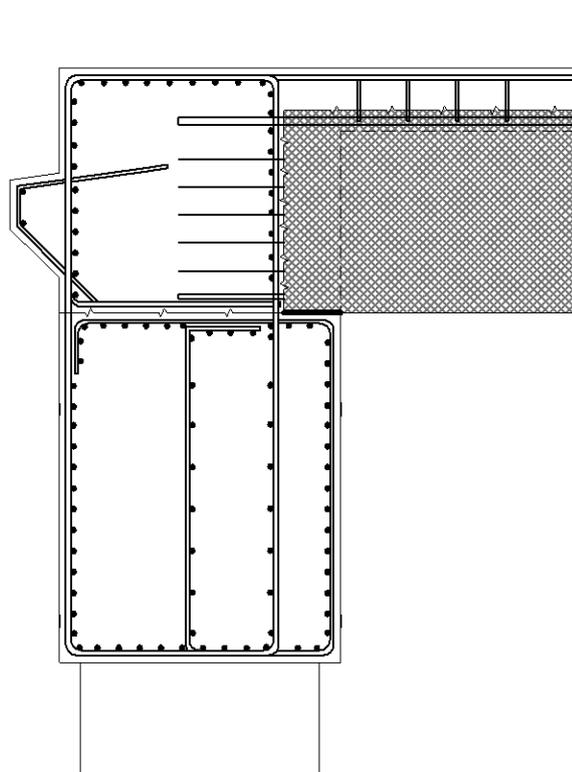
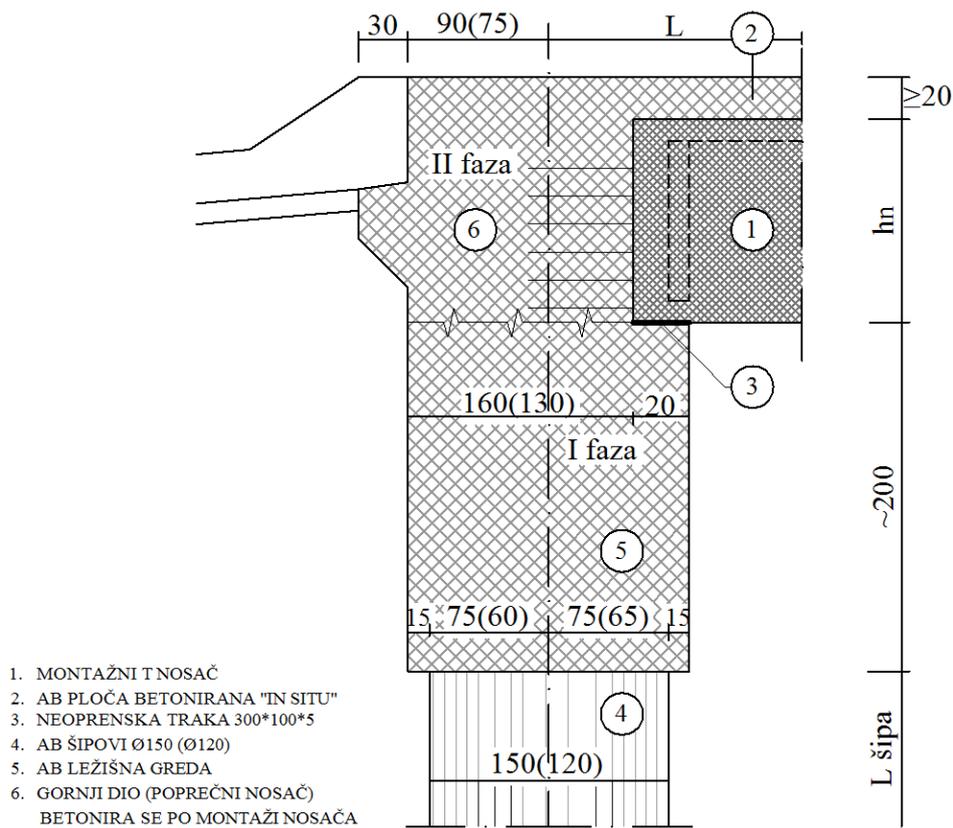


Fig. 26

An integral bridge concrete superstructure can also be constructed of prefabricated prestressed reinforced concrete T-girders of a wide and thin upper flange. By in-situ casting of the slab and cross girders a composite precast-monolithic frame integral structure is formed. In Fig. 27, a detail of such a structure at the abutment is shown.



$L_{\text{šipa}} = L_{\text{pile}}$, Faza=stage, 1=prefabricated girder, 2=cast-in-situ RC slab, 3=neoprene bearing 300*100*5, 4=RC piles, 5=RC bearing beam, 6=upper part (cross girder) cast after erection of girders

Fig. 27

Above the bored piles measuring 120 or 150 cm in diameter, a bearing beam is cast in the stage I up to the construction joint. At the edge of the bearing beam, neoprene bearings for provisional elastic

os opornika=abutment axis, 1=Superstructure, 2=waterproofing, 3=bituminous coating, 4=fill of stony material, 5=road pavement, 6=asphalt on bridge, 7=RC transition slab, 8=waterproof expansion joint, 9=bearings, 10(!)=bearing beam, 11=RC piles, 12=superstructure extension, 13=ground, 14=working area for pile execution

7. DESIGN ANALYSIS OF INTEGRAL BRIDGES

One of the reasons, why integral bridges are insufficiently used, is the aspiration of the designers for clear applicative static systems of beam bridges.

A state-of-the-art hardware and software based on the FEM theory, allow a more accurate and rapid design analysis of integral bridges on a 3D-model (Fig. 30).

Integral and conventional bridges differ from each other in the method of taking actions due to temperature changes, concrete creep and shrinkage, and deformations.

In conventional bridges the horizontal deformations are free, i.e. not restrained, whereas in integral bridges they are partially hindered due to the contact with both ground and fill.

The interaction bridge - foundation ground and fill is of essential importance for the structural behaviour when taking actions and deformations, particularly parasite deformations.

The static analysis of individual load bearing elements of an integral structure cannot be performed separately, as the bearing structure is integral, i.e. of a complex interactive function of the superstructure, abutments with wing walls, piers, foundations (piles), foundation ground, and road body.

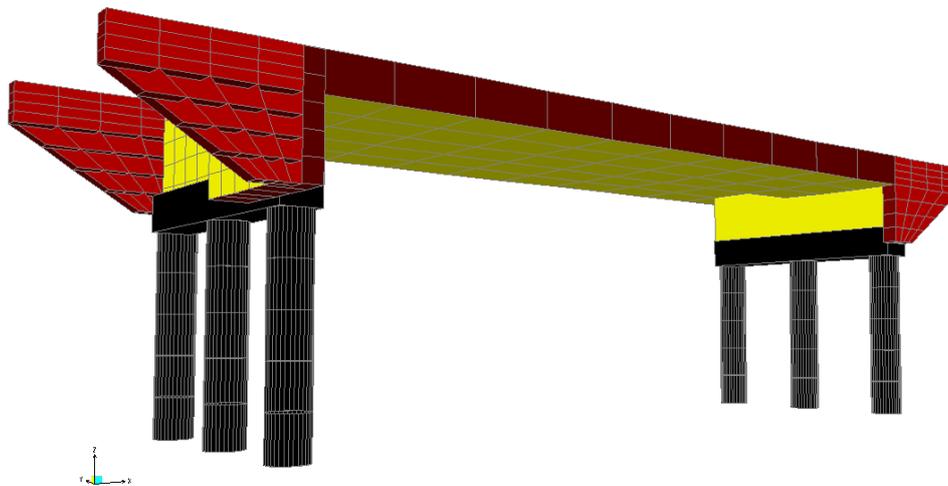


Fig. 30

The magnitude of parasite loads depends on the structural geometry, the ratio of the superstructure stiffness to the pier stiffness, as well as on the foundation ground stiffness. In case of a monolithic (rigid) connection of the superstructure with the abutments, a realistic assessment of the foundation ground stiffness is of particular importance. In the integral bridge design, the cooperation between the designer and the soil mechanics specialist shall be more intensive than in the conventional bridge design. The risk of an incorrect assessment of the ground stiffness can be most successfully avoided by calculating the forces, moments and deformations of an integral structure introducing two extreme values of the foundation soil characteristics. The assessment of realistic ground stiffness and of changing the stiffness value by depth is objectively very difficult. If, for example, low values of coefficients of ground stiffness are adopted for an integral bridge as shown in Fig. 30, values of moments and deformations, which are by approximately 15% higher, will be attained in the

superstructure middle. For higher values of coefficients of ground stiffness, values of moments, which are by approximately 10 to 15% higher, will be calculated at the connection between the deck and the piers. By foreseeing a small amount of extra reinforcement or tendons, extreme actions shall be taken for both cases.

Forces and moments due to parasite actions also depend on the coefficient of expansion due to temperature change, and on the module of elasticity of concrete. Such material characteristics can be affected by selecting suitable aggregate.

If the static analysis shows that the parasite actions, particularly those resulting from temperature changes, cannot be taken by a monolithic rigid connection and by a modified fill, a rigid connection shall be omitted and a quasi-integral structure designed.

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