UP-TO-DATE CONCEPTS OF OVERPASSES ON MOTORWAYS

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Abstract
Overpasses are the most frequent structures on the motorways. The overpasses are important from the point of view of the traffic safety on themselves as well as on the motorways. Their appearance gives an impression on the entire motorway and on its harmonisation with the natural environment. The article intends to assist the road designers looking for suitable solutions of geometrical conditions of the crossings, as well as the structural designers for a correct layout conception and for an adequate structural design of the overpasses.

The contents of the article are as follows:
1. Introduction
2. Design bases, in particular solutions of roads on the overpasses
3. Layout conceptions of overpasses on flat ground
4. Layout conceptions of overpasses in cuts
5. Structural solutions and overpass construction technologies

1. Introduction

The motorway construction represents a major intervention in both physical space and nature, thus motorways have a substantial influence from the functional, ecological, and psychological-visual aspect.
The main purpose and a tendency towards an economical construction of greater lengths can jeopardize the basic values of both environment and nature. In most European countries the environment and nature are protected by an adequate legislation. A consistent implementation of those acts represents a test of the civilization and cultural maturity of inhabitants and institutions.
The selection of a motorway route is a base of placing a motorway into the particular space. The motorway route shall be accommodated to the environmental changes.
The natural environment and the structures shall be combined by an interdisciplinary cooperation of designers. A motorway, harmonically designed from both spatial and visual point of view, increases the traffic safety and allows a pleasant view of the motorway as well as from the motorway. A perfectly arranged space along the particular motorway is such a space, where an observer from the motorway or from the surrounding location cannot perceive any interventions in the nature. The environment where a human being grows up and lives provides the population with certain criteria

and feeling to value the world and phenomena, as well as with the sense of beauty and harmony.

An important part of the motorway design is civil engineering structures such as bridges, viaducts, overpasses, underpasses, galleries, portals of tunnels, and retaining structures. These structures shall be mutually harmonized on a certain motorway section. The visual concept results from valorised principles taking account of the past experience from the already constructed motorways. Placing the roads into the environment represents knowledge and skill, which designers win during the years of their work as well as by a critical assessment of roads already completed.

A good motorway route planning also comprises the design of slopes of cuts and fills, of the geometry of retaining structures, portals of tunnels, overpasses, and equipment, especially noise barriers. There are plenty of noise barriers on the up-to-date motorways, and the contact of the motorway users with the nature is cut off.
Overpasses and other bridges come into being as a composition of the motorway geometry and the road running on the particular overpass, of morphological-geological properties of the location of the civil engineering structure, intention of use, material, form, construction method, safety, durability, economy, and placing into the physical space.

An overpass shall be designed on the basis of the conditions determined by the obstacles, road or railway elements as well as the provisions of the construction theory and practice. The success of a bridge composition is a result of knowledge, experiences, and skills of the designing engineer.

The bridge shape cannot be discussed apart from its load bearing structure. A well and correctly designed bridge bearing structure is harmonic and logically shaped as well.
The rapid development of the structural theory, computer aided calculations and designing, have dislodged the feeling for the tradition, structure, and shape. New construction technologies do not always bring harmonic proportions of the material, form, and purpose.
Any successful bridge composition brings its own aesthetical level being the result of the author’s spiritual maturity. The time always shows the difference between good and bad bridges.

By their definition, overpasses are bridges to carry other roads/railways over the considered road or railway. In our practice, overpasses are the most frequent bridges to allow the crossing of a road with a motorway or expressway at split level.

2. Bases for overpass design

The design of overpasses and other reinforced concrete bridges is based on the spatial and town planning, traffic, surveying, road, geological/soil mechanical, hydrological/ hydro-technical, climatic, and seismic bases as well as on the design requirements given in the terms of reference. Quality, functionality, stability, and economy of the designed overpass depend to a great extent on the accuracy and the correct application of the abovementioned bases. In this place, the solution of the road running on the overpass and next to the overpass, as well as the geometrical relations in view of the motorway are emphasized. The two fundamental geometrical parameters are the crossing angle of the motorway axis to the axis of the road running on the overpass, as well as the solution of the vertical alignment from the point of view of both height and form.

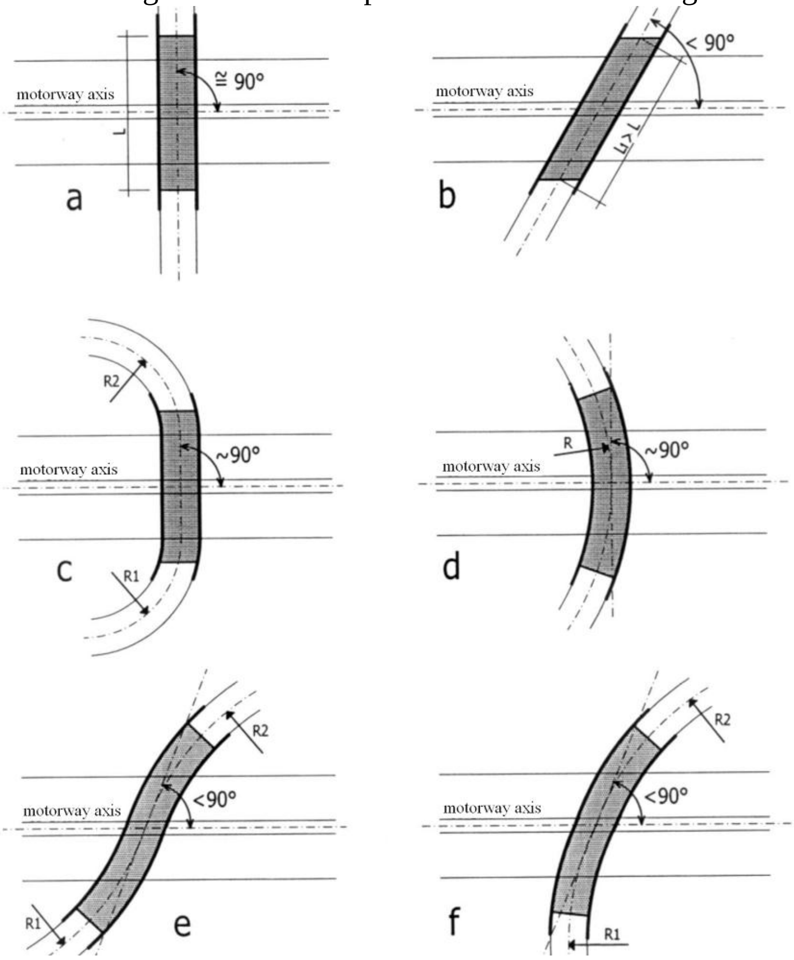

Fig. 1

In Fig. 1, possible plan geometries of solutions of crossings are shown schematically.
The solution presented in Fig. 1a, is a wished-for one: the crossing angle of the motorway axis to the axis of the road on the overpass amounts to 90°; the overpass length is as small as possible, and all the supports are rectangular.

By increasing the obliqueness of overpasses, the length and the costs of the structures increase as well due to the increased overpass area and to quite a complex construction.
The smallest possible length and the most pleasant appearance of an overpass can be achieved by designing a rectangular structure whose vertical alignment runs in a symmetrical convex curvature or in a one-sided fall of 0.5 – 1.5%.

A low vertical alignment on an overpass does often not admit sufficient room for an optimum solution of the construction depth of the overpass superstructure. If the construction depth of the superstructure is too small, more material is required, the solution is less economical, and the structure more deformable.

The overpass clearance gauge depends on several factors. The minimum clearance gauge is determined by the cross section of the motorway, expressway, or any other type of road. The actual clearance gauge of overpasses is essentially greater than the minimum one.

3. Arrangement schemes of overpasses on a flat ground

An overpass arrangement scheme is mainly affected by the following:
- ground morphology (flat ground or cut)
- motorway total width
- motorway geometry and central reserve width
- position of the motorway in view of the ground (fill height)
- possibility of motorway widening – increase of the number of lanes
- road geometry and vehicle speed on the overpass
- spatial and town planning conditions.

A split level crossing of roads with the motorway on a flat ground with 6 – 8 m high fills visually cuts the physical space and limits the sight width of the motorway users. Overpass structures are straight integral frame structures of one, two, or more spans.

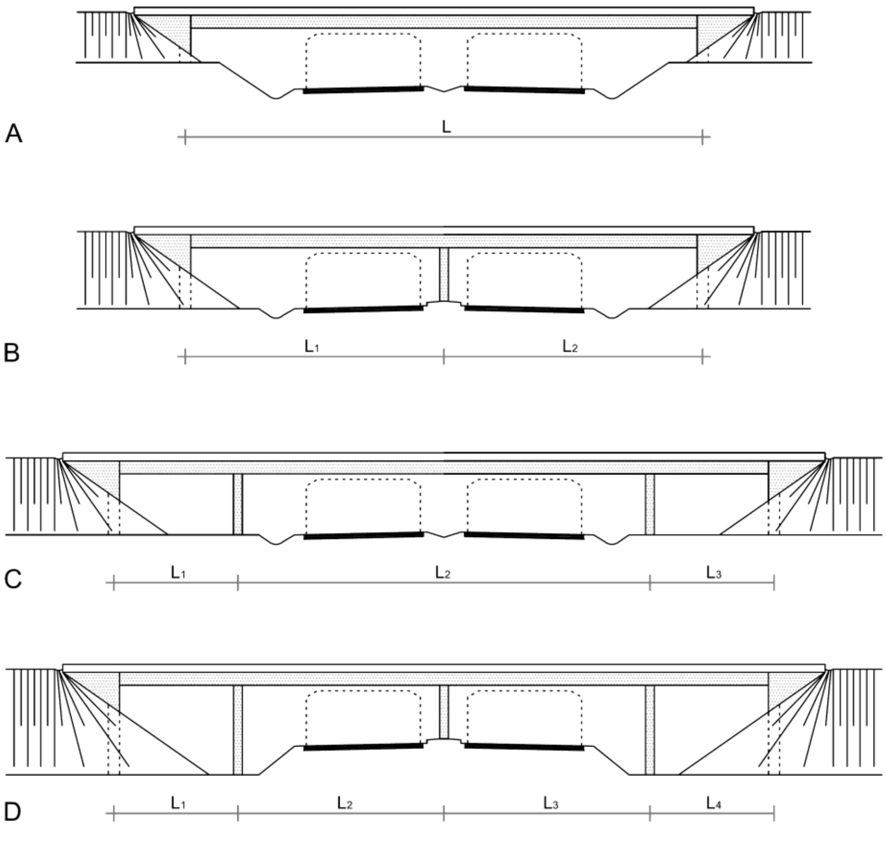

Fig. 2

Overpasses with a single opening are recommended for motorways running in partial cuts, particularly where the central reserve width is less than 3 m. The fill height of the road running on the overpass amounts to 4-5 m. The overpass opening varies between 25 and 45 m. A constant or a variable superstructure height is possible (Fig. 2a and Fig. 3).

Fig. 3

Overpasses with two openings are suitable to motorways running on a flat ground or in a shallow cut, with a central reserve width greater than 3 m. The fill height does not exceed 6 m. The superstructure spans amount to 15 – 25 m. The span length shall be such as to allow continuous running of lateral ditches and to ensure the berm width of at least 1 m below the cone (Fig. 2b and Fig. 4).

Fig. 4

Overpasses consisting of three or of a greater odd number of spans represent a good solution for motorways/expressways on a flat ground, where a pier in the central reserve has to be avoided. The length of spans amounts to 20 – 30 m for the intermediate openings and 14 – 20 m for the end ones. The superstructure height is constant (Fig. 2c and Fig. 5).

Fig. 5

Overpasses consisting of four or of a greater even number of spans are recommended for motorways on a flat ground or in a shallow cut, where the central reserve is wider than 3 m and there is a possibility to increase the motorway width by additional lanes. Overpasses of several spans represent a good solution on motorway running in the vicinity of towns where no high fills are recommended. The spans above the motorway measure 20 – 30 m, while the other spans follow the static conditions and the obstacle characteristics (Fig. 2d and Fig. 6).

Fig. 6

In solutions with a pier located in the central reserve, special attention shall be paid to the selection of the shape and dimensions of the pier cross section, as well as to the protection of the pier against vehicle impacts, to the traffic safety, and drainage.

The aesthetical appearance of an overpass is also affected by the abutment design. A major part of overpass abutments shall be backfilled with grassed cones. The portion of an abutment, which is above the cone in a triangular shape, shall not be longer than 6 m and not higher than 3 m.

4. Arrangement schemes of overpasses in cuts

In motorway running in deeper cuts the solution of an overpass as well as of the road next to it can be simple and economical. Deep cuts limit the field of sight of the motorway users. The overpass structures act as unnatural obstacles, which limit the already restricted view even more.

Beam overpasses with piers located in the central reserve or on the cut verges at motorways would represent a longer disturbance of the sight and a reduced traffic safety; therefore such solutions are not wished-for.

Where an overpass crosses a motorway running in a deep cut, it is recommended to design a single span arch, quasi-arch, or frame structure of a span of 30.0 – 50.0 m (Figs. 7a and 7b).

In overpasses crossing a motorway running in a wide cut with gentle slopes, one span of 50 – 100 m with a slender transparent superstructure and stay cables is convenient (Fig. 7c).

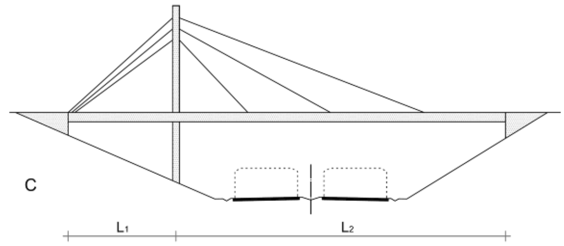

Fig. 7

In Fig. 8 an arch overpass above deep stone cuts is shown. Fig. 9 shows a frame overpass structure in a cut, where in Fig. 10 a steel arch overpass in a cut is presented. All these examples are taken from the Slovenian motorways.

Fig. 8

Fig. 9

Fig. 10

5. Structural solutions of overpasses

Up-to-date structural and static schemes of overpasses are frame integral structures without bearings and expansion joints. Such a solution is limited to the overpass total length of 70 m (80 m). For greater overpass lengths, however, only piers can be monolithically connected with the superstructure, while bearings and expansion joints shall be foreseen at abutments. Such structures are called semi-integral structures. Special attention shall be paid to the overpass structural design, which particularly applies to the piers, in order to enable overpasses to act not only functionally, but also as an important spatial element. It is not necessary to design uniform overpasses on the particular motorway. The majority of overpasses have their own specificities, which shall be taken into consideration. Motorway users probably prefer logical changes and pleasant visual surprises instead of monotonous structures.

Integral overpasses are built monolithically, and the dimensions of the load bearing members are more robust. Such structures are less prone to damages, as the main sources of damages are eliminated: areas of discontinuity, expansion joints, and bearings. The maintenance costs are reduced, and the traffic is safer. Frame structures contain system reserves due to redistribution of loads as well as internal forces and moments. When designing integral structures, it is recommended not to foresee dimensional discontinuities thus avoiding stress concentrations and cracks as well.

A bridge design worked out in compliance with regulations and standards is not a sufficient guarantee for a quality and durable bridge. A correct conception is of extreme importance as well, which, in addition to codes, also takes account of experiences, state-of-the-art construction technologies, and the information obtained from the maintenance service. The interaction structure – foundation soil is an essential component of the deformational behaviour of an integral structure, particularly where the structure is founded on piles. Cooperation between the designing engineer and the expert in soil mechanics is required in specifying realistic soil mechanical data.

In Fig. 11 a scheme of reinforced concrete prestressed integral structures of overpasses with four spans of a total length of up to 80 m is shown, without bearings and expansion joints; such a scheme has been designed on Slovenian motorways. The superstructure ends as well as the abutments founded on bored piles can be solved simply and economically. In Fig. 12 a detail of such a solution is presented.

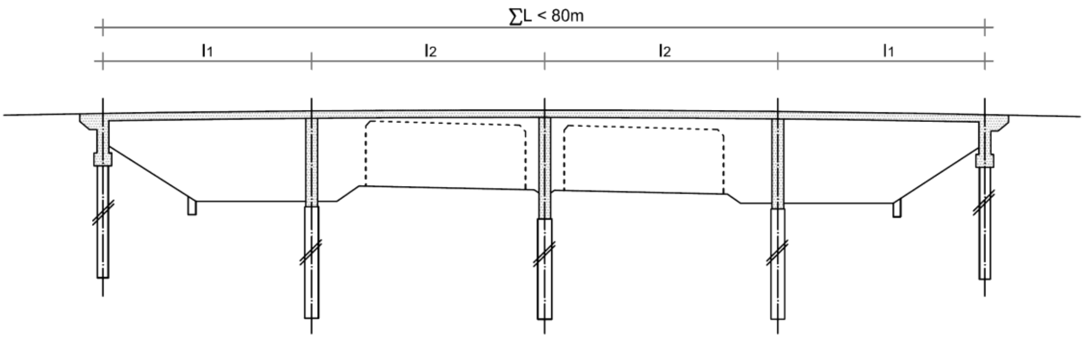

Fig. 11

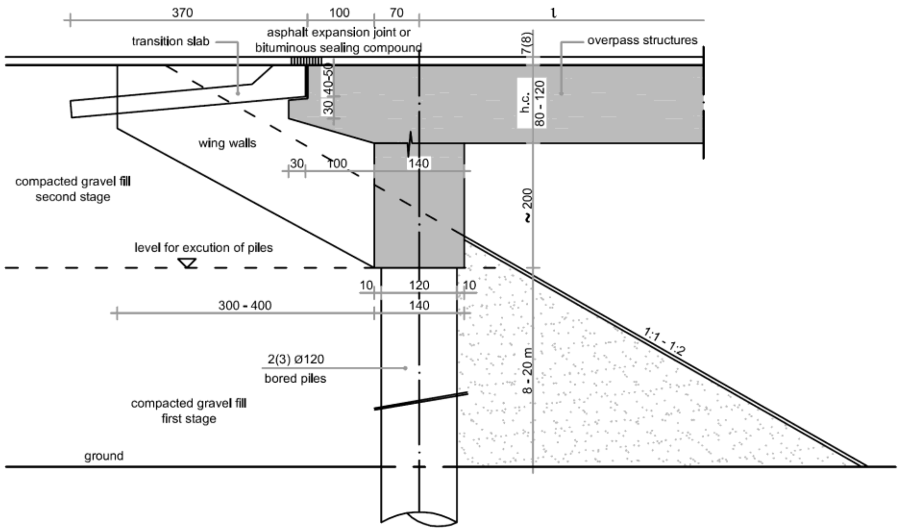

Fig. 12

The superstructure cross sections are slab girders of thickness 0.8 – 1.2 m, with two cantilevers, each measuring 2.0 – 2.5 m in width. The width of the slab girder allows the installation of tendons in one line, and their simple arrangement without any deviations in the horizontal plane.

In Fig. 13, a scheme of an integral frame reinforced concrete prestressed overpass structure crossing a motorway is shown. The motorway runs in a cut. The overpass span amounts to 30 – 40 m. The widened part of the supporting wall in the continuation of the cross beam is structurally indispensable, as it enables a correct arrangement of the reinforcement of frame walls in the corners, without any coincidence with the tendon anchorages. By reducing the wall thickness at the joint with the foundation block, and by a variable thickness of the superstructure, the distribution of internal forces and moments can be substantially affected.

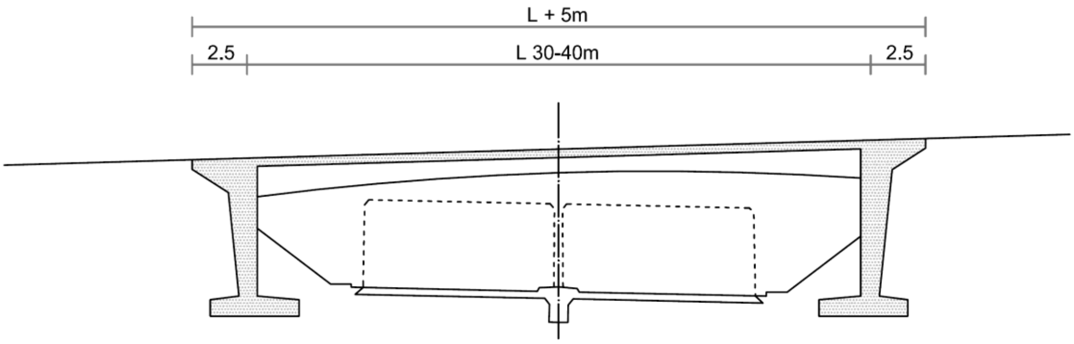

Fig. 13

Arch reinforced concrete overpass structures can also be designed as integral, i.e. without any bearings and expansion joints. In Fig. 14, a structural scheme of an overpass above the motorway running in a stone cut in Slovenia is shown. In addition to a pleasant appearance, the structure is very economical and simple.

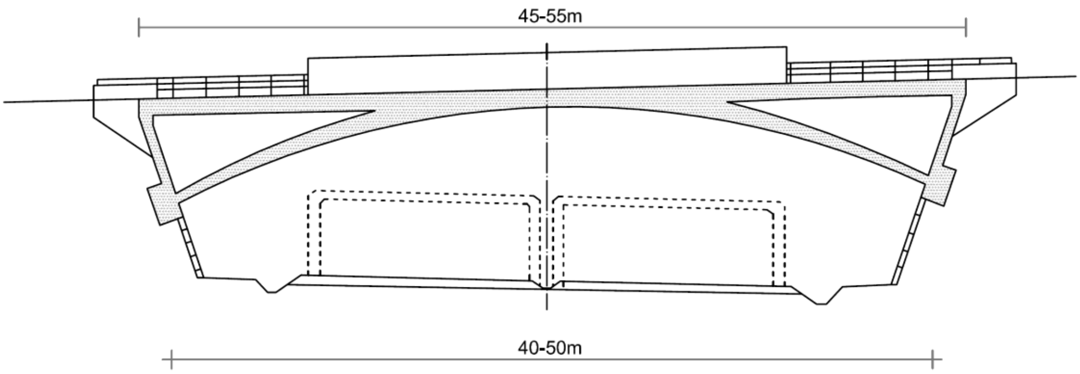

Fig. 14

Conclusions:

- Overpasses are the most frequent structures on the motorways.
- Good bases are the most important for good designing of overpasses.
- The two fundamental geometrical parameters are the crossing angle of the motorway axis to the axis of the road running on the overpass, as well as the solution of the vertical alignment.
- An overpass arrangement scheme is mainly affected by ground morphology and motorway total width.
- Where an overpass crosses a motorway running in a deep cut, it is recommended to design a single span arch, quasi-arch, or frame structure of a span of 30.0 – 50.0 m
- Up-to-date structural and static schemes of overpasses are monolithically frame integral structures without bearings and expansion joints.