USING PRE-CAST CONCRETE IN INNOVATIVE ECOLOGICAL BRIDGES DESIGN AND CONSTRUCTION

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ABSTRACT

The paper is focused on innovative methods of ecological bridges (ecoducts, green bridges): planning and construction. The ecological bridges are planed and constructed to mitigate negative aspects of transport infrastructure like habitat fragmentation and the loss of diversity of biotopes.

Nowadays in the European countries, the decision to build an ecological bridge is based on data from before the start of the motorway construction, while the situation changes rapidly during and after the construction and start of the operation.

Innovative pre-cast structures, which can be built after the start of the operation of the motorway without influencing it, can on one hand mitigate the habitat fragmentation and on the other hand save financial resources by being built only when really necessary and when all the compensation measures were depleted.

Construction systems which satisfy these criteria are presented in this paper together with negative examples of structures which have been built recently but do not serve to their purpose.

Keywords: Accelerated Construction, Creative/Innovative Solutions and Structures

INTRODUCTION

The paper is focused on innovative methods of ecological bridges (ecoducts, green bridges): planning and construction. The ecological bridges are planed and constructed to mitigate negative aspects of transport infrastructure like habitat fragmentation and the loss of diversity of biotopes. The ecological bridges can be regarded as an important instrument for the sustainable development of the transport infrastructure.

The first part of the paper focuses on the effect highly used transport infrastructure on the biotopes, the habitat fragmentation. Further in the text, the compensation measures for mitigating the habitat fragmentation are dealt. The usual approach to ecological bridges design and construction is described with a few examples of structures built which do not serve their purpose mainly due to the reasons of irresponsible planning, narrow surroundings considerations, etc.

In the second part of the paper, the new approach to ecological bridges design and construction is presented. Its aim is to diminish the disadvantages of the usual one. The ecological overbridges should be constructed after all the compensation measures have been depleted on the spots chosen by long-period monitoring during the operation of the motorway. Accordingly, structures for the new approach to ecological bridges design and construction are presented together with the possible construction sequence. The use of pre-cast concrete is preferred because of easy assembly and improved durability in comparison to other possible construction materials.

THE EFFECT OF FENCING THE MOTORWAY NETWORK

The ecological bridges are planned and constructed to mitigate negative aspects of transport infrastructure like habitat fragmentation and the loss of diversity of biotopes. These can be caused by fenced transport infrastructure network which the animals can not cross to satisfy its migration needs.

When the transport network is dense but not fenced, the crossing animals can collide with passing vehicles thus causing severe accidents with fatal consequences on both the animals and users of the infrastructure. So the fencing on one hand increases the safety of the users of the infrastructure, on the other hand can cause habitat fragmentation with all its consequences.

In case of low traffic, the fencing is not needed. The transport infrastructure causes a migration obstacle only while used. Anyway, an accidental hit of an animal still has its fatal consequences but can be avoided by careful driving (not possible in railways).
As for a conclusion to be drawn, fencing the transport infrastructure saves lives of both the transport infrastructure users and the animals. The side effects on the wildlife must be studied and mitigated in an adequate way.

COMPENSATION MEASURES FOR MITIGATING THE HABITAT FRAGMENTATION

The compensation measures for mitigating the habitat fragmentation and preserving the diversity of biotopes vary according to the countryside where the motorway is planned. Three basis possible types of countryside can be distinguished: dissected countryside, semi-dissected countryside and "featureless" countryside. They are described further in the text.

MOTORWAY IN A DISSECTED COUNTRYSIDE

The dissected countryside can be characterized by very often natural obstacles which are crossed by the motorway.

Creeks, rivers, ponds or valleys crossed by the motorway by under bridges (properly fenced and with adequate arrangement under the bridge) can provide more than sufficient migration capacity of the countryside thus not causing habitat fragmentation and the loss of bio-diversity.

The effect of fencing the motorway in a dissected countryside has beneficiary effects on the safety of both animals and users of the motorway.
To ensure that the animals will use the under bridges for migration, proper measures must be undertaken at design and realization, like:

- generosity in span arrangement
  - bigger voids at water flows, which often form migration routes for animals (= one-span integral bridge instead of one pipe 1m in diameter)
  - avoiding high embankments, replacement by elevated highway
- generosity in the formation line arrangement
  - avoiding long cuts
  - avoiding long embankments
- earthworks to lead the wildlife to the migration objects
- special considerations at underbridges which are crossing both natural and artificial obstacle, like roads or railways:
  - generosity in span arrangement for avoiding the "tunnel effect"
  - noise barriers
  - dazzling barriers
  - earthworks for dividing the migrating wildlife from the passing traffic
  - combinations of the previous measures
- special surface arrangement of the underbridges which are to satisfy the migration needs
  - avoiding concrete or stone pavements, gravel spreading or other arrangements under the bridges which cause noise while passing
  - providing adequate moisture and sunlight conditions under the bridges not to form an island of a different (or even none) plant life which prevents animals from passing

In general, no special migration objects need to be constructed in a dissected countryside to ensure its natural permeability for wildlife when the under bridges are built according to the principles listed higher in this chapter.

MOTORWAY IN A SEMI-DISSECTED COUNTRYSIDE

The semi-dissected countryside can be characterized by average density of natural obstacles which are crossed by the motorway.

Creeks, rivers, ponds or valleys crossed by the motorway by under bridges (properly fenced and with adequate arrangement under the bridge) can provide satisfactory migration capacity of the countryside thus not causing habitat fragmentation and the loss of bio-diversity. The smaller number of migration objects in a semi-dissected countryside must be arranged according to the principles listed earlier in the text and the wildlife must be guided to these rare objects. The possibilities how to guide the wildlife to the migration object will be explained further.

In general, still no special migration objects need to be constructed in a semi-dissected countryside to ensure its natural permeability for wildlife when the under bridges are built according to the principles listed higher in the previous chapter and the wildlife is guided to these objects.

MOTORWAY IN A “FEATURELESS” COUNTRYSIDE

The “featureless” countryside can be characterized by a very low density of natural obstacles which are crossed by the motorway.

Bad formation line arrangement can make the countryside less permeable for wildlife. Flatland crossed by motorway in small cuts or embankments (less than 2m), long cuts in forests, etc. all these cases prevent the wildlife from passing.

In general, migration objects can be constructed in a “featureless” countryside to ensure its natural permeability for wildlife. But do they really need to be constructed? What if there is a much easier, cheaper and more effective way to preserve the diversity of biotopes? These questions will be answered in the following paragraphs.

NEEDS OF THE WILDLIFE FOR MIGRATION

The wildlife does not migrate just for the joy of motion. It must have specific reasons to run into the way of a truck. Here are some of the possible reasons for the wildlife to migrate:

- need for food
- need for reproduction
- changes in the original habitat caused by
  - human presence
  - construction works
  - changes of the water regime of the habitat

- others

Most of these reasons can be identified by detailed observations and removed in an appropriate manner.

COMPENSATION MEASURES FOR HABITAT FRAGMENTATION OTHER THAN ECOLOGICAL BRIDGES CONSTRUCTION

Forests in the central Europe are (with some rare exceptions) part of the cultural countryside maintained by agriculture, forestry and gamekeeping. The role of human is unavoidable. Some of the compensation measures for habitat fragmentation other than ecological bridges construction are following:

- changing the places for feeding the animals so that they do not need to migrate across transport infrastructure
- providing guided routes to the migration objects, so that the animals get used to using them
- in case of risk of losing the bio-diversity bringing in new pieces for enriching the gene pool of the present population

The costs of these compensation measures within the horizon of the service life of a structure do not even near the cost of a new ecological bridge[1].

As a summary, the ecological bridges should be constructed after all the compensation measures have been depleted.

THE USUAL APPROACH TO ECOLOGICAL BRIDGES DESIGN AND CONSTRUCTION

In the most common approach the construction sites for ecological overbridges are chosen from ecological maps or, in a better way, from long-time observations in the nature. The problem of this approach is that the situation changes rapidly during and after the construction and start of the operation of the motorway.

The motorway construction represents a huge intervention into the balance of the countryside. Old wildlife migration routes are disrupted, new arise and vanish, all according to the construction process.

The other point is that during the motorway construction, the animals get used to visiting the site at night to collect scraps. After the motorway is put into operation, the animals still want to use the easy way to get food.

As already told, the disadvantage of the usual approach to ecological bridges construction is that the construction sites are chosen according to the data before the motorway construction.

In the end, due to the changes of the environment during and after the construction, many structures are useless though the effort laid in their design and construction.

The usual approach to ecological bridges design and construction is summarized in the following flowchart, see Fig. 1.

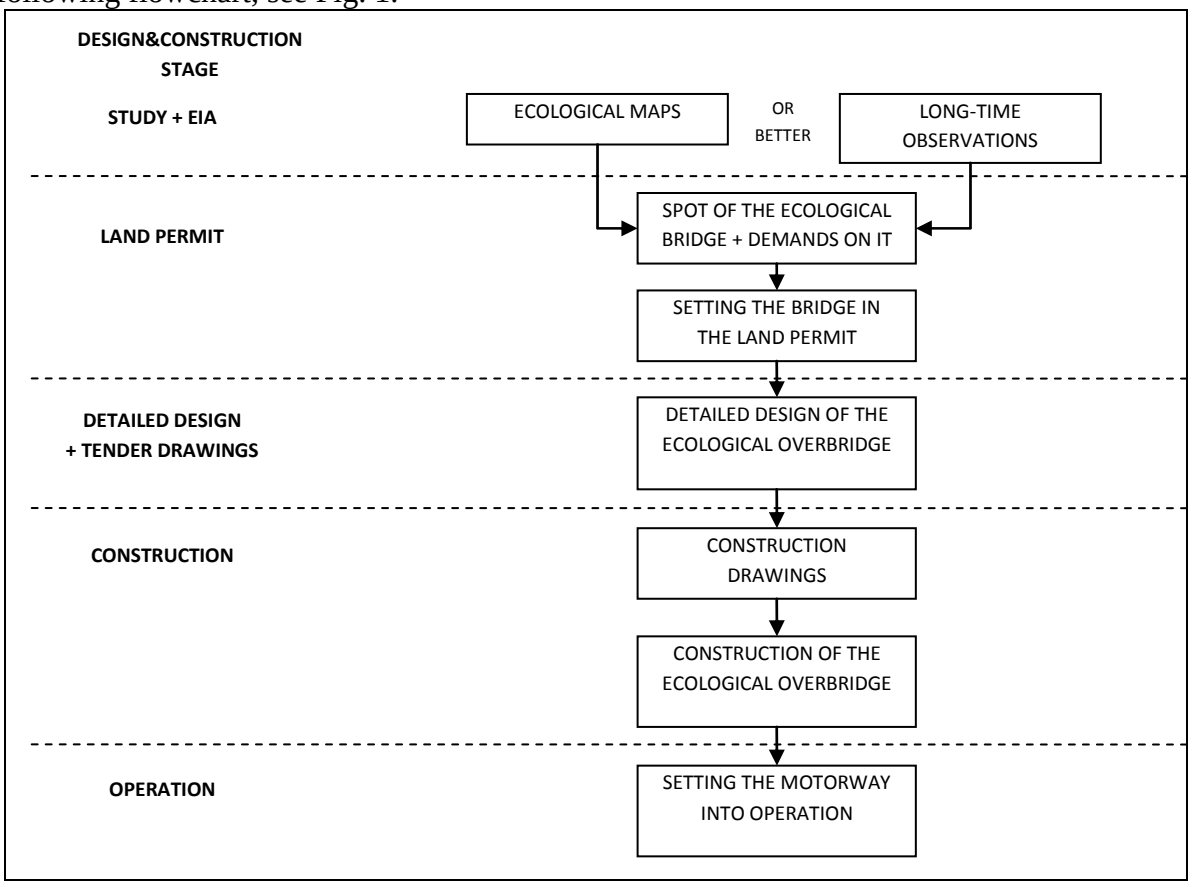

Fig. 1 The usual approach to ecological bridges design and construction

EXAMPLES OF ECOLOGICAL BRIDGES BUILT ACCORDING TO THE USUAL APPROACH TO ECOLOGICAL BRIDGES DESIGN AND CONSTRUCTION

This chapter presents examples and brief descriptions of ecological bridges which have been built recently, but do not serve their purpose mainly due to the reasons of irresponsible planning, narrow surroundings considerations, etc.

THE ECOLOGICAL BRIDGE AT DRHOVLE, CZECH REPUBLIC

This ecological bridge was built near Drhovle in southern Bohemia. The good purpose to connect two forests is completely devaluated by insensible earthworks, see Fig. 8-9.

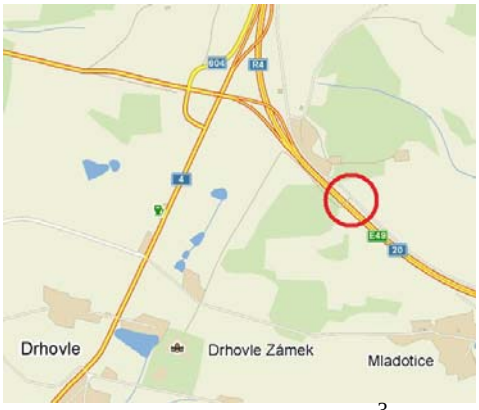

Fig. 2 The location of the ecological bridge near Drhovle[3]

Fig. 3 Insensible earthworks at the ecological bridge near Drhovle

THE ECOLOGICAL BRIDGE AT VELKY UJEZD, CZECH REPUBLIC

The ecological bridge at Velky Ujezd in central Moravia represents a clear example of insufficient wider considerations at ecological bridges planning and construction.

Fig. 4 Insufficient wider considerations at the ecological bridge near Velky Ujezd[3]

Fig. 5 The ecological bridge near Velky Ujezd

THE NEW APPROACH TO ECOLOGICAL BRIDGES DESIGN AND CONSTRUCTION

The new presented approach to ecological bridges design and construction tries to diminish the disadvantages of the usual one.

The ecological overbridges should be constructed after all the compensation measures have been depleted on the spots chosen by long-period monitoring.

The underbridges which also contribute to the permeability of the countryside for the wildlife should be planed and constructed according to principles listen in the previous sections.

The decision whether to build or not to build an ecological overbridge must be based on long-time monitoring. That is supposed to start at the time when the alternative alignments of the motorway are studied. When the documentation reaches stage of the land permit, detailed spots of placement should be monitored in detail. This is the spot, where the decision making process reaches it's most important bifurcation where three possible cases can be distinguished:

CASE 1

Where the migration need is obvious and indubitable (p. e. the only connection of two biotopes with a verifiable migration need) and no appropriate compensation measures can be undertaken, the bridge is set into detailed design as usual and constructed together with the rest of the motorway. The detailed monitoring continues throughout the construction to the first years of operation.

This case is very extraordinary, yet it can happen and should be dealt accordingly.

CASE 2

Where the migration need is obvious for the specific countryside (dense network of wildlife paths) but there is a doubt whether it will be still present after the accomplishment of the motorway, foundations for the future construction of an ecological bridge should be laid.

These make possible to build the ecological overbridge after the motorway is already in operation without interrupting it for a long period of time in the case that the compensation measures have failed.

The foundations should be standardized together with possible arrangement of the superstructure. The structural arrangement of these overbridges is dealt thoroughly in the next section.

CASE 3

Where the migration need is usual for the specific countryside (normal density network of wildlife paths) and there is a severe doubt that the migration need will be present after the accomplishment of the motorway, only compensation measures should be prepared and monitored throughout the construction and operation of the motorway.

When the compensation measures are successful, there will be no need to build an ecological overbridge and financial resources will be saved for more needed constructions.

In the case when the compensation measures are not successful and the migration need is still present and recognized by the on-site monitoring, an ecological overbridge should be built during the operation of the motorway with the use of standardized structures. These structures are dealt thoroughly in the next section.

The new approach to ecological bridges design and construction is summarized in the following flowchart, see Fig. 2.

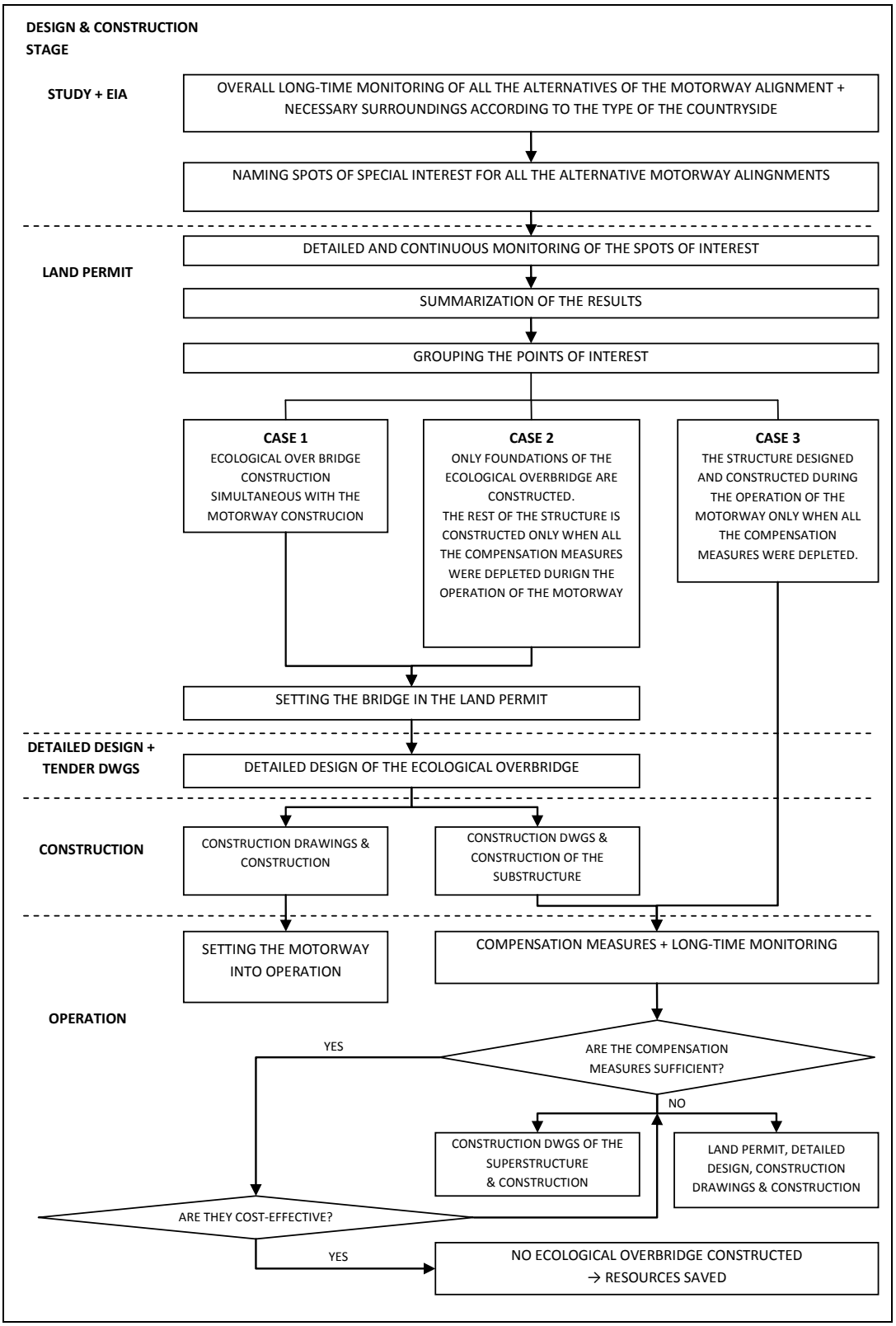

Fig. 6 The new approach to ecological bridges design and construction

STRUCTURES FOR THE NEW APPROACH TO ECOLOGICAL BRIDGES DESIGN AND CONSTRUCTION

As stated in the previous section, the ecological overbridges should be constructed after all the compensation measures have been depleted on the spots chosen by long-period monitoring.

Possible scenarios of construction sequence and structural arrangement are described for the cases named in the previous section. As from divisions in the previous section and on Fig. 2, only the Cases 2 and 3 are dealt in this section.

The Case 1, as a usual construction process simultaneous to the motorway construction, is not dealt in this section.

DEMANDS ON THE STRUCTURES FOR THE NEW APPROACH TO ECOLOGICAL BRIDGES DESIGN AND CONSTRUCTION

The key property of the structures designed and constructed according to the new approach to ecological bridges design and construction is that they are to be constructed during the operation of the motorway. Short time closures of one carriage way are acceptable but the traffic cannot be interrupted as a whole for more hours.

The structures have to be lightweight and easy to assemble – the use of pre-cast concrete and composite structures is quite logical.

These demands lead to two possible structural arrangements: a hinged arch, and a lightweight integral frame structure. The hinged arch is able to cross both the carriageways of the motorway, while the integral frame structure has to have a support in the central reserve (the median).

HINGED ARCH STRUCTURES

The arch is the most natural structural shape. Proper designed shape of the centre line reduces the bending moments and saves the construction height. The horizontal force from the superstructure has to be properly anchored – by foundation blocks in the case of good soil conditions, or by piles in the case of bad soil conditions.

For an example of a hinged arch ecological overbridge in good soil conditions, see Fig. 3, for a hinged arch ecological overbridge in bad soil conditions, see Fig. 4.

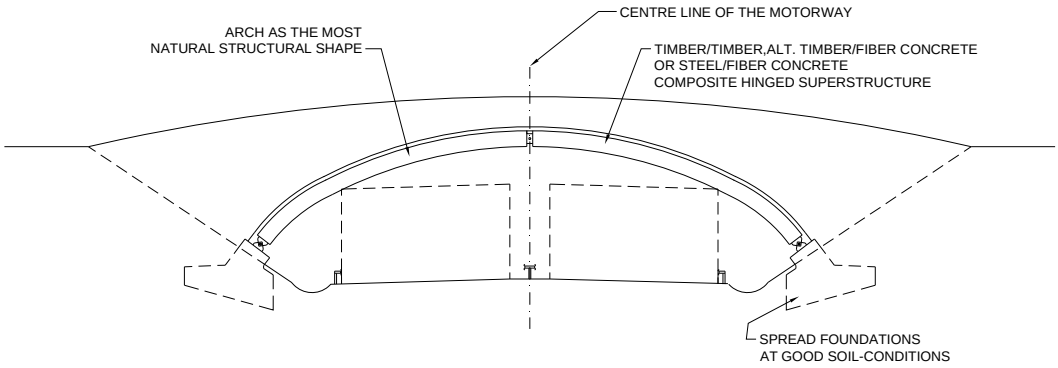

Fig. 7 Hinged arch ecological overbridge in good soil conditions

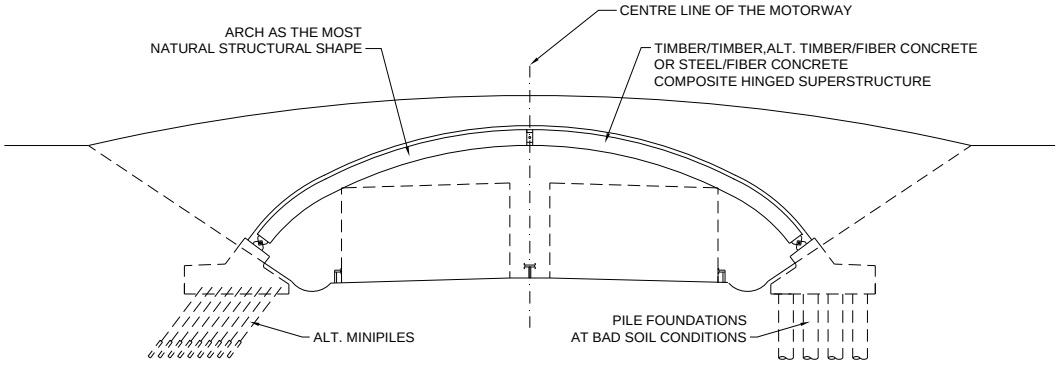

Fig. 8 Hinged arch ecological overbridge in bad soil conditions

The main girders can be made of timber[2] or steel. Concrete is not suitable because of its big weight. The composite deck can be made of timber or fiber concrete slabs and is covered by insulation and soil backfill.

The superstructure of a hinged arch ecological overbridge can be assembled in following steps:

- erection of lightweight temporary supports in the median, no permanent formwork has to be assembled
- assembly of the main girders by two cranes, one in each carriageway, first in the bottom hinges, then in the top hinge, short-time traffic closure in both directions (the structural hinges simplify the construction)
- bracing the adjacent main girders by timber or steel bracing according to the material of the superstructure, short-time traffic closure in both directions
- technological break for dismantling the two cranes, then setting the traffic free temporarily for diminishing the congestion

- assembly of the composite deck over the closed carriageway, traffic in the other carriage way is limited on speed and lanes width
- assembly of the composite deck over the other carriageway, traffic in the other carriage way is limited on speed and lanes width
- insulating the composite deck, traffic in both carriageways, only speed limitations
- simultaneous backfilling the superstructure, the traffic is limited to one lane on both carriageways
- finishing works on the bridge, speed and lane widths limitations on both carriageways

In the CASE 2 as defined in the previous section, only the foundations of the ecological overbridge are laid with the motorway construction. These have to maintain their mechanical and structural properties for a long period of time with less maintenance possible. Emphasis must be put on the details of the structural hinge, selection of materials, whether to anchor the hinge with the construction of the substructure or anchoring it only when needed with the construction of the superstructure, proper coating of the decisive structural details etc.

An example of a CASE 2 site ready for the construction of a hinged arch ecological overbridge can be seen in Fig. 5.

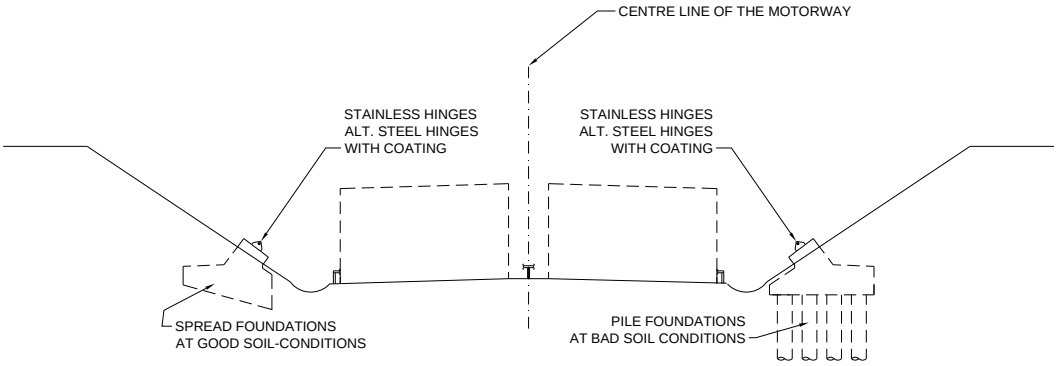

Fig. 9 CASE 2-site ready for construction of a hinged arch ecological overbridge

INTEGRAL FRAME STRUCTURES

The integral frame is a common structural type thus widely used and favored by the contractors. Proper designed pre-cast pre-stressed concrete girders or steel girders are easy to manufacture, assemble and to maintain. There is no risk of biological attack unlike by timber structures. No lateral force is transmitted to the soil thus the dimensions of the substructure can be reduced.

For an example of an integral frame ecological overbridge in both good and bad soil conditions, see Fig. 6.

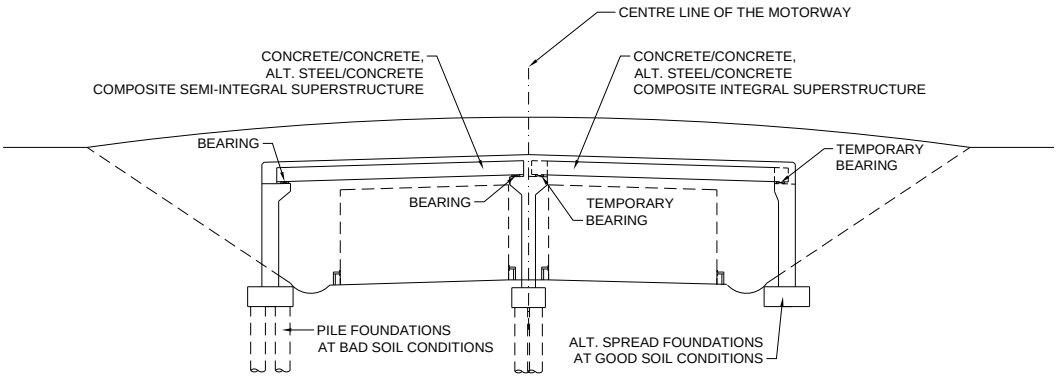

Fig. 10 Example of an integral frame ecological overbridge in both good and bad soil conditions

The main girders can be made of pre-cast pre-stressed concrete or steel. The use of pre-cast concrete is preferred because of easy assembly and improved durability in comparison to other possible construction materials. The concrete composite deck is covered by insulation and soil backfill. The main girders carry lost formwork thus no permanent formwork for the deck is needed.

The superstructure can be semi-integral or fully integral. In the case of the semi-integral bridge, the superstructure has permanent bracings and suspended backwalls; in the case of the fully integral bridge, the superstructure has only temporary bearings and integrated frame corners.

The superstructure of an integral frame ecological overbridge can be assembled in following steps:

- casting the abutments and the middle pier, the traffic is limited to one lane on both carriageways
- assembly of the main girders by one crane over one carriageway, temporary bracing of the main girders, short-time traffic closure in one direction, speed and lane width limitations in the other direction
- assembly of the main girders by one crane over the other carriageway, temporary bracing of the main girders, short-time traffic closure in one direction, speed and lane width limitations in the other direction
- assembly of the lost formwork of the deck over one carriageway, short-time traffic closure in one direction, speed and lane width limitations in the other direction
- assembly of the lost formwork of the deck over the other carriageway, short-time traffic closure in one direction, speed and lane width limitations in the other direction
- casting the composite deck, speed and lane width limitations in the both direction
- insulating the composite deck, traffic in both carriageways, only speed limitations
- simultaneous backfilling the superstructure, the traffic is limited on speed and lane width on both carriageways

- finishing works on the bridge, speed and lane widths limitations on both carriageways

In the CASE 2 as defined in the previous section, only the foundations of the ecological overbridge are laid with the motorway construction. These have to maintain their mechanical and structural properties for a long period of time with less maintenance possible. Emphasis must be put on selection of the materials, whether to make the starter bars of the abutments and middle pier of stainless steel (coated steel) or to glue the starter bars into newly made boreholes when needed with the construction of the superstructure, etc.

An example of a CASE 2 site ready for the construction of an integral frame ecological overbridge can be seen in Fig. 7.

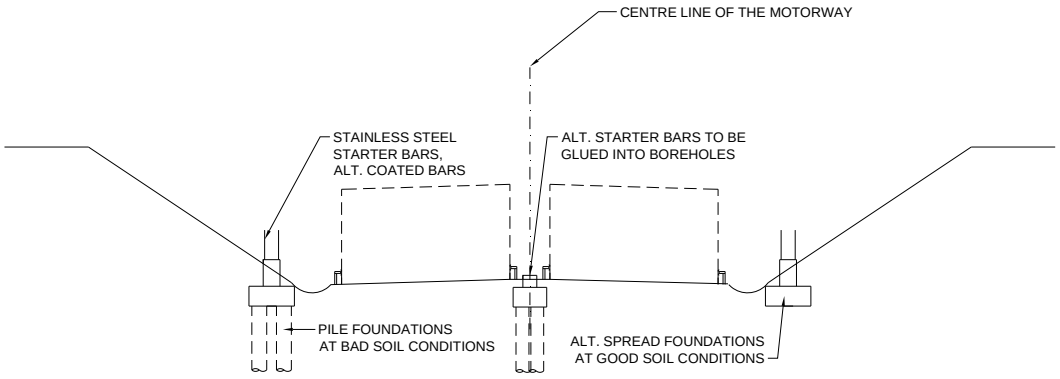

Fig. 11 CASE 2-site ready for construction of an integral frame ecological overbridge

CONCLUSIONS

The paper was focused on innovative methods of ecological bridges (ecoducts, green bridges) design and construction.

The new approach to ecological bridges design and construction was presented. Its aim is to diminish the disadvantages of the usual one by building ecological overbridges after the motorway is set into operation only when all the compensation measures were depleted on the spots chosen by long-period monitoring thus presenting a valuable contribution to sustainable development of the transport infrastructure.

Innovative pre-cast structures, which can be built after the start of the operation of the motorway without influencing it, can mitigate the negative impacts of transport infrastructure and save financial resources. Construction systems which satisfy the criteria of the new approach to ecological bridges design and construction were presented in this paper with special emphasis to the use of pre-cast concrete which is preferred because of easy assembly and improved durability in comparison to other possible construction materials.

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