THE USE OF FIBRE CONCRETE IN STRUCTURES FOR THE INNOVATIVE ECOLOGICAL BRIDGES DESIGN AND CONSTRUCTION

Marek Foglar[1], Vladimír Křístek[2], Jan Pěnčík[3]

Abstract:

This paper presents pre-cast construction systems which satisfy the criteria of the innovative method of design and construction of ecological bridges (i.e. ecoducts or green bridges) (presented in a referenced article) and can be built after the start of the operation of the motorway without influencing it. For these structures, the use of fibre concrete can present a significant reduction of construction time and costs and is presented in this paper.

Keywords: Ecological Bridges, Fibre Boncrete, Accelerated Construction, Creative/Innovative Solutions and Structures

1 Introduction

The ecological bridges are planed and constructed to mitigate negative aspects of transport infrastructure like habitat fragmentation and the loss of diversity of biotopes. This paper presents pre-cast construction systems which satisfy the criteria of the innovative method of design and construction of ecological bridges (presented in [1]).

Innovative pre-cast structures, 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 on the spots chosen by long-period monitoring, dealt in detail in [1] and [2].

For these structures, the use of fibre concrete can present a significant reduction of construction time and costs. Examples of such structures and the use of fibre concrete within is presented below.

2 Structures for the innovative ecological bridges design and construction. The use of fibre concrete

[1] Ing. Marek Foglar, Ph.D., OSVVP ČSSI Komornická 15, 160 00 Praha 6 a ČVUT, Fakulta stavební, Thákurova 7, 166 29 Praha 6, marek.foglar@fsv.cvut.cz

[2] Prof. Ing. Vladimír Křístek, DrSc., OSVVP ČSSI Komornická 15, 160 00 Praha 6 a ČVUT, Fakulta stavební, Thákurova 7, 166 29 Praha 6, kristek@fsv.cvut.cz

[3] Ing. Jan Pěnčík, Ph.D., OSVVP ČSSI Komornická 15, 160 00 Praha 6 a VUT v Brně, Fakulta stavební, Veveří 331/95, 602 00 Brno, pencik.j@fce.vutbr.cz

Possible scenarios of desing&construction sequence are described in [1]. As from divisions in that article, only the Cases 2 and 3 (the ecological overbridge is constructed after the motorway is set into operation) are dealt in this section. The Case 1, as a usual construction process simultaneous to the motorway construction, is not dealt in this section.

Short time closures of one carriage way are acceptable but the traffic cannot be interrupted as a whole for more hours. The demands on the structures designed and constructed according to the new approach to ecological bridges design and construction are following:

- The overbridges are to be constructed during the operation of the motorway.
- The structures have to be lightweight and easy to assemble – the use of pre-cast concrete, fibre 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).

The possible structural arrangements are dealt briefly in the following sections. For detailed description of the structural arrangement and construction system, see [2].

2.1 Hinged arch

The arch is the most natural structural shape. Hinged arch with three hinges can be assembled easily and only in a short traffic closure.

Proper designed shape of the arch 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.

The main girders can be made of timber 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.

For an example of a hinged arch ecological overbridge in good soil conditions, see Fig. 1.

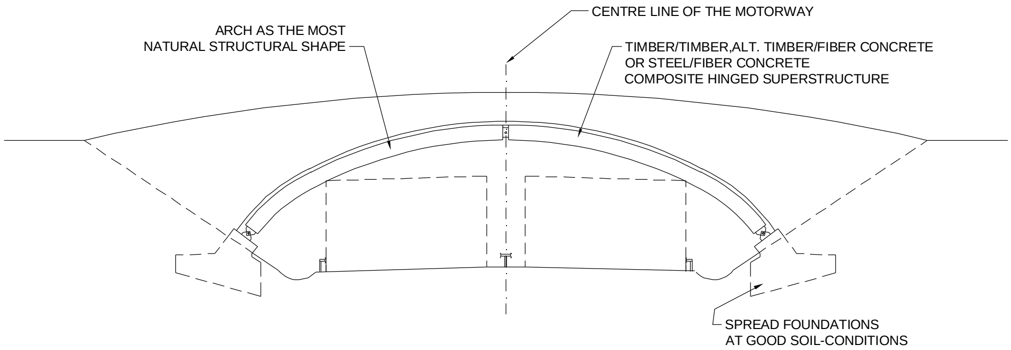

Fig. 1 Hinged arch ecological overbridge in good soil conditions

Fibre concrete can be used as sheeting over the timber or steel main girders. Pre-cast deck elements of fibre concrete can be made in precisely defined shapes. The improved resistance in tension can enable to place the main girders in bigger distances thus saving the construction costs. The insulation layers are put on the sheeting.

2.2 Integral frame

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.

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 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.

For an example of an integral frame ecological overbridge in both good and bad soil conditions, see Fig. 2.

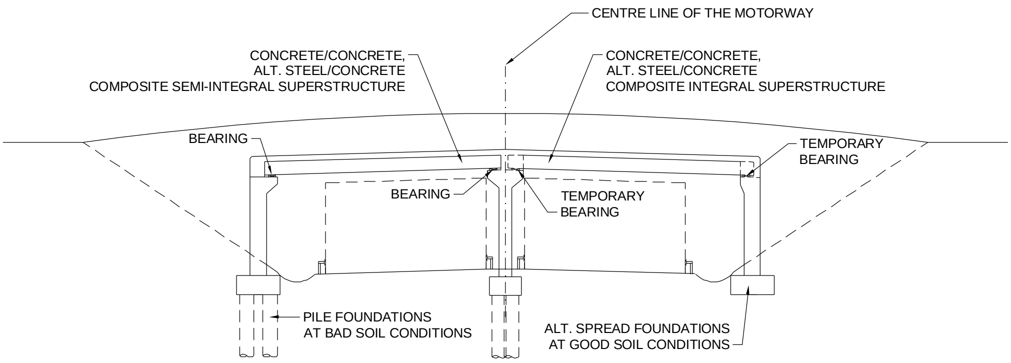

Fig. 2 Example of an integral frame ecological overbridge in both good and bad soil conditions. Semi-integral and fully integral alternative displayed.

Fibre concrete can be used in the pre-cast pre-stressed concrete main girders. Its improved tensile characteristics reduce the amount of reinforcement in anchorage areas (in case of the combined pre- and post-tensioning, the crucial detail of the girder) thus simplifying the casting and improving the quality of the whole structural element.

Fibre concrete can be also used with a big advantage in the lost formwork of the composite concrete deck between the main girders. The improved resistance in tension can enable to place the main girders in bigger distances thus saving the construction costs.

3 Optimizing the shape of the centre line of concrete arches

Optimizing the shape of the centre line of concrete arches is the way to reduction of the bending moments, saving reinforcement or reducing the construction height.

Precisely designed arch can be made of plain or just slightly reinforced concrete because simply no or negligible bending moments occur at the construction during its operation. Bending moments occurring during the construction of the backfill of a concrete arch ecological overbridge, Case 1 of [1] – usual construction process simultaneous to the motorway construction, can cause cracks in a plain or slightly reinforced concrete section. These can be resisted by using fibre concrete instead.

Usual concrete arches used for ecological overbridges have their centre line in a form of a 2nd grade parabola which passes tangentially into circle arches in direction of the footings. The change of the structural shape is motivated by the need to get the biggest possible headway near the footings. The parabola can be described by the following equation, see Eq. 1:

$$z = \frac{x^2}{\left(\frac{l_0^2}{h_0}\right)}$$

Eq. 1 Equation of the 2nd grade parabola – usual centre line of concrete arches used for ecological overbridges. For the definition of used symbols, see Fig. 3.

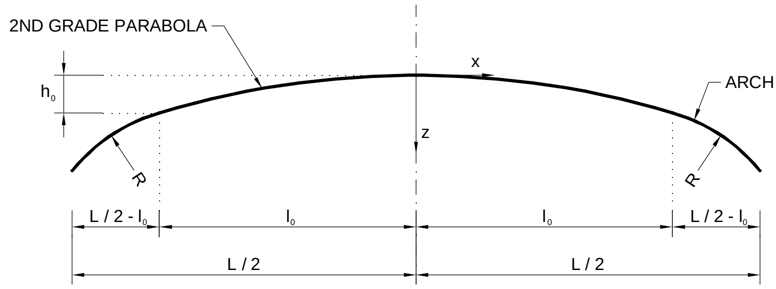

Fig. 3 2nd grade parabola combined with circle arches as a centre line of concrete ecological footbridge

The second possible arrangement of a centre line of an ecological overbridge comes from the theoretical derivation for an arch with backfill exposed only to axial force.

The centre line can be described mathematically in a form of a function:

$$y = f(x) \qquad \textbf{Eq. 2}$$

The horizontal force is introduced as *H*. Assuming that the load is proportional to the height of the backfill; the problem leads to a differential equation:

$$H \cdot y'' = g \cdot y \qquad \textbf{Eq. 3}$$

The general solution to Eq.3, assuming $\alpha^2 = g / H$ is sought for in the following form:

$$y = C_1 \cdot \sinh(ax) + C_2 \cdot \cosh(ax) \qquad \textbf{Eq. 4}$$

Considering the marginal conditions from Fig. 4, the centre line is described by following equation:

$$y = y_0 \cdot cosh(ax) \qquad \textbf{Eq. 5}$$

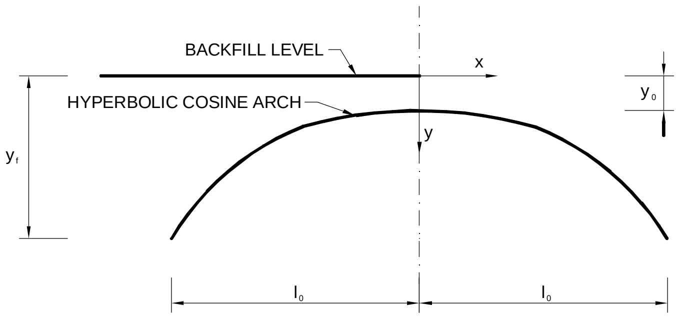

Fig. 4 Hyperbolic cosine arch as a centre line of concrete ecological footbridge. Definition of symbols for Eq. 2-5.

For comparison of bending moments on a real ecological overbridge with parabolic and hyperbolic cosine centre line, see [4].

4 Conclusions

This paper presented the use of fibre concrete in structures for the innovative ecological bridges design and construction, i.e. pre-cast construction systems which satisfy the criteria of the innovative method of design and construction of ecological bridges (presented in [1]).

Aknowledgements

This paper was supported by the Czech Science Foundation, project No. 103/09/2071, No. 103/08/1278 and 103/08/1677 and Czech Ministry of Education project MSM 6840770005.

References

[1] Foglar, M., Bocek, R.: *Innovative Method of Design and Construction of Ecological Bridges*, Sborník příspěvků vědecké konference Ekodukty – Umožnění migrací nebo plýtvání penězi z veřejných prostředků?, Brno, 2009, pp. 1-7.

[2] Foglar, M., Křístek, V., Pěnčík, J.: *Structures for the Innovative Ecological Bridges Design and Construction*, Sborník příspěvků vědecké konference Ekodukty – Umožnění migrací nebo plýtvání penězi z veřejných prostředků?, Brno, 2009, pp. 9-13.

[3] Křístek, V., Foglar, M.: *Modelling the Structural Behavior of Ecological Bridges* (in Czech), Sborník příspěvků vědecké konference Ekodukty – Umožnění migrací nebo plýtvání penězi z veřejných prostředků?, Brno, 2009, pp. 15-22.

[4] Křístek, V., Vráblík, L., Hanuš, F.: *Dálnice D 11 PRAHA - HRADEC KRÁLOVÉ - Návrh oblouků na polních cestách přes D1105-1*, Betonářské dny 2004, Praha ČBS ČSSI, pp. 477-482.

[5] Pěnčík, J.: *Ecoducts on Slovak Motorway D1 near Poprad* (in Czech), Sborník příspěvků vědecké konference Ekodukty – Umožnění migrací nebo plýtvání penězi z veřejných prostředků?, Brno, 2009, pp. 35-42.

[6] Pěnčík, J., Míča, L., Foglar, M.: *Modelling of Surface and Deap Pile Foundations of Ecoducts Using FEM System ANSYS* (in Czech), Sborník příspěvků vědecké konference Ekodukty – Umožnění migrací nebo plýtvání penězi z veřejných prostředků?, Brno, 2009, pp. 43-51.

[7] Foglar, M., Křístek, V.: *Economical Aspects of Ecological Bridges Construction* (in Czech), Silnicni obzor, Vol. 5, May 2006, pp. 140-144.

[8] Foglar, M., Křístek, V.: *Ecological Bridge at Wilhmhagen – an Innovative Timber Structure* (in Czech), *Silnice a zeleznice*, Vol. 2, April-May 2006, pp. 27-28.