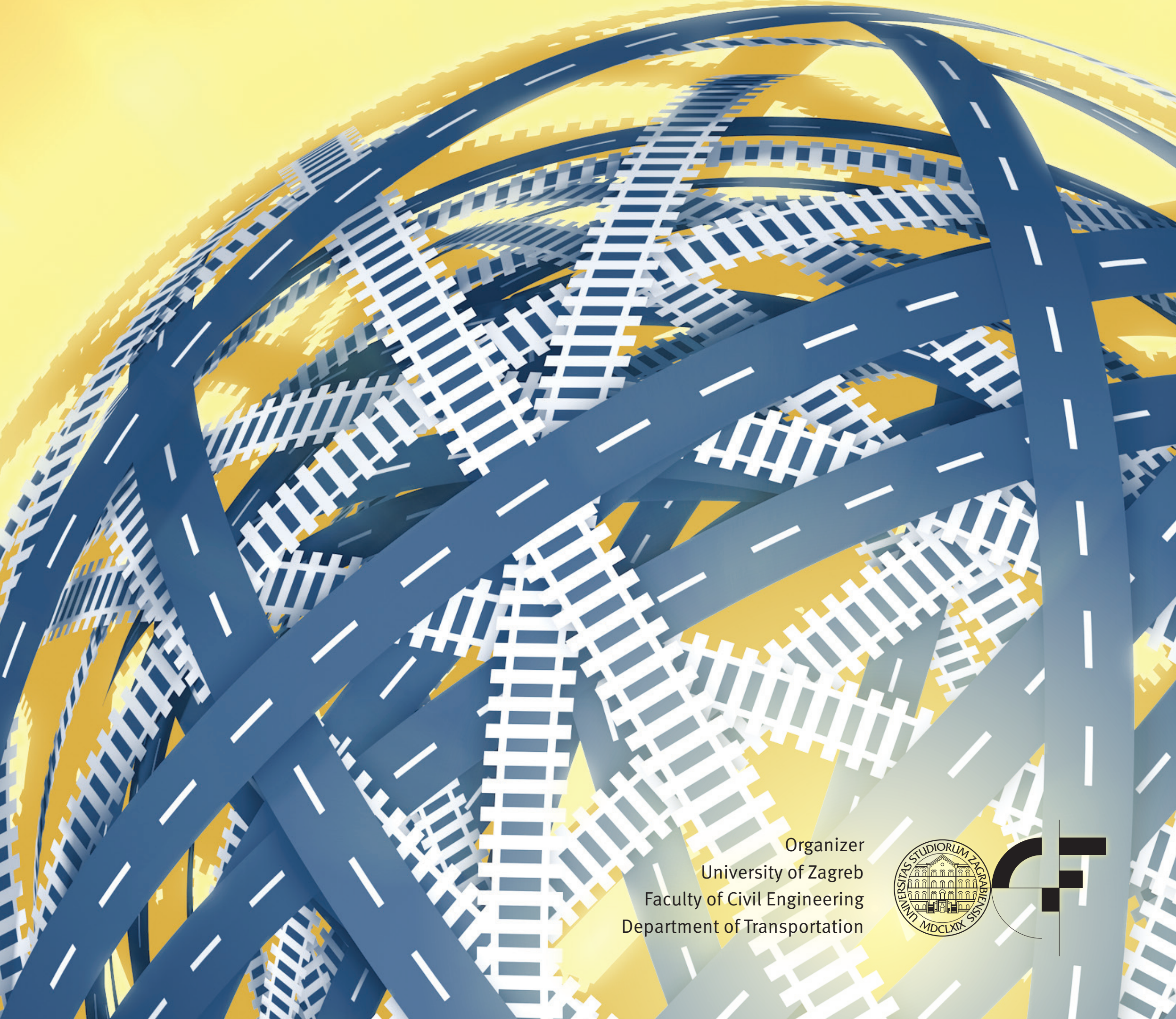
CETRA[2016]

4[th] International Conference on Road and Rail Infrastructure
23–25 May 2016, Šibenik, Croatia

Road and Rail Infrastructure IV

Stjepan Lakušić – EDITOR



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EDITOR
Stjepan Lakušić
Department of Transportation
Faculty of Civil Engineering
University of Zagreb
Zagreb, Croatia

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USE OF SPIRAL STEEL PIPES DURING CONSTRUCTION OF SOUTHERN BYPASS FOR DONJI MIHOLJAC

Hrvoje Pandžić[1], Adam Czerepak[2], Mario Bogdan[3]
[1] *Agenor d.o.o., Osijek, Croatia*
[2] *ViaConSp. z o.o., Rydzyna, Poland*
[3] *Protekta d.o.o., Đakovo, Croatia*

Abstract

The technology of construction and rehabilitation of culverts using spiral steel pipes has been only sporadically applied in our region, and is often referred to as a “new” technology, although it dates back to the second half of the 19th century. According to design work based on long-standing experience gained on the worldwide and European scale, and based on fifteen years of experience acquired in Croatia, this technology was applied in the design documents by the designers and in construction work by the contractor in the scope of the project involving construction of the southern bypass for the town of Donji Miholjac – Phase II. This paper describes experience gained and procedures applied during working design of spiral steel pipes, and during assembly and construction of these pipes. Advantages in their use as compared to “old” conventional culvert construction methods are also presented.

Keywords: spiral steel pipes, culverts, construction technology, design, experience, advantages

1 Introduction

This professional paper describes the culvert and passage building technology involving the use of HelCor and Multi Plate spiral steel pipes during the second phase of the southern bypass construction for the town of Donji Miholjac.
The town of Donji Miholjac lies in the north-eastern part of the Republic of Croatia along the Drava River at the border with the Republic of Hungary. A total of 10,265 residents live in the town of Donji Miholjac, which is made of seven local communities. The zone in which the town of Donji Miholjac is situated is mostly characterized by a low-lying area (95-97 m a.s.l.), by the Drava River and its tributaries, and by several lakes along the northern border with the Republic of Hungary, and the Karašic River in the southern and south-western part of the municipality [1].
The section under study is 3,544.87 m in length. The route begins at the existing national road D34, to the west of the entrance to the town of Donji Miholjac, and ends at the new roundabout situated at the national road D53. The roundabout is also the starting point of the route of the previously built first phase of the southern bypass of the town of Donji Miholjac [1], Figure 1.

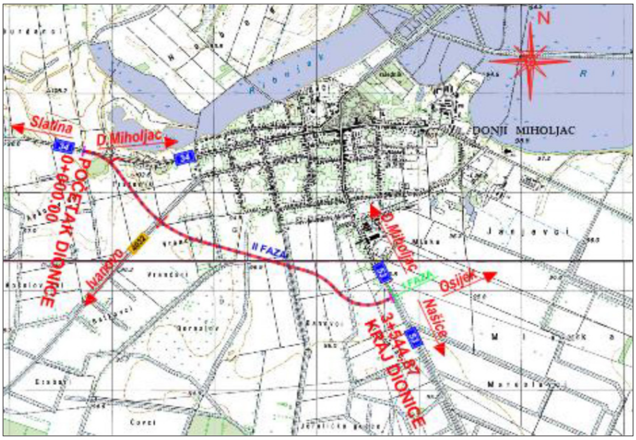

Figure 1 General layout of southern bypass of the town of D. Miholjac, Phase II [1]

2 Requirements for building southern bypass of the town of Donji Miholjac

2.1 Terms of reference

The Client Hrvatske ceste d.o.o and the designers (Institut IGH d.d., Projektni biro Palmotićeva 45 d.o.o. and Agenor d.o.o.) defined the terms of reference taking into account numerous problems that have been plaguing the town of Donji Miholjac for quite some time. The backbone of the town of Donji Miholjac is formed of two transport corridors that intersect one another at the very centre of the town. The first of these two corridors is the national road D53, which is the transverse route of eastern Croatia connecting the Sava and the Drava transport corridors, and the border crossing to the Republic of Hungary. The second corridor is the national road D34 which represents the longitudinal route of Eastern Croatia running along the Drava River toward the town of Osijek. Because of the mentioned problems, the need arose to build the Donji Miholjac bypass in the east-west direction, to the south of the town, the purpose being to move the Drava corridor through traffic away from the centre of Donji Miholjac.
A daily equivalent traffic load, expressed through the number of 82 kN axle passes, was obtained by analysing the data gathered at the traffic counting point No. 2403 (Donji Miholjac-East, D34). This traffic load belongs to the group of heavy traffic loads (according to HRN U.C4.010). The bypass route is situated about 300 m to the southwest of the first and second water protection zones defined for the water supply well "Donji Miholjac Well Field". In addition, the entire route runs through the third sanitary water well protection zone. In order to safeguard the quality of drinking water coming from the above mentioned water supply well, appropriate protection measures were planned for a high-level maintenance of the system for evacuation of water from the said road section during the service life of the road. The zone traversed by the route is agricultural in character, it is undeveloped and intersected with drainage canals and field paths that are used to gain access to the existing plots. The watercourses running toward the north and the Drava River will be cut off by construction of the Donji Miholjac southern bypass, which is why it was necessary to plan construction of culverts through the roadbed.

2.2 Advantages of using culverts made of spiral steel pipes

Advantages of culvert construction technology involving the use of spiral steel pipes at the Donji Miholjac southern bypass construction project have been proven from the standpoint of their cost-effectiveness, technology and time savings, based on comparison of cost items and time schedules with the corresponding data from other culvert construction technologies, based on category proofs and standards compliant with the EU regulations, and based on fifteen years of experience in Croatia on various projects including [5-7]. Numerous clients, supervisory bodies and engineers, designers and contractors have successfully used spiral steel pipes in the design and construction of culverts in highly demanding conditions. In fact, that this road infrastructure construction technology has been adequately implemented for more that hundred and twenty years in many parts of the world, while it has been used for more than seventy years in Europe and also in Croatia, thanks to its proven low cost, short construction time until resumption of traffic, compliance with rules of professional practice, considerable bearing capacity under all load conditions for roads and railways for speeds up to 200 km/h, easy lengthening, easy rehabilitation and extension, flexibility of solutions, great choice of forms and spans – diameters, low weight of the pipe and structure, high level of corrosion protection, and design life of more than one hundred years.

3 Culvert design using HelCor® spiral steel pipes

3.1 Selecting sheet geometry and thickness for HelCor® spiral steel pipes

Various longitudinal and cross-sectional culvert profile requirements have determined the geometry of culverts made of spiral steel pipes. Thus, the cross section and the bottom level are dictated by hydraulic elements and by water regulations, and so the following HelCor® spiral steel pipe types have been developed: DN 800, DN 1200, DN 1400, DN 1600 and DN 2000. The selection of various profiles has enabled considerable transport cost savings as up to 68 m HelCor® spiral steel pipes can be transported per a single track using the pipe “telescoping” (pipe-in-pipe) method, Figure 2.

Figure 2 Transport of HelCor® spiral steel pipes

The flexibility of solutions used, and especially a good coordination between the working design designer AGENORd.o.o. and contractor OSIJEK KOTEKS d.d., combined with technical assistance of HelCor® engineers, enabled maximum reduction in the number of pipe elements (Figures 2 and 3) per culvert. Thus the culvert length of over 30 m was realized using three pipe elements, and the maximum length of individual pipe elements amounted to 13.60 m. The Table 1 present specification of culverts used at the southern bypass of Donji Miholjac [2]. On Figure 4 we can see the on-site storage of HelCor® spiral steel pipes.

Table 1 Specification of culverts used at the southern bypass of Donji Miholjac [2]

No.	Chainage	Diameter Φ	Sheet diameter GP?	Sheet thickness IP?	Over-burden h	Intersec-tion angle ?	Length in axis Lo	Total length Lu	No. of cou-plings
	(km)	(mm)	(mm)	(mm)	(m)	(º)	(m’)	(m’)	
1	0+247,88	80	2	2	1,04		22,40	22,45	1
2	0+669,24	120	2,5	2	1,05		9,20	10,15	
	0+669,24	120	2,5	2	1,68		14,93	15,51	1
	0+669,24	120	2,5	2	1,05		10,36	10,50	
3	0+827,82	160	2,5	2	1,50		31,24	34,38	3
4	1+060,00	120	2,5	2	1,62		30,76	30,76	3
5	1+100,00	120	2,5	2	1,23		30,95	30,95	3
6	1+349,25	200	2,5/3,5	2,5	2,10		22,99	24,57	2
	1+349,26	200	2,5/3,5	2,5	0,31*		9,37	9,82	
7	1+712,16	120	2,5	2	1,93		18,03	18,73	1
8	1+999,48	160	2,5	2	1,94		15,79	16,33	1
9	2+428,42	140	2,5	2	0,74		15,57	16,26	1
10	2+446,47	200	2,5/3,5	2,5	0,81		15,98	16,98	1
	2+446,48	160	2,5	2	0,20*		7,96	7,96	
11	1+543,00	80	2	1,5	0,34*		30,08	30,08	3
12	Ratkovci I	120	2,5	2	0,00		14,06	14,86	1
13	Panjik	120	2,5	2	0,00		13,65	14,05	1
14	Đanovci I	140	2,5	2	0,00		13,95	14,75	1
15	%	40	2	2	0,00		%	%	%
16	%	40	2	2	0,00		%	%	%
	Total	40	Cost estimate Detailed design	New Working design	16	According to design	%	%	%
		80			55		52,48	52,53	4
		120			150		141,94	145,51	10
		140			31		29,52	31,01	2
		160			60		54,99	58,67	7
		200			55		48,34	51,37	3
	Total:	All Φ	Cost estimate	Cost estimate	367	According to design	327,27	339,09	26

Figure 3 Transport and unloading of HelCor® spiral steel pipes

Figure 4 On-site storage of HelCor® spiral steel pipes

Static analysis of spiral steel pipe culverts, conducted separately for each pipe diameter, is an integral part of the working design. The sheet metal corrugation and thickness were selected based on load analysis according to EU categorisation and standards, and the decision was made to reduce the sheet metal thickness compared to specifications given in the detailed design, which resulted in additional savings.
In addition to the cost of the total structure, an additional advantage, which is by several times more favourable compared to all other technologies, is the rate at which the works can be carried out, [5], [6], and [7]. When selecting longitudinal geometry of the spiral steel pipe, and in addition to meeting the above mentioned requirements, it is also necessary to provide for: proper incorporation of pipe inlets and outlets into road embankment slopes [3], [5], vertical walls at culvert inlets and outlets, embankment and channel slope revetment, possible discharge of the channel or pipe drainage into the culvert, passage of infrastructure service ducts/installations, and possible additional pipe connections under the footways or other structures. The working design called for factory-made pipe inlets and outlets in form of a “mouth”, which follow the slope of embankment or are positioned at an angle with respect to the road axis.

4 Construction of culverts made of HelCor spiral steel pipes

4.1 Assembly and backfilling

Based on perfect coordination between the client, designers and supervising engineers, and thanks to technical assistance of the manufacturer’s engineers, and the contractor’s proper time scheduling, the unloading process constituted at the same time the assembly of individual spiral steel pipes onto the previously prepared bedding. In order to ensure perfect fit of the steel structure, the bottom base was covered with a gravel and sand layer approximately 20 cm in thickness. This layer thickness can be regarded as one of the smallest culvert bedding thicknesses applied on similar projects. The compaction in unfilled zones or “pockets” between the pipe and the bedding was conducted with due care using hand rammers and water. To backfill the unfilled space, it was necessary to provide a working area of 0,70 m on each side of the structure. In the immediate vicinity of the culvert backfilling zone, and especially in the zone of soil influence on the start of composite action of the structure, there should be no external forces (e.g. foundations), which often happens in case of rehabilitation or removal of non-functional RC culverts.

Figure 5 Assembly of pipe with coupling, backfilling and wall construction

Figure 6 Both-sided backfilling with compaction and construction of walls

The backfilling with compaction was conducted simultaneously from both sides of the pipe in uniform layers each 30 cm in thickness, along the entire width of the foundation pit, using light construction machines – vibratory tampers or vibratory plates (Figure 5 and 6). Time needed to connect pipes with couplings was negligible as this work was conducted simultaneously with the backfilling and compacting activities. It was possible to resume road traffic as soon as the level of 60 cm above the top of the pipe was reached [5], [6], and [9]. The construction of each spiral steel pipe culvert lasted two days, and the traffic could resume immediately after this activity. It is precisely this rapid construction rate that greatly facilitated on-site communication along the 3.5 km long route. This culvert construction activity was conducted simultaneously with construction of vertical walls, which was followed by slope improvement at pipe inlet and outlet zones (Figure 7).

Figure 7 Culvert under traffic load during wall construction activities

4.2 Culverts in use

Eighteen culverts were built at the Donji Miholjac southern bypass using the culvert construction technology involving spiral steel pipes. Out of this total number, eleven culverts were built in the road bed and seven at parallel field paths (Figures 8, 9, and 10). The flexibility of solution regarding construction of inlet and outlet parts of culverts enabled designers to use various materials to speed up the construction work, to optimise the costs, and to blend harmoniously the culvert with the surrounding scenery. Maintenance is unnecessary for culverts built in accordance with the manufacturer's instructions, design requirements, and supervising engineer's instructions, Figure 11.

Figure 8 Completed culvert at roundabout entrance (first phase of construction) during construction work

Figure 9 Culverts in use in road bed and service road

Figure 10 Culvert in road bed (HC 2000) and culvert in service road (HC 1600)

Figure 11 Completed culvert (CH 2000) in road bed during road use

5 Conclusion

Corrugated steel sheets were formerly dominantly used in the construction of culverts and passages by the countries with the developed steel industry and expensive labour [1]. Based on worldwide and European experience [9], and experience gained in Croatia [5], [6], [7], this construction technology is now increasingly being used in our country. One of examples of such use is the Donji Miholjac southern bypass project, which was completed in late 2015. Excellent coordination of all participants in this project, and experience and knowledge gained during realisation of the project, resulted in high quality of construction work and in significant advantages compared to “conventional” culvert construction procedures. In addition to culvert construction complying with rules of professional practice, most notable advantages include several times shorter construction time, flexibility of solution used, and considerable financial savings [5], [6], [7].

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