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A NEW CROSSING OF MUREŞ RIVER IN ARAD COUNTY

Dorel BOLDUŞ[*], Radu BĂNCILĂ[**], Bogdan BOLDUŞ[***]

[*] "Politehnica" University of Timişoara
[**] "Politehnica" University of Timişoara
[***] S.C. BB-CONS SRL Timişoara

Corresponding author: Dorel BOLDUŞ, E-mail: d.boldus@yahoo.com

Abstract: This paper presents many constructive solutions studied for crossing the river Mures by road DJ 709E between the localities Pecica and Sanpetrul German in Arad County, western Romania. The bridge will be located in a protected area, as a natural park, so the design solutions and erection technologies are tailored conditioning. The infrastructure will be made by reinforced concrete and the superstructure by steel with steel-concrete composite deck slab. The paper explores five design alternatives for the static system: differently continuous beams, arches and cable-stayed structure and compares the costs and time of execution. Finally, we recommend the most cost effective solution.

Key words: road bridge, Mures river, multi span deck-plate continuous girder bridge, arched-trough bridge, cable-stayed bridge.

1. INTRODUCTION

County road DJ 709E connects the town of Pecica and the localities on the left bank of river Mureş, in Arad County: Sampetrul German, Secusigiu, Satu Nou (on DJ 682) and continuing toward the localities in Timiş County: Periam and the national road DN 69 Timisoara-Sannicolau Mare-Cenad, respectively the localities downstream the right bank: Semlac, Seitin, Nadlac (on DJ 709D). At the present moment the crossing of the river Mureş is done, for all the above mentioned localities, in difficult conditions and only for lightweight vehicles, by a floating bridge, manually manoeuvred.

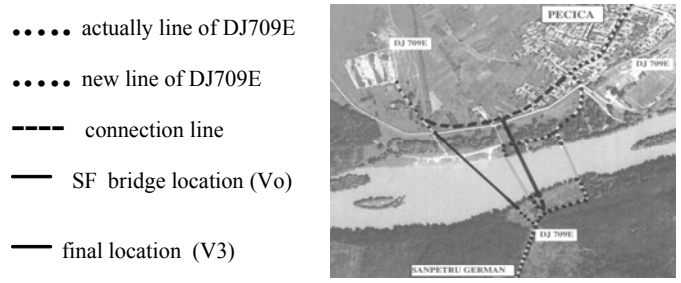


Fig. 1 Aerial view of the bridge location

Fig. 2 Bridge's position in natural park area

Because of this fact, approximately 37,000 people (from the towns in Arad County) have to suffer. The only possibility of crossing the river on a road bridge in using the one in the town Arad, approximatively 25 km upstream, while downstream, the only place to cross would be the bridge in Mako, Hungary, about 55 km away. The intersection of DJ 709E and the river Mureş is located south-south-west of Pecica, in the river plane, close to the dam on the right bank

Presently, the floating bridge has two stations, about 30 m away from each other, one upstream, for the situation of deep water caused by prolonged floodings, and one station downstream, for shallow or normal water depth. The dam on the left bank is situated rather far from the minor bed, approximatively 850 m, and the county road being situated on the major bed.

2. CHARACTERISTICS OF THE PROJECT

2.1 Location of the bridge

After the discussions with the local authorities, following the analysis of the natural relief of the region and of the present route of the DJ 709E road it was decided that the bridge be located in the same area where the present floating bridge is, the heads of the new bridge would be established in the major bed on the left side and behind the dam protecting Pecica, on the right side.

The deviation of the county road to the south-south-west part of the Pecica outskirts and its connection with DJ 709C (County Road 709C) and DN 7 (National Road 7) will be studied in a separate paper. This new concept will help decongesting the traffic from the central area of the town and will facilitate the access to the road and the bridge for the inhabitants from the downstream towns - Semlac, Seitin, Igris etc. – as well as the transit from the Nadlac-Arad highway and DN 7/E 68 Nadlac-Arad. When choosing the location we considered the necessity to ensure the navigable span on the river Mureş. The bridge is designed for a service period of 100 years, during which further development of the region is expected. We also had in mind the connections between the upstream and downstream regions, done by roads that will ensure traffic free from any clearance or tonnage restrictions.

In order to establish and locate the bridge axis a topographic survey of the area was necessary as well as a preliminary geotechnical study, in order to determine the physical mechanical characteristics of the soil in the location.

As a result of the topographic survey of the terrain in the location area we saw that the best location – leading to the shorter bridge, which implies minimal alterations of the existing road, to less affect the natural environment and to allow the realization of the investment, in two distinctive stages – is at about 80 m upstream from the lower position of the present floating bridge.

The position of the bridge centre-line is marked on the annexed drawings [1], superimposed on a plan for aerial surveying of the site, in three additional locations from the original version V0, initially presented in SF to be the most economical version, called V1, V2 and V3 (figure 13).

2.2. Cross section

In conjunction with the road characteristics and with the prescription requirements and the technical design standards in force [2], [3], [4],[5] (national standards and EU standards) at the time of the study, the cross section of the bridge has been chosen so that it includes (fig.)

- two lanes with a width b = 3.00 m each and a widening due to the optical narrowing effect E0 = 0.5 m, resulting in carriage way c = 7.00 m;
- the space for the guard rail will be S_p = 0.50 m on each side; the guard rails installed will be concrete DELTA BLOCK-80AS-R type;
- cycling track with p_c = 1.25 m in width on each side;
- pedestrian sidewalks, having the width T = 0.75 m on each side, bordered by the cycling track.

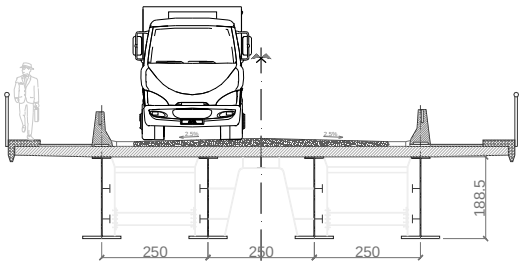


Fig. 3 Typical cross section of the bridge deck

Under the bridge the Romanian type II navigable span is ensured on the river Mures, having the 5x40 m navigation rectangle (5.0 m height above the maximum quota of navigation and 40.0 m in width).

It also provides a space under the bridge for approx. 2.40 m above the ridge height of the embankment and thus, the necessary free space from the high waters is ensured (N.A.E. height).

2.3. Data on water and navigation

Mures river is currently not navigable but considering the expected life of the new bridge and the perspective of starting navigation, the design has taken into consideration the type II navigation span (5x40m navigation rectangle).

In order to establish the optimum solution the following preliminary data have been used:

Maximum flow:	2440 mc/s
Average flow:	184 mc/s
The level of the bottom of the river bed (thalweg):	+94.32m nMN (Black Sea level)
Width of the river bed:	106.25m
Water level (July 2009):	+96.82m nMN
Embankment heights:	~102.90m nMN left bank
	~103.11m nMN right bank

3. CONSTRUCTIVE VARIANTS

3.1. Analysed constructive variants

Within the feasibility study six constructive variants were studied, having the most common and used construction variants: multi span deck-plate continuous girder bridge, with unequal or equal spans, arched trough bridge, cable-stayed bridge.

Following the bridge site analysis, correlated with the specific shape of minor bed - the deepest water being near the left shore and not to the middle as it would be ideal, it was found that in Variant 0 (after dividing into spans, according to the principle of the continuous beams economics – the marginal span in the range 0.7-0.8 of the current span) the navigation clearance cannot be provided and pier 1 will fall exactly on the water line in the deep water area, which leads to difficult working conditions and added cost. Because of this fact this variant was dropped.

a) Variant 1 : Deck-plate continuous girder structure, 5 equal spans: L = 5x70.0m =350m

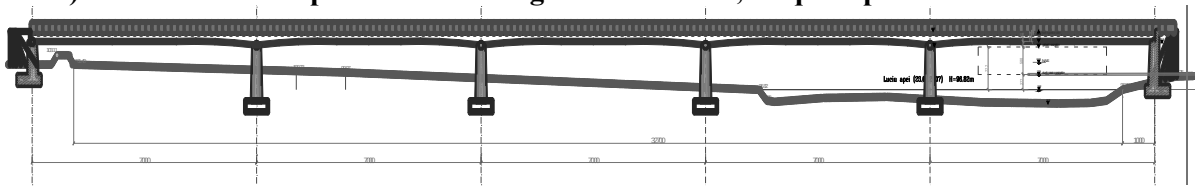


Fig. 4 Elevation of Variant 1

Spans : 70.00+70.00+70.00+70.00+70.00 m
Total bridge length : 350.00m
Superstructure type: composite, 4 continuous beams with connectors and 24cm concrete slab
Superstructure height : 208 cm beam on abutments/168 cm field beam /288 cm pier beam
Construction height : min.=1.86 m; max.=3.06m
Number of piers : 4
Total number of foundation pile (D=1008mm)/length: 82/1388m
Surface of the bridge : 4200m2

b) Variant 2 : Main span arched trough and continuous deck plate-girder bridge, 4 unequal spans : L = 100.0m + 55.0m + 2x70.0m + 55.0m =350m

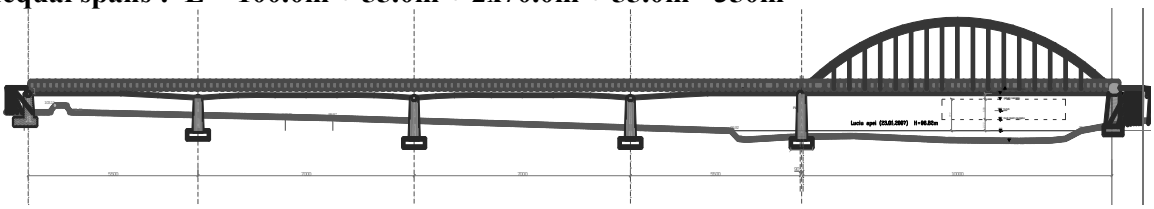


Fig. 5 Elevation of Variant 2

Spans : 100.00+55.00+70.00+70.00+55.00 m
Total bridge length : 350m
Superstructure type : main span Langer beam and composite deck/deck plate-girder bridge
Superstructure height : arc =18.00m
Construction height : 2.20/min.=1.86m;max.=3.06m
Number of piers : 4
Total number of foundation pile (D=1008mm)//length : 93/1574m
Surface of the bridge : 4337 mp

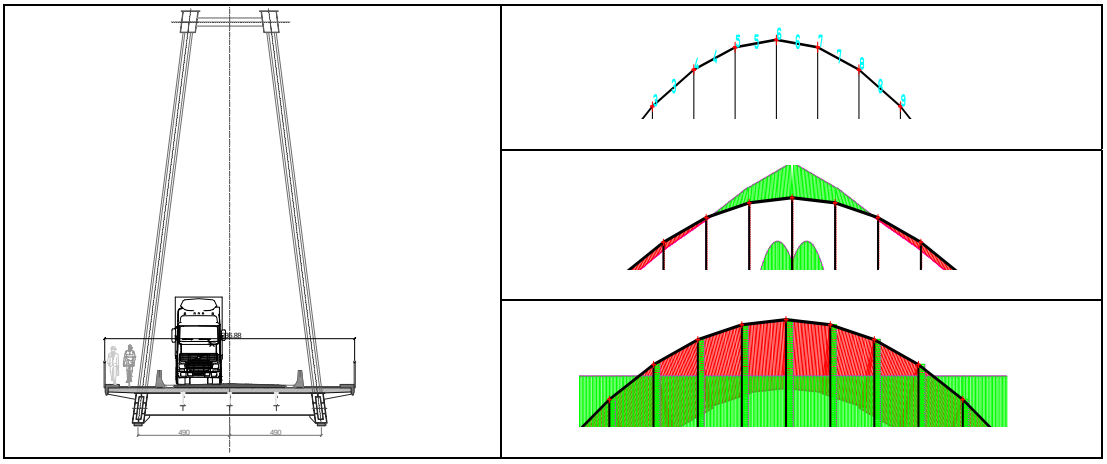


Fig. 6 Variant 2 – Structural arch scheme, and significant stress diagrams

A main span of 100 m was designed, over the minor bed on the water line. The span was covered with an arch superstructure with reinforcement beam and a cable-stayed structure (fig.6). The dimensions of the parabolic arch are: the span L=100 m and the spring chamber (elongation) H=18 m. The cables that support the reinforcement beam are placed 10 m away from each other, at every tenth of the span. The plan of the arches is placed behind the guard rails and has a 20° inclination from the vertical line. The sidewalks and the cycling tracks are built in bracket.

c) Variant 3 : Arched trough bridge, 3 equal spans and 50 m dam: L=3x100.0 = 300 m
Total bridge length : 300.0m
Spans : 100.00+100.00+100.00 m

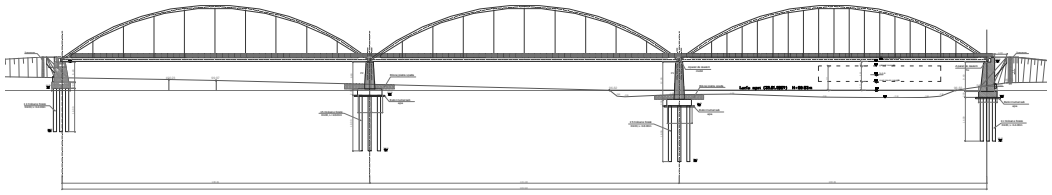


Fig. 7 Elevation of Variant 3

Superstructure type : Langer beam and composite deck
Number of piers : 2
Total number of foundation pile (D=1008mm)/length : 66/1076
Surface of the bridge : 3011 m^2

A bridge with three equal spans of 100 m each has been designed. The same arch structure as in main span-variant 2 was used. The sidewalks and the cycling tracks are built in bracket.

d) Variant 4 : One-tower cable-stayed bridge by a total length L=350 m

Bridge with central pylon, H=60 m high and with three bracing wires symmetrically set as compared to the middle of the bridge (Fig. 8). Eight spans are thus realized. The bracing is made in twofold plan. An A shaped pylon has been chosen.

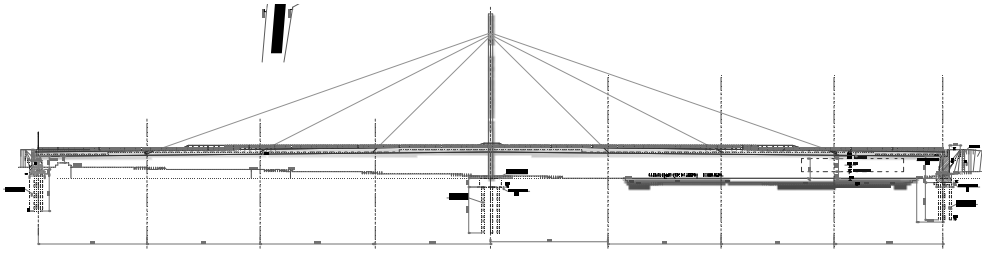


Fig. 8 Elevation of Variant 4

Spans : **42.00 + 44.00 + 44.00 + 45.00 + 45.00 + 44.00 +44.00+ 42.00 m**
Superstructure type : steel box girder with orthotropic plate
Superstructure height : 2080mm
Pylon height : 60.00m
Construction height : 2.26m
Number of piers : 1
Total number of foundation pile (D=1008mm)/length : 97/1778m
Surface of the bridge : 4200 m^2

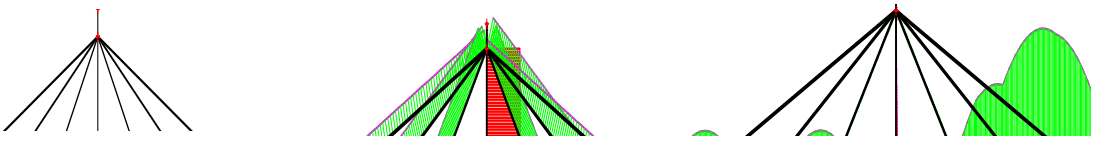


Fig. 9 Structural scheme and significant stress diagrams of Variant 4

Besides the outstanding aesthetic aspect the bridge has the advantage of having one single pier, in the centre of the major bed.

e) Variant 5. Two-tower cable-stayed bridge by a total length L=350 m

Two tower bridge, symmetrically set and having 6 bracing wires. Seven spans are thus obtained. (Fig. 10). The twofold bracing for the pylon was chosen to be A shaped. This solution asks for two towers to be placed in the river bed. The structure is aesthetical and gives the impression of a very slim structure. The same superstructure type as Variant 4 was chosen.

Spans : **42.00 + 47.00 + 57.00 + 58.00 + 57.00 + 47.00 + 42.00 m**
Superstructure type : steel box girder with orthotropic plate

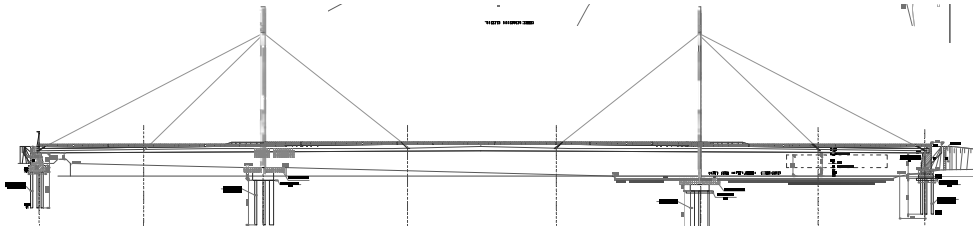


Fig. 10 Elevation of Variant 5

Superstructure height :	2080mm
Pylon height :	60.00m
Construction height :	2.26m
Number of piers :	2
Total number of foundation pile (D=1008mm)//length :	64/1256
Surface of the bridge :	4200 m^2

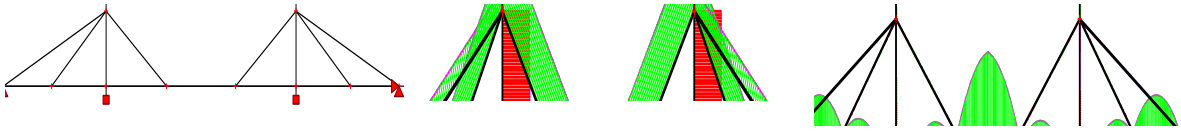


Fig. 11 Structural scheme and significant stress diagrams of Version 5.

A 12.0 m wide bridge deck formed by 2.0 m deep steel box girder and orthotropic plate (Fig .12) is intended for the deck. The bridge has two traffic lanes, 2 x 3,5 m, the guard rail and the sidewalks of 2 m width. The pylon has an „A" shape, with a twofold plan bracing and cross girder. Its height is H = 60 m.

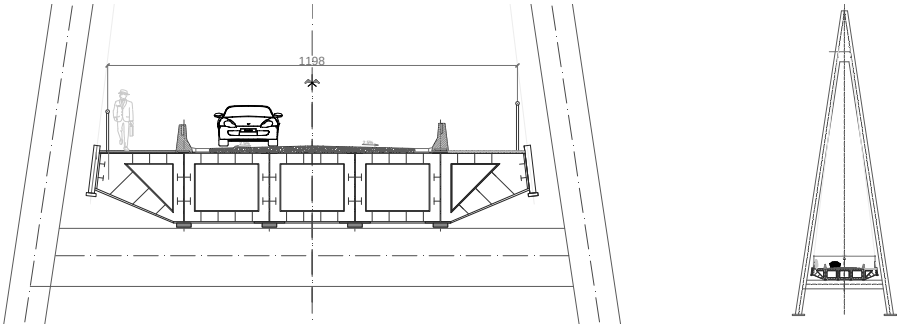
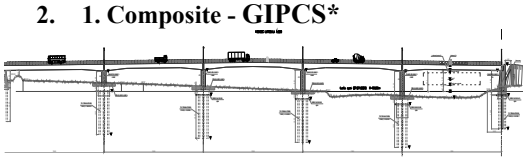
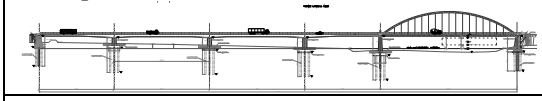
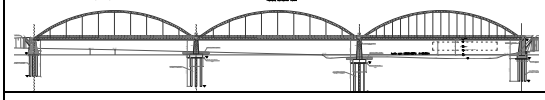
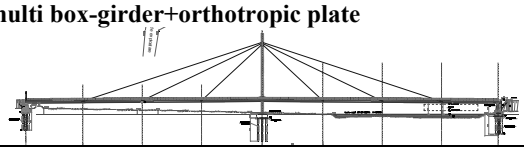
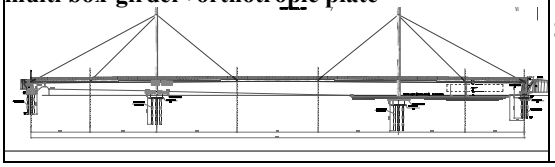


Fig. 12 The cross section proposed and the design of the „A" type pylon.

3.2. Comparative analysis of the studied solutions

After choosing the possible technical solutions and after a summary designing of the structural elements, the economic analysis was done by evaluating the work process difficulties and the necessary amount of work, determining the cost, based on the actual catalogue prices and than the estimation of the value of the whole investment. Following the technical economical analysis of the studied variants – table 1, the analysis of the difficulties and mounting requirements, of the dimensions of the investment and the duration of the execution, in accord with the beneficiary, we considered that the optimum variant is VARIANT 1, the continuous beam with five equal spans, of 70.0 m.

TABLE 1 Comparative characteristics and prices of the bridge's studied variants

Construction variant	Spans No. and L(m)	No. of piers	Surface	VALUES, without VAT		VALUES, with VAT	Spec. PRICE
				C+M bridge	Invest-ment	Invest-ment	total
			(mp)	1000 RON	1000RON/ 1000 €	1000RON/ 1000 €	€/mp
1. 2. 1. Composite - GIPCS* 	5 x 70m	4	4200	**23000,-**	**26778/ 6341**	**31672/ 7500**	**1786**
2. Composite - Arch CJ** + GIPCS* 	1 x 100m 55+2x70+55	4	4337	26647,-	30992/ 7339	36658/ 8681	2002
3. Composite deck - 3 Archs – CJ** 	3 x 100m	2	3011	32206,-	37415/ 8860	44258/ 10481	3481
4. Cable-stayed 1 central tower multi box-girder+orthotropic plate 	2x 175m	4	4200	31196,-	36248/ 8548	42878/ 10154	2418
5. Cable-stayed 2 symmetrical towers multi box-girder+orthotropic plate 	89+172+89 m	2	4200	29840,-	34682/ 8123	41025/ 9715	2313

***GIPCS** = Plain girder deck bridge; ****CJ**= bottom-road; (BNR quotation /09.01.2009 : 1€ = 4.22 RON)

4. CHOOSING THE FINAL VARIANT

At the moment when the necessary approvals, in order to authorize the new construction, were obtained it was discovered that part of the location chosen for the bridge was private property and had to be expropriated. Due to the fact that in Romania the expropriation procedures are difficult, costly and slow, we have studied other bridge layout (figure 13), respectively three new site position, named V_1, V_2 and V_3, downstream from initial location named V_0 in SF. (highlighted in red on the figure 1). Finally it was decided, in agreement with the beneficiary, that the location of the bridge be moved downstream from the floating bridge, so that it would be exclusively on public terrain. Location B was chosen (highlighted in blue on the figure 1), with the following technical alterations:

- Execution of an skew bridge (83º skew), having the total length of 444,0 m, with six equal spans of 74,0 m and the total surface of the bridge of 5328 m^2 ;
- The Pecica abutment would exceed the dam and would be connected with the future alignment of the County Road DJ 709E, which will bypass the town Pecica;

- The new trace of County Road DJ 706E, on the left bank in order to connect the new position of bridge.

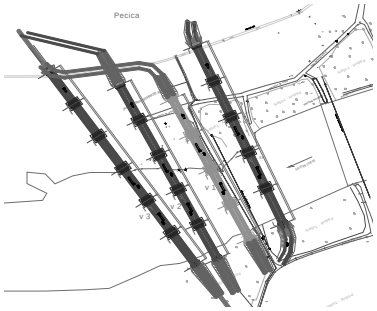


Fig. 13 Other bridge layout

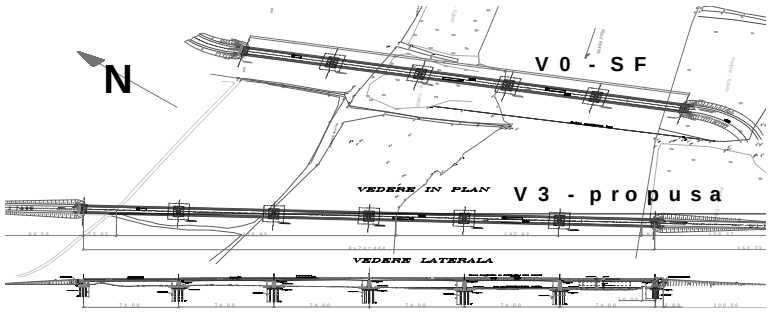


Fig.14 The final general position of the skew bridge

5. CONCLUSIONS

The final variant chosen as variant V3 has continuous beams structure, 6 equal spans, skew bridge. The main characteristics of this solution are:

Spans : **74.0+74.00+74.00+74.00+74.00+74.00** m
Total length of the bridge : 444.00 m
Skew : 83°
Surface of the bridge : 5328 m^2

This variant (drawing 80-SF-v3,[1]) implies the construction of the bridge with six equal spans of 74.0 m each and the location of the bridge downstream the floating bridge, skew, in a way that the Pecica abutment would overpass the dam zone and be connected with the deviated route of the County Road DJ 609E, close to the town Pecica in the direction of the National Road DN7, Nadlac-Arad-Bucuresti. The actually trace of County Road DJ 706E will be deviated over 106.0 m, on the left bank that the road and bridge approach can rich the left abutment.

This variant would imply extra costs of 10-16%, as compared to the initially calculated costs.

REFERENCES

1. UNIVERSITATEA POLITEHNICA TIMISOARA. *Studii de fezabilitate pentru traversarea raului Mures de catre DJ 709E intre Pecica-Sampetru German;* CONTRACT NR. 80/2009: beneficiar: Consiliul Judetean Arad, 2009.
2. *SR EN 1993-2:2007 EUROCODE 3: Design of steel structures – part 2: steel bridges;* ASRO BUCURESTI, 2007.
3. *SR EN 1993-2/NA-2008 EUROCODE 3: Design of steel structures – part 2: steel bridges. National annex;* ASRO BUCURESTI, 2008.
4. *SR EN 1994-2: 2006 EUROCODE 4: Design of composite steel and concrete structures – part 2: general rules and rules for bridges;* ASRO BUCURESTI, 2006.
5. *SR EN 1994-2/NA-2008 EUROCODE 4: Design of composite steel and concrete structures – part 2: general rules and rules for bridges. National annex;* ASRO BUCURESTI, 2008.

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