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RESEARCH REGARDING TECHNICAL SOLUTIONS CHOICES FOR ROMANIAN FOREST ROADS CROSSING WORKS

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Abstract: *The crossing works, afferent to forest roads network from Romanian mountain forests, constitute an important percent of forest roads execution cost. In present paper there are proposed criteria for crossing works solutions choosing for forest roads, including the presenting of some diagrams regarding the expedite evaluation of different solutions costs in rapport with technical characteristics and specific dimensional elements, as well as in function of the crossing works location characteristics.*

Key words: *bridges, culverts, costs, choosing criteria.*

1. Introduction

The existence of a judicious dimensioned forest road network contributes to forest resources capitalization, and, principally, to timber transportation optimization, from the felling site to manufacturing units or directly to the consumers [1]. In the absence of these roads, the wood, with considerable weight and dimensions, is moved by hauling, in undeveloped terrain, or, when this fact is possible, on summary developed nonconsolidated tractor roads, which in accentuated humidity conditions, especially in spring and in autumn, leads to important erosions followed by alluvial material movement in the riverbeds. In this order of ideas, the opposition of some ecologists regarding the forest roads network development appears to be unjustified.

The crossing works, bridges and culverts, cumulate an important percent from forest roads execution costs, the reason for which, in the design phase, there must be given a special attention in order to develop the most efficient solutions for these works [1], [2].

The choice of the bridge solution represents the most significant aspect in the bridge design. This paper is referring to bridges built on forest roads, over small streams requiring small spans. The two basic requirements for forest bridges tend to be considered: that the bridge construction should be as cheap as possible and it should require minimal maintenance. Higher maintenance costs are accepted if they are accompanied by substantial capital savings.

The decisions must be made by considering of field surveys and data logging information regarding the following main aspects:

- the local terrain and site condition;
- the required design life of the bridge;
- the expected traffic volumes;
- the available resources.

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2. Site Selection for Crossing Works

Regarding the site selection for crossing works, there are some considerations to keep in mind:

- a bridge site must offer appropriate vertical and horizontal alignments;
- the base earth must be strong enough to ensure the stability of the structure;
- the bridge and its associated works should not have an adverse impact on the surrounding areas, or themselves be susceptible to damage under the local environment actions;

The only way to complete the appraisal is to evaluate all the alternative solutions and to compare them.

There are some important points to be considered:

- a smaller span may lead to more expensive abutments;
- sub-soil site investigations are expensive and for the small bridge in question they are not needed to be carried out prior to construction. The design should be prepared and based on assumptions which are checked when the foundations are excavated. Rock near the surface is ideal, especially if constructing piers mid-stream where the undercutting can be a problem;
- high bridge decks can require expensive abutment and piers;
- a slight detour may permit a crossing above a river junction who will reduce the catchment area and, thus, the risk of flooding.

3. Choosing a Bridge Type

Having chosen the site the approximate span will be known by planning the road levels and calculating the required waterway area. The abutments or piers are then chosen on the basis of aesthetics and bearing capacity. The choice of bridge type is generally based on span, but there are parallel choices which, for example, may be more economic, involving less capital but requiring more maintenances or limit on usage.

3.1. Concrete bridges

The great availability and flexibility of concrete material and reinforcing bars have made the reinforced concrete bridge a very competitive alternative. Reinforced concrete bridges may consist of precast concrete elements, which are manufactured at a production plant and then transported for construction at the job site, or cast-in-place concrete, which is formed and cast directly in its setting location. They usually provide a relatively low maintenance cost and better earthquake-resistance performance.

Reinforced concrete sections, used in the bridge superstructures, usually consist of slabs, T-beams, I-beams and Π-beams. Safety, cost-effectiveness, and aesthetics are generally the controlling factors in the selection of the proper type of bridges. Occasionally, the selection is complicated by other considerations such as life-cycle cost, traffic maintenance during construction stages, construction scheduling and worker safety, feasibility of false work layout, passage of flood debris. In some cases, a pre-stressed concrete may be a better choice.

3.2. Corrugated steel bridge

Corrugated steel bridges and culverts represented by corrugated steel and granular material structures can support the permanent loads as well as those from traffic.

The resistance structure of corrugated steel bridges and culverts can be realized from pipes with unitary sections or with sections realized from one or more parts jointed together.

The plate corrugation presents the role of increasing the structure resistance to bending. The plate's thickness and the corrugation step and height are adopted on a resistance calculus basis, from produced variants. The plate as well as the bolts are covered (at hot temperatures) with an aluminum, asphalt oil, resin, epoxy or plastic protector layer, which confers an acceptable durability in comparison with other materials from bridges construction practice.

The granular material filling is included in the road's embankment, and it assures the bearing capacity of the culvert. The bearing capacity results from corrugated steel and granular filling con-working, the last one being realized in the lateral zones of the pipe in order to prevent the pipe deformation.

The stress on the pipe is determined by the circulation load, and it decreases in rapport with the filling thickness on the pipe and with geological load which increases in rapport with the filling thickness.

It is very important the filling's correct and strong compaction. In this order of ideas, the filling is alternately realized in both the lateral parts of the pipe, progressing with layers of approximate 20 cm in thickness, and manual or mechanical beaters compaction in the pipe proximity (avoiding of the heavy compactor cylinders which could deteriorate or deform the pipe). The used material should present a homogeneous structure (the same deformation modulus), without rock inclusions which could, both, provoke local deformations of the plate and reduce the bearing capacity of the structure.

3.3. Timber Bridge

The structural use of wood and wood-based materials has increased steadily in recent times, including a renewed interest in the use of timber as a bridge material.

Wood has been widely used for short- and medium-span bridges. Although wood has the reputation of being a material that provides only limited service life, wood can provide long-standing and serviceable bridge structures when properly protected against moisture. Today, wood preservatives which inhibit moisture and biological attack have been used to extend the life of modern timber bridges.

Wood can withstand short-duration overloading with little or no residual effects [3]. Wood bridges require no special equipment for construction and can be constructed in virtually any weather conditions without any negative effects. Wood is competitive with other structural materials in terms of both first costs and life-cycle costs.

Important advances were made in wood fastening systems and preservative treatments, which would allow for future developments for timber bridges. The use of glulam has grown to become the primary material for timber bridges and has continued to grow in popularity (Figure 5). The future use of timber as a bridge material will not be restricted just to new construction. Owing to its high strength-to-weight ratio, timber is an ideal material for bridge rehabilitation of existing timber, steel, and concrete bridges.

4. Expeditious Determination of Cross Working Costs

For an expedite evaluation of the approximative costs for crossing works in the technical solution choosing stage, there have been elaborated and presented below cost related diagrams for different deck types and abutments for bridges as well as for steel corrugated culverts.

The costs were determined for average acquisition costs, terrain conditions, labour force and materials, characteristic to the Romanian market and representig total costs per object without TVA.

4.1. Π-beam Prefabricated Reinforced Concrete Decks

These decks are composed from **π-**beams with, ajiacently setted and consolidated through transversal bridgings, setted on the bridge extremities, and concrete monolithizations between beams. The beam width is, usually, of 50 cm. On the beams a variable width slope concrete concrete in realized, as a support for the concrete roadway. In Figure 2 there is presented the costs diagram for Π-beams concrete decks, for deck widths between 4.0 and 6.0 m, and deck lenghts between 2.6 and 11.0 m.

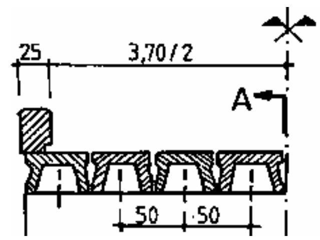
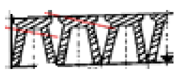


Fig. 1. *Π-Beam Deck*



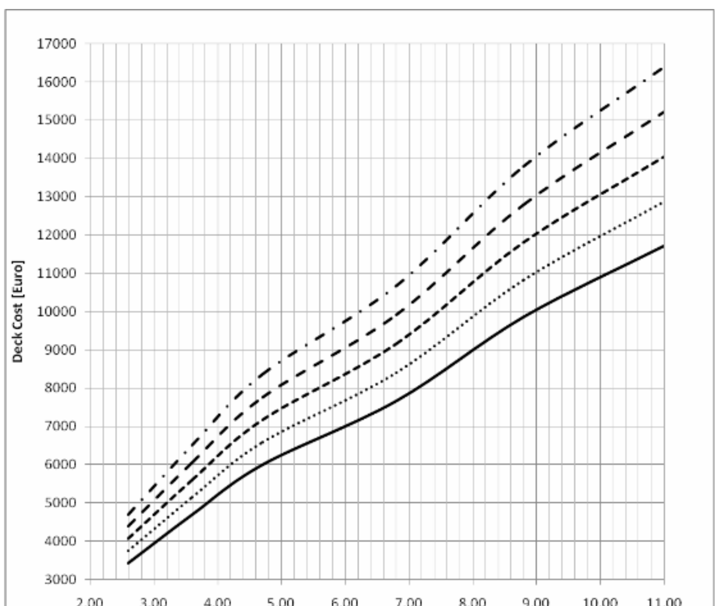


Fig. 2. *Π-Beam deck costs, in function of width and length*

4.2. Prestressed Reinforced Concrete ⊥-Beams Decks

These decks (Figure 3) are composed from prestressed concrete beams with ⊥-transversal section, with width of 60 cm adjacently settled and consolidated both, through monolith concrete settled on them and transversal reinforcements of the deck. In Figure 4 there is presented the costs diagram for deck widths between 4.2 and 6.0 m, and lengths from 6.0 to 12.0 m.

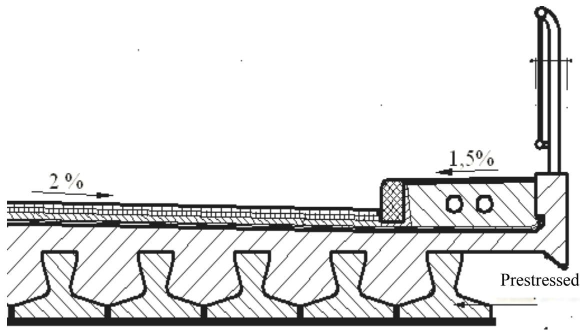
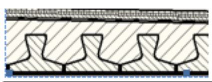


Fig. 3. *Prestressed concrete ⊥-beams decks*



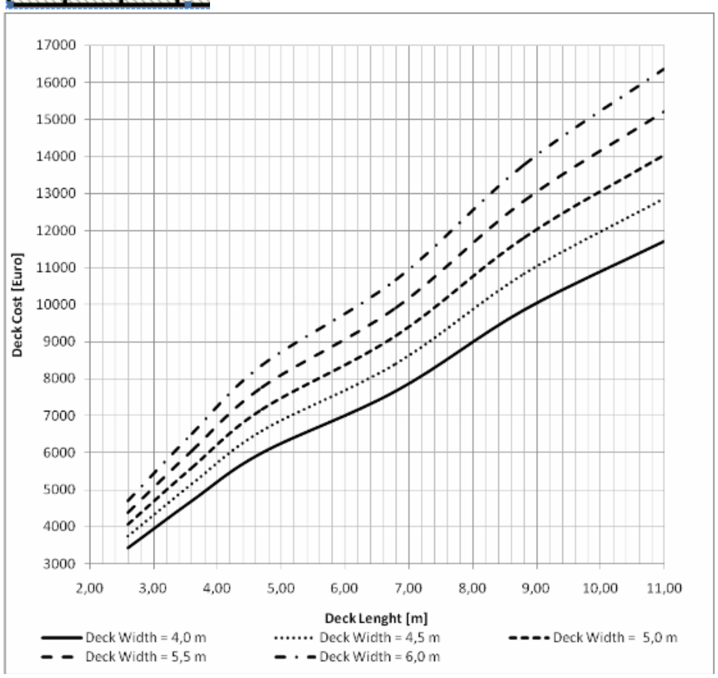


Fig. 4. *The cost of ⊥-beams decks, in function of width and length*

4.3. Abutment Cost

The abutments used on bridges from forest roads are currently represented by massive concrete abutments, as shown in Figure 6, realized with wings and/or reverse walls. In order to compare from cost point of view the concrete bridges with the corrugated steel bridges, there appears as necessary the expedite evaluation of the abutments costs.

4.3.1. Elevation Costs

In the diagram from Figure 7, there are presented the costs for elevations realized

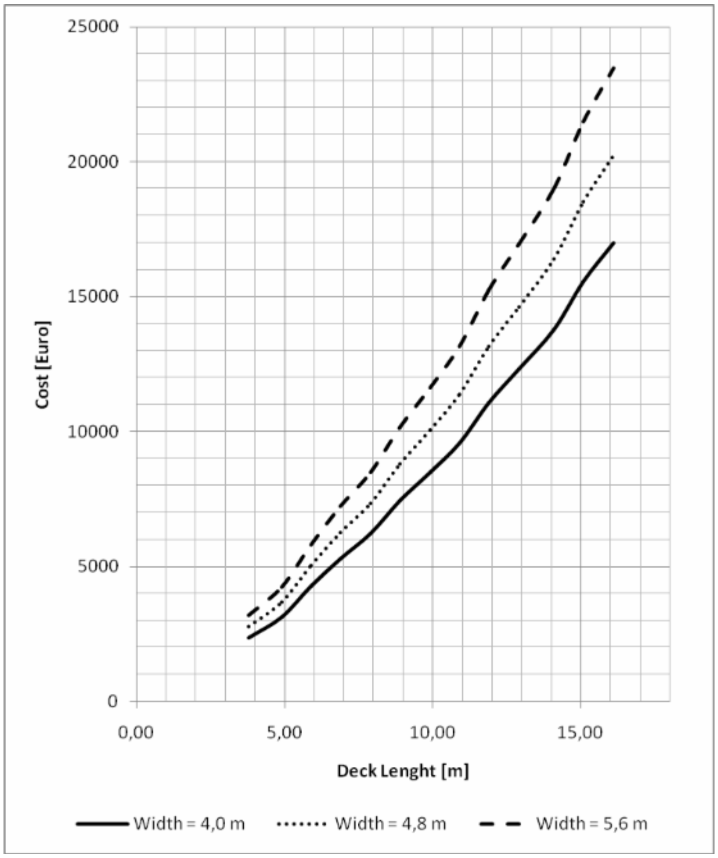


Fig. 5. *The cost of glulam decks, in function of width and length*

from C12/15 concrete class, for the following dimensional characteristics: length of 4 meters, widths from 0.5 to 1.5 meters and heights between 1.5 and 5.0 meters.

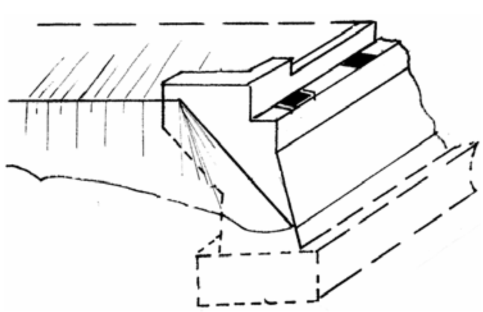


Fig. 6. *Concrete abutment*

4.3.2. Foundation Cost

In diagram from Figure 8 there are presented the costs for foundations with rectangular section realized from C8/10 concrete class, with length of 4 meters, widths between 0.5 and 1.5 meters and heights between 1.5 and 5.0 meters.

4.3. Corrugated Steel Culverts

In Figure 9 there is presented the cost for a corrugated steel structure for diameters between 1.40 and 3.80 m and pipe lengths of 5, 6, 7 and 8 m. In the mentioned diagram, the curves breaking points are the result of the plate thickness modification.

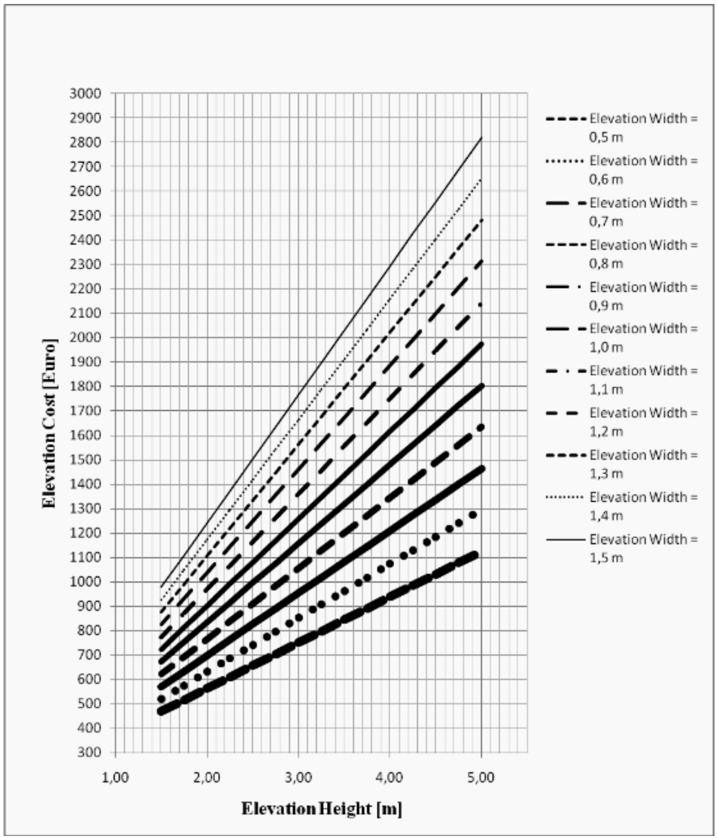


Fig. 7. *Elevations costs in function of dimensional elements*

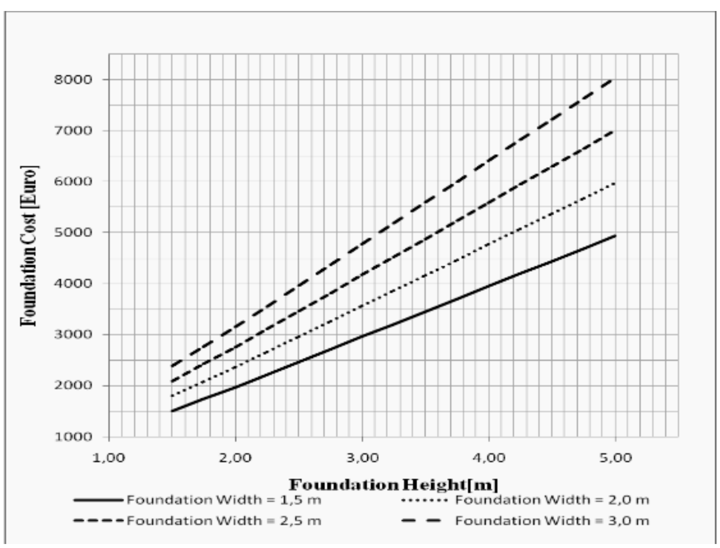


Fig. 8. *Foundations costs in function of the dimensional elements*

Fig. 9. *Costs for corrugated steel culverts in function of length and span*

5. Conclusions

Technical solutions choices for crossing works (bridges and culverts) is very important because it involves high capital investments for their realization [1], [2], and, at the same time they are necessary for water streams protection and their biodiversity. The technical solution choices criteria are multiple and they refer to: location characteristics, foundation terrain, the necessary work duration, but the most important criterion is represented by the overall work cost. The costs diagrams presented in the paper permit the execution cost evaluation for concrete reinforced prefabricated decks, glulam decks, foundations and elevations for concrete abutments, as well as for corrugated steel bridges and culverts. In case of concrete bridges, the cost diagrams for decks and abutments facilitate a span optimization by considering that the small spans are frequently associated with higher abutments and more expensive foundations. Also, for spans smaller than 6-8 m, especially in terrains where a deep foundation is required due the inadequate bearing capacity of the superficial terrain layers, the first solution to be considered is represented by corrugated steel culverts.

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