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DESIGN OF A PRECAST REINFORCED CONCRETE BRIDGE ON THE „VALEA ROŞIE" MAIN FOREST ROAD, KM 1+110

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Abstract

This project contains the designing of a precast reinforced concrete bridge on main forest road "Valea Roşie", km 1+110. The bridge will be sized for 2nd category of loading (according to STAS 3221-74) and it will be designed with one lane. The hydraulic capacity was determined after the flow hazard and river geomorphology. .It is necessary to size the main beams of the bridge to support the load, the bending moments and the oblique section of them. The deck size must be calculated to resist its own weight and the layers above it. There are differences between beam and deck design; the load being the common factor design for both. The final phase consists of predimensioning, designing and verification of abutment. The design process ends with determining optimal size in correlation with service the bridge is expected to provide.This project contains the designing of a precast reinforced concrete bridge on the "Valea Roşie" main forest road, km 1+110. The bridge will be sized for 2nd category of loading (according to STAS 3221-74) and it will be designed with one lane. The hydraulic capacity was determined based on the flow hazard and river geomorphology. It is necessary to size the main beams of the bridge so as to support the load, the bending moments and their oblique section. The deck size must be calculated to resist its own weight and the layers above it. There are differences between beam and deck design, the load being the common factor design for both. The final phase consists of predimensioning, designing and verification of abutment. The design process ends with determining the optimal size in correlation with service the bridge is expected to provide.

Key words: *flow hazard, river geomorphology, lateral erosion*

INTRODUCTION

The space for water flow under the bridges is sized at maximum flows, with higher or lower probabilities of occurrence depending on the class of importance they are assigned to. The bridges and culverts located on forest roads are dimensioned in terms of hydraulic for the same degree of protection (insurance) as the roads they serve.

It is considered that a bridge operates under normal conditions when the water leakage occurs by ensuring adequate space for floating debris moving. In these conditions, a long time operation does not endanger traffic on the bridge.

The flow calculation Qc is the water flow at which the dimensional elements of the bridge (opening, deck bench-mark, depth of foundation, etc.) are calculated and has a theoretical probability of exceeding equal to the degree of protection required for normal operating conditions.

As compared to the flow calculation Qc, the verification flow Qv is a higher water flow which enables the verification of the applied solution. It has the probability of exceeding equal to the degree of protection required for special operating conditions. At this level, the operation of the bridge is limited to short periods of time. When the verification flow Qv is determined using indirect methods, its value is increased by 20%.

MATERIALS AND METHODS

For the execution of the bridge's design and its use in safety conditions, it was necessary to determine several parameters, as it follows: hydraulic calculation of the bridge, to determine the maximum water flows, depending on the class of importance the bridge is enclosed to; calculation of the main beams of the bridge, which is done according to the loads they are subjected to, requests and resistance to bending moments; calculation of the component slabs; predimensioning, calculation and verification of abutment.

RESULTS AND DISCUSSIONS

Building a bridge over a stream changes its natural flow regime. The reduction of section through partial occlusion of the riverbed by bridge piers and abutments determines an increasing speed under the bridge and its level upstream the bridge. Increased water velocity subject to a modified regime as compared to the natural one, should be moderate so as not to brutally affect the natural balance of the riverbed, not to cause dangerous scouring for the bridge foundations or other downstream arrangements.
Water flow and velocity at a given level are determined using the relations:

$$Q = A \cdot V$$

$$V = C \cdot \sqrt{R \cdot J}$$

Where:
A – area of the cross section of the watercourse;
R – hydraulic radius, R = A/P;
P – wetted perimeter of the cross section;
J – hydraulic slope;
C – Chezy coefficient, C=Ry/η;
η - riverbed roughness;
y – coefficient, 1/6 for water courses in lowland areas and ¼ for water courses in hilly areas.

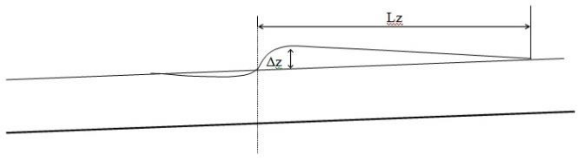
When determining the opening, the following assumptions are allowed:

- The level of water under the bridge subject to a modified regime is the same as under natural conditions;
- The speed water under the bridge V_p is higher as compared to its natural regime V; V_p = E V, where E is the scouring coefficient of the riverbed, E = 1,1…1,5; Vp = 2,518 m/s;
- The riverbed is not subject to scouring;
- Increased water velocity under the bridge is based on its increasing level upstream of the bridge.

The area required for water flow under the bridge Ap, measured between abutments, the natural water level in natural conditions and the riverbed not affected by scouring, are determined following the relation:

$$A_p = \frac{Q_c}{\mu \cdot V_p}$$

Where:
Qc – flow calculation;
μ - coefficient of riverbed occlusion by bridge piers and abutments (μ = ε e);
ε - hydraulic contraction coefficient;
e – coefficient that takes into account the area occupied by bridge piers.
The deck bench-mark is established so that the water level at the flow calculation, respectively the verification flow and the lowest part of beams, ensure the normal height for free passage of the floating.
Reducing the drainage section, through partial occlusion of riverbed by bridge piers and abutments, increases the level of water upstream the bridge, which is called backwater (Δz). It is necessary to know the value of the backwater in order to prevent the overflow of water over the sides.



The cant level value can be calculated approximately using the relation:

$$\Delta z = \frac{V_p^2 - V^2}{2 \cdot g}$$

where:
Vp – average speed in the bridge section;
V – speed in natural conditions;
g – gravitational acceleration.
The cant level extends on a length (Lz) which is determined base on the relation:

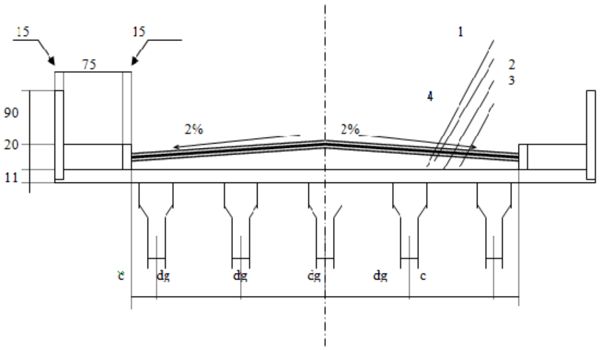
$$L_z = \frac{2 \cdot \Delta z}{J}$$

where:
J – free surface water slope which can be approximated with the riverbed slope.
If the average velocity under the bridge (Vp) is higher than the average drive speed of the material within the riverbed (Va), in flood conditions, the riverbed is deepening by scouring. General scouring (afg) occur throughout the section of the riverbed and are proportional to water depth (h).

afg = ha-h = h(E-1) = 0,422 m

Because of local currents, around bridge piers and abutment, supplementary scouring can appear, also called as local scouring. The evaluation of local scouring by calculation is often accompanied by large errors due to their dependence on many factors with random appearance, difficult to master via formulas.

Cross section scheme of the bridge



1. road 2*2,5cm---------------ashpalt concrete;
2. protection blanket 2cm--- cement concrete;
3. waterproofing 1cm--------3 mill board layers cemented with bitumen;
4. slope concrete and levelling blanket, min. 2 cm------- cement concrete.

Over the slab, a slope concrete is poured, having a 2% inclination and a border height of at least 2 cm. On top of all comes the road which consists of 2 layers of asphalt concrete (2x2,5 cm), the waterproofing (1 cm) and some layers of waterproofing protection (3 cm).

The payloads are given by loading of people, convoys of vehicles A10 and tracked vehicles S40. Loading of people is calculated by formula:

$$p_o = 1{,}4 \cdot p_n \cdot 2 \cdot T$$

where p_n = 3 kN/m^2, and T = 0,75 m.

Therefore, p_o= 6,3 kN m.

The transverse distribution calculus requires the calculation of the stiffness coefficient of the network of beams, that represents the base on which the lines of influence of the reaction are removed from the tables for the network with three simply supported beams.

The distribution coefficient Z is established using the formula:

$$Z = \frac{I_a}{I_g} \cdot \left(\frac{L_c}{2 \cdot d_g} \right)^3$$

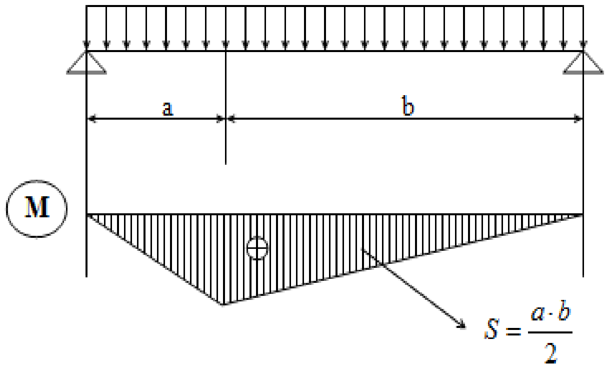
where:

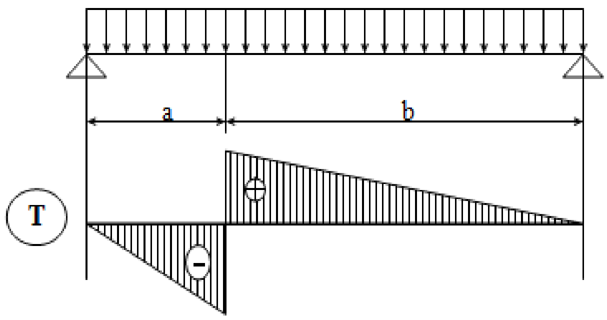
- I_a – moment of inertia of the crosspiece,

$$I_a = \frac{(2 \cdot d_g + b_2) \cdot h_g^3}{12};$$

- I_g – moment of inertia of the main beam;
- L_c – calculating opening;
- d_g – distance between beams.

In order to capture as accurately as possible the way that the beams are loaded, they will be divided into 10 sections. Due to the fact that the values are symmetrical, the calculus will be made only for 5 sections of the beam. The drawing of the calculus hypothesis is presented as it follows.





For the calculation at bending moments, it is used the B300 concrete brand with the tensile strength Rc = 140 daN / cm^2. It is also used the reinforcement PC52 that has a torsion resistance R_a = 29 kN/cm^2. The beam is treated as a section in the form of "T". For this, from the maximum available width of a beam (bk), only a beam portion is taken (bp), which is calculated as it follows: bp = mc*bk, where mc is a coefficient that depends on the ratio between bk and calculating opening. The values of mc are given in tables according to this ratio.

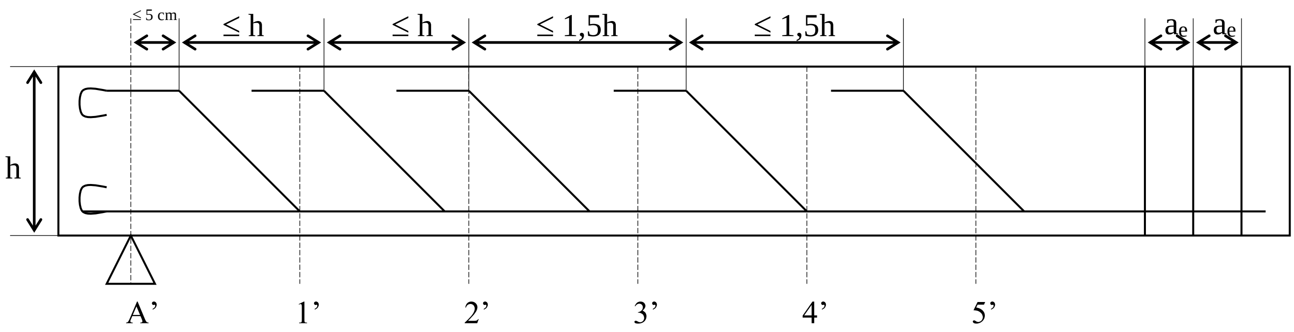
In order to increase the resistance of the beam to the effect of shear forces, used stirrups and inclined reinforcement will be used. The inclined reinforcement is made by raising a maximum of 70% of the longitudinal reinforcement resistance, as it is no longer necessary for taking the bending moments. The remaining 30% and at least 2 bars remain straight up beyond the abutment. The reinforcement scheme is shown below:

- ➢ The concrete brand B300 with Rt = 10 daN/cm2

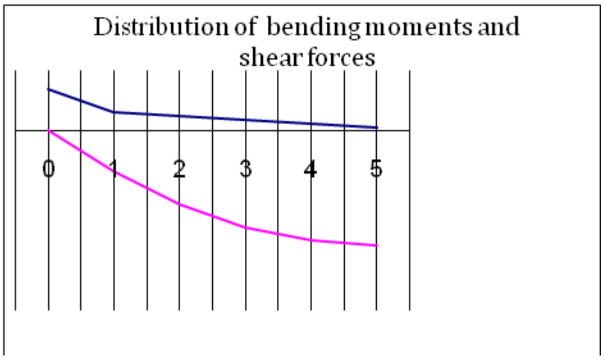
The bridge slab is loaded by its own weight and the layers above the slab (road, waterproofing, slope concrete), as well as the weight of payloads (vehicles, people). The calculation of slab in console is different from the calculation of central slab, having in common only the loadings.

Loading of parapet is a concentrated action. Loading of slab and the protective layers can be distributed evenly or unevenly, but in order to simplify calculations, one uses a uniform loading of pavement and another loading of road.

Experimentally it has been found that the loading determined by the concentrated force is distributed within the slab by angles of about 45o, so that only a part of the slab is subject to loadings. Based on this finding, one can calculate also the slabs in console from the bridges made of beams.



The distribution of shear forces and bending moments is as shown below:



For calculations readiness, the following considerations are taken into account:

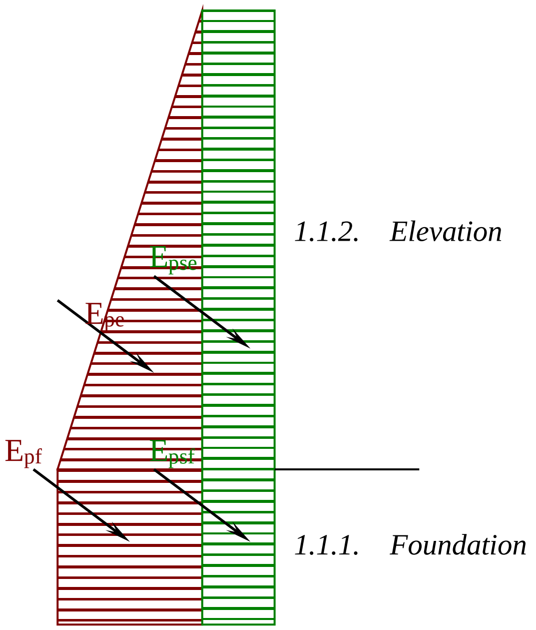
- ➢ The stirrups will be adopted from OB37 with Retr = 2100 daN/cm2;
- ➢ The distance between stirrups, ae = 20 cm, in compliance with the conditions imposed;
- ➢ The diameter of stirrups, d = 10 mm;

The surface on which the loading of the wheel is transmitted to the slab, is obtained from the distribution of loading at 45o and is considered to be a rectangle with sides a and b, where a= a0+2s and b= b0+2s, "s" being the thickness of the layers of the road.

The central slab is charged by the direct loading of vehicles and the permanent one, as well as the compound effect of the main beams. The dominant loading results from the direct charge. Since the ratio of the length and width of the panel is higher than 2, the slab is calculated and it is reinforced only on the short side direction.

The abutment is calculated using the method of limit states, mainly on the strength and stability. This calculus standardized by STAS 10111/1-1997.

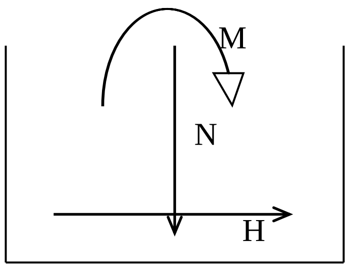
The diagram of ground pushing is shown below:



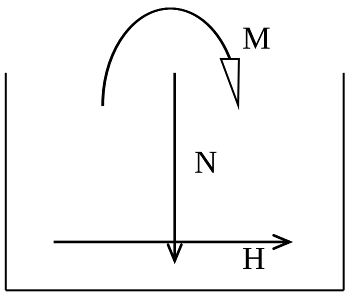
Usually, it is checked the base of the elevation and the base of the. The checks that are made are the following:

- sliding check;
- tilting check;
- resistance of the foundation soil check;
- concrete sections check.

Sliding check

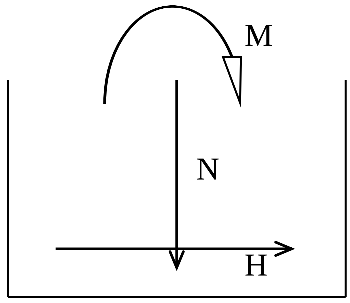


Tilting check

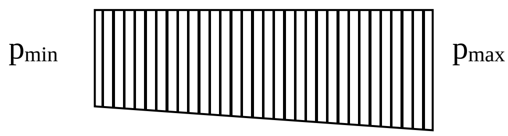


In practice, one of the terms of the equilibrium expression is much lower than the other. Usually, the bridges with one or two lanes, a_x is much lower than a_y and as a result the relation becomes: $\frac{e_y}{a_y} \le \sqrt{m}$.

Resistance of the foundation soil check



$$p_{\min,\max} = \frac{N}{A} + \frac{M}{W} \le p_c$$

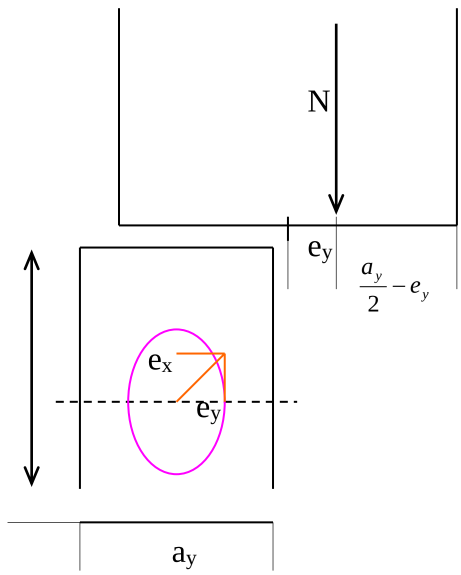


A – surface of the base; $A = a_y \cdot a_x$

$$W = \frac{a_x \cdot a_y^2}{6}$$

p_c – conventional pressure

Concrete sections check



$$\frac{\sum H_i}{\sum N_i \cdot \mu} \le 0.8$$

$$H \leq 0.8 \cdot T$$
$$T = \mu \cdot N$$

$N \leq 0{,}9 R_b A_a$
R_b – concrete resistance to compression;
A_a – active area.

$$A_a = 2 \cdot a_x \cdot \left(\frac{a_y}{2} - e_y \right)$$

These checks are made in the following calculation assumptions:

- C_1 – abutment without drainage and embankment, acts only its own weight. Abutment can only be tilt back to the wall. Tilting check is carried out;
- C_2 – abutment with drainage and embankment set-up, acts its own weight and ground pushing. Tilting and sliding checks are carried out;
- E_1 – abutment deck loaded of convoy A_{10};
- E_2 – abutment deck loaded with special vehicles S_{40}.

CONCLUSIONS

In conclusion, if all these steps will be respected and followed accordingly when designing a bridge, a durable and resistant construction work will be achieved.

ACKNOWLEDGEMENTS

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