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Analysis of stress state on plates of concrete bridges with prefabricated beams

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Abstract

The calculation methods necessary for dimensioning the concrete bridges, in force in Romania, stipulate a simplified calculus for these ones by taking into account the ratio between plate sides. Thus, the plates supported on their contour, for which the sides ratio is bigger than 2, called long plates or plate bands, the calculation is made considering that significant bending moments could appear only on the direction of the plate short side. The calculus is made for plates with unitary width assimilated to simply supported beams on the short direction. The maximal bending moment, resulting according to this static scheme, is distributed between the middle of the plate and its support, through coefficients, which take into account the ratio between the beam height and the plate width. The fixing of plate on beams is not a perfect one, but an elastic fixing and the fixing degree of plates on beams is not quantified because the utilized coefficients are considered to cover all possible situations that could occur.

A detailed analysis of stresses acting upon reinforced concrete bridge plates could be achieved either through at site measurements, or using numerical methods of calculation. In order to validate some generally applicable results a great number of measurements on reinforced bridge plates are necessary, which means a special financial effort. Providing that the finite elements are correctly chosen, the analysis of bridge structures by means of the finite element method offers results much close to reality and the number of structures to be studied is practically unlimited.

The present paper presents the structural analysis of a reinforced concrete bridge with simply supported prefabricated beams made of prestressed concrete and the superstructure plates represent the interest area. The purpose has been to emphasize the maximal stress states in the bridge plates (bending moments on their short direction), dimensioning their characteristic sections, as well as the eventual appearance of non-characteristic moments in the same section caused by their interaction with beams and cross beams.

Within the study the nonlinear behavior of materials has been taken into consideration by changing the rigidity of elements in plate areas with big stresses in two variants, depending on their magnitude. The analysis using the finite elements method has been verified through the calibration of the utilized model

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based on the results of previous tests and the final results are presented and debated in detail.

1. INTRODUCTION

Because it is frequently found in the Romanian network of roads, the behavior of a bridge superstructure made up of 4 prefabricated beams joined through monolith plates, built according to standard projects, has been studied.

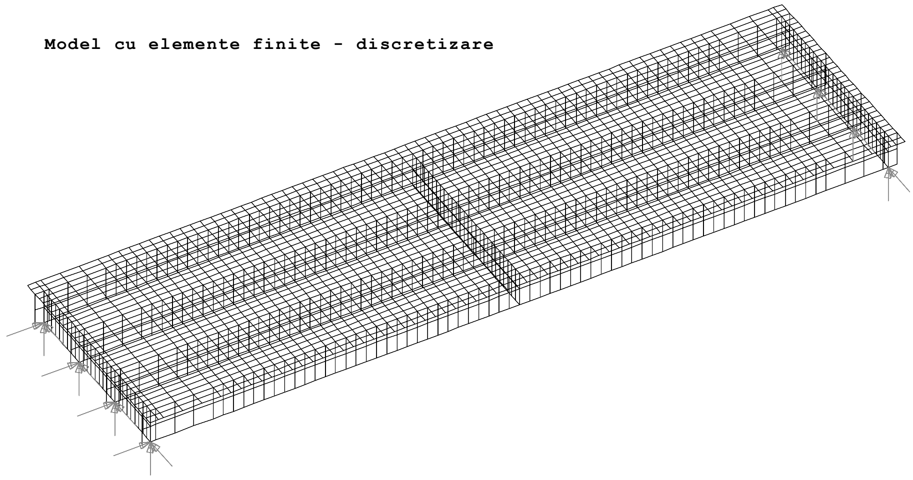

Figure 1. Model used in numerical analysis

The superstructure of the analyzed bridge consists of a concrete flooring with four simply supported beams of 33 m length, prestressed concrete prefabs.. The prefabricated beams have a T section with bulb, 1,80 m height and 1,20 m the top flange width. The core thickness is of 0,16 m and the bulb of beam's inferior side is of 0,60 m width. The beams are achieved of B500 concrete mark (C32/40) and are reinforced with 7 fascicles 44ϕ5 SBP I. The monolith plates are reinforced with steel PC52 and are achieved of B400 (C25/30) concrete mark, with 0,18 m width. The distance between the prefabricated beams is of 2,70 m, the bridge traffic road has 7,80 m width and two bracket pavements of 1,00 m. The cross beams are achieved of B400 (C25/30) concrete mark and are prestressed with two fascicles 24ϕ5 SBP I. Above the resistance structure are disposed the layers of the road, represented by the inclination concrete, with 2 cm minimal thickness and 2% inclination, 1 cm waterproofing made of bituminous aluminum foil and two layers of cast asphalt 2.5 cm each.

In order to study the stress state that can occur in the bridge plates, an analysis by means of the finite element method has been made. Using the calculation program

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LUSAS, a linear static calculus has been achieved. The discrete model used keeps the same geometry as the real structure (fig. 1).

When testing the bridge, deflections in different points of the flooring have been measured. For the calibration of the model, the aim was that the discrete structure in the LUSAS program analysis to have the most appropriate behavior to the real one. In table 1, the measured displacements and the calculated ones using the LUSAS program in beam area, in the middle of the bridge opening, under the loading utilized for bridge testing, are presented.

Table 1

Displacements (cm)	Beam 1	Beam 2	Beam 3	Beam 4
Measured	13,70	12,60	9,00	6,20
Calculated	13,70	11,57	9,10	6,44

In order to discrete the flooring component elements, two type of finite elements [3]: "shell", with both plate and QS14 type membrane behavior, with regular rectangular form and "beam", BMS3 type, have been utilized.

To discrete both monolith and prefabricated flooring plates and the cores of prefabricated beams and cross beams, elements "shell", QS14 type, with sides ratio between 1.50 and 3 have been utilized. To discrete the prefabricated beam bulbs elements "beam", BMS3 type, have been utilized. By using these types of finite elements and by choosing such dimensions for "shell", elements QSI45 type, the softest discreting of interest areas and the achievement of available results, that should not be influenced by the wrong chose of finite elements [2;4], have been taken into account.

The loadings took into consideration are the ones provided in the design existing Romanian standards and regulations for design, grouped so that the maximal stresses state in the superstructure plates should be obtained. Both, the construction technological process of the bridge and the age of concrete at the loading moment were taken into consideration.

Thus, on a model made of 4 independent beams, their own weight, the prestressing forces, the fresh concrete weight of the monolith plates and cross beams as well as the weight of the necessary casings and scaffoldings have been taken into consideration. At the geometrical model of the entire bridge it has been considered, in different loading steps, the putting out of center of the scaffoldings simultaneously with taking over by the entire structure of the monolith plates and the cross beams; the cross beams prestressing, losses of tensions in longitudinal and transversal fascicles; the contraction of plates monolith, the proper weight of permanent loadings (inclination concrete, waterproofing, cast asphalt; pavements).

The loading class for which the bridge was designed is the E loading class. Therefore this particular one has been also taken into consideration in this study. After preliminary verifications it can be concluded that the loading of bridge plates with the special vehicle V80 is more disadvantageous than loading it with truck convoys A30 [1], and that is why this loading has been used for the final study only. The vehicle position was established in order to obtain the greatest stresses in the superstructure plates. During the study, the nonlinear behavior of materials was taken into consideration by modifying the element rigidity in the plate areas with great stresses (bending moments on plates short direction).

A comparative analysis regarding the influence that the rigidity of superstructure components has on stress state in plates has been achieved for the calculus of stresses caused by the special vehicle V80. Considering two variants for modeling the material, two discrete models have been taken into account.

In the first variant we considered that the rigidity of the element is given by the elasticity module E, according to STAS 10111/2-1987 [7] and that upon the entire concrete superstructure there is an elastic, isotropic and homogenous material, with the same rigidity. Therefore it was considered:

- E1 = 36 000 N/mm^2 – for the concrete in prefabricated beams, C32/40 class;
- E2 = 32 500 N/mm^2 for the concrete in cross beams and monolith plates, C25/30 class;.

Since it is extremely difficult to model non-homogenous, anisotropic and elastic-plastic behavior of reinforced concrete for the entire bridge superstructure, the reduction of finite element rigidity in strongly stressed areas was taken into consideration.

The second finite elements model has been achieved using reduced elasticity modules, according to STAS 10111/2 – 87 provisions for the verification at limit states of normal operation (verification at limit state of strain):

- E1 = 30 600 N/mm^2 – for the concrete in cores and bulbs of prefabricated beams, C32/40 class, representing 0.85 E C32/40;
- E2 = 21 600 N/mm^2 for the concrete in plates of prefabricated beams, C32/40 class, representing 0.6 E C32/40;
- E3 = 19 500 N/mm^2 for the concrete in monolith plates, C25/30, representing 0.6 E C25/30;
- E4 = 27 625 N/mm^2 for the concrete in cross beams, C25/30 class, representing 0.85 E C25/30.

The superstructure plates are bent mainly on the short direction, on which both monolith plate elements and prefabricated plate elements behave as reinforced concrete elements. For this reason, their rigidity has been considered as 60% of the

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rigidity of the entire concrete section. The cores and the bulbs of beams as well as the cross beams work mainly on the prestressing direction and for this reason their rigidity has been considered as 85 % of the rigidity of the entire concrete section.

2. ACQUIRED RESULTS

The aim was to point out the maximal stress states in the bridge plates (bending moments on their short direction) dimensioning their characteristic sections (on the support and in field), as well as the eventual appearance of non-characteristic bending moments in the same sections, caused by the interaction with beams and cross beams.

The results acquired for bending moments in plates are presented comparatively, in the diagrams from figures 2 and 3 representing the variation of moments on the support and in the field of the plate.

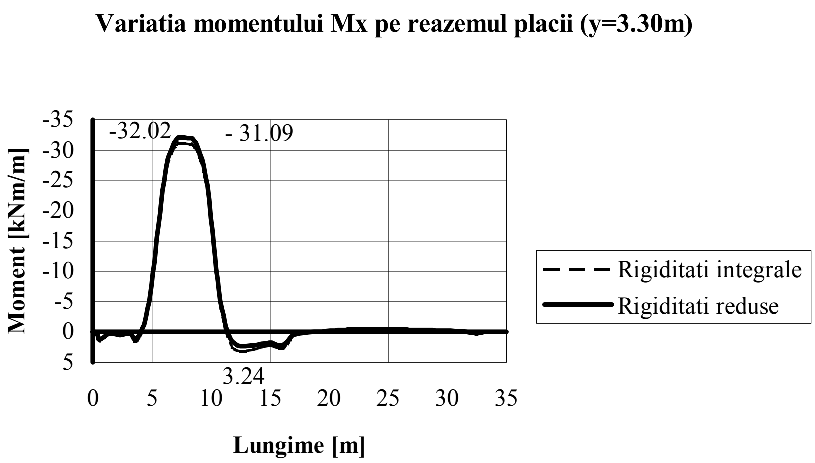

Figure 2 Variation of bending moment Mx on the support of the plate (y=3.30m)

From the point of view of stress state in the superstructure plates the differences between the two considered cases are insignificant.

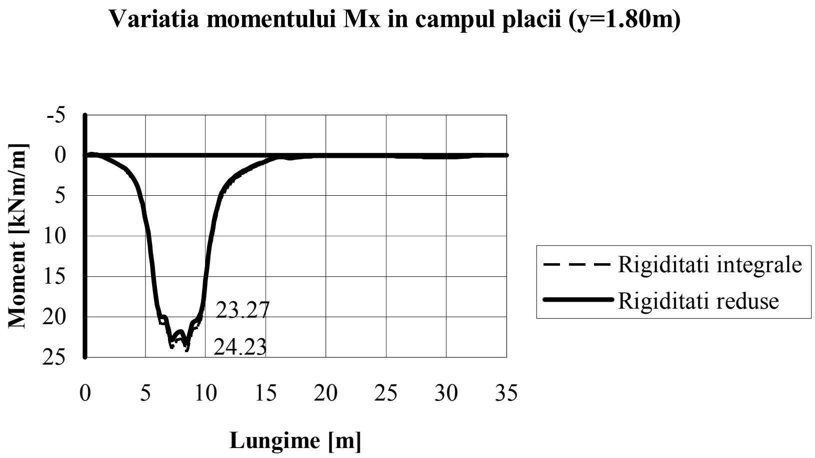

Figure 3 Variation of bending moment Mx in the field of the plate (y=1.80m)

In figures 4 and 5, the diagrams of moments in plates, in the ordinates where their maximal values are registered, are also presented.

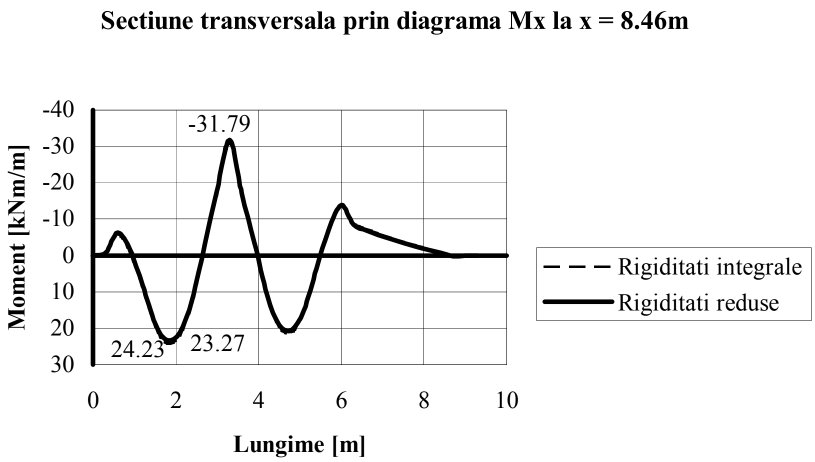

Figure 4 Diagram of bending moments Mx, for x=8.46m

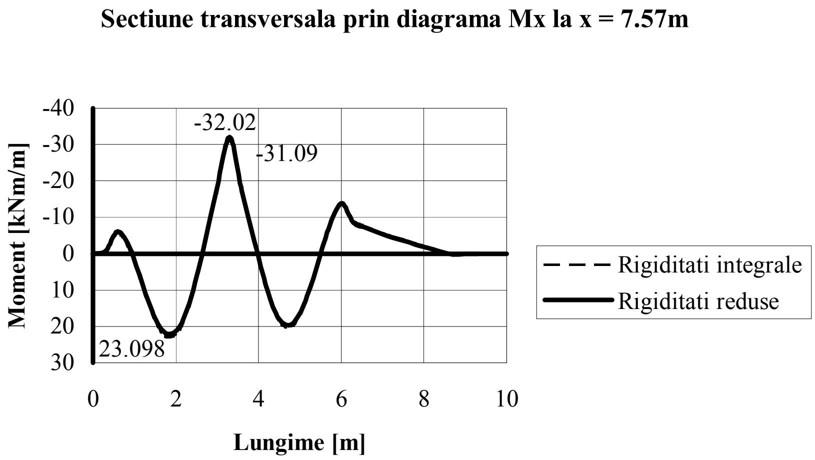

Figure 5 Diagram of bending moments Mx for x=7.57m

Thus, in the second case, an increase of 0.93KNm of the moment on plate's support, representing 3% of the global value and a reduction of 0.96KNm of the moment in the plate's field, representing 4% of the global value, are registered.

These differences appear not only by considering reduced rigidities for plates, but also by considering a reduction of rigidity different for plates and beams. Thus, while the rigidity of plates is reduced to 0.6 Eb, the rigidity of beams cores and bulbs is reduced only to 0.85 Eb.

The plate supports on the long direction, formed by the cross beams, as well as the increase of the thickness of beams core in the flooring support area, are influencing the presented diagrams by disturbing their form. Since the special vehicle V80 has been placed in the middle area of the plate panel and its influence extends for a sufficiently small length (7.60 m, meaning 23.5% from the opening of the bridge, respectively 47% of plate's length between two cross beams), in the remaining part of the plate the bending moments on its short direction have extremely small values. This phenomenon implies the fact that the disturbances produced by the cross beams and by beams core thickening are only qualitative.

Considering the analysis of the acquired results we can point out that, in the two studied variants, the major influence of a loading with the special vehicle V80 is a local one. Even in case of reducing the rigidity for the elements of the most stressed monolith plate, the participation in stresses taking over of plate areas far from the vehicle is reduced and bending moments with insignificant values (smaller than 0,42 KNm/m) appear.

3. CONCLUSIONS

Based on the numerical analyses that have been made, the conclusion is that the plates of these types of bridges, especially their middle sections, are dimensioned with a small safety coefficient and any construction deficiency could have a rather serious negative effect upon the construction behavior during the operation period.

It can also be observed that, taking into consideration reduced rigidities is practically not important from the point of view of stress state in the bridge plates, because the differences between the values obtained in these two studied cases is at most 4%.

If for a certain bridge superstructure there is no information to suggest the different reduction of rigidity, then for the calculus of the bridge plate, a most elaborated analysis by taking into consideration the reduction of its rigidity in certain areas can be avoided. This much complex approach is justified only when the real data suggest a significant reduction of rigidity in certain areas of superstructure plate.

References

1. Chiotan, C., *Contribuţii privind comportarea şi calculul plăcilor podurilor de şosea din beton armat ţinând seama de conlucrarea cu celelalte elemente ale suprastructurii,* Teză de doctorat, Universitatea Tehnică de Construcţii Bucureşti, 2000.
2. FEA ltd., *LUSAS 12.0 Theory Manual.*
3. FEA ltd., *LUSAS 12.0 Finite element library.*
4. Fierbinţeanu, V, *Calculul automat al structurilor*, Institutul de Construcţii Bucureşti 1984.
5. I.C.P.Tc – *Încercarea a două deschideri la podul de la Podu Vadului,* Contract 4197/1984, 1984.
6. Radu, P.I., Negoescu, E, Ionescu, P., *Poduri din beton armat*, Editura Didactică şi Pedagogică, 1981.
7. STAS 10111/2-87 *Poduri de cale ferată şi şosea. Suprastructuri din beton, beton armat şi beton precomprimat. Prescripţii de proiectare*.