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Analysis of efforts state from bridge decks with hinged beams when the hinges are blocked

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Summary

For the construction of bridge superstructures, especially of road bridges, have been used widely beams with hinges (Gerber girders). Due to some design deficiencies in the hinges area, after a 40-50 years operating period, these beams had to be rehabilitated. In most cases the rehabilitation meant their transformation into continuous beams, thus modifying the efforts state from the structure.

The present paper analyses the modification of the efforts state from a bridge superstructure with hinged beams transformed after the rehabilitation works into continuous beams, by blocking the hinges. The paper also analyses the measures which have to be taken for increasing the bearing capacity, as a result of the modification of efforts states. The analysis concludes that the major modifications of the efforts states are given by the traffic load.

KEYWORDS: Bridge, superstructure, hinged beams, rehabilitation, main beam, secondary beam, efforts state.

1. INTRODUCTION

In Romania, between the 1950s and 1970s a large number of bridges were constructed, especially road bridges, from reinforced concrete and fewer steel bridges.

From all the solutions that were used in the construction process, the one which was mostly used for long spans bridges is the solution of using hinged plate beams (Gerber beams). In this context, the following reinforced concrete structures and steel bridges could be mentioned, table 1.

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Tabelul 1. Examples of bridges with Gerber beams superstructure

Nr. Crt.	Super-structure Type	Roadway Number	Km. point	Obstacle (River)	Locality/ construction year	Spans Disposal (meters)
1	Roadway reinforced concrete bridges	E 85	226+377	Trotuş	Adjud 1951/2001	19,00+7x22,00+20,00
2		E 85	288+765	Bistriţa	Bacău 1954(2007)	34,50+7x35,00+34,50
3		DJ 208G	34+312	Moldova	Tupilaţi	17,00+13x22,00+17,00
4		DN 24	33+205	Berheci	Berheci 1960/2002	12,10+13,00+12,10
5		DN 15D	51+021	Siret	Gîdinţi 1966/2001	23,60+7x27,50+23,60
6		DN 15B	60+665	Moldova	Timişeşti 1961	19,60 +9x25,65+19,60
7		DN2D	33+161	Putna	Vidra 1965	19,50+7x26,20+19,50
8		DN11	109+142	Oituz	Oituz 1961	14,00+28,00+14,00
9	Railroad steel bridges	Linie CF Bucureşti - Constanţa	-	Dunăre	Cernavodă (pod Carol I) 1890	2x140,00+ +190,00+2x140,00

In the following images some of the bridges mentioned in table 1 are depicted.

Photo. 1 Bridge over Berheci river, at Berheci (constructed in 1960/rehabilitated in 2002)

Photo.2 Bridge over Moldova river, at Timişeşti (constructed in 1961)

Photo.3 Bridge over Putna river, at Vidra (constructed in 1965)

While steel bridges with hinged beams had a good reaction in time, most concrete bridges constructed in the same way had degradations in the hinges area, from which the following should be mentioned: concrete and reinforcement corrosion, concrete exfoliation, cracks, crevices etc.

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The degradation state from the bearing areas of the independent decks for some of the bridges mentioned above is depicted in the following images.

Photo.4 Bridge over Bistriţa river, at Bacău

Photo.5 Bridge over Berheci river, at Berheci

Photo.6 Bridge over Moldova river, at Timişeşti

Photo.11 Bridge over Oituz river, at Oituz

Photo.12 Bridge over Putna river, at Vidra

These degradations were a result of the fact that the expansion joints covering devices between the main and secondary beams failed to ensure tightness against water infiltration from the carriageway and were aggravated over time, repair of these areas being almost impossible due to difficult access.

There were some bridges where the superstructure had to be replaced as a result of degradations and serious flaws (the bridge over Bistriţa river, on E85) and in the case of other bridges the hinges were blocked and the main longitudinal stress carrying members of the superstructure were transformed into continuous beams (the bridge over Trotuş river, at Adjud, on E85).

The solution of using Gerber beams for bridge superstructures was chosen between the 1950s and 1970s because structures with hinges are less sensitive to bearing devices displacements caused by accidental foundation settlements; a frequently encountered phenomenon in the case of direct foundations, widely used in that period. Nowadays, bridge infrastructures are constructed with deep foundations for which settlements are rarely encountered, thus superstructures with continuous beams can be chosen unreservedly.

2. THE EFFORTS STATE IN HINGED BEAMS OR CONTINUOUS BEAMS

If at a continuous beam acted by a uniform distributed load (the superstructure weight), hinges are introduced in the sections of zero bending moment, the beam is transformed into a hinged beam for which the distribution of bending moments is identical with that of the continuous beam (fig.1) [2].

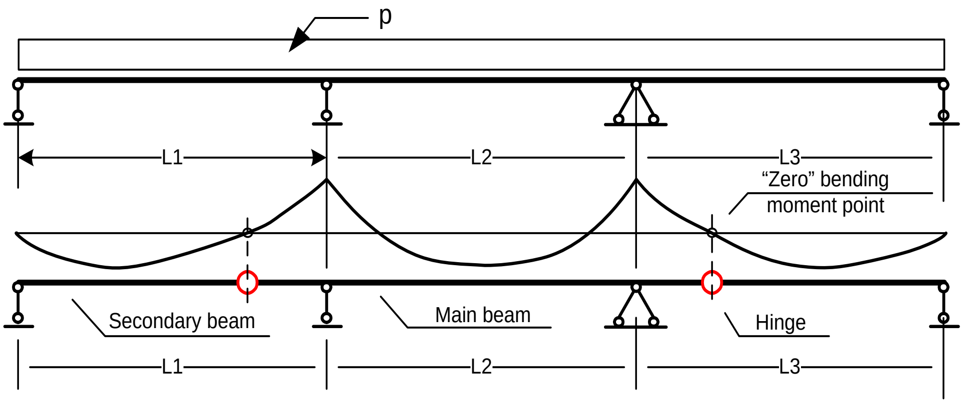

Fig.1

As a result, in the case of the rehabilitation of a bridge superstructure by blocking the main beams hinges and by transforming them into continuous beams, the efforts state produced by permanent loads is the same in both cases (supplementary efforts appear when the superstructure weight increases as a result of rehabilitation, for example, by placing an overcast concrete slab).

Things are completely different as regards the working loads, road or rail type convoys, even when the elevation of the loading class/category is not necessary. In this case, if we are referring to the bending moments, some relevant differences appear for the same sections of both static systems; in the areas where the bending moments from the beams, which became continuous beams as a result of rehabilitation, are higher than the ones corresponding to the hinged beams, an increased bearing capacity is necessary.

The bearing capacity is increased using different methods, the most widely-used are:

- In the case of reinforced concrete superstructures:
    - through additional reinforcement bars installed in the tensioned beam section which are linked to the existing reinforcement bars through connectors of different forms; the new reinforcements are

embedded into a concrete coating poured into framings, when they are located at the lower beam foot (fig. 2a), or embedded into the overcast concrete slab, if they are located at the top of the beam (fig.2b) [3];

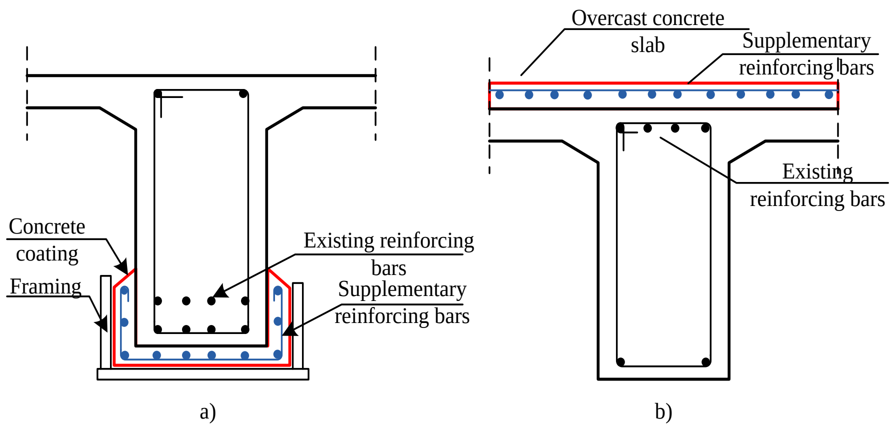

Fig.2 Consolidation methods of reinforced concrete beams

- through additional longitudinal pre-stressing using external pre-stressed cables (without being embedded into concrete) [4];
- In the case of steel superstructures [5],[6]:
  - Enhancement of the girders section by adding additional steel plates at the top flange and/or inferior flange;
  - Through additional longitudinal pre-stressing using pre-stressed cables;

The sections along the main beams, on which consolidation will take place, are determined by drawing of the bending moment distribution diagrams from the working loads considered for the initial structure and the rehabilitated structure, diagrams obtained from the maximum bending moments calculated in different beam sections.

3. CASE STUDY

Those specified in chapter 2 will be exemplified by analysis of the consolidation process of a road bridge superstructure, originally built with Gerber beams which were transformed, through rehabilitation, into continuous beams with three equal spans of 30 metres (fig. 3).

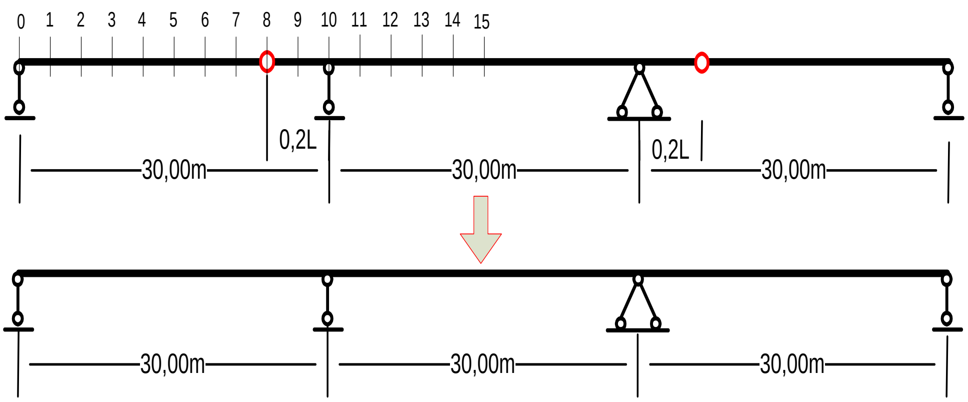

Fig. 3 Gerber beam transformed into continuous beam by blocking the hinges

The live-loads corresponding to E class (A30, V80) are taken into consideration and the maximum and minimum bending moments for each type of live-loads distribution is determined in the sections 0 – 15 of the two static systems. The maximum value of the of the positive and negative bending moments, for each section, is retained and their diagrams for each type of beam (fig. 4) are marked out.

Table 2 Sectional efforts in typical beam sections

Secţiune		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
M^+ (kN m)	Gerber Beam	0	960	1620	2040	2160	2040	1620	960	0	0	0	1008	1776	2304	2592	2760
	Continuous Beam	0	957	1620	2106	2244	2208	1962	1557	942	466,20	392,40	447	1026	1422	1738	1884
M^- (kN m)	Gerber Beam	0	0	0	0	0	0	0	0	0	1110	2220	1998	1974	1974	1974	1974
	Continuous Beam	0	69,20	187,20	279	369	469,50	568	663	758,70	1027,8	1845	1087,20	911,10	750,30	725,40	702,90

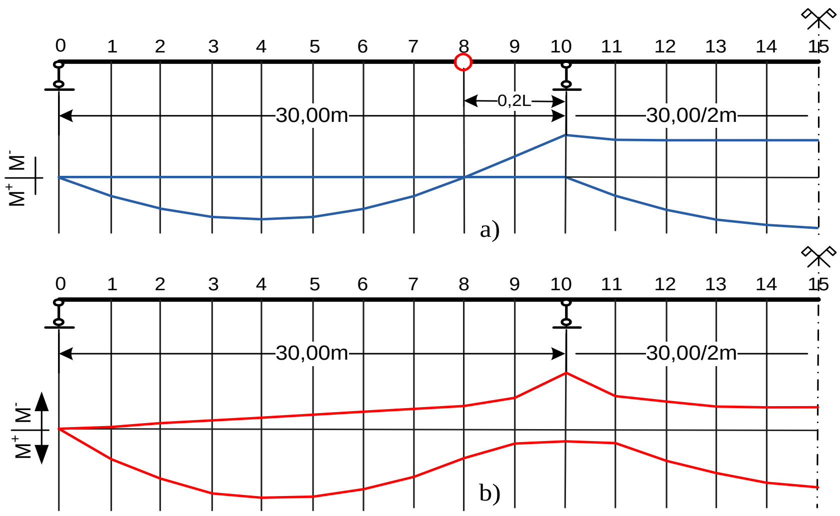

Fig. 4 Bending moments distribution diagrams:
a) Hinged beam; b) Continuous beam

The superimposing of the two bending moment diagram, fig. 5, shows the beam areas which have to be consolidated, in order to increase the bearing capacity, by using one of the procedures described in chapter 2.

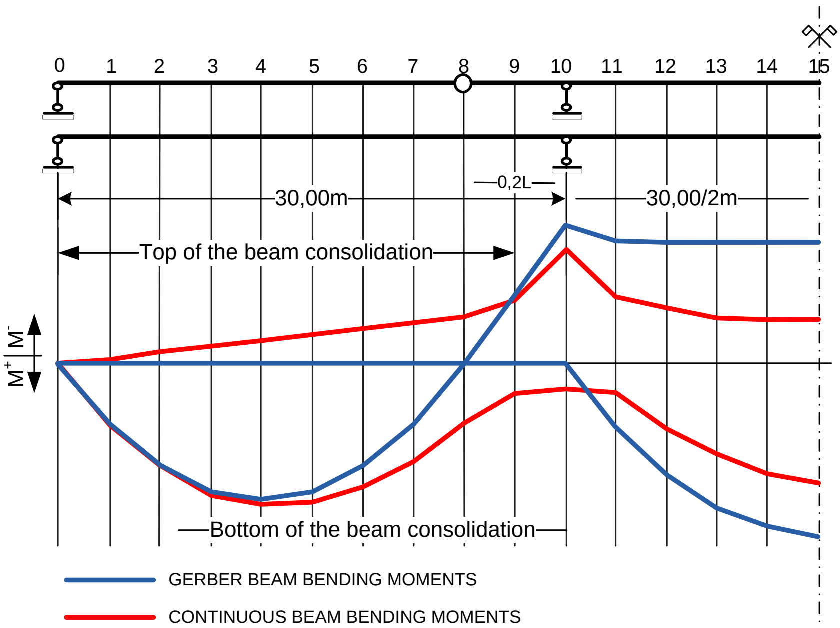

Fig.5 Identifying the beam areas whose section needs to be consolidated

The analysis of the two bending moments distribution diagrams, fig 5, shows that the beam needs to be consolidated in the marginal span at the upper level on the length between 0 ÷9 sections, and at the level of the lower foot on the length between 2÷11 sections, on the other areas the bending moments in continuous beam hypothesis have lower values than those for the Gerber beam.

4. CONCLUSIONS

- The rehabilitation of bridge superstructures with hinged main beams by transforming them into continuous beams, by blocking the hinges, is a widely used solution since it eliminates the discontinuity path from the joints and the danger of roadway water infiltration into the structure of resistance;
- The transformation of a Gerber beam into a continuous beam, by blocking the hinges, does not modify the superstructure effort state, caused by permanent loads when the hinges are placed in the continuous beam sections of zero bending moment, or insignificant changes occur when there are differences in placing the hinges;
- In case of the working loads, large differences appear between the bending moment diagrams of the two structures, unfavourable for the continuous beam in certain sections. As a result, it is necessary to increase the bearing capacity of the superstructure in the areas found on this regard. The differences are large even if the same working loads are taken into consideration, the differences are larger if it is necessary to increase the loading class.

References

1. Blejeru, C., Ionescu, C., The Reconstruction Of Beam Superstructures. Case Study – Bearing Devices Replacement For The Independent Deck, the 6th International Symposium “Actual Trends in Highway and Bridge Engineering”, December 12, 2008, Faculty of Civil Engineering Iași;
2. Mazilu, P., Statica Construcţiilor, vol I, Sisteme Static Determinate, Editura Tehnică, Bucureşti 1957;
3. Viorel, G., Suciu, M., Poduri de beton.Întreţinere şi reparaţii, Editura U.T. Press, Cluj Napoca, 2004;
4. Virlogeux, M., La conception et la construction des ponts a precontrainte exterieure au beton, annalles des travaux publique, Nr. 498, Novembre,1991;
5. Blejeru, C., Jantea, C., The Consolidation of Steel Bridges Superstructures Without Introducing Initial Stress States, the 6th International Symposium “Actual Trends in Highway and Bridge Engineering”, December 12, 2008, Faculty of Civil Engineering Iași;
6. Jantea, A., Jantea, C., The Consolidation of Steel Bridges Superstructures With Introducing Initial Stress States, the 6th International Symposium “Actual Trends in Highway and Bridge Engineering”, December 12, 2008, Faculty of Civil Engineering Iași.