Economical reinforced concrete overpass. Graphical method of calculation.

A V Makarov¹, S A Kalinovsky²

¹Department of Research and design of transport structures, Volgograd state technical University, 1, Academic st, Volgograd 400074, Russia.
²Department of hydraulic and earthwork structures, Volgograd state technical University, 1, Academic st, Volgograd 400074, Russia.

e-mail: sk0522@yandex.com

Abstract. The article considers the issue of designing cost-effective underpasses on the roads. With the wide spread of multi-level transport interchanges, the relevance of this issue is constantly increasing. Currently, mainly designed two and three-span girder viaducts (and most three-span), therefore, in the framework of this research, a comparative analysis of two-span and three-span overpass from the point of view of economy of their construction. It is known that the economic efficiency of bridge structures depends significantly on the size of the cross sections of their structural elements, which in turn depend on the internal forces arising in them from the impact of the entire complex of operating loads. As a result of calculations of internal forces in continuous beams, which are structural elements of overpasses, a graphical method for determining bending moments in two-span continuous beams is proposed, which has sufficient accuracy from an engineering point of view on the one hand and allows speeding up the design process on the other hand. In the process of developing this method, a graph of changes in the bending moments in the main beams of span structures of bridge structures is drawn up depending on the ratio of permanent and temporary loads acting on them.

1. Introduction

A safe intersection of highways is the intersection of roadways at different levels. This intersection has many advantages and is widely used in the construction of main roads. Transport communications of megacities have multi-level intersections, without which the life of the city is impossible [1-3]. Level traffic has the following advantages:

- does not create traffic jams on roads;
- eliminates the conditions for the occurrence of road traffic accidents (RTA),
- slightly improves the environmental situation, since the car emits more combustion products into the atmosphere at the start of the movement,
- reduced fuel consumption, because it does not require a speed reset and stopping vehicles [4-6].

This movement is possible when creating overpasses. The theory and practice of designing urban overpasses is constantly being improved [7-9], taking into account various aspects and features of bridge structures, both newly created [10,11] and existing ones being reconstructed [12]. Usually overpasses are designed one, two or three-span. Single-span overpasses are used mainly on Railways. The efficiency of such bridge structures is determined by their compactness and the minimum number
of structures: box beam and abutments. Operation under load of a single-span overpass is investigated in [13]. In the past, overpasses on highways were designed mainly as three-span ones. Typical projects were also created for three-span structures [14]. Many three-span overpasses are still being built in Russia (Figure 1), which have a number of disadvantages:

1. Only one working span, since the two extreme ones are absorbed by the embankment slope;
2. Inability to widen the road if it is necessary to transfer it to another technical category during reconstruction;
3. More structures require additional funds to maintain and repair the structure.

The disadvantage is also the increased cost of construction due to the greater number of span beams, crossbars, support posts and foundations.

Figure 1. Three-span overpass at an oblique intersection.

On the wide highways and three-span overpasses are used sparingly because of the inability to place in podmoskovnom the envelope the appropriate number of lanes. Therefore, they began to use overpasses with four spans: two working and two side ones to accommodate the embankment slopes. This is the best solution from the point of view of safety, since oncoming traffic is separated by a dividing strip (Figure 2). However, numerous reinforced concrete structures increase the cost of construction, increase construction time and overhead costs, which makes the construction of such overpasses not economical.

2. Classification of public spaces and systematization of requirements for them

The most economical are two-span overpasses that do not have these disadvantages. Such bridge structures can be either split or non-split according to the static scheme. The non-cutting scheme is more effective in this case, because the cross section will be smaller due to the reduction of bending moments and it is not necessary to arrange deformation seams [15]. If you design two-span overpasses as continuous, the moments in the span are reduced by 40%, and the reference moment is reduced by 10%, rather than in the split one. The cost of its construction and operation is less (Figure 3).
3. Proposal of the concept of an updated level public space  
When designing bridges of a continuous system, the internal forces in the main beams are determined by the lines of influence and the designer's reference books. This method is approximate, since the ordinates of the influence lines are defined in some sections, and between sections are approximated by a complex curve. Creating cost-effective overpasses and bridges requires an accurate analytical solution. For three-span continuous bridges, the ratio of spans \( l + 0.794 \ l + l \) is obtained, in which the span moments are equalized [16]. The same bending moments operating in all spans of the continuous lash allow to unify the design of the span structure [17], which will reduce its cost.

For overpasses with two spans, the forces can also be determined analytically. The spans are the same length. A continuous two-span overpass is calculated using the scheme shown in figure 4. A
constant cross-section beam is used for the calculation, as usual, continuous span structures of overpasses are designed [18].

Spans are loaded with a constant $q_{\text{const}}$ load on both spans (Figure 4, b), and each span separately by a time load (Figure 4, c). The bending moment in the cross section of the intermediate support when both spans are loaded with a constant load is determined by the following expression:

$$2M_{R} \cdot 2l = -6\left(\frac{q_{\text{const}} l^3}{24} + \frac{q_{\text{const}} l^3}{24}\right), \text{then} \quad M_{R} = -\frac{q_{\text{const}} l^2}{8}.$$

The bending reference moment from loading one of the spans with a temporary load will be:

$$2M_{R} \cdot 2l = -6\left(\frac{q_{\text{temp}} l^3}{24} + 0\right), \text{then} \quad M_{R} = -\frac{q_{\text{temp}} l^2}{16}.$$

A comprehensive plot of bending moments that takes into account the total impact of a constant and temporary load in an unfavorable combination [19] is presented in (Figure 4, d). The temporary load represents part of the full load on the superstructure. Its size and placement on the span structure is regulated by the normative literature [20].

Usually, the useful temporary vertical load is a fraction of the constant (the own weight of the structure, bridge bed, and equipment). This percentage may vary depending on the amount of constant
load. The constant load, in turn, varies depending on the size of the spans, the material of the span structure, the bridge structure, and other factors. To determine the greatest moments acting in the main beam of the superstructure, a number of calculations with different ratios are performed equal: 0.25; 0.5; 0.75; 1. Based on the results of calculations, a graph of changes in the reference and maximum span bending moments that occur in the main beam from this load ratio is constructed (Figure 5). The maximum span bending moment occurs in the cross section \( \frac{3}{8} l \).

\[ q_{\text{temp}}/q_{\text{const}} \]

The resulting graph makes it possible in a number of cases to determine the bending moments in the main beam graphically with a sufficient degree of accuracy, which will help speed up the design process.

4. Conclusions
1. Two-span overpasses on highways are the most economical bridge structures.
2. When designing such structures, you can use a graphical definition of the calculated bending moments with a sufficient degree of accuracy.
3. The presented graph allows you to immediately determine the maximum calculated bending moments acting in the main beam by the load ratio.
4. Thus, today it is rational to build two-span overpasses of continuous type.

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