IOP Conference Series: Materials
Science and Engineering

PAPER • **OPEN ACCESS**

Economical reinforced concrete overpass. Graphical method of calculation

To cite this article: A V Makarov and S A Kalinovsky 2020 *IOP Conf. Ser.: Mater. Sci. Eng.* **962** 022051

IOP Conf. Series: Materials Science and Engineering **962** (2020) 022051 doi:10.1088/1757-899X/962/2/022051

Economical reinforced concrete overpass. Graphical method of calculation.

A V Makarov[1], S A Kalinovsky[2]

[1]Department of Research and design of transport structures, Volgograd state technical University, 1, Academic st, Volgograd 400074, Russia.
[2]Department 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).

Figure 2. Reinforced concrete overpass with four spans.

Figure 3. Two-span continuous overpass.

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].

a)
b)
c)
d)

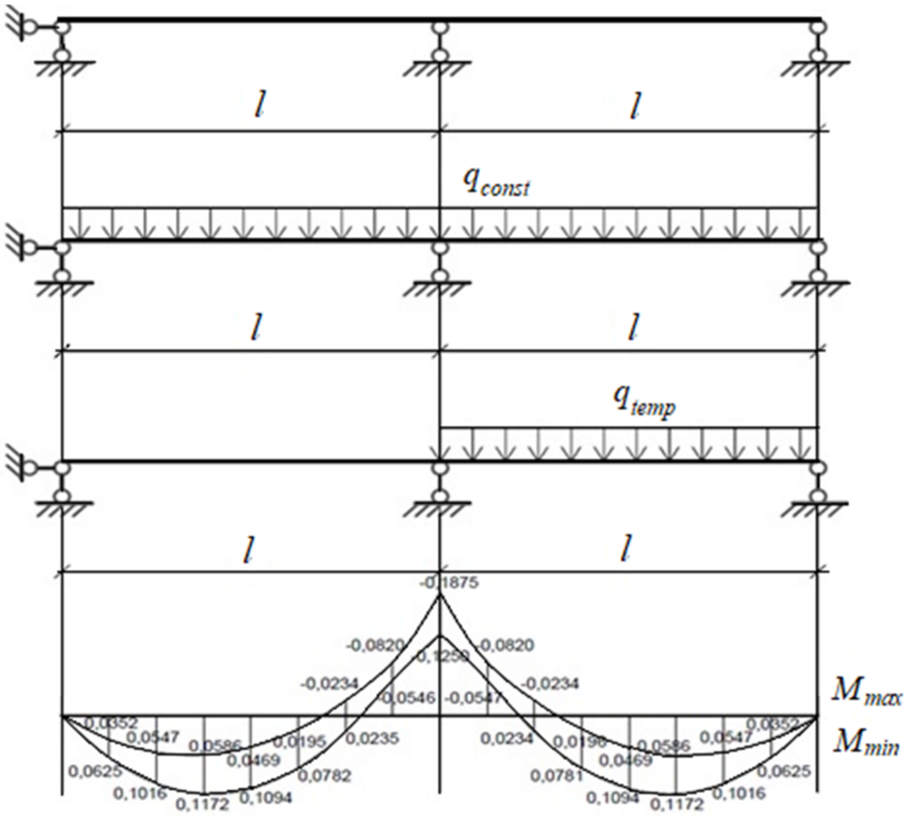

Figure 4. Design schemes of the overpass
a) design scheme; *b*) loading with a constant load, *c*) loading a temporary to span load; *d*) comprehensive plot ($q_{temp} = 0,5q_{const}$), multiplier to plot ordinate values – ql^2 .

Spans are loaded with a constant q_{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:

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

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

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

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 $q_{temp.}/q_{const.}$ 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 $3/8l$.

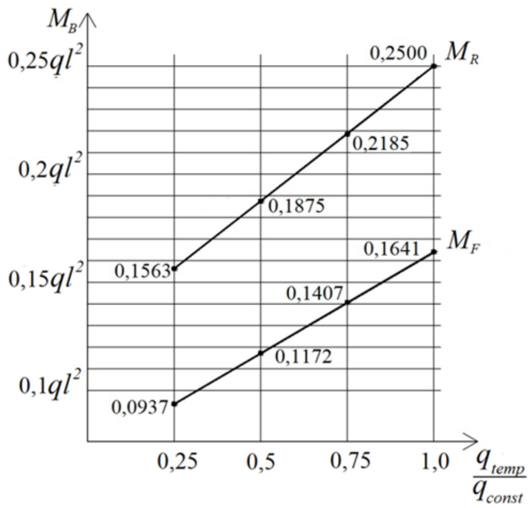

Figure 5. Graph of changes in bending moments from the corresponding loads; multiplier to the values of moments – ql^2. The reference bending moments in the graph are given by absolute value.

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.

References

[1] Storchak Y A 2015 Planning characteristics of bridge crossings of transport systems of cities and their agglomerations *Roads and bridges* (Moscow: Russian road research Institute) **2(34)** p 17

[2] Ovchinnikov I G, Ovchinnikov I I, Karakhanyan A B 2015 Modern trends in the design of pedestrian bridges *Roads and bridges* (Moscow: Russian road research Institute) **1(33)** 177–194

[3] Ovchinnikov I I, Gorbacheva I A, Ovchinnikov I G 2019 Influence of innovations on the aesthetics of bridge structures *Transport construction* (Puplishing house "World of science") **6(1)** p 1

[4] ODM 218.4.005-2010 Recommendations for ensuring safety on the roads. http://docs.cntd.ru/document/1200084056 (accessed 01.02.2020)

[5] Pugachev I N, Kamen'chukov A V, Yarmolinsky V A 2018 Comprehensive approach to improving road safety based on the analysis of the transport and operational state of the road *Roads and bridges* (Moscow: Russian road research Institute) **1(39)** p 21

[6] Lushnikov N A, Nevelsky D O 2018 On the impact of road surface wear on the environmental situation *Roads and bridges* (Moscow: Russian road research Institute) **1(39)** p 27
[7] Nigamatova O I, Ovchinnikov I G, Shvartz A Y 2018 *On the development of intelligent systems for designing and evaluating the technical condition of bridge structures. Part 1. Transport construction* (Puplishing house "World of science") **5(1)** p 10
[8] Sivtsov A A, Tenth G V 2014 *Examples of calculation of metal overpasses: textbook* (Yekaterinburg: Urgups Publishing house) p 125
[9] Salamakhin P M 2011 *Design of bridges and building structures textbook for students of higher educational institutions* (Moscow: Puplishing house "KnoRus") p 402
[10] Vasiliev A I 2017 Features of bridge design in conditions of dense urban development (to exit SP 259.1325800.2016) *Transport construction* **8** 12–15
[11] Ishchenko M T, Dukhovnitsky V V 2010 *Calculation of road and railway reinforced concrete span structures textbook* (Rostov-on-don: Rostov state building universitet) p 166
[12] Kazaryan V Y 2014 Widening of bridge structures using steel ropes *Internet-journal "Naukovedenie"* **5(24)**
[13] Popov V I 2017 Pham Tuan Thanh, Nguyen van Hien Analysis of the behavior of single-span overpasses with integral abutments *Roads and bridges* **38/2** 233–246
[14] Model project 3.503-28 2019 *Typical project of overpasses on highways*. https://meganorm.ru/Index2/1/4293797/4293797663.htm (accessed 20.01.2020)
[15] Karakhanyan A B, Pavlova E S, Ovchinnikov I G 2018 The Roadway of the bridge structure without deformation seams. *In the book: Progress of vehicles and systems-2018 Materials of the international scientific and practical conference*. Edited by Kalyaev I A, Chernousko F L, Prikhodko V M pp 295–296
[16] Makarov A V, Kalinovsky S A 2019 *Design features of bimetallic bridges*. E3S Web of Conferences. Vol. 97. *XXII International Scientific Conference "Construction-the Formation of Living Environment"* (FORM 2019) (Tashkent, Uzbekistan, April 18-21, 2019) p 9. https://www.e3s-conferences.org/articles/e3sconf/pdf/2019/23/e3sconf_form2018_06001.pdf
[17] Makarov A V, Kupreschenkov A E 2018 *On the issue of designing bimetallic bridges Engineering Bulletin of the Don* **2** p 12 http://www.ivdon.ru/ru/magazine/archive/N2y2018/4961
[18] Salamakhin P M 2008 *Bridges and structures on roads. Part 1. Transport* (Moscow)
[19] Shaposhnikov N N, Kristalinsky R E, Darkov A V 2012 *Construction mechanics: studies. for higher education institutions* (St. Petersburg: LAN) p 704
[20] SP 35.13330.2011 2011 *Bridges and pipes* Updated version of SNiP 2.05.03-84*. Ed. CPP (Moscow)