Possible scope of filler beam bridges on the Russian Railways

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Abstract. One of the most stable trends is the use of multi-component solutions in the practice of bridge construction, one of which is the use of rigid reinforcement elements in bridge girders and decks. The purpose of this work is to assess the possibility of using filler bridge girders on the Russian railway network and determine the scope of their effective application. In the course of the study, the analysis of design solutions was carried out taking into account foreign experience in design and operation and the study of relevant regulatory documents. Also in the course of the work, a comparison of the cost indicators of rigid-reinforced girders and the existing standard projects of the reinforced concrete and steel simple beam bridges was performed. The results of the study are presented by the formed list of the main advantages and disadvantages of girders with rigid reinforcement and the definition of the area of their most effective application. The practical significance of the work is because steel-concrete girders with rigid reinforcement are the most effective solution for the short span bridges up to 15 meters length from both technical, operational and economic sides. The proposed solution allows reducing the resource intensity of the construction and labor costs for its construction and maintenance.

1. Introduction
Filler beam are a structure of closely spaced steel rolling profiles combined with concrete [1]. The main advantages of this solution are high load capacity, rigidity, aesthetics, ease of maintenance and construction. A general view of the cross section of the structure is shown in Figure1.

The first bridge structures with the use of rolling profiles as reinforcing elements appeared in France at the end of the XIX century [2, 3]. However, the availability of constructions of this type have become available only in the 1970s. At the same time, design rules and regulations were developed and the effectiveness of the solution was confirmed by the European States and the International Union of Railways (UIC) [3, 4, 5]. Subsequently, part of the developed norms was included in the European standards for the design of Eurocode [6].

![Figure1. Scheme of the cross-section of the filler beam.](image-url)
Leading countries in the number of bridge structures with rigid reinforcement [1] is Germany (26%), Italy (24%) and France (20%). The total percentage of distribution on the European railway network is between 20 and 25%.

2. Design description
As reinforcement elements, the most widely I-beam assortment EU 53-62 steel S235-355. As a rule, transverse reinforcement is performed only in the stretched zone by reinforcing bars passed through the holes in the wall of the rolling profiles.

The thickness of the concrete layer above the steel elements according to Eurocode is determined from the following conditions:
1. the minimum thickness of 7 cm (protective layer, the distribution of efforts on the reinforcement elements, preventing buckling of beams reinforcement);
2. the thickness is not more than 1/3 of the total height of the section.

To improve the efficiency of the material in the section, it is possible to use closed elements [7] and T-beams with an arrangement in the stretched section zone. Thus, from all possible variants of designs, the most widespread structure with rigid reinforcement in the form of a wide-beam I-beam, located in a compressed and stretched zones and the distribution of concrete over the entire cross-sectional area (Figure 2.). The graph of distribution of internal forces in the compressed zone of concrete, compressed and stretched zones of the I-beam is presented in General in Figure 3.

![Figure 2. Cross-section of the bridge with rigid reinforcement of German Railways.](image)

![Figure 3. A graph of the efforts of the elements of the cross section depending on the span length.](image)

It should be noted the possibility of producing prestressed structures with rigid reinforcement. The presence of prestressing provides minimal deflections from the time load, which allows the use of these superstructures on high-speed Railways [8].

3. Advantages of filler beam
The analysis of existing structures allows to reveal their following advantages:
1. small construction height;
2. high rigidity of the girders;
3. high structural endurance;
4. variety of construction methods;
5. possibility of effective utilization.

These advantages determine the possibility of using filler beams on high speed railways [9,10].

4. Determination of the scope of possible application

The experience of such companies as Deutsche Bahn [10,11] and Czech Railways [4] shows that span structures with filler beam are most effective for covering spans from 6 to 20 m [6,7]. This area of application relates to small bridges – one of the most common types of bridges on Railways (from 100 to 250 structures per 1000 km) [12]. Span structures of small bridges in Russia are usually built according to standard projects.

To compare the technical and economic indicators and determine the scope of possible application, a preliminary calculation of giders was made according to the method given in [3, 6]. The calculation was carried out on the effects of temporary loads CK (K=14) with the use of assortment GOST 26020-83. Materials submitted B30 class concrete and steel 15HSND design resistance of 295 MPa.

According to the requirements [3, 6], the number of I-beams in the section is determined based on the approximate width of the span structure of 4.9 m. the distance between the axes of the beams is determined:

\[ b_s = h / 3 + 0.6 \]

where \( h \) is the height of the I-beam

The number of I-beams \( n \) and the span width \( B'_{pr} \) are determined by formulas respectively:

\[ n = \frac{B_{pr}}{b_{st} + b_m} \]

\[ B'_{pr} = n \cdot b_{pr} + (n - 1) \cdot b_m + 2 \cdot 0.8 \]

Where \( B_{pr} \) – approximate width of the superstructure equal to 4.9 m;
\( b_{st} \) – width of I-beam shelf;
\( b_m \) – distance between I-beams;
\( n \) – number of I-beams;
\( 0.8 \) – minimum distance from the axis of the extreme I-beam to the outer face of the cross section.

The design scheme of the cross section is shown in Figure4. The moment of internal forces \( M_{RD} \) in the cross sections of this type of structures is determined by the expression:

\[ M_{RD} = F_{sc}X_{FSC} + F_{sc}X_{FBC} + F_{sc}X_{FST} \]

Where \( F_{BC}, F_{SC}, F_{ST} \) – the stress in the compressed concrete, compressed and stretched zones of rebar;
\( X_{FBC}, X_{FSC}, X_{FST} \) – shoulders internal efforts

The calculation was carried out for spans with the value of a span from 3 to 18 m in increments of 0.5 m. For each span length was made to select the most economical combination of the height of the I-beam and the thickness of the covering layer of concrete.
Comparison and analysis of the results and indicators of existing typical reinforced concrete girders with filler beam of similar length confirmed that this solution is the most economical and effective for covering spans up to 15 m (Figure 5).

The preliminary calculation of cross sections made by the method [3, 6] for girders with a length of 3 to 18 meters allowed obtaining dependences that allow determining the size of the main elements of the section in the first approximation.

The obtained calculated values of I-beam height depending on the span length and their subsequent approximation (Figure 6) allowed concluding about the possibility of assigning the height of the I-beam expression.

\[ h = \frac{L}{20} \]
Figure 6. Calculated values of the height of the I-beam, depending on the span length and the approximating function.

Similarly, the dependence of the thickness coefficient of the concrete layer to the height of the I-beam c/h depending on the span length was obtained (Figure 7.). The approximating function is:

\[ \frac{c}{h} = 13.2L^{-1.7} \]

Figure 7. Calculated values of the ratio of the concrete layer thickness and I-beam height depending on the span length and the approximating function.

Thus, the dependences were obtained, allowing determining in the first approximation in the sketch calculation the basic necessary dimensions of the cross section elements.

6. Conclusion
Despite the fact that the use of girder bridges with filler beam requires the development of appropriate technical conditions and methods of calculation, they have great potential for implementation on the network of Russian Railways. The analysis of the design solution and its technical and economic indicators shows that the superstructures with filler beam are the most effective and economical solution for the overlap of spans up to 15 m.

Expressions were also obtained to determine the basic dimensions of the cross section in the first approximation in the sketch calculation.
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