Structures of steel-reinforced concrete beams of bench manufacture for bridge spans

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Abstract. The issue of optimizing the span structure of road bridges is considered. The proposed method is excluding reinforced concrete from stretched zones and replacing it with steel. The combined work of reinforced concrete in a compressed zone and steel in a stretched zone makes it possible to achieve the most rational solution in terms of material consumption, but leads to additional costs. The article describes the history and experience of using steel-reinforced concrete beams with the span length varying from 12 to 33 m. The advantages of the proposed structure over the typical design of non-diaphragm beam spans are confirmed. Comparison of typical and proposed cross sections of span structures is given. Advanced design of steel-reinforced concrete beams was developed, excluding monolithic beam on concrete slab, which simplifies installation and reduces the complexity of spans. Design solutions are verified by patents of the Russian Federation. Photos of steel-reinforced concrete beams and bridge structures are provided – both built and under construction.

Keywords: steel-reinforced concrete structures, span structure, bridges, patents, building, construction.

1 Introduction

In the construction of road bridge spans with a full length of up to 33.0 m, prefabricated reinforced concrete beams with both conventional [1, 2] and pre-stressed working reinforcement [3,4] are widely used. During their maintenance, obvious disadvantages are revealed [5-7], the main factors are insufficient durability [8-10], high maintenance costs and high cost of reconstruction and reinforcement.

To a large extent these disadvantages are due to the low strength of concrete in relation to tensile stresses [11, 12]. One of the ways to overcome these disadvantages is to replace the stretched part of the main beam’s stiffener with a shape corresponding to the plot of the main tensile stresses (Figure 17.52), [13].

2 Methods

The technology of manufacturing the structure is simplified - a constant height of the steel beam is accepted. In 1995, a project (by "LIRM" company) was developed for steel-reinforced concrete beams to widen and strengthen beam spans of length differing from existing standard projects. Spans can usually be of the following sizes: less than 12 m in length; from 12 to 15 m; from 15 to 18 m; from 18 to 24 m and from 24 to 33 m. T-section beams in a cross section consist of a steel stiffener-I-beam and a reinforced concrete slab combined with it. For spans up to 18 m long, rolled I-beams are often used. For spans over 18 m – welded I-beams [14], but the main criterion is the cost of metal structures. Welded beams, in general, prove to be more efficient.

The reinforcement of roadway slab is close to its analogues – both standard projects of non-diaphragm reinforced concrete beams with reinforcement at a span length of 18 m and pre-stressed non-diaphragm reinforced concrete beams at a span length of more than 18 m, taking into account the requirements.
The lateral rigidity of the span structure is provided by combining the beams with each other by lattice diaphragms. The placement of the diaphragms along the length of the span is performed with a step determined by the calculation. The process of joining beams for their combined work in the span structure is carried out by monolithic longitudinal seams on a reinforced concrete slab (see Figure 1).

Figure 1. Cross section of a steel-reinforced concrete beam.

The reinforced concrete slab of the roadway is combined on the stand with a metal I-beam during production by means of special stops. The lifting during construction can be arranged by pre-bending a steel beam on a rigid stand using hydraulic jacks. During the construction process, two joints of a steel beam are usually created.

The main advantages of steel-reinforced concrete beams over standard reinforced concrete ones are [15]:
- Lower mounting weight [16-19];
- Possibility of reducing the number of beams in the span structure [20-23];
- Possibility of manufacturing beams of any span length with minimal changes to the production drawings;
- The usage of the strength advantages of materials, since compressive stresses are perceived by a reinforced concrete slab, and tensile stresses are perceived by a steel beam [24-27];
- The possibility of manufacturing metal beams in small sections, transportation by low-tonnage transport to the place for final assembly on the stand, concreting the roadway slab on the construction site;
- Heavy crane equipment is necessary only at the final stage - during the installation of beams on the bridge supports.

In 1996, the first experimental beam with a length of 15 m was manufactured at the reinforced concrete factory in Kama (Naberezhnye Chelny). Complex tests were then performed.

In 1997, steel-reinforced concrete beams with lengths of 11.36 m were used in the reconstruction of the road bridge on the M7 Volga motorway in the Republic of Tatarstan with the extension of the span structures by additional beams.

During the 20-year operation period of the reconstructed structure, steel-reinforced concrete beams proved to have many advantages, and their technical condition was significantly better than the condition of reinforced concrete beams.

An obvious advantage of steel-reinforced concrete beams of bench manufacture over conventional ones is the work under load in one stage [28, 29], which reduces their material consumption to 8-10 % [30].

In 2000, a bridge with steel-reinforced concrete beams was built in the Republic of Tatarstan according to the “3 x 15.0 m” scheme.

The use of steel-reinforced concrete beams was restrained by the excess of the manufacture cost of steel-reinforced concrete beams relative to conventional reinforced concrete beams.

Enterprises engaged in the manufacture of metal structures are equipped with modern welding equipment. Because of that, it is now possible to manufacture metal beams in many regions of the
Russian Federation. There is also a network of modern reinforced concrete plants that produce concrete of classes B30 - B40 with stable characteristics that meet the requirements of “GOST” regulatory document.

An important factor to take into consideration is the increase in both the railway fares and the cost of road freight transport. This fact not only leveled, but in some cases made it preferable to use steel-reinforced concrete structures.

Figure 2 shows the layout of spans in cross section using steel-reinforced concrete and conventional pre-stressed reinforced concrete beams.

Figure 3 shows the construction of steel-reinforced concrete beams ready for installation. The manufacturer of this construction is "Mostotrest" company.

Figure 4 shows commissioned bridge over the Yaran river with steel-reinforced concrete beams. Wide-flange I-beams are used as metal beams.

Figure 5 shows steel-reinforced concrete beams manufactured at the construction site during the reconstruction of the bridge over the Sheshma river.

Figure 6 shows the span of the same bridge during the process of installation (2018).

Further improvement of the structures of steel-reinforced concrete beams of bench production is implemented in the Russian patent under application no. 2019117132. Longitudinal seams between beams are excluded. During the installation of beams with reinforcement outlets, the upper row of reinforcement outlets must be temporarily bent up. It is not possible to install two identical beams with equally spaced reinforcement outlets without sliding in the longitudinal direction. Double bending of reinforcement outlets is not only a labor-intensive operation, but also requires compliance with “GOST” regulatory document for the minimally allowable bending radius.

**Figure 2.** Layout of steel-reinforced concrete (a) and prestressed (b) reinforced concrete beams as parts of the span structure.
Figure 3. Steel-reinforced concrete beams on the construction site.

Figure 4. Bridge over the Yaran river on the Vyatka highway.
Figure 5. Steel-reinforced concrete beams at the construction site of the major reconstruction of the bridge over the Sheshma river.

Figure 6. Installation of span structures of the bridge over the Sheshma river.

3 Results and discussion
Span structures with a full length of beams from 8 to 21 m have been successfully constructed. Bridge overpass with 33 m beams is currently under construction. All design solutions have passed state expertise, and work is continuing to improve the design and technology of spans.

4 Conclusions
Steel-reinforced concrete beams for road bridges spans are competitively relative to the standard counterparts and have their own range of conditions for rational use.

The ongoing improvement of structures and construction technology is far from completion. The improvement process will continue as we gain experience in design, construction, and conduct the necessary research on the effectiveness of steel-reinforced concrete beams.
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