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Reinforced structures type "Filler Beam" – advantages in reconstruction of bridge superstructures.

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Abstract. Reinforced concrete superstructure type "filler beam" would be appropriate in future reconstruction of such structures with span length of 5 - 30m. They can be applied in road and railway bridges as their advantages are significant. They have a small construction height, simplified installation, steel elements are simplified and produced in factory conditions, less formwork, as well as easy maintenance in operation. This type of structure would be appropriate in urban environment as besides the above – mentioned advantages, it also has low noise emission during the passage of vehicles.

1. INTRODUCTION.

The main types of bridge superstructures used in our country are made from reinforced concrete (monolithic or prefabricated) with normal or prestressed reinforcement, from steel or from combined steel and reinforced concrete sections.

For a number of reasons, the most widespread system in Bulgaria is the one of prestressed GT beams for spans of 20, 40 and even 60m (Viaduct Bebresh on Hemus motorway). During the operation of bridges of this type due to the accumulation of several unfavorable factors (Some omissions or "optimizations" in the design, insufficient quality of the execution, poor maintenance) after only about 30 years of operation (according to BDS EN 1990 the regulated service life for bridges is 100 years) some serious damage is registered. In some cases, even partial or total replacement of the top structure is necessary (Viaduct Eleshnitza on Hemus motorway, bridge on km 67 on Hemus motorway).

On the secondary roads can be located also a significant number of operational bridges with shorter spans, up to 20m, made from ordinary concrete. Poor execution, combined with poor concrete quality and inadequate maintenance are the main reasons why a significant part of these bridges in Bulgaria are in unsatisfactory technical condition. In a number of cases, partial or complete replacement of the superstructures is necessary. In this case, the question of choosing a feasible new superstructure is important. The basic requirements in these cases are low cost, high reliability, fast execution, minimizing the negative effects on traffic in the area of the facility (especially in urban conditions).

For spans up to 20-25m (for road bridges), the standard monolithic reinforced concrete construction (with or without prestressing) has the lowest cost in terms of input material, but is a serious step back from the other listed criteria of innovative (for the practice in our country) solutions, such as the filler beam system (rolled steel 2T profiles, imbedded in the reinforced concrete).

In the case of a monolithic reinforced concrete solution, it is necessary to have a densely placed scaffolding to maintain the formwork and this adversely affects the traffic under the facility, which is extremely undesirable especially in urban conditions – Figure 1.

Figure 1. Densely placed scaffolding and limiting the traffic during the execution of a bridge of prestressed concrete at crossroad with heavy traffic in Sofia – 2014.

In the area of 20-22m span lengths, the combined steel-reinforced concrete superstructure is usually more expensive than monolithic reinforced concrete (by input material), but in European and world practice such a solution is often preferred for its speed of execution, lack of necessity of densely placed scaffolding (depending on the solution, the temporary supports may be completely absent), minimizing the formwork and supporting it on the self-supporting steel structure. With the filler beam system, a minimum design height can be achieved by providing the same bending stiffness as compared to other bridge superstructure designs. To speed up the execution time, it is possible parts of the superstructure to be pre-prepared and assemble them in situ – Figure 2. With the bridge static system being a continuous beam, the system with imbedded steel profiles can be successfully implemented for railway bridges with span lengths up to 30-35m and road bridges with span lengths up to 40-50m. The implementation of this system is possible also for road bridges in their transversal direction. Superstructures with imbedded asymmetrical steel beams are also possible. The limited application of the above-mentioned efficient construction solutions for bridge superstructures in Bulgaria is mainly due to the lack of experience of a significant number of the designers and builders in the field of combined steel-reinforced concrete bridges. For this reason, it is not uncommon for the old well-known reinforced concrete solutions to be applied outside their area of technical and economic efficiency.

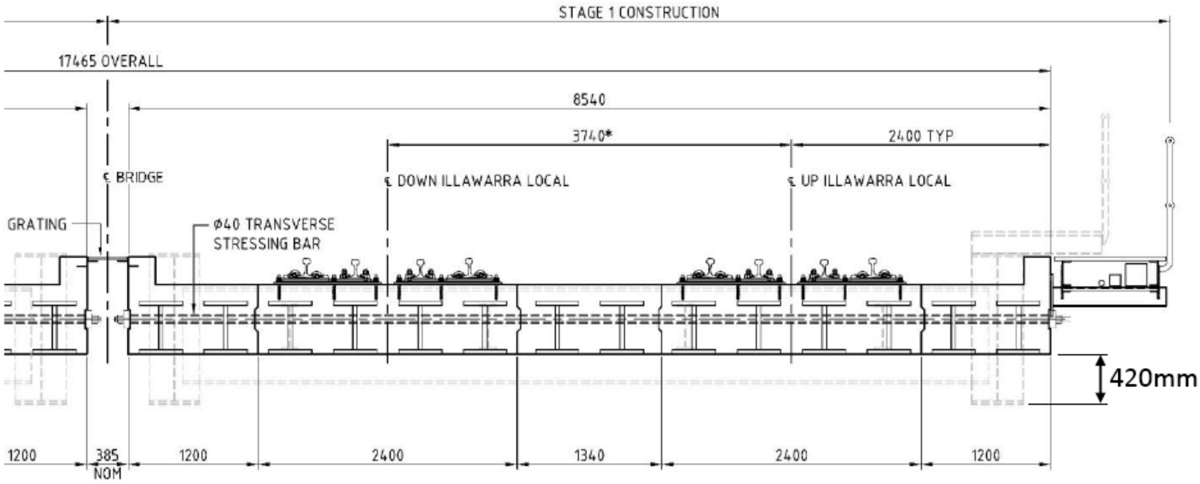

Figure 2. Substitution of old riveted railway bridge with 13,1m span (dashed) with prestressed in transversal direction superstructure of imbedded steel profiles (filler beam)

Figure 3. Railway bridge superstructure from imbedded steel profiles in transversal direction

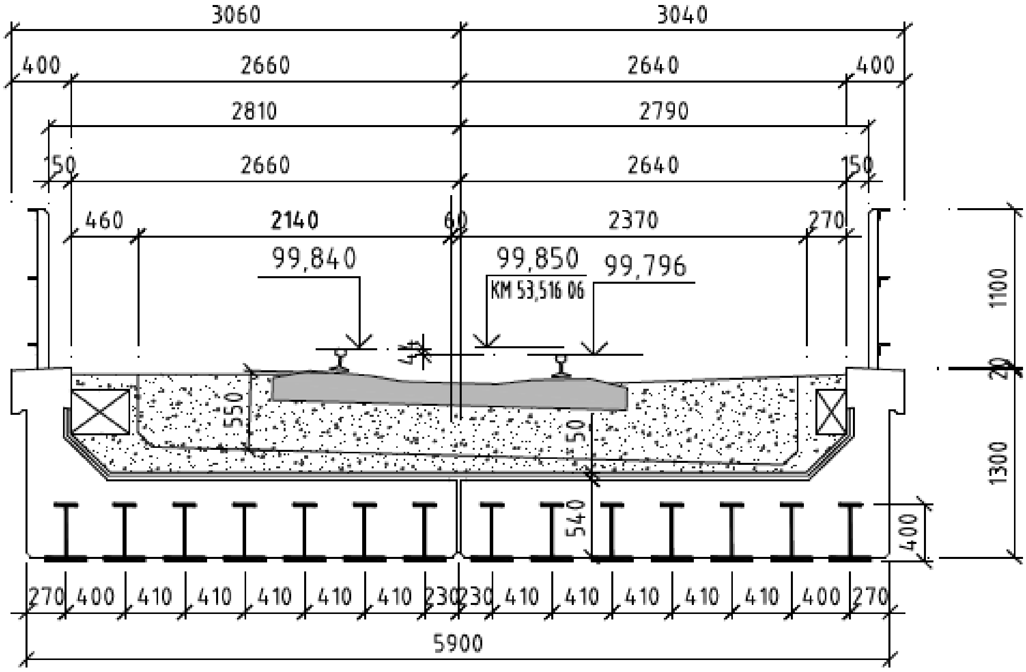

Figure 4. Railway bridge with 10m span from imbedded asymmetrical steel beams

2. OPTIONS FOR APPLICATION OF BRIDGE SUPERSTRUCTURES WITH IMBEDDED STEEL PROFILES IN BULGARIA

2.1. Proposal for repair of facilities, part of a rehabilitation project on Route III - 811 "II - Bogyovtsi - Slivnitsa - Rakita - Breznik - Pali Lula" with a total length of 42,520 km.

a) Bridge at km. 12 + 839

The superstructure of the facility has a total length of 7.00 meters and a span of 6.50 meters. The transversal gauge of 6,00 m includes a roadway with a width of 4,60 m and two pavements of 0,70 m each. The superstructure consists of 4 monolithic beams, combined with a slab, and in the middle of the span there is a cross beam. The structure is in a dangerous condition and in our opinion, the best solution is to be completely replaced with a new superstructure with imbedded profiles. The advantages are that the construction height is less, which would ease the hydraulic regime in the area of the facility. The difference is about 20 centimetres, which would allow the construction of a normal reinforced concrete bearing coffin as stated in the proposal.

Noticed disadvantages:

i) lack of concrete cover for the beams;
ii) extremely poor quality of the concrete even when it was poured;
iii) poor connection between the bridge and the embankments at both ends of the facility;
iv) very poor state of safety fences;
v) railings are missing.

Rehabilitation / reconstruction measures:

i) dismantling the existing structure;
ii) implementation of new reinforced concrete bearing coffin;
iii) implementation of facing for the invert and protecting the area under the bridge from undermining;
iv) installation of the new construction according to the chosen option;
v) making transition areas of gabion mattresses;
vi) shaping of longitudinal and transverse joints in the new road surface.

Figure 5. Existing situation

Figure 6. Existing situation

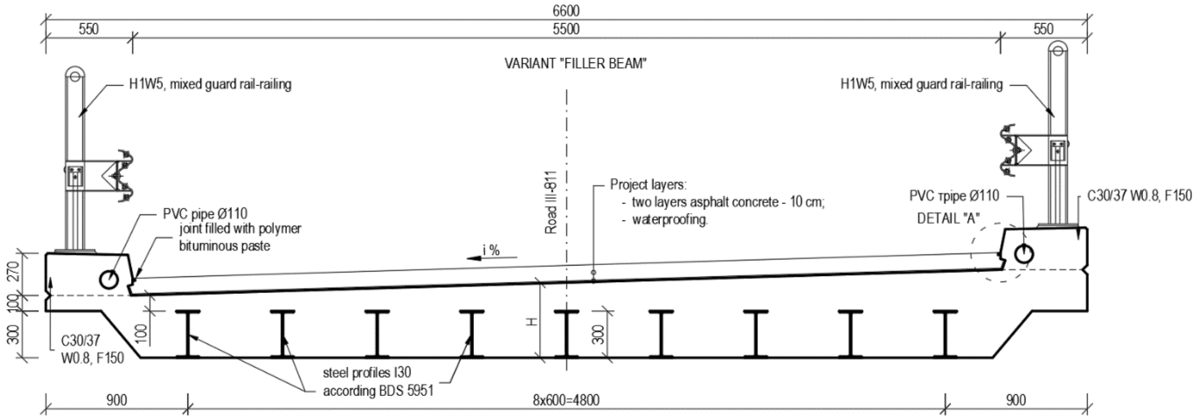

Figure 7. Proposal for a new superstructure.

b) Bridge at km. 19 + 760

The facility has a total length of 7.40 m and a span of 6.00 meters. The transversal gauge of 5.40 m includes a 4.50 m roadway and two pavements of 0.45 m each. The superstructure consists of 4 monolithic beams, combined with a slab, and in the middle of the span there is a cross beam. The structure is in a dangerous condition and in our opinion, the best solution is to be completely replaced with a new superstructure with imbedded profiles. The construction height is smaller, which would ease the hydraulic regime in the area of the facility. The difference is about 30 centimetres, which would allow the construction of a normal reinforced concrete bearing coffin as stated in the proposal.

Noticed disadvantages:

i) lack of concrete cover for the beams;
ii) extremely poor quality of the concrete even when it was poured;
iii) poor connection between the bridge and the embankments at both ends of the facility;
iv) very poor state of safety fences;

Rehabilitation / reconstruction measures:

i) dismantling the existing structure;
ii) implementation of new reinforced concrete bearing coffin;
iii) strengthening / widening of the existing abutments, incl. invert facing;
iv) installation of the new construction according to the chosen option;
v) making transition areas of gabion mattresses;
vi) shaping of longitudinal and transverse joints in the new road surface.

Figure 8. Existing situation

Figure 9. Existing situation

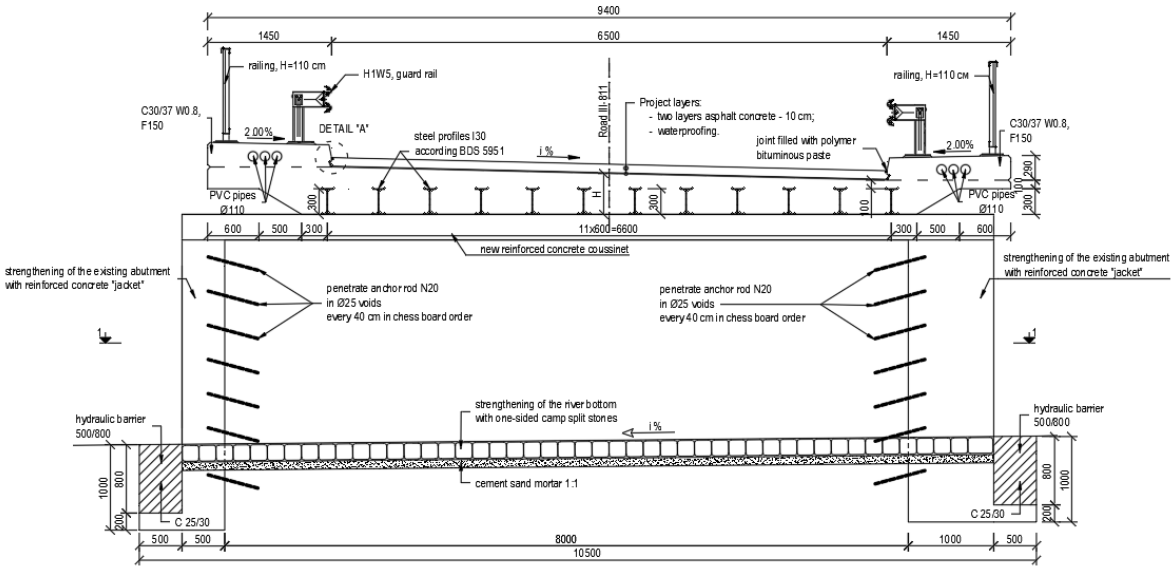

Figure 10. Proposal for a new superstructure

2.2. Proposal for replacing the existing superstructure in the conditions of a single-track railway in operation from the line Plovdiv - Burgas (near Chirpan).

a) Bridge at km 67+363 – In this case, the old superstructure is without ballast bed. The main beams are solid steel beams in good condition and their incorporation in the new superstructure as "filler beams" is appropriate and reduces the cost of reconstruction. The beams are cut into two halves, which leads to reduction of the overall height and allows the implementation of gravel bed.

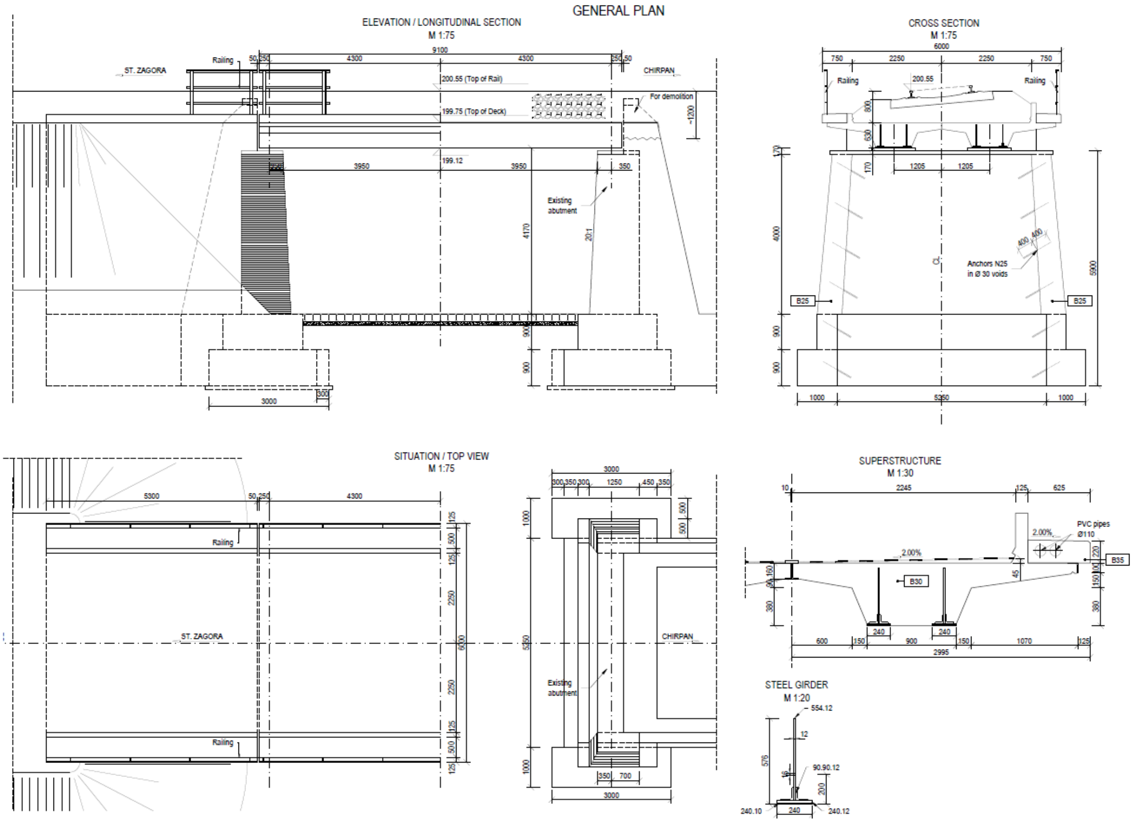

Figure 11. General plan

Technology of embodiment

Figure 12. Temporary bridging and dismantled construction

Figure 13. Cutting the existing structure and embedding it into a new one filled beams

Figure 14. Beams and "soft" reinforcement of semi - structure

Figure 15. Mounting of the second semi – structure

3. CONCLUSION.

The replacement of old bridge superstructures and implementation of new ones with the filler beams system has a certain number of advantages, compared with the old well-known reinforced concrete solutions for bridges with short and middle-length spans.

3.1. For superstructures with filler beams the needed bending stiffness is achievable at minimal construction height, which is a serious advantage at tight conditions. Their possible implementation is for spans up to 30-35m for road bridges and spans up to 40-50m for railway bridges.

3.2. The steel profiles are self-supporting and can be used for supporting the needed formwork. With this, besides the serious formwork reduction and the needed work for it, a significant reduction or even elimination of the necessary scaffolding can be achieved (for monolithic reinforced concrete superstructure a densely placed scaffolding is needed for supporting the formwork and taking the weight of the soft concrete). For replacement of superstructures or construction of new bridges in urban areas, the most significant factors are the time needed for implementation and minimizing or complete elimination of the temporary scaffolding, which prevents the normal traffic conditions under the facility.

3.3. An extra construction time reduction is possible, if parts of the filler beams superstructure are manufactured in a factory.

3.4. An advantage of the filler beam implemented bridges is the relatively low maintenance costs as well as lower sensitivity from hits on the superstructure from vehicles passing under it.

3.5. The application of the filler beams system for replacing an existing superstructure of bridges with short or middle-length spans has a certain number of advantages over the old well-known solutions in our country. The limited application of the above-mentioned efficient construction solutions for bridge superstructures is mainly due to the lack of experience of a significant number of the designers, builders and institutions in the field of combined steel-reinforced concrete bridges. In the future, this problem should be overwhelmed by making the necessary efforts from the aforementioned groups, in interest of the possibilities for implementation of rational and effective solutions for bridge superstructures, which solutions should correspond to the social needs and resources.

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