Fibre-Reinforced Plastic (FRP) deck substitution of a fatigue damaged steel deck

Kees VAN IJSELMUIJDEN
Civil Engineer
Royal HaskoningDHV
Amsterdam, The Netherlands
Kees.van.ijselmuijden@rhdhv.com

Kees van IJselmuijden, born 1972, received his civil engineering degree from the Hogeschool Amsterdam and betonverening TUDelft both in the Netherlands. He is a lead engineering at Royal HaskoningDHV. His speciality is the design and implementation of Fibre Reinforced Polymer in civil structures.

Liesbeth TROMP
FRP engineer and consultant
RoyalHaskoningDHV
Rotterdam, the Netherlands
liesbeth.tromp@rhdhv.com

Liesbeth Tromp has a degree in aerospace engineering (Delft University of Technology) and 15 years background in FRP design. She specialises in development of new solutions in FRP and is leading in the development of FRP design guidelines for infrastructure.

Summary

This paper presents three options to replace a fatigue damaged steel deck with an infusion Fibre Reinforced Polymer (FRP) deck. Current traffic loading is now heavier than in the 1970's, so a deck sensitive to fatigue loading will be controlled by a more onerous loading regime. The project task is to replace the original damaged steel deck with a lighter deck and thereby relieve the main girders. The additional benefits of substituting the damaged steel deck is, that the original deck will not have to be repaired and also the FRP deck has lower stresses than the steel deck so therefore less fatigue sensitive.

Keywords: Fibre Reinforced Polymer (FRP), light weight constructions, composite constructions, renovation of steel bridges, reuse existing substructure.

1. Introduction

The subject of this study is a typical bridge situated on a main highway in the Netherlands. We shall assume that this bridge is built in 1969 and has 2 main girders. The main field length is 95 m. The steel grade quality of the deck and main girders are St52 (S355). The steel deck is assumed to be fatigue sensitive because it has a thickness of 10mm. In current design practices the thickness of the steel deck is at least 18mm and still found to be fatigue sensitive. In the analysis it is assumed that the bridge is in use during the renovation works.

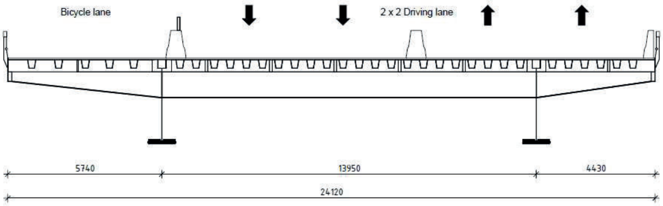

Figure 1:cross section original bridge (non-structural asphalt directly on a metal deck)

2. Fibre Reinforced Polymer (FRP)

Fibre Reinforced Polymer is a lightweight, strong, freedom in form, durable and sustainable material. FRP, in all its varieties, is used in industries such as aerospace, yacht building, wind energy and automotive because of these properties.

Historically FRP has only a limited used in civil engineering structures but its use is increasing as a coming material. An update Dutch national design recommendation is under development and many bridges are now built in FRP in the Netherlands using the current recommendation (CUR96).

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3. Bridge structure in steel and FRP

Based on the properties of the FRP material a deck design is undertaken. The original steel orthotropic deck and the FRP-deck are shown in figure 2. The web plates of the FRP deck have a centre to centre distance of 100 mm, therefore wheel loads are always on a web and local moments in the deck flange do not occur, so fatigue problems in the FRP deck are prevented.

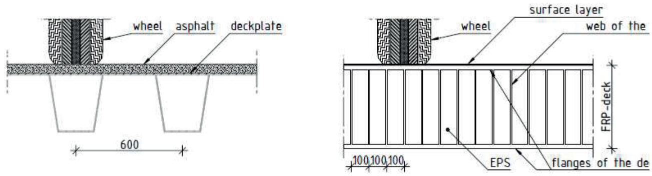

Figure 2: wheel load on the steel deck (left) and the FRP-deck (rig

4. Structural calculations

In this paper only the preliminary design calculations are presented for the three FRP deck options, FRP decks containing glass, hybrid (glass and carbon) and carbon fibres. These calculations are compared to the original steel deck (all have the EN 1991-2 traffic loads). These preliminary design calculations are used to determine the maximum sagging and hogging moment and shear capacity in order to determine the influence of the FRP deck on the steel main girder. Before these tests are made the effective width is calculated. The sagging moment in the main field has an effective width of 11,15 m and provides the following results for one steel girder and half a deck (12 m).

Table 1:The main results at main field, b_e = 11,15 m.

Properties field		Steel	FRP Glass	FRP hybrid	FRP Carbon
Total height	(mm)	3021	3621	3479	3353
EI	kNm^2)	1,480*10^8	1,521*10^8	1,503*10^8	1,618*10^8
σ_{deck} (Steel or FRP)	(MPa)	-199	-49	-52	-68
$\sigma_{girder\ at\ connection\ deck}$	(MPa)	-197	-325	-211	-160
$\sigma_{flange\ girder}$	(MPa)	+362*	+324	+304	+288

** Maximum stress for steel is been exceeded.*

The steel deck is over-loaded, the stresses in the flange of the girder are more than 355 MPa, only by the sagging moment. It is expected that this will occur, because the mobile loads (EN 1991-2) are heavier, than the initial design load used in 1969. The three FRP decks reduce the stresses in the main girder in the flanges in comparison with the original steel construction. However, it is observed that the stresses in the steel girder increase at the connection of the steel deck with the FRP glass. This can be explained by the relatively large difference in the E-modulus. As a result, the centroid of the main steel girder with the FRP deck in relation to the total height is lower than the original steel structure. The global stresses in the deck itself are for all FRP decks much lower (16 till 22% of the maximum stress) than the steel deck (56% of the maximum stress).

5. Conclusion

Historical steel bridge construction, which exhibits fatigue damage of the deck can be repaired, however they are still not able to carry the new loads according EN 1991-2. Apart from repairing the deck, the structure must also be reinforced. In the Netherlands this is usually achieved with a high strength concrete overlay, but this system increases the weight even more. By replacing the steel deck by an FRP deck, strengthening of the construction is not necessary and the damaged deck does not have to be repaired. The construction will be less sensitive to fatigue problems and is lighter than the steel deck.