Feasibility and Life Cycle considerations of Fiber Reinforced Polymer (FRP) deck solutions for renovation of steel highway bridges

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Summary

This paper describes the feasibility of FRP deck solutions for refurbishment and reinforcement of steel orthotropic bridges. Several Dutch steel bridges suffer from fatigue damage, because of the increased traffic intensity. The currently solution in the Netherlands is reinforcing the steel deck with a High Performance Concrete (HPC) layer. The main disadvantage is the relatively high dead weight it adds to the bridge structure. Fiber Reinforced Polymer (FRP) deck structures are strong, lightweight and fatigue resistant. FRP does not corrode and requires hardly any maintenance. Different solutions for both deck materials and configurations are evaluated for various types of steel bridges, over a realistic extended life time period of 30 years. Life Cycle considerations are included to show the value and opportunities for the FRP alternatives.

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

1. Problem analysis and scope

This study concerns a generation of steel bridges that have been built in the 1960's and 1970's. In general the steel bridge structures of the bridges under consideration suffer from severe fatigue damage in both deck and main structure because they:

- have a very thin top plate (10 mm – 12 mm instead of 18 mm – 20 mm)
- were designed for a lower tyre load and lower maximum vehicle load
- were designed for lower levels of traffic intensity

To extend the life of the bridges with 30 years, it is necessary to repair the damage and apply reinforcements. In this paper we study different generic bridges based on actual bridge cases that are considered representative for the current situation in steel orthotropic bridges in the Netherlands.

HPC deck reinforcement

Technically the HPC-reinforcement functions. Main advantage of this solution is that it provides the required addition of stiffness and strength in a robust way. When applied in-situ, the material fills all unevenness of the steel deck. The weight of the HPC is 100kg/m^2 higher than that of the removed asphalt layer and thus requires additional reinforcement. This is a significant disadvantage, especially for weight sensitive bridge structures such as a tied arch bridge. The application process is critical and an unsuccessful batch of UPC not only increases material costs, but also results in delay of approximately one week.

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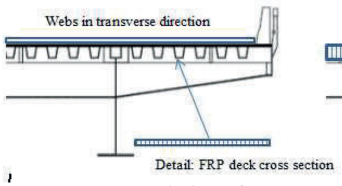
2. FRP deck solutions

Two different FRP deck solutions have been considered, see Figure 1a and b:



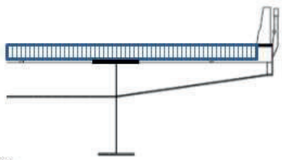


Figure 1a Type I: FRP deck reinforcement panel *Figure 1b : Type II FRP deck replacement panel*

The FRP deck elements have been considered in three FRP materials: Glass Fibre Reinforced Polymer (GFRP) Carbon Fibre Reinforced Polymer (CFRP) and Hybrid GFRP/CFRP flanges and GFRP webs, see table 1 and 2.

Table 1: estimated comparative properties type I FRP deck reinforcement solutions

	Weight [kg/m²]	Height [mm]	Costs [EUR/ m²]	Maintenance Costs [EUR/ m²]
Reference HPC	250	90	250 + 140 HPC + strengthening	-
GFRP -panel	90	90	500-550	-100
Hybrid CFRP/GFRP	65	85	550-600	-100
CFRP-panel	40	66	600-650	-100

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Table 2: estimated comparative properties FRP deck replacement solutions

	Weight [kg/m²]	Height [mm]	Costs [EUR/ m²]	Maintenance Costs [EUR/ m²]
New steel orthotropic deck	185	320	1000-1200	-
GFRP -panel	185	488	1300 - 1500	-250 - -350
Hybrid CFRP/GFRP	151	388	1400 – 1700	-250 - -350
CFRP-panel	108	332	2400 - 2900	-250 - -350

3. Conclusions

For Type I FRP steel deck reinforcement it was seen that significant weigh savings are achieved. Considering life cycle aspects this solution can be competitive with HPC. It must be further investigated if significant reductions in execution time are to be expected. This solution is very valuable for lightweight bridges where reinforcements are complex or expensive. In case of even more weight critical solutions the steel deck can be replaced by a Type II FRP steel deck replacement panels. Significant weight savings with respect to a new modern orthotropic steel deck are only feasible when more than 500 mm construction height is available or when carbon fiber panels are used. Due to the reduced maintenance, significant cost reductions are expected over the life time. A GFRP-panel is most economical and it is expected that it can be competitive on both initial and life cycle costs. This solution is most easily implemented in case of an independent deck or when reinforcements to compensate for additional weight are expensive. This solution is especially interesting for moveable bridges and also very interesting for new built bridges.