Fibre-Reinforced Polymer (FRP) deck for a cable stayed bridge

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Summary

This paper presents a cable stay bridge with a deck, entirely constructed from Fibre Reinforced Polymer (FRP). FRP materials are normally chosen because they are low maintenance, but heavy material like reinforced concrete are prone to maintenance issues as well as light steel structure systems (or a combination of both these materials). FRP is an upcoming material, and has the best properties of both new and traditional materials. On the basis of a preliminary design of a typical cable stayed bridge, this paper demonstrates that an FRP deck is possible.

Keywords: Fibre Reinforced Polymer (FRP), light weight structures, composite structures, bridges, long span bridges and cable stayed bridges.

1. Introduction

FRP has been utilised in bridges for some time now. There are composite forms using pultruded decks on steel beams, there are cables of FRP for cable stayed bridges and there is an example of FRP being used for a cable stayed pedestrian bridge in Scotland (Aberfeldy Bridge). In the Netherlands we have almost finished a design code for FRP and in Europe we are now writing a technical report for Eurocode FRP. So FRP is an upcoming material which can be used in civil structures, as well for buildings. So with some design codes soon to be readily available and the benefits of FRP: light weight, low maintenance, sustainable, high specific strength, fatigue resistant, fast installation, freedom in shape and high specific energy absorption, we believe that this material can be used for long span bridges. In this paper we take the first step for a cable stayed bridge (figure 1).

Fig. 1: Cable stayed bridge design impression by architect Jorge Nogueira de Moura

2. Cable stayed bridge provided with a FRP deck

The bridge has a main span of 150 m and the side span is 75 m long (figure 2). There is one pylon with a height of 75 m above the deck and the cables [1] are every 12,5 m connected to the bridge. The pylon has 2 arms under the deck, which supports the deck in the same line as the cables at the pylon (there is no cable supporting the deck at the pylon). For the traffic and cycle road we used

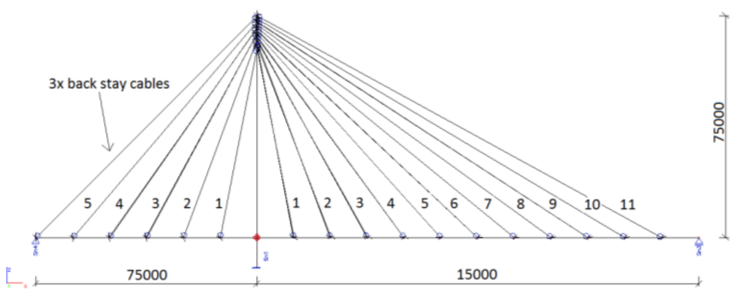

Fig. 2: Longitudinal section of the cable stayed bridge

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respectively LM1 and an UDL of 5 kN/m^2 (ψ=0,4) according to the Eurocode. For the fatigue load, we assume 50% of the full live load (LL).
The deck is constructed fully out of Fibre Reinforced Polymer; the fibres are glass fibres (fibre 50% (55/15/15/15) and fibre 50% (25/25)). The structure is built up from sandwiches with webs between the top and bottom plates. FRP has different properties in each direction what depends on the percentage material of glass fibres in each direction. In the CUR96 [2], the properties of the most common lay-up are given. With the material properties of FRP and the geometry of the deck the stiffness properties are calculated.

The dead load (DL) for one side of the bridge is 72,1 kN/m, the tandem system (TS) of the live load (LL) is 890 kN per side and the uniform distributed load (UDL) of the LL is 60,0 kN/m per side. These loads are used to calculate the necessary cross-sectional area for the stayed cables. From this we found that the dimensions of the cables are governed by the fatigue loads. This is what is to be expected for a light weight bridge. The dead load is not a critical design case for determining the cable dimensions.

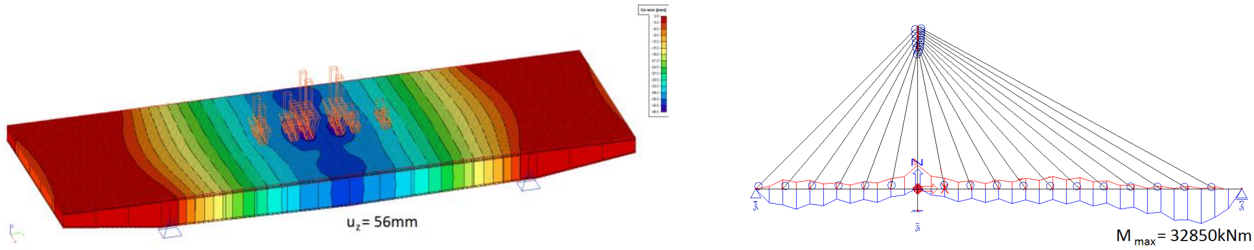

Fig. 3: FEM models (SCIA Engineer) for calculating deflections (SLS) and moments (ULS)

In the FEM program (SCIA Engineer) the deck is modelled (figure 3) for one section deck of 12,5 m. On top of the deck the UDL en TS of the traffic loads are modelled, what result in a displacement of 56 mm. With a SCIA model (figure 3) for the longitudinal direction the maximum bending moment of M = 32850 kNm is calculated. $\sigma_y = M/(I_y/e) = 32850\times10^6/(0{,}92\times10^{12}/1251) =$ 45 MPa << 0,012×15900MPa/1,8 (material factor) = 106 MPa. The FRP deck is a closed box structure with the centre point of gravity in almost the middle of the height of the structure. Therefore the deck structure can have both positive and negative bending moments compared with an open structure. Finally the dynamic response of the structure is studied both by the model and analytical. A value of $\varepsilon = f_t/f_b = 1{,}16$ is calculated by hand and 1,30 is found by making use of SCIA Engineer. The hand calculation is made according the book of Holger Svensson “Cable-Stayed Bridges, 40 Years of Experience Worldwide” [3].

3. Conclusions

An FRP structure was analysed for a cable stayed bridge.

- The weight of the deck is 346 kg/m2. As a consequence of the low weight of the deck (DL) in ratio to the live load, the fatigue of the cables is dominant.
- The sandwich structure provides stiffness buckling resistance and allows efficient use of the fibres high strength.
- The dynamics need some more detailed calculations or even wind tests, to find out how this kind of structure made by FRP reacts. FRP can be easily constructed in aerodynamic shapes.
- The FRP deck is common practice to fabricate with infusion and because of the repetition of the elements the production can reduce the price as compared to unique structures.
- FRP is a sustainable material, which needs minimal maintenance in comparison with steel.

4. References

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