Structural limits of FRP-balsa sandwich decks in bridge construction

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Summary

The span limits of two glass fiber-reinforced polymer (GFRP) bridge concepts involving GFRP-balsa sandwich plates are discussed. The sandwich plates were either used directly as slab bridges or as decks of a hybrid sandwich-steel girder bridges. In the latter case, the potential of the sandwich decks to replace reinforced concrete (RC) decks was also evaluated. Taking the limits of manufacturing into account (800 mm slab thickness), maximum bridge spans of approximately 19 m can be reached with FRP-balsa sandwich slab bridges, if a carbon-FRP (CFRP) arch is integrated into the balsa core. Above this limit, hybrid sandwich-steel girder bridges can be used up to spans of 30 m. RC deck replacement requires timber and steel plate inserts into the balsa core above the steel girders. GFRP-balsa sandwich slabs or decks exhibit full composite action between lower and upper face sheets.

Keywords: Balsa core; complex core assembly; sandwich decks; composite bridges; timber inserts; RC deck replacement.

1. Introduction

Two basic concepts of GFRP bridge systems exist: orthotropic systems composed of adhesively bonded pultruded shapes and sandwich constructions. Both are used either as bridge decks in deck-girder bridges or as slabs in the case of slab bridges. Sandwich decks or slabs have the advantage, amongst others, of flexible thickness contrary to pultruded decks or slabs and can thus be used for much larger spans. Currently, they are composed of GFRP face sheets and honeycomb or foam cores. In the latter case, additional GFRP webs are normally required to provide sufficient shear capacity of the core [1]. However, the honeycomb walls and internal GFRP webs in the foam core provide a non-uniform stiffness support for the upper face sheet, which – under frequent wheel loads – may lead to the debonding of the upper face sheet from the core [2]. To overcome this drawback, i.e. provide a core with sufficient shear capacity and uniform support for the upper face sheet, balsa wood was used as core material in the new Avançon Bridge, in Bex, Switzerland [3]. The use of balsa with fibers transverse to the upper face sheet and thus in line with the wheel load direction did no longer require reinforcements by internal webs and provided a high indentation resistance against concentrated wheel loads. The new 11.45 m span and two-lane Avançon Bridge, composed of a GFRP-balsa sandwich deck adhesively bonded onto two steel girders, replaced an old one-lane reinforced concrete (RC) bridge.

A further disadvantage of pultruded decks is manifested in the case of RC deck replacement. RC decks normally act as top chord of hybrid RC-steel girders in the longitudinal bridge direction. Pultruded GFRP decks, however, have low stiffness in this direction (which is transverse to the pultrusion direction) and are thus not able to transfer the longitudinal forces which are in the RC chord. Furthermore, depending on the geometry of the cells, composite action between the upper and lower face sheets may be reduced, which further decreases the possible contribution as top chord [4]. The effects of these drawbacks are increased deflections in the longitudinal bridge direction and significant longitudinal stress increases in the upper flanges of the steel girders, which may require an additional strengthening of the bridge. This was demonstrated in [5], where the compressive and tensile stresses in the upper and lower steel girder flanges increased by 109% and 12% respectively, if the RC deck of a 17.5 m span bridge would have been replaced by a pultruded

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