DESIGN OF COMPOSITE (FIBER REINFORCED PLASTIC) BRIDGES IN HUNGARY

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SUMMARY: Short span (3 to 15 m) pedestrian and bicycle bridges were designed and are planned to be built in Hungary in 1998. The main driving force of the design was the cost. Glass fiber reinforced polyester was selected as the material and pultrusion as the manufacturing process. Attention was paid to the manufacturability of the elements of the bridge and their applicability in other fields. The design was governed by stiffness (displacement and vibration) and not by strength. The erection cost of the superstructure is slightly higher than that of conventional bridges, but their maintenance cost are very low.

KEYWORDS: bridge, pedestrian bridge, bicycle bridge, FRP, design

INTRODUCTION

Bridges in Hungary are usually made of conventional materials such as reinforced concrete, timber or steel. Because of the environmental effects, especially to the salting during winters, the bridges, both the old and the relatively new ones, are severely corroded. The costs of the rehabilitation of these corroded bridges are comparable to the erection costs of new ones. This is one of the main reasons why fiber reinforced plastics, due to their resistance to salt corrosion, are excellent candidates for bridge construction. Several examples of FRP bridges can be found in the literature [1-6].

SELECTION OF THE MATERIAL AND THE MANUFACTURING PROCESS

The selection of the material was based on financial considerations. Glass fiber and polyester resin were used which are significantly cheaper than graphite or epoxy. A comparison was made with conventional materials, such as timber, steel and reinforced concrete (Fig. 1) [7]. This comparison shows that the super-structure made of glass/polyester is slightly more expensive than the structure made of conventional materials. Pultrusion was selected, again because of financial considerations, as the manufacturing process. In the above calculation (Fig. 1) the price of the tooling was not included which is acceptable if big series of bridge decks are manufactured.
The use of FRP as super-structure has several advantages in addition to the corrosion resistance: because of the reduced weight the elements can be assembled without any special equipment, the abutments can be cheaper etc.

![Price of the super-structure](image)

**Fig. 1: Price of the super-structure**

### DESIGN OF THE FRP BRIDGE

Two cross sections of pultruded bridge decks were considered and designed [8,9] which are shown in Fig. 2a and b. The elements can be joined together without interlocking planks (such as necessary in the ingenious bridge designed by Maunsell [1]). The closed element (Fig. 2a) behaves more effectively for concentrated loads, however its manufacturing is more complicated. The open cross-section (Fig. 2b) must be strengthened by cross girders.

For short spans the beams can be used directly (Fig. 3), while for longer spans external post-tensioning were designed (Fig. 4).

![Cross-section of the bridge-decks, a) closed, b) open](image)

**Fig. 2: Cross-section of the bridge-decks, a) closed, b) open**
The pultruded elements were tested for tension and four-point bending [10], and their Young’s modulus and strength were determined:

$$E = 20-22 \text{ kN/mm}^2$$  \hspace{1cm} $$f = 350-400 \text{ N/mm}^2$$

These material data and the traffic load due to the Hungarian Standard (5 kN/m² with a safety factor of 1.4) were considered.

The deflection of the middle section and the maximum stress of the bridge without external post-tensioning (Fig. 3) was calculated as a function of the span. The height of the cross section was h=200 mm, while the thickness (t) was varied between 4 and 8 mm. For simply supported bridges the results are shown in Fig. 5. The allowable deflection in Hungary is L/400, where L is the total span of the bridge. Fig. 5 shows that this bridge can be used up to a span of 4 m. At this span the maximum stress (for the 4 mm thick section) is 24 N/mm², and hence, the safety factor of the material is ~15. The required safety factor of the material is
about 3-4 [11], hence the design is governed by the deflection. The eigen frequency of the bridge is 25 Hz.

![Graph showing deflection and maximum stress of a simply supported bridge](image_url)

**Fig. 5: Deflection and maximum stress of a simply supported bridge**

If external post-tensioning is used, the bridge can be precambered by stressing the cables. The calculated deflection and the maximum stresses are shown in Fig.6. (In the calculation we assumed that the precamber of the unloaded bridge due to post-tensioning is equal to the
deflection of the bridge under the total load.) The design is governed again by deflection, the maximum span is 11 m, while the safety factor for compressive strength is again ~15.

![Graph showing deflection and maximum stress of a bridge with and without external post-stressing.](image)

**Fig. 6: Deflection and maximum stress of a bridge with and without external post-stressing**

**CONCLUSIONS**

Preliminary design of the first Hungarian FRP pedestrian/bicycle bridge was presented. The erection cost of the super-structure is higher than that of conventional bridges. However, the maintenance cost of the composite bridge is very low. Taking the total life-time of the structure and the additional costs beyond the super-structure into account, the FRP bridges are competitive with steel or reinforced concrete bridges. The bridge deck will be manufactured
this year by the Hungarian firm NITROKÉMIA and the bridge will be built, hopefully, early next year.

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REFERENCES


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