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EVALUATION OF THE DYNAMIC BEHAVIOUR OF A GFRP-SFRSCC HYBRID FOOTBRIDGE

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Summary: *This paper presents results of numerical investigations on the dynamic behaviour of a hybrid footbridge made of glass fiber reinforced polymer (GFRP) pultruded profiles and a steel fibre reinforced self-compacting concrete (SFRSCC) slab. Finite element (FE) models were developed to simulate the dynamic response of the footbridge when subjected to human induced vibrations. Results obtained were compared with requirements defined in several standards in order to verify the performance of the footbridge regarding the fulfilment of comfort criteria. In addition, direct and indirect verification methods were compared to assess the applicability of the latter when used with GFRP-SFRSCC hybrid structures.*

1 INTRODUCTION

The design of footbridges is often governed by their serviceability behaviour, namely regarding the fulfilment of pedestrian comfort criteria. In general, such criteria are met by limiting the structural accelerations induced by pedestrians crossing a bridge. Standards, such as Eurocode 0, provide simplified indirect verification methods based on the natural frequencies of the footbridges. This paper presents results of numerical investigations [1] about the dynamic behaviour of a hybrid footbridge made of glass fibre reinforced polymer (GFRP) pultruded profiles covered by a steel fibre reinforced self-compacting concrete (SFRSCC) layer. The footbridge under study presents a high strength-to-stiffness ratio and is considerably slender. However, GFRP damping is relatively low, raising doubts about the adequacy of the above mentioned indirect verification methods. Attributing distinct geometries for the GFRP profiles and SFRSCC layer, accelerations were determined for different types of pedestrian action. This study aims (i) at investigating the viability of the structural concept proposed for footbridge and (ii) assessing the applicability of indirect verification methods for comfort criteria.

2 STUCTURAL CONCEPT

Figure 1 illustrates the bridge prototype conceived, which is made of GFRP pultruded profiles combined with a SFRSCC top cover layer in a simply supported span of 11.5 m. While the GFRP material presents high tensile strength, its low Young's modulus combined with the thin-walled geometry of pultruded profiles makes them prone to instability phenomena. The SFRSCC, on the other hand, presents high compressive strength and toughness (when compared to regular concrete) and, being used in a relatively thick layer (when compared to the GFRP profiles walls), is less susceptible to instability. In tension, the SFRSCC, unlike regular concrete, presents considerable post-cracking tensile strength, provided by the steel fibres that offer resistance to crack propagation due to fibre pullout mechanisms. Given the material characteristics presented above, the structural concept includes two GFRP beams working mostly in tension and a layer of SFRSCC material working in compression. Furthermore, the connection of the top flange of the GFRP profiles to the SFRSCC slab – provided by epoxy adhesive and bolts – prevents local buckling of the profiles' top flange. In the transverse direction, the SFRSCC slab guarantees the load transfer to the profiles without any rebar reinforcement – this is possible due to the post-cracking tensile strength of SFRSCC.

3 NUMERICAL SIMULATION OF DYNAMIC BEHAVIOUR

Three-dimensional (3D) FE models were developed using shell and solid elements in the commercial software SAP2000 (Fig. 2). In each model, several types of pedestrian movement were simulated, with a varying number of people placed in different positions in the bridge. Natural frequencies and accelerations (at a quarter of span and at mid-span, Fig. 3) were calculated and compared with performance requirements defined in several standards (Fig. 4).

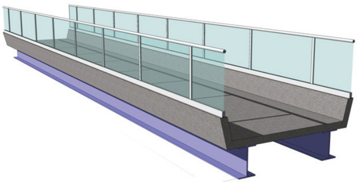

Figure 1: Illustration of the hybrid footbridge.

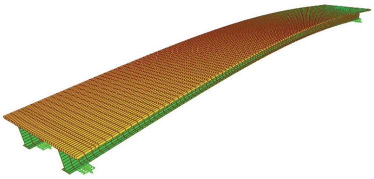

Figure 2: Fundamental vibration mode.

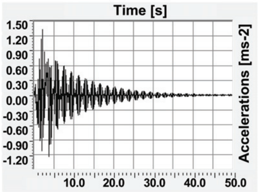

Figure 3: Mid-span accelerations for a pedestrian jogging.

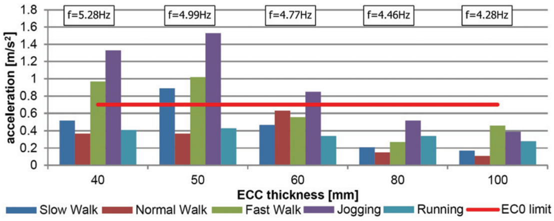

Figure 4: Maximum accelerations for several types of movement and natural frequencies of each model.

4 CONCLUSIONS

The structural solution presented in this study is viable, namely in what concerns its dynamic behaviour upon human induced vibrations. However, indirect methods of verification proposed by Eurocode 0 do not seem to be valid for GFRP-SFRSCC structural solutions, most likely due to their particular characteristics – high slenderness, low stiffness and low damping.

REFERENCES

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