COMPOSITE SANDWICH FOOTBRIDGE - NUMERICAL ESL FEM CALCULATIONS VS. IN SITU MEASUREMENTS

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1. Introduction

This paper compares selected results of a static analysis of composite sandwich footbridge with the corresponding in situ measured values. The analyzed bridge is a research object, which was built in 2015 and is currently located at the Gdańsk University of Technology campus. Since it is a novel structure [1], a proper definition of the bridge numerical model, allowing its safe design, is very important. Therefore, instead of some preliminary research, carried out on sandwich beams [2] or on the bridge segment [3], also the calculated structural properties of the full scale bridge should match the experimentally predicted response. This verification is required to obtain permission for the bridge exploitation, according to the government regulations.

2. The bridge properties, numerical model and results comparison

The footbridge is a simply supported structure, having a 14m long span. The girder has an U-shape cross section and is formed as an arch with low elevation. The bridge is a multilayered sandwich structure. The outer skins are made of laminated polymer composites, comprising of stitched and balanced BAT [0/90] and GBX [45/–45] E-glass fabrics (reinforcement) and flame retardant vinylester resin (matrix). A 100mm foam core, having a density of 100kg/m^3, is applied between the skins. The whole structure is formed using the infusion technology in a single production cycle [1].

The bridge was among others tested to predict its static response using concrete plates, as it is described in details in [1]. The deflections measured for the U1 test cases (~140kN applied to the bridge deck) in the middle of the span (U2/3 point) are referred to the corresponding numerically calculated values in this paper. Static linear calculations are performed using ABAQUS 6.14-2 FEM code in order to recreate the experimental tests.

Since the thickness of the cross section elements is small as compared with the span length, a numerical model comprising only of shell finite elements is create. This is a one of many possible methods of the bridge numerical modeling, regarding recreation of its static mechanical behavior. Equivalent Single Layer technique and First Order Shear Deformation kinematics (see e.g. [4]) are used to describe the behavior of shell fiber. The mesh of finite elements comprises of 86 671 nodes and 84 236 S4 elements. It is very fine, thus the discussion about the mesh convergence is avoided.

The layers of laminated composites are modeled using plane stress, elastic, orthotropic material law, while the foam is treated as an elastic isotropic continuum. The foam core is a one layer of the full stacking sequence similarly, as in [5]. The following layer sequence [BAT/GBX/BAT/BAT/GBX/BAT/FOAM/BAT/GBX/BAT/BAT/GBX/BAT] is applied as the basic one in the analyzed bridge.

Such an approach, regarding creation of the numerical model is chosen, because it is intended to analyze the global bridge behavior only using a simple and easily available method of sandwich composite structures mechanics description, that allow to provide accurate results in the shorter possible time. The precise state of stress in foam core or in local zones of possible highly concentrated actions does not need to be verified here. In order to analyze the aforementioned local influences a model can be utilized in which the laminate skins are made of multilayered shells and the foam core is divided in the thickness direction using brick elements.

The calculated static displacements of the bridge in the middle of the span (U2/3 point) are compared with the in-situ measured ones in Figure 1. Also a photo of U1:1+2+3+4 stage of static load test is shown in the Figure 1.

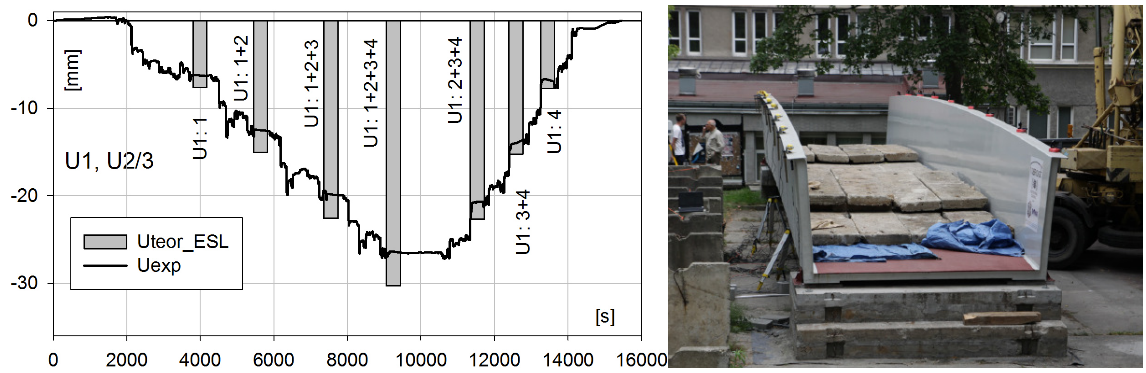

Figure 1. Calculated and measured values of displacements in U2/3 test point for different U1 test stages (left). U1:1+2+3+4 static load test – fully loaded bridge (right)

3. Final remarks

The results of static analysis of the bridge described in this work correspond well with the experimentally measured values. The numerically predicted bridge response under static loads is a little bit overestimated. This may be attributed to the environmental conditions, e.g. temperature, which may affect elastic properties of the materials. Nevertheless, it means that all the global design variables and assumptions, allow creation of a safe structural solution. However, it is recalled that a careful attention needs to be paid in the areas of highly local influences during the design process.

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5. References

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