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EXPERIMENTAL AND NUMERICAL ANALYSIS OF CONCRETE GIRDER WITH PRE-STRESSED GFRP REINFORCEMENT

EXPERIMENTÁLNÍ A NUMERICKÁ ANALÝZA BETONOVÉHO NOSNÍKU S PŘEDEPNUTOU SKLENĚNOU VÝZTUŽÍ

Abstract

The aim of this paper is to give an overview of the behavior of the concrete element with GFRP (Glass Fiber Reinforced Polymers) reinforcement during the experiment. In the experiment stress and deformations are recorded. Moreover numerical model is carried out to give a more precise overview. Recorded values, equality of the experimental and numerical data are discussed.

Abstrakt

Cíl tohoto výzkumu je posoudit chování betonového deskového nosníku vyztuženého předepnutou výztuží na bázi skleněných vláken (GFRP – Glass Fiber Reinforced Polymers). V průběhu experimentu jsou zaznamenávány jak deformace tak napětí. Součástí práce je i numerický model. Naměřené hodnoty a porovnání obou modelů je součástí tohoto článku.

1 INTRODUCTION

Nowadays a considerable attention is paid on new materials with better characteristics and longer lifetime as well. Regarding reinforced concrete, one of the most important things that come to one's mind is reinforcement itself. Corrosion, electric and thermal conductibility can decrease the material characteristic of the metallic reinforcement and therefore decline the lifetime of the structure as well. Nevertheless a non-metallic reinforcement offers an excellent behaviour in terms of corrosion-proof ability, thermal and electric non-conductivity and other excellent characteristic.

1.1 Material Characteristic

Corrosion-proof ability, thermal and electric non-conductivity was mentioned already. Another important characteristic is strength itself. Moreover if the ration of the strength and self-weight is taken non-metallic reinforcement exceeds significantly over the metallic reinforcement.

Tab. 1 Table title

	GFRP	R10505
Tensile Strength [MPa]	650	490
Modulus of Elasticity [GPa]	32	210

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2 EXPERIMENT

Experimental works are carried out in the labs of the faculty of civil engineering. Dimensions of the concrete girder are therefore given by the laboratory requirements. Girder is tested in four point bending test driven by the force.

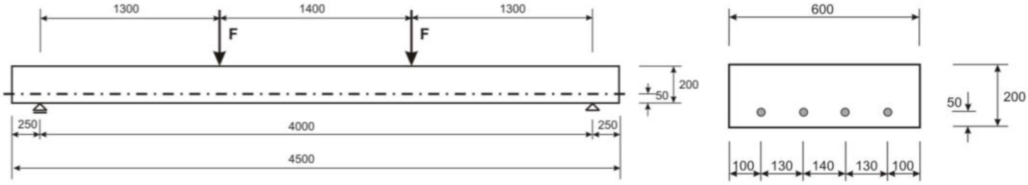

Fig. 1 Girder dimensions

Four GFRPϕ14 bars are pre-tensioned up to 215 MPa corresponding to the one third of the tensile strength of the bar. Concrete C30/37 is used. Strain gauges are glued on the both upper and lower fibres of the girder. Therefore stress development can bee seen on the figure 3. For deflection measurement a deflectometr is placed under the girder. It has been verified experimentally that working diagram of the beam with GFRP bar is bilinear with hardening.

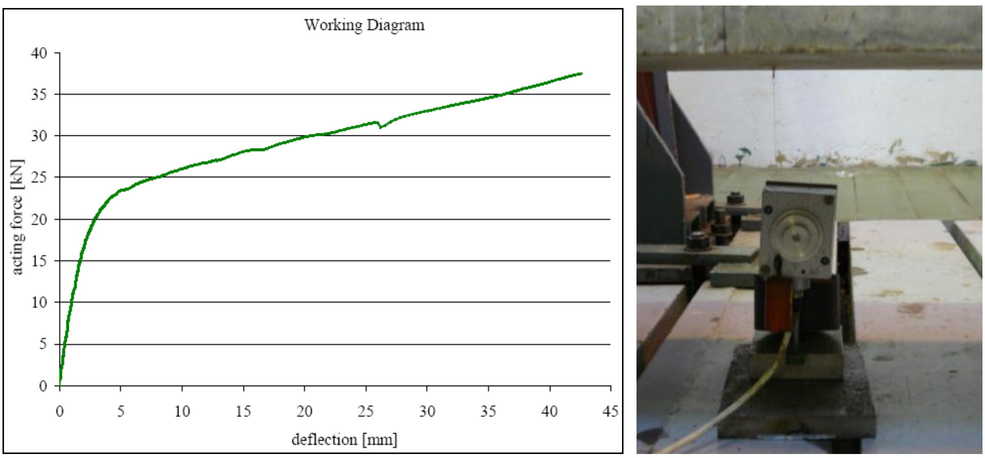

Fig. 2 Bi-linear working diagram and deflectometr

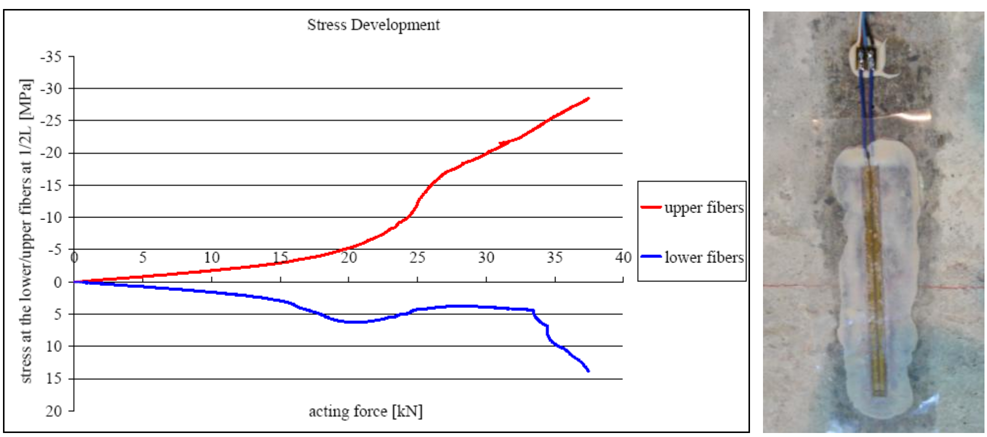

Fig. 3 Stress development and strain gauge

3 NUMERICAL MODEL

Numerical model is carried out in ATENA 3D in order to establish a sophisticated instrument for behaviour prediction of these special concrete structures. Four nodes tetra elements are used for meshing. Monitoring points are placed at the model in order to measure deflection and stress in dependce on the acting force.

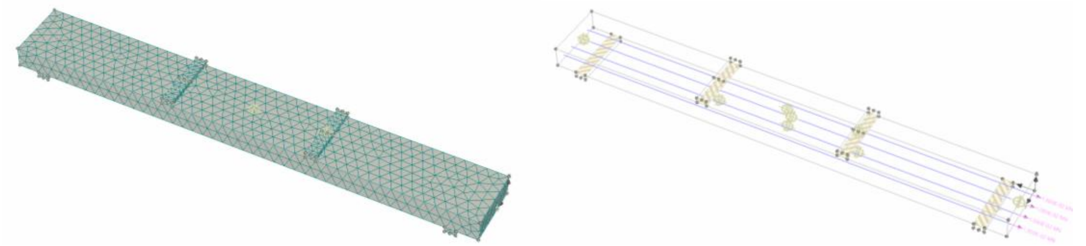

Fig. 4 ATENA model – mesh and pre-tensioning

Newton-Raphson method was used for computation. This method proceeds in small increments since the problem is generally non-linear. According to the experiment the N-R method was driven by force increments up to the failure. Additionally line-search can be added to the N-R method in order to speed up the procedure when small none-linearity is expected. This leads in less iteration in every step. Further on another monitoring point was placed on the GFRP bar in order to record stress development in the bar itself.

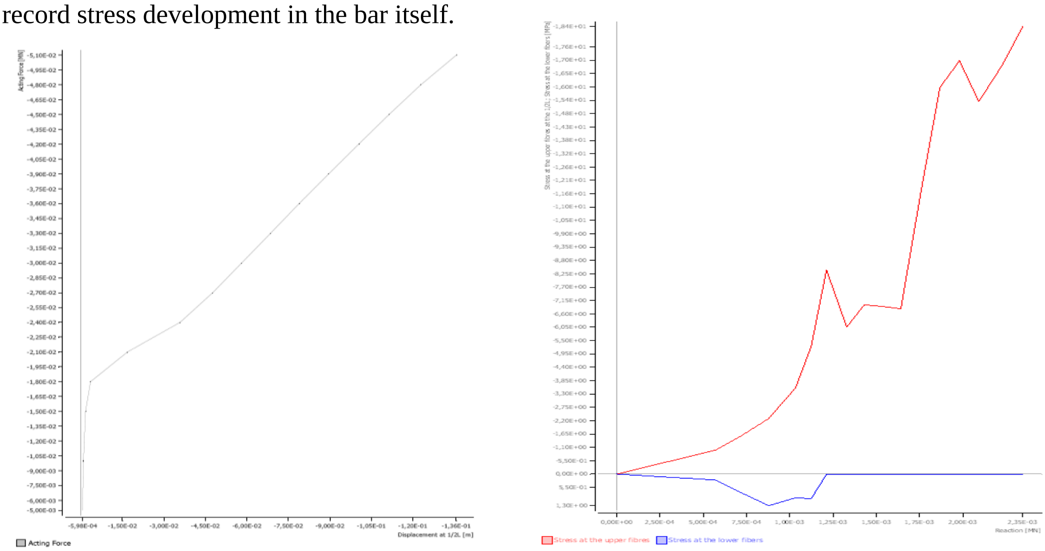

Fig. 5 Bi-linear working diagram and stress development

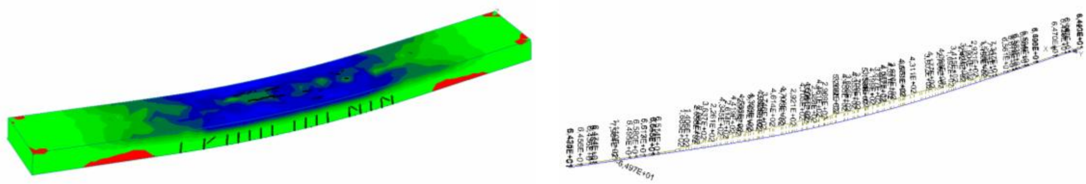

Fig. 6 Stress in the concrete and in the GFRP bar

4 CONCLUSIONS

Working diagrams in both numerical and experimental model are bi-linear. In the first phase deformation grows rather slowly since the stiffness of the girder is undisturbed. Breakage of the line in the working diagram corresponds to the tensile cracks in the concrete girder. Therefore GFRP bars take all the tensile strength in the girder. Within tensile cracks stiffness of the girder decreases and deformation speeds up in the second phase up to the failure. Second phase is linear as well. The sudden rupture of the GFRP bar causes failure where the tensile strength is reached.

Deflection of the girder is rather big and unacceptable. Bigger deformations are given by the low Young’s modulus of the GFRP bar. Within 4 m span 100 mm deformation is reached which equals to the deflection of 1/40 of the span. For SLS (serviceability limit state) and in terms of good appearance and usability value of 1/250 of the span should not be overshoot. For 4 m span girder SLS predict maximal deflection 16mm, which is 6 times less that experiment. Therefore and most probably SLS is limiting factor for design of the concrete structures with GFRP bars.

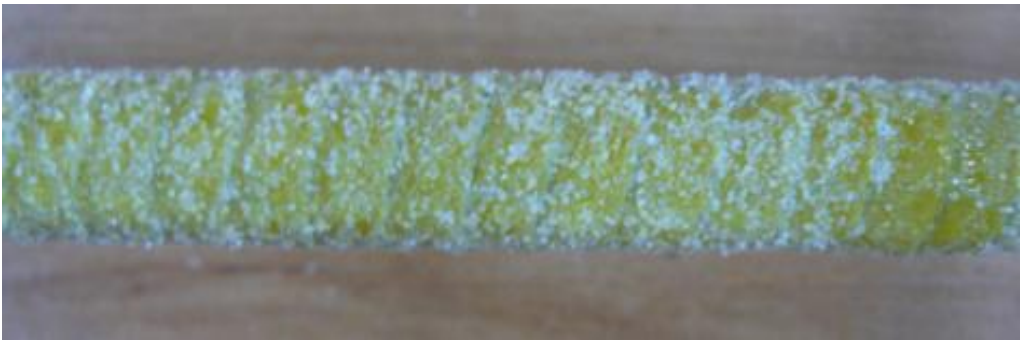

Fig. 7 Detail of the GFRPϕ14 bar

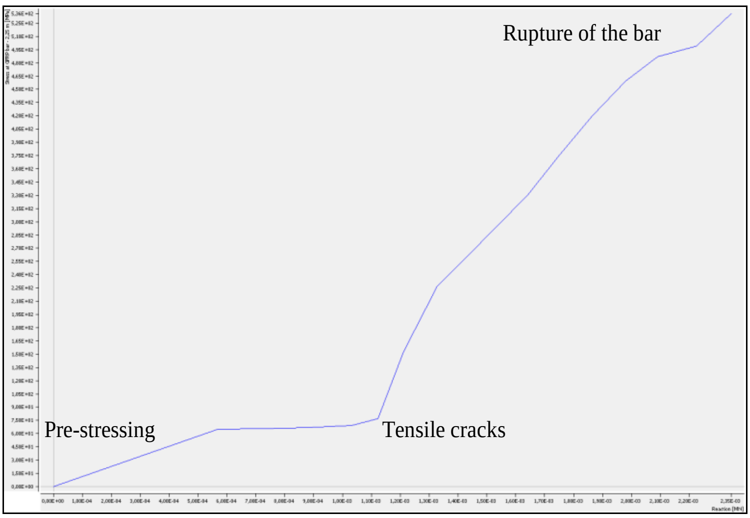

Fig. 8 Stress development in the GFRPϕ14 bar

REFERENCES

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