Numerical analysis of strengthening the construction

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Abstract

The paper deals with the problem of numerical modeling reinforcement (strengthen) of composite structure. The aspect of strengthening can be analyzed with the use of bar model in the elastic range by doing suitable superposition of internal forces. In composite construction there is often a lack of information about the stage of assembly. Due to that fact finally superposition of stress can by incorrect. Plastic analysis is more accurate but requires application of more precise three-dimensional model. That model was applied in presented numerically analysis. Analysis was parted into two steps. In the first step the level of stresses and displacement for three-dimensional model were determined before the reinforcement in the state of partial unloading Next reinforcement and load equal to the imposed loads was added. In this way the new level of stresses and displacement were determined. This paper shows the power of FEM analysis with non-linear model of materials and geometry.

Keywords: composite beams, numerical modelling, construction strengthen

1. Introduction

Steel - concrete composite structures are more and more popular in civil engineering. They are mostly used as load - bearing structures in bridges, but also in building structures. The typical examples are floors composed of steel beams and reinforced concrete slabs or steel columns, which are partly or fully covered with concrete.

As this kind of structures becomes popular, soon repairs, adaptations and strengthening will be necessary, like in case of typical steel or concrete structures.

The question how to strengthen structures is often much harder, than designing a new object. The reason for that situation is the necessity to estimate the degradation, to plan the proper technology of works, to design the additional support structures, and what is the most important, a precise static analysis of reinforcement construction.

This precisely static analysis is the topic of this paper. The results of FEM analysis are compared and illustrated by diagrams of paths of static balance.

2. Numerical model

2.1 Actual model

The object of analysis was one - span, simply supported, composite beam of 3000mm length. A cross - section of composite beam presents fig. 1.

The slab (dimensions 600x60mm) was made of concrete C25/30. Concrete reinforcement was made of ϕ6 stirrups and ϕ8 ribbed reinforcing bars (fig. 1). Steel beam was H - profile of high 160 mm and was made of S235JRG2 steel. The connection between slab and beam was made with use of shear studs ϕ10 mm and 50 mm high (fig. 1) or in the second variant by strip connectors.

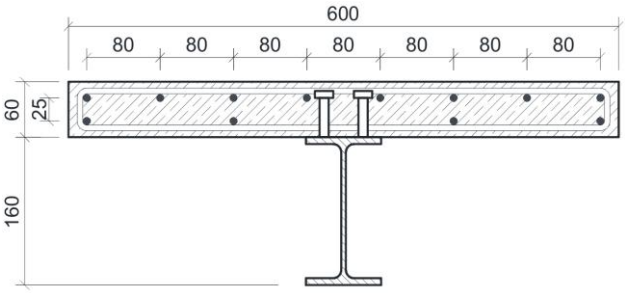

Figure 1: Cross - section of composite beam

2.2 Three - dimensional model

A discrete model of the beam was created in Abaqus software. The idea was: on the one hand, to simulate most precisely a real object, on the other hand, not to waste too much time and work. The assumptions were as follows:

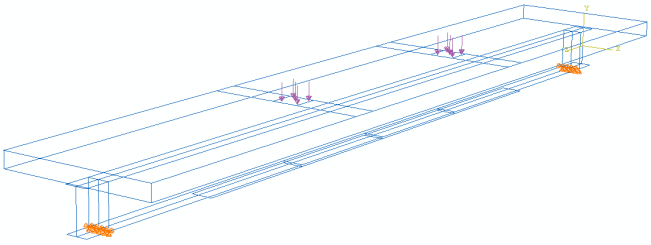

Figure 2: Three-dimensional model

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Constitutive law of material.
Materials that were used (steel, concrete) apparently differed in mechanical features, therefore various physical laws of material were applied in model.

- Steel was taken as elastic - plastic material with plastic range (three line model).
- Concrete was defined by Concrete Damage Plasticity model [1]. This model in full range described concrete's behavior, both in compressive and tensile stresses.

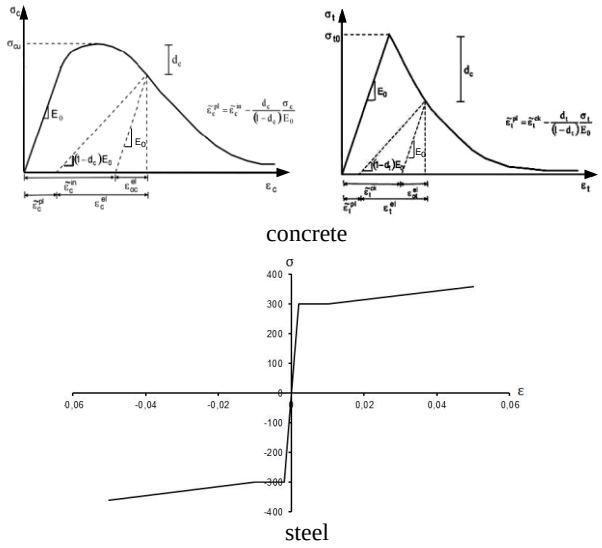

Figure 3: Physical law of material

Discrete Elements.
The analyzed beam was composed of two materials that had completely different geometry. That's why different final elements were applied, which described the particular parts of the beam in the best way:

- The concrete slab was defined as 8-node linear solid elements with reduced integration C3D8R,
- The steel profile and extra steel plate, which was the strengthening, were defined as 4-node thick shell elements with reduced integration S4R.

Connection.
The assumption was, that the connection between concrete slab and steel beam was complete, what was confirmed by the conducted physical experiment.
Loads.
The load was defined in two ways. In the first option there were two concentrated forces in the shape of pressure on a small slab's area (as a better way of the real method of imposing a load and also to get stability of numerical analysis). In the second option, the kinematic excitation was applied as a better representation of the load in physical experiment, what allowed to get a more exact static path.

3. Results

Results of the running analysis are maps of displacements, strains, stresses, plastic ranges and static path P-δ, that enables defining load capacity and post - critical behaviors.

Figure 4 shows a map of stresses in accordance with Misses's hypothesis in a basic beam and strengthening.

Figure 5 shows a static path of strengthening beam. In the figure there is a tangent put to a basic shape of the static path, which presents how the load capacity grows after the strengthening.

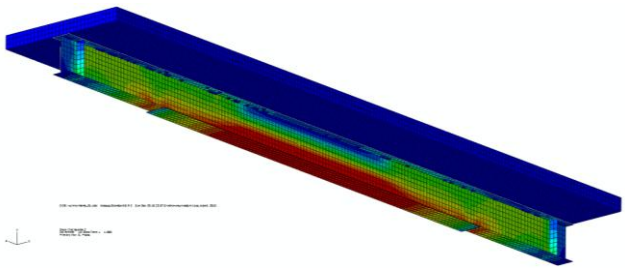

Figure 4: Stress in the beam and in the plate

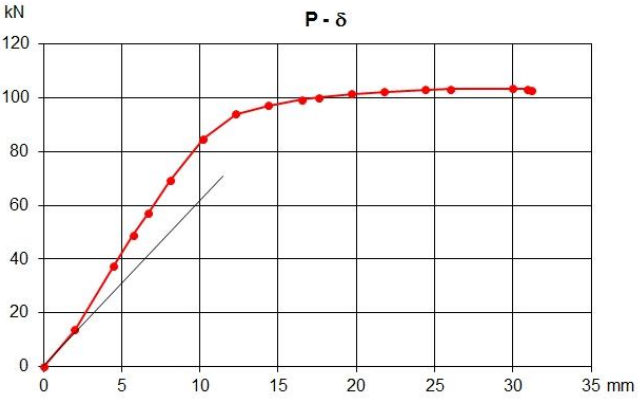

Figure 5: Static path P-δ

4. Conclusion

On the basis of running numerical analysis for the bar model and three - dimensional model, comparing to initial results of physical experiment it was shown as follows:

- the analysis of strengthening steel - concrete composite elements by using bar model is correct and precise only in elastic range,
- in case of the lack of information about method of the composite structures' assembly, it is hard to evaluate correctly initial state of stress, that has to be taken into consideration in superposition of the internal forces from each part of work,
- therefore it is necessary to use the three - dimensional model, which allows defining the exact static path (load capacity and plastic redistribution of forces in strengthening model[3])

Physical study will verify the presented three - dimensional model and consider additional factors (the influence of kind of connection and residual stresses)

References

[1] Abaqus User's Manual. Version 6.8, USA 2008

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[3] Masłowski E., Strengthening of Building Structures, Arkady, Warsaw 2000