INFLUENCE OF FRICTION BETWEEN THE CONTACTING PHASES OF THE FIBER COMPOSITE ON ITS STRESS-STRAIN CONDITION

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Summary Based on the finite element modeling the work analyses the effect of friction between the contacting phases of the composite on its stress-strain condition. There have been defined the ranges of cohesion limits when the significant stress and strain changes in the construction are observed. The influence of changes for reinforcement and matrix elasticity moduli on their stresses is being analysed.

INTRODUCTION

In order to estimate the tension in the areas of reinforcement-composite matrix interactions for certain and take into consideration the effect of friction between the contacting phases of the composite on its stress-strain condition it is necessary to model the reinforcement by a 3D deformable solid body. This paper sets the problem of determining the deformation characteristics of fiber composite with different characteristics of contact interaction between its phases taken into account.

The object of research is a cantilever beam of 1 m length and 20×30 cm rectangular cross-section the reinforcing of which has been done by 5 steel rods with 2 cm in diameter. It has been assumed that the elastic moduli of the matrix material and reinforcing steel are 27 and 200 GPa respectively. To reduce the intensiveness of computations for the load acting symmetrically with respect to the vertical plane of beam symmetry there has been created a model being half of the real beam and divided by the longitudinal vertical plane.

The reinforcement and composite matrix have been created by 20-nodes prismatic finite elements. The necessity to identify the areas of internal slips has caused the usage of contact elements with the size that does not exceed 2 cm of the length of the reinforcement. It's allowed with the sufficient degree of accuracy to determine the areas of internal slips. Therefore, the total number of model finite elements has been found to be 144000. The performed computations are based on the fact that between the composite materials there is the Coulomb's dry friction. The values of friction coefficients have been taken over the range 0 to 1 which correspond to different physical properties of surfaces in the composite contact phases. Accounting the adhesion between the materials can lead to the values of friction coefficient exceeding 1. The load of a beam has been carried out by the gravity forces of its elements and the uniformly distributed pressure of 170 kPa applied to the upper side.

SOME RESULTS

The analysis of the contact between the contacting surfaces of the reinforcement and the matrix under the action of transversal forces only and when friction coefficients are less than 1 has shown that there is no slippage only in small areas of contact between the reinforcement and the matrix of the composite. These areas are located in the upper parts of the reinforcing bars at distances not exceeding 5 diameters of the reinforcement from pinch points.

In the absence of friction the maximum equivalent stresses are observed in the clamped cross-section. With the increase of friction coefficient the area with the maximum equivalent stress is shifted from clamped end of the beam. While computing there have been obtained the distribution of contact stresses on the upper generatrix of the upper reinforcing bar depending on the distance to the clamped end of the beam. The analysis of the results shows that the maximum contact stresses occur at a distance equal two diameters of the reinforcing bar from the clamping place. In the absence of friction contact stresses gradually decrease towards the free end of the beam. Friction accounting has revealed that at the free end of the reinforcing bar there is a contact pressure jump.

A series of computations has been completed to determine the dependence of the maximum contact pressure and contact pressure at the free end of the beam on the friction coefficient between the reinforcement and the composite matrix. As a result of numerical computations have revealed that the maximum contact stresses are monotonically decreasing with the increase of friction coefficient and contact stresses at the free end are gradually increasing. The dependence of the interpenetration of one material to another is similar to the law of contact pressure change. Note that for large values of friction in some areas there are gaps between the reinforcement and the composite matrix. The analysis of values the maximum equivalent stresses on Mises in the reinforcement material has shown that they are monotonically increasing with the increase of friction coefficient. A similar dependence has been observed for the first principal stress (see Fig. 1).

In addition to computation of the stress-strain condition for the beam with small coefficients of friction between the reinforcement and concrete the deformation of the latter when the friction coefficient is over 1 has been analyzed. The

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computation results have shown that for large f values the friction forces are insufficient to keep the reinforcement from sliding in regard to the matrix. With the increase of the friction coefficient the relative displacement of the upper rods stops, and the lower rods are displacing within the concrete matrix. For large values of the friction coefficient the relative displacement of the rod stops. Note that the “average” values of the friction coefficient significantly worsen the solution convergence and expend the computation time. For example, if the friction coefficient $f = 0$ the computation time – 3 hours, if $f = 2$, the time – 147 hours, if $f = 10$, the time – 3,5 hours.

Thus, the results by numerical computations of the stress-strain condition of the beam allow to determine the effect of friction between the contacting phases on the strength and rigidity of the structure as well as on the maximum gap between the reinforcement and the matrix that appears during the work of the structure under load.

Also there has been carried out a series of computations to determine the effect of cohesion between the reinforcement and the composite matrix on the stress-strain condition of the structure. The analysis of the results shows that if the cohesion does not exceed 10 kPa its changes do not affect the strength and rigidity of the structure. In exactly the same way the increase of cohesion over 100 kPa does not lead to a significant change in the stress-strain condition.

Thus, the results of the computations show that over 10 to 100 kPa range there is a significant change in the stress-strain condition of the composite: the tensions/strains in the reinforcement increase to 30%, the stresses in the concrete matrix are reduced by 12-20%, the maximum deformation of the structure increases by 20%, the maximum gap between the reinforcement and matrix increases by 15% and the contact pressure increases by 30%.

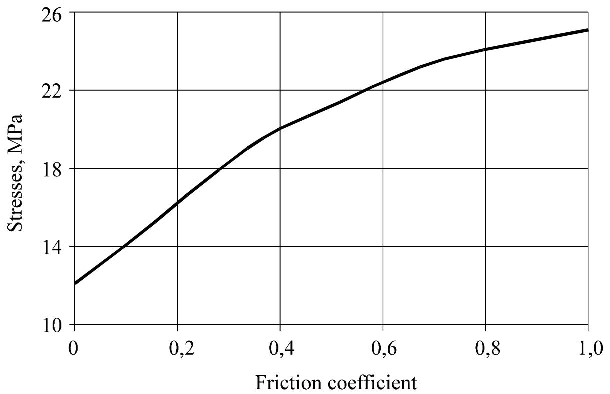


Fig. 1. Dependence of the reinforcement equivalent stresses on the friction coefficient

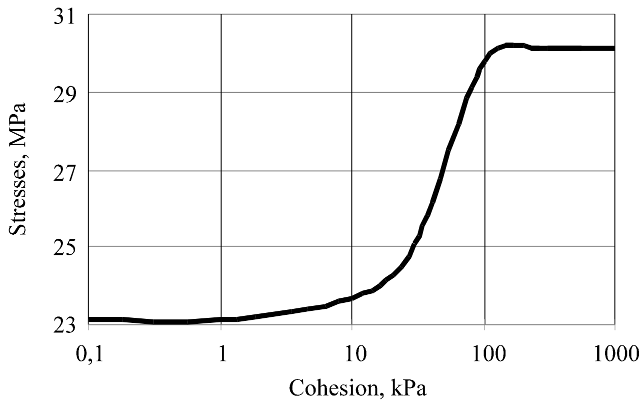
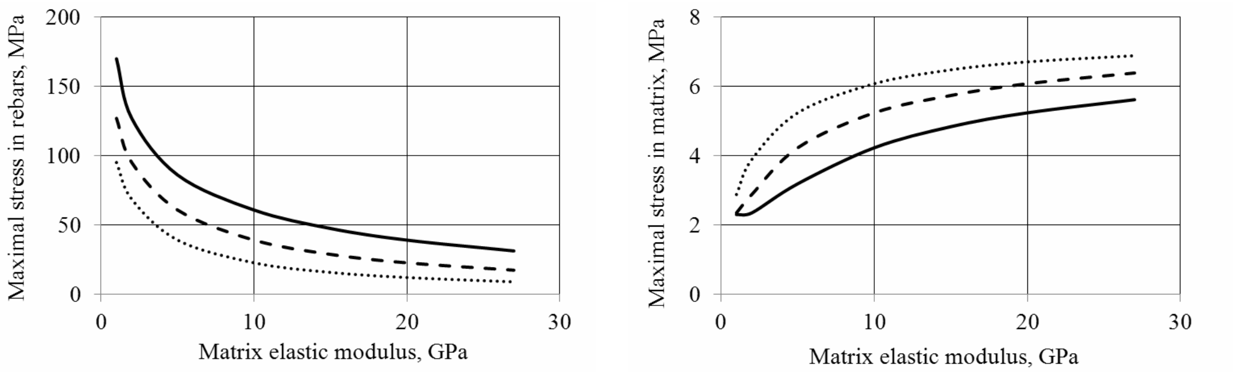


Fig. 2. Dependence of the reinforcement stresses on the reinforcement-matrix cohesion

In addition, the dependence of concrete maximum stresses on the modulus of concrete elasticity for various values of reinforcement elasticity modulus has been determined (Figure 1). The approximate double increase in the modulus of elasticity leads to Mises maximum increases by 14%. When computating there have also been obtained the dependence of the maximum displacements of beam points on the elasticity modulus of concrete for different values of the elasticity modulus of reinforcement. The approximate double increase in the elasticity modulus reduces the strain points of reinforced concrete beams by 32%. Note that for various values of the elasticity modulus of reinforcement the maximum stress in the reinforcement decreases by 35% with the double increase for the elasticity modulus of concrete.



Rebars elastic modulus: —— 200 GPa; – – – 100 GPa; ········ 50 GPa

Fig. 3. Dependence of concrete and reinforcement maximum stresses on the elasticity modulus of concrete

CONCLUSIONS

The received results show the influence of properties of composite materials and friction between the reinforcement and matrix on the stress-strain condition of a fiber composite. They allow to make a conclusion that it is reasonable to apply various materials as reinforced construction.