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Research Article

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Simulation Investigation on Reinforced Concrete by Carbon Fiber Reinforced Polymer

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Abstract In this work, we present a simulation investigation of static finite element of reinforced concrete beam reinforced by carbon fiber reinforced polymer subjected to a load of 500 kN. Preliminary results in term of simulation using a code-program (abaqus) are presented. The material model was simulated in abaqus finite element package and is capable of developing the stress-strain curves. The beam was loaded in three-points. The mechanical properties of the steel and the concrete used in our simulation are obtained from the data of the literature. The results obtained in terms of constraints and displacements are discussed. By this study, we intend to contribute to a better understanding stress-strain by using steel fiber as reinforcement in concrete beam.

Keywords Carbone fiber; Concrete beam; Finite element; Stress; Strain, Strengthening

1. Introduction

Nowadays, the use of reinforced fiber in civil engineering increase rapidly, various type of fiber is used such as glass, carbon, asbestos and steel. Otherwise, it's well known that when a beam is not sufficiently reinforced to resist load, many phenomena takes place such as mixed-mode cracks [1-3]. The results of an experimental investigation on reinforced concrete (RC) T-beams retrofitted in shear with prefabricated L-shaped carbon fiber–reinforced polymer (CFRP) plates were presented by Mofidi et al. [4]. They show that the performance of the specimens strengthened with partially and fully embedded L-shaped CFRP plates in the beam flange was superior to that of the beams strengthened with EB FRP sheets and L-shaped CFRP plates with no embedment. Rena et al. [5] studied one of the most devastating failure models in reinforced concrete structures i.e. the diagonal tension failure. Numerical model was used capable of dealing with both static and dynamic crack propagation.

This work presents a finite-element study by abaqus code simulation on reinforced concrete by carbon fiber reinforced polymer subjected to flexion at a point in the middle with 500 kN. This beam rests on two movable supports. In the first one the displacement is fixed along the Y axis (U2 = 0), and in the second, the displacement is fixed along the X axis and the Y axis (U1 = 0 and U2 = 0). All the mechanical properties of the steel and the concrete used in our simulation are obtained from the data of the literature.

2. Materials details and Simulation Procedures

2.1. Materials details

The FE model of reinforced concrete beam consists of two types of materials, concrete and steel fiber. The beam cross section was reported in Fig. 1. The reinforced layer by steel fiber is embedded within the concrete element using embedding technique available in Abaqus.

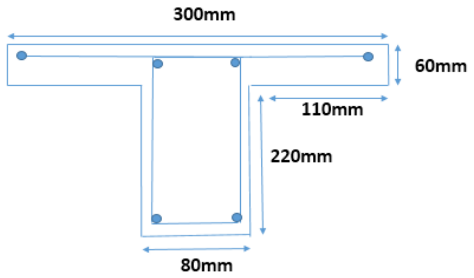

Figure 1: Cross section of the beam

The mechanical properties of concrete and carbon fiber used in the simulation were presented in table 1. It's the material parameters that are fed to the numerical model.

Table 1: Mechanical properties of concrete and carbon fiber

Concrete:	
Density	$\rho = 2400kg/m^3$
Young's modulus	$E = 29.5N/m^2$
Poisson's ratio	$\vartheta = 0.2$
Dilatation angle	30
Eccentricity	0.1
Fb0/fc0	1.16
K	0.6667
Viscosity parameter	0
Compressive strength	$f_c = 2.4.10^7$ N/m²
Tensile strength	$f_t = 2.4.10^6$ N/m²

Carbon fiber:	
Density	$\rho = 1.55$ kg/m³
Young's modulus	$E = 70.10^{10}\ N/m^2$
Poisson's ratio	$\vartheta = 0.77$
Yield stress	$f_y = 2.1\ .10^8$ N/m²

3.2. Simulation Procedures

Numerical tests were carried out using the well tested commercial finite element Abaqus software (CAE 6.13-1). It's provides the capability of simulating the damage using either of the three crack models for reinforced concrete elements: (1) Smeared crack concrete model, (2) Brittle crack concrete model, and (3) Concrete damaged plasticity model. Out of the three concrete crack models, the concrete damaged plasticity model is selected in the present study as this technique has the potential to represent complete inelastic behaviour of concrete both in tension and compression including damage characteristics. Further, this is the only model which can be used both in ABAQUS/Standard and ABAQUS/Explicit and thus enable the transfer of results between the two. Therefore, development of a proper damage simulation model using the concrete damaged plasticity model will be useful for the analysis of reinforced concrete structures under any loading combinations including both static and dynamic loading.

The finite element method (FEM) is applied widely in the calculation of structures with reliable results. The FEM makes it possible to solve in a discrete manner a partial differential equation whose approximate solution is "sufficiently" reliable. In general, this partial differential equation relates to an approximation function u (x) defined on a domain jx (x). It contains boundary conditions to ensure the existence and uniqueness of a solution. In this study, the linear 3D element 4 points of integration (C3D4) are used for the concrete model. The bar element T3D2 is used when it is for the reinforcement by carbon fiber. Moreover, the armatures of the numerical model are simplified and present only axial forces.

3. Results and discussion

The numerical results on beam loaded in three-points in the absence and in the presence on reinforced by carbon fibers are presented in Fig. 2 and Fig. 3. The load was about of 500 kN. Fig. 2 (a) and Fig. 3 (a) give the stress, and Fig. 3 (b) and Fig.3 (b) the strain. The mechanical properties of concrete and steel used in the simulation sere presented in table 1. It's the material parameters that are fed to the numerical model. The comparison of FEM results on flexing shows that the reinforced beam resists sharp stresses and can reach up to a factor of 6. In order to elucidate this exaltation, we plot the stress-strain curve of concrete in the presence and in the absence of reinforcement (Fig. 4). The maximum stress of reinforced beam is located at 1.1 MPa and for beam without reinforcement at 0.17 MPa. The maximum strain is attained at the same point for each beam. Strengthened beam had a slope of line more pronounced then the unstrengthened one. A similar phenomenon was experimentally observed by Mofidi et al. [4] with beam strengthened by fiber-reinforced polymer. Moreover, the shear results show that reinforcement of the beam is not obtained.

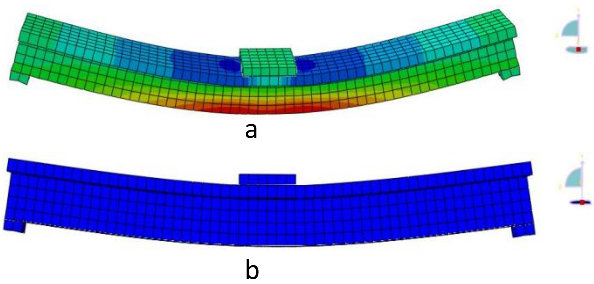

Figure 2 : (a) Stress of the concrete beam, (b) strain of concrete beam.

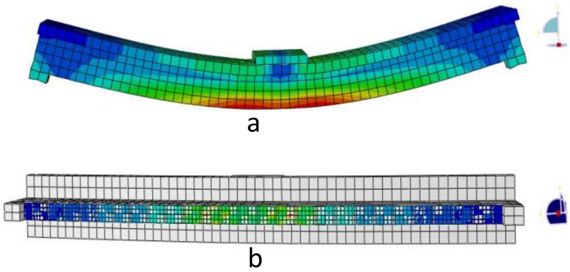

Figure 3 : (a) Stress of the reinforced beam, (b) strain of the reinforced beam

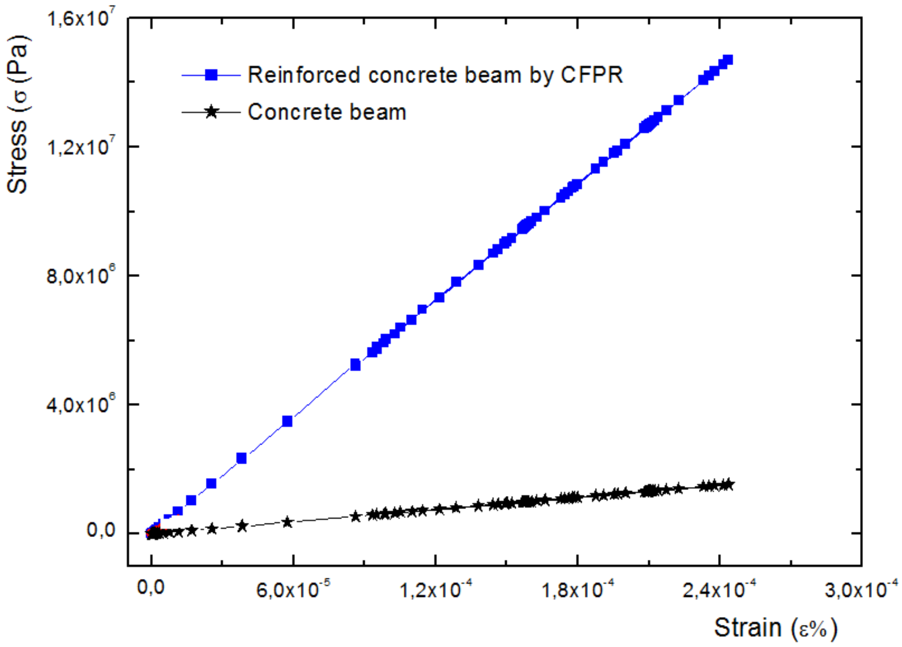

Figure 4: Stress–strain curve of concrete in the presence and in the absence of reinforcement

In the other hand, different forms simulation models presented in the literature as reviewed in the paper by Nayal al [5]. The model developed was used in the study of Wahalathanri et al. [6] and it was applicable for both reinforced and fibre reinforced concrete with only minor changes. Also, this method indicates similarity to the tension stiffening model that is needed for ABAQUS concrete damaged plasticity model. This tension stiffening model was originally based on the homogenized stress-strain relationship developed by Gilbert et al [7] which accounts for tension stiffening, tension softening and local bond slip effects. Two descending portions of the tensile stressstrain graph has accurately captured the response caused by primary and secondary cracking phenomena. The layered tension stiffening parameters used is replaced with a single set of stiffening parameters applicable to the entire tensile zone by the Nayal et al. [5].

Experimental analysis was done with addition of steel fibers by Hannant ae al. [8]. They found that the addition of steel fibers has more influence on the flexural strength of concrete compared to its tensile/compressive strength. As reported by Oh et al. [9], the flexural strength of SFRC has been increased about 55% with the addition of 2% by volume of steel fibers. Johnston [10, 11] has found that the compressive strength of SFRC is increased about 20% with the addition of 1.2% by volume of steel fibers. Research conducted by Johnston [12] showed that the compressive strength of sfrc has been increased from 0 to 15% with the addition of up to 1.5% of steel fibers by volume. in a research conducted by hartman [13] twelve different sfrc beams containing two different sfs amount of 60 and 100 kg/m^3 of dramix rc- 65/35-bn type were tested and it was concluded that the ratio of the experimental ultimate load to the theoritical ultimate load was bigger for those sfrc beams having a 60 kg/m^3 amount of sfs.

4. Conclusion

The study of strengthened and unstrengthened beam by FE - abaqus code showed that reinforcement is better with flexion. However, it remains limited for shear stresses. It is therefore proposed to study the shear behavior and the failure modes of reinforced beams with fiber reinforced polymer sheets. Also, it is envisaged to improve the database on shear reinforcement and then validate the approach of the model proposed in the literature.

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