Numerical Simulation of Beams

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Abstract

Response of structural components like beams have been studied by different methods. One of the methods which is widely used is experimental testing. But since it produces real life response, it is time consuming, and the use of materials can be quite costly. However, finite element analysis has been used a lot due to capabilities of computer software and hardware. The use of computer software to model structural elements is much faster, and cost-effective.

Various computer packages are available now a days and finite element analysis can be done with high accuracy. In this project the software named as ABAQUS was used to simulate the load-deflection of different types of beams. Also, an excel sheet based on Branson's equation was generated to simulate the load-deflection curve of reinforced concrete (RC) beams.

Simulating a composite beam which is concrete filled steel tube was done, the effect of B/T ratio, yield strength of steel tube, compressive strength of concrete, and the stiffness on the capacity of the composite beam was studied. beam resulted in an increase in the capacity. Simulating the load-deflection of RC beam was conducted by using the excel sheet which is based on finding the effective moment of inertia by using Branson's equation.

Introduction

Beam is a structural component that transfers loads to columns, then loads are transferred to the foundations, and then to the supporting soil beneath. Understanding the response of these structural components under loading is crucial to the development of an overall efficient and safe structure.

Different methods have been utilized to study the response of structural components. Experimental testing is one of the methods that has been widely used to analyze individual elements and identify the effects of strength under loading. While experimental testing is a method that produces real life response, it is time consuming, and the use of materials can be quite costly.

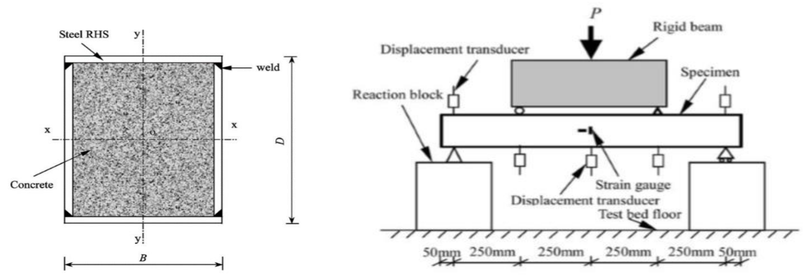
One of the methods which is used to predict the response of beams under the application of loads is the numerical simulation. Numerical simulation is a calculation that is run on a computer following a program that implements a mathematical model for a physical system. Then this model can be used to determine and analyze the behavior and response of that structure components.

Literature Review

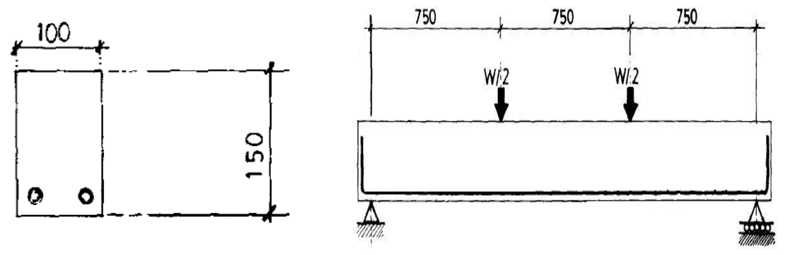
A lot of papers on the application of the numerical simulation and experimental testing for the analysis of composite and RC beams have been investigated and studied. R. Jones et al. (1982) performed tests on the strength and deformation characteristics in flexure of RC beams, The ultimate strength of the beams is theoretically predicted and is shown to give good agreement with experimental results. Lin-Hai Han (2004) developed a mechanics model that can predict the behavior of concrete-filled hollow structural section (HSS) beams. A series of concrete filled square and rectangular tube beam tests were carried out. The predicted curves of load vs. mid-span deflection are in good agreement with the presented test results. A.S.D. Salama et al. (2018) explored the feasibility of strengthening RC beams in flexure by side-bonded CFRP composite sheets. It is observed from the load-deflection response curves, and failure modes that specimens strengthened with similar amount of reinforcement are comparable with percent increase in the flexural strength over the control beam.

Methodology

ABAQUS is a powerful engineering simulation programs. It can solve problems ranging from relatively simple linear analyses to the most challenging nonlinear simulations. It will be used to simulate the following composite and RC beams:

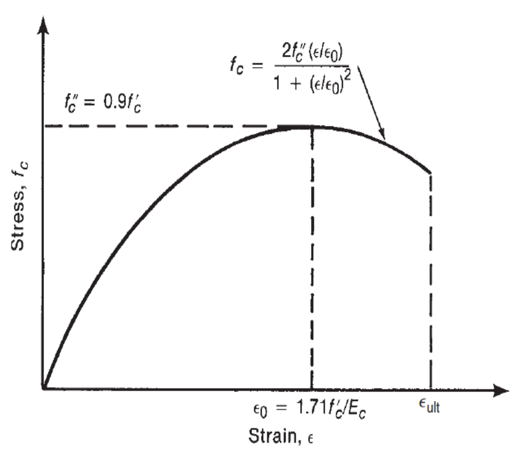


Composite beam tested by Lin-Hai Han (2004)

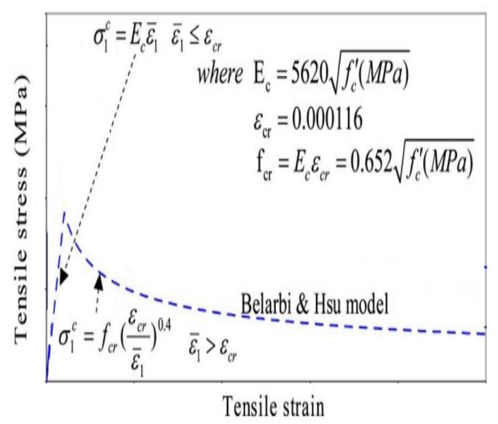


RC beam tested by R. Jones (1982)

Since the constitutive model of the concrete in both tension and compression were not provided in the experimental studies, Todeschini and Belarbi models were considered. Whereas a bilinear behavior was assumed for the steel.



Todeschini model for compression behavior



Belarbi and Hsu model for tension behavior

An excel sheet was developed for simulating the load-deflection curve of RC beam. It was based on finding the load at which concrete cracks, the load at which steel yields, and the load at which the concrete crush, then calculating the corresponding deflection for each load by using the following equation:

$$\Delta = \frac{(P/2)a}{24E_cI_e}\left(3l^2 - 4a^2\right)$$

Note since the cracking of concrete is not uniform along the length, Branson suggested to use the following formula to find the effective moment of inertia:

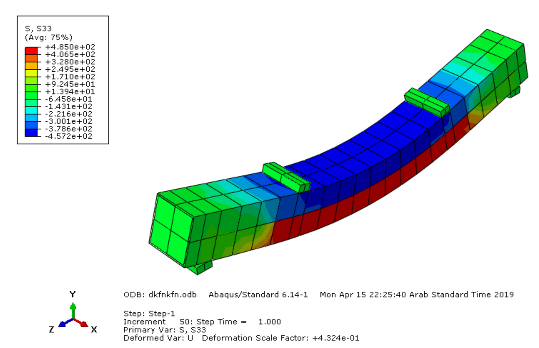
$$I_e = \left(\frac{M_{cr}}{M_{max}}\right)^3 I_g + \left[1 - \left(\frac{M_{cr}}{M_{max}}\right)^3\right] I_{cr}$$

Where M_{cr} is the cracking moment, M_{max} is the moment acting at the condition under which deflection is computed, E_c is the modulus of elasticity of concrete, a is the location of applied load, and l is the length of the beam.

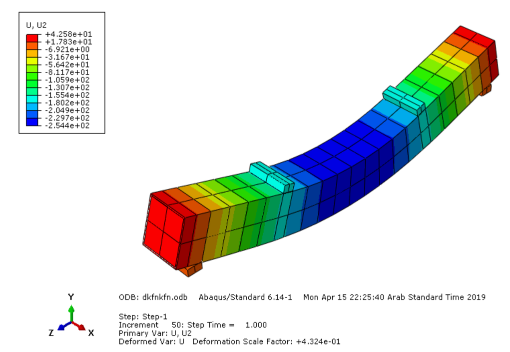
Results

❖ **Results of simulating the composite beam:**

Simulating composite beam was done using ABAQUS, following are the variation of stresses and deflection along the length of the beam:

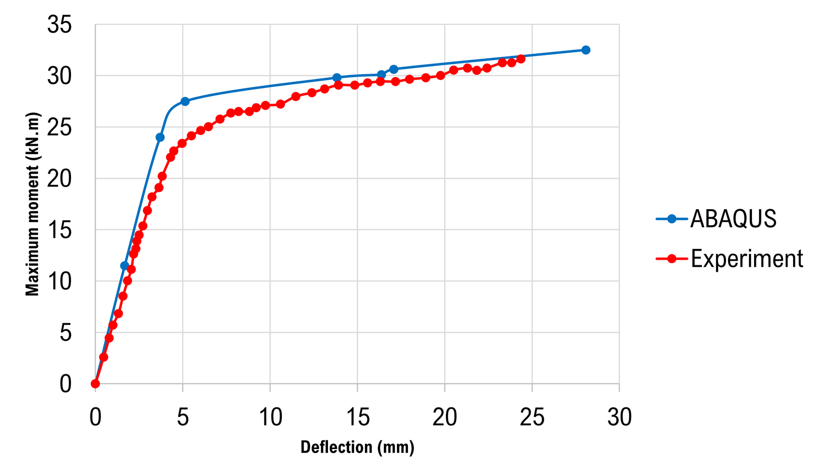


Variation of stresses along the length of the beam



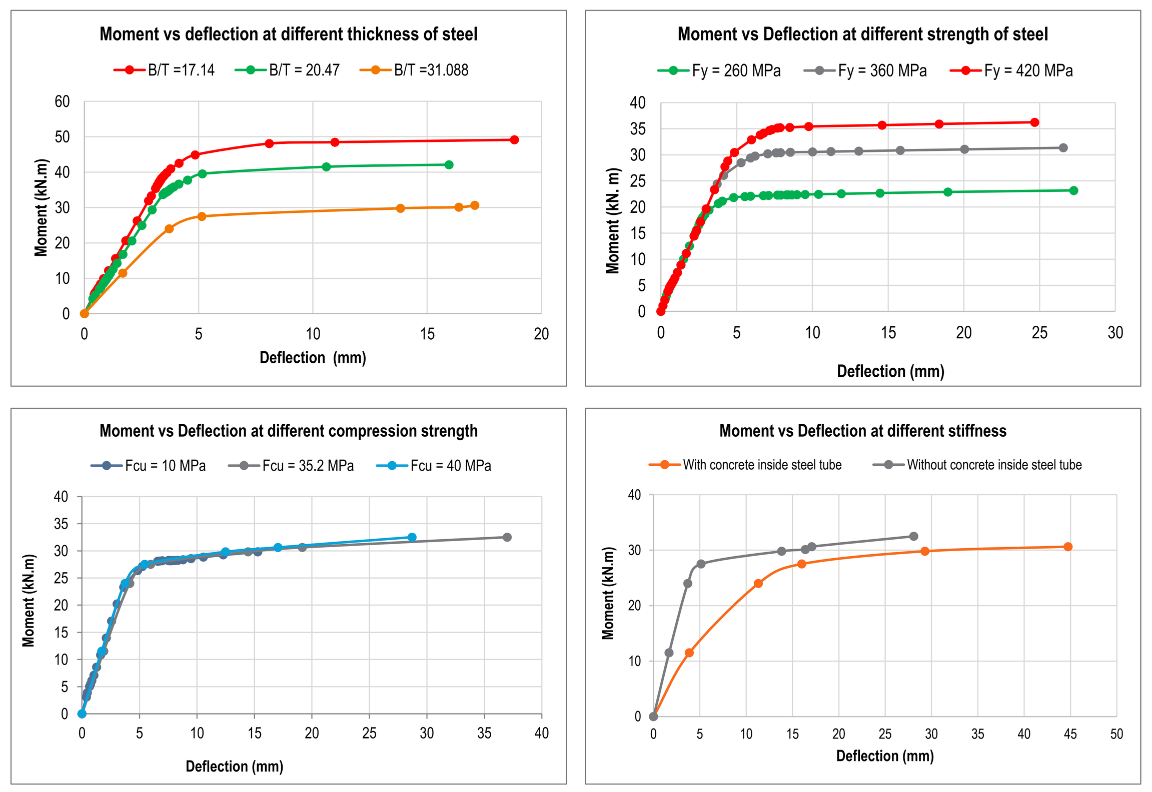
Variation of deflection along the length of the beam

The following is the load-deflection curve of both experimental and numerical simulation, which shows a good agreement between them:



Numerical and experimental load-deflection curve of composite beam

The following cases were studied to investigate their effect on the capacity of the composite beam:
(1) Effect of the B/T ratio, (2) Effect of the strength of steel, (3) Effect of strength of concrete, and (4) Effect of the stiffness on the capacity of the composite beam.



Moment-deflection curves of different case studies

Results (cont.)

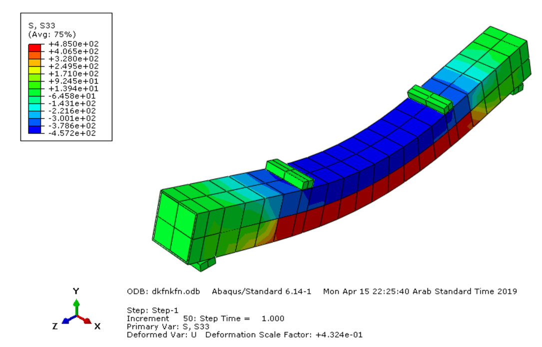
By plotting maximum moment against the B/T ratio and strength of steel (F_y), the following two simple formulas were developed to predict the capacity:

$M_{max} = 0.0148\ (B/T)^2 - 1.8751\ (B/T) + 71.46$

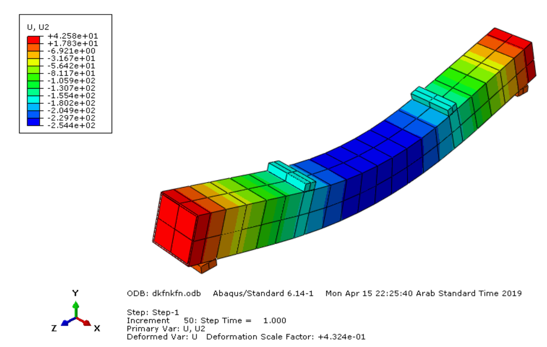
$M_{max} = 0.0811\ F_y + 2.1304$

❖ **Results of simulating the RC beam:**

Simulating composite beam was done using ABAQUS and by excel sheet, following are the variation of stresses and deflection along the length:

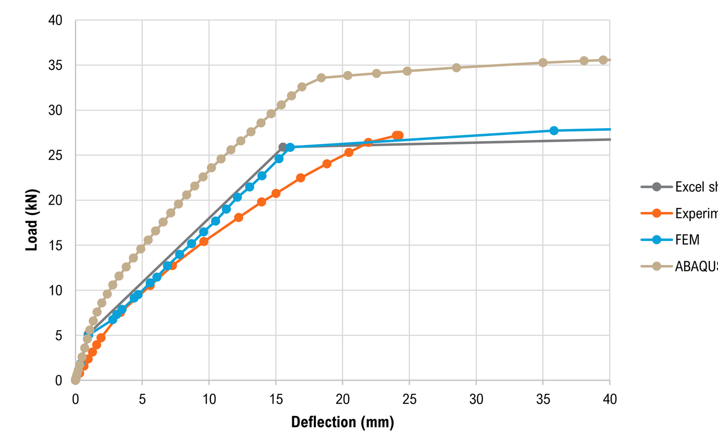


Variation of stresses along the length of the beam



Variation of deflection along the length of the beam

The following is the load-deflection curve of RC beam by different approaches:



Load-deflection curve of RC beam by using different approaches

Conclusions

- ❑ Composite beam has been simulated by using ABAQUS, the results were very close to the experiment which means that the simulation results are validated.
- ❑ The decrease of B/T ratio results in an increase in the capacity of the composite beam, because the stiffness was increased.
- ❑ The increase of the yield strength of the steel tube results in an increase in the capacity, which means the failure of composite beam will be governed by yielding of steel tube.
- ❑ The increase in the compressive strength of concrete filled steel tube did not change the capacity of the composite beam.
- ❑ Removing the concrete from inside the steel tube results in a decrease in the maximum moment capacity of the composite beam because the stiffness was reduced.
- ❑ The results of simulating RC beam by the excel sheet showed a good agreement with the experiment and FEM analysis, whereas ABAQUS results did not. The reason maybe because the constitutive model and modulus of elasticity of concrete were not provided in the experiment. Bond properties between steel bars and concrete were also missing. Assumed bond properties may also affect the numerical simulation of RC beam.