Research Proposal

EXPERIMENTAL AND NUMERICAL STUDIES ON THE BEHAVIOR OF RC T-BEAMS STRENGTHENED WITH FRP RODS AND FRP SHEETS UNDER MONOTONIC AND CYCLIC LOADING

Abstract

The use of Near Surface Mounted (NSM) strengthening technique to retrofit reinforced concrete (RC) members using Fiber Reinforced Polymer (FRP) rods has been increasing more and more in recent years, as the engineers have become more familiar with the appealing attributes of FRP. A critical point of the NSM technique is the bond behavior, since the most typical failure modes are due to the loss of the bond either within the adhesive layer or at the FRP bar/adhesive or adhesive/concrete interfaces and, therefore, the ultimate capacity of the reinforced elements will depend on the bond behavior. To address and analyze the influence of the most critical parameters, test series should be conducted. In addition, a closer examination of the open literature shows that there is limited work on the effect of FRP rods as a negative moment region flexural strengthening on the RC T-beams. Thus, in order to bridge the knowledge gap, it is important to continue the research into experimental test and accurate numerical modeling so that engineers and the scientific community have access to a better understanding on the bond performance of FRP rod embedded in concrete with various depth well as the response of RC T-beams strengthened in the negative moment region with NSM FRP rods and sheets subjected to monotonic and cyclic loading.

Preliminary Results

A. Nonlinear 3D model of double shear lap tests for bond of near-surface mounted FRP rods in concrete with various embedment depth

Though there has been widespread use of FRP strengthening systems, it is important to carry out further experimental, analytical and quantitative assessment so as to comprehend the impact of various strengthening factors on the effectiveness of RC members. Abaqus, which is sophisticated numerical modeling software, is employed in this work to formulate a 3D non-linear finite element (FE) model that is capable of accurately simulating double shear lap tests that can appropriately illustrate the nature of bond between FRP rods and concrete. For this purpose, the implementation specifically stresses on the modeling of the interface behavior among the near surface mounted (NSM) FRP rods/bars and concrete by making appropriate adjustments for the parameters of the bond stress/slip law used (Figure 7). In addition, an extensive 3D non-linear FE model is formulated that is capable of accurately forecasting the load-carrying capacity and reaction of RC T-beam strengthened with NSM FRP rods and sheets exposed to three-point bending loading (Figure 8). To validate the FE models formulated, the forecasted behavior and response are contrasted with the computed previous experimental data.

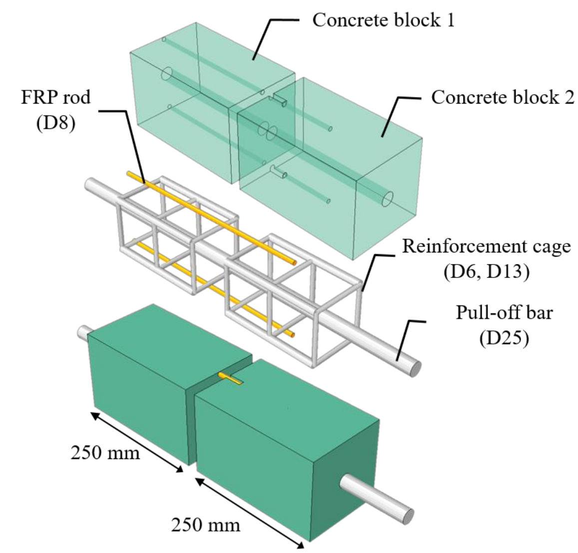


Figure 7. Geometry of double shear lap test model

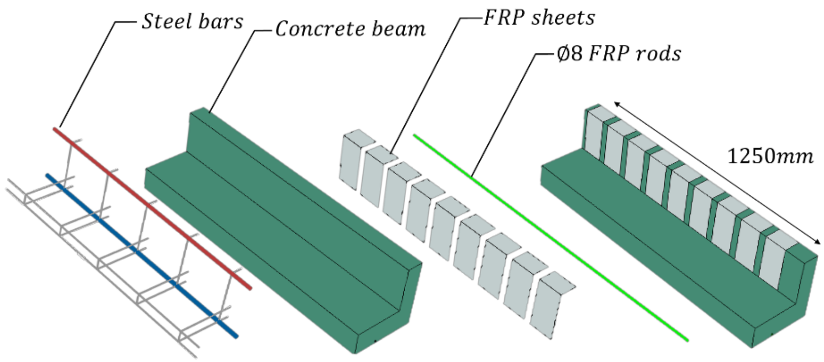
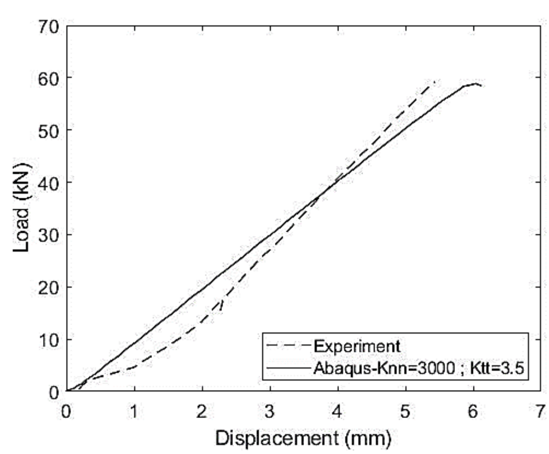
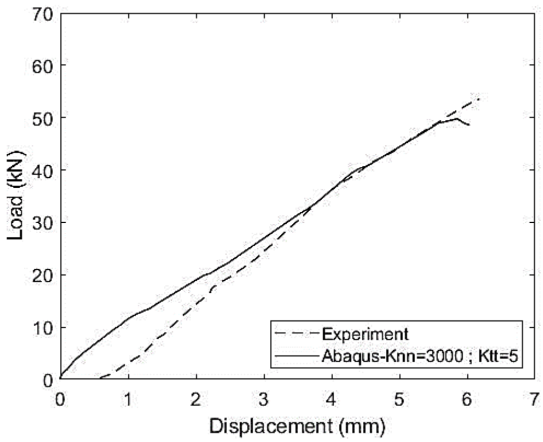


Figure 8. Geometry of 3-point bending test model

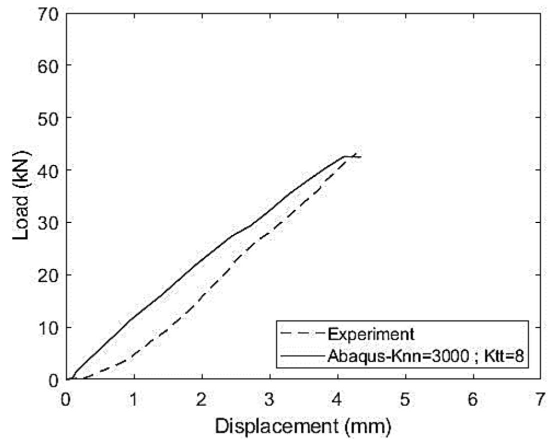
Knowing the influence of K_{nn} and K_{ss} (= K_{tt}) on the analysis results of double shear lap test model, K_{nn} was defined as a certain value in the simulation for its little effect on the analysis results, and the value of K_{ss} (= K_{tt}) was defined by numerical validation as shown in the Figure 9. The coefficient of determination R^2 are used to evaluate whether the simulation fits to the experimental data and the results are shown in Table 1. The range of R^2 is 0 to 1, and the closer to 1 the more consistent the simulation result is with the experiment. As for the errors of ultimate load by comparing the numerical and experimental results are shown in the Table 2.



a) Full-embedment



b) Edge-embedment



c) Half-embedment

Figure 9. Numerical validation of double shear lap test model

Table 1. Coefficient of determination for the simulation

	Full-embedded model	Edge-embedded model	Half-embedded model
r^2	0.954	0.931	0.920

Table 2. Errors for ultimate load (kN)

Model	Experiment (average)	Numerical analysis	Error
Full-embedded	59.10	58.86	-0.40%
Edge-embedded	51.81	49.79	-3.90%
Half-embedded	43.17	42.55	-1.43%

B. Flexural behavior of RC T-beams strengthened in the negative moment region by using FRP rods with different embedment depth - Validation of a FEA model

Next, in order to verify the correctness and applicability of the CDP model and the idealized model for steel used in the simulation of 3-point bending test, the BM model (control beam) was first created. Figure 10 and Table 3 show the validation result of the model, which show that material models used for concrete and steel are feasible in the simulation.

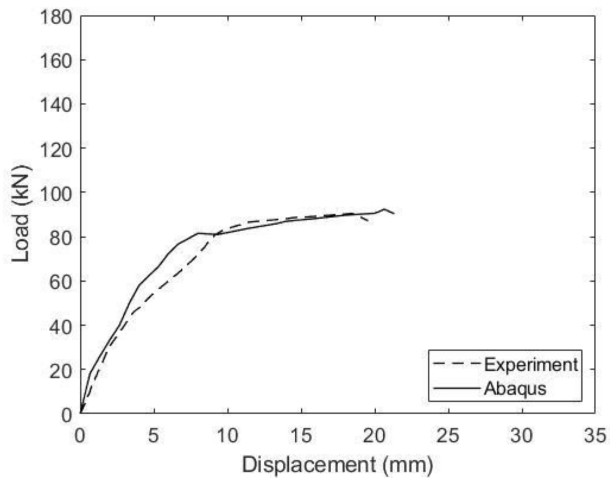


Figure 10. Numerical validation of double shear lap test model

Table 3. Validation of BM model

	Experiment	Abaqus	Error
Yield point load	83.0	81.	1.75%
Ultimate load	90.5	92.4	2.04%
r^2	0.957		/

Then, the FRP plates and FRP rod were added to the BN model and become the two strengthened models BF and BH mentioned earlier. Figure 11 and Table 3 show the validation of the two strengthened beam model.

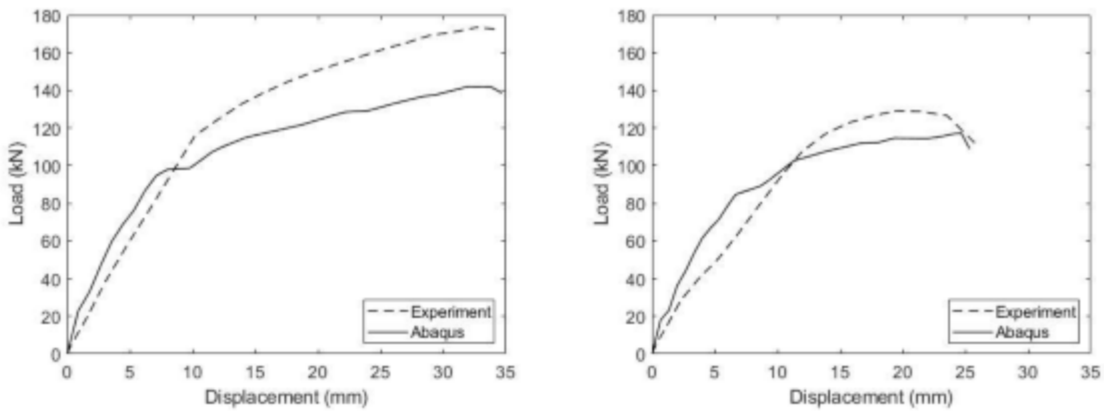


Figure 11. Validation of strengthened beam models

(a) BF beam; (b) BH beam

Table 3. Validation of Strengthened beam models

a) BRF beam			
	Experiment	Abaqus	Error
Yield point load (kN)	116.1	98.0.	15.63%
Ultimate load (kN)	173.5	142.1	18.12%
r^2	0.87		/
b) BRH beam			
	Experiment	Abaqus	Error
Yield point load (kN)	83.0	81.	1.75%
Ultimate load (kN)	129.2	117.3	9.22%
r^2	0.957		/