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Modeling of A Cracked Concrete Beam Repaired with FRP

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Abstract

The load capacity of concrete structures is affected by the cracking behaviour of concrete. Since the tensile strength of concrete is much lower than its compressive strength (approximately 10 times), concrete belongs to the group of brittle materials but it is not perfectly brittle. Since concrete is thought to be a quasi-brittle material, the study of failure and crack formation in concrete beams is addressed in this work. The code calculate ABAQUS was utilized in the current study, which is numerical in nature, to discretize the model utilizing the MEF approach. Its goal is to comprehend how fractured concrete beams reinforced with various composite materials behave. In addition to failure factors of the structure's behaviour like Von Mises stress and stress intensity factor, other variations of Patch reinforcement have been examined.

Keywords: *Concrete Beam, Crack, Composite Materials, Stress Intensity Factor, Vonmises Stress.*

1. INTRODUCTION

Plastic analysis has been used traditionally to assess the collapse behavior of structures on the basis of yielding of cross sections under proportionally increasing loading. However, there are some circumstances under which the traditional methods of plastic analysis cannot be applied. For example, there are materials that may not be able to sustain plastic moment throughout the loading history because of lack of ductility in the materials [M. Bill Wong, in Plastic Analysis and Design of Steel Structures, 2009]

In the late 1940s A. L. L. Baker published several papers on the plastic behaviour of concrete. Research at Imperial College indicated that reinforced concrete was not too brittle for plastic analysis and in 1956 A. L. L. Baker's book7 was published, and gave recommendations for the plastic hinge design of reinforced concrete beams. In our work we analysed the behaviour of concrete beam throughout the study of plastic, and fructure parameters such as Von Mises stress Displacement and Stress intensity factor, using Finite Element method implemented in the code calcul Abaqus, for different loads, crack sizes, and different Composite materials used to repair the cracked beam.

Nowadays, several materials are used in civil engineering projects, concrete is one of them. In fact, thanks to its excellent performance, especially its high compressive strength and versatility of use, concrete is omnipresent in buildings bridges, pavements, dams and more. To compensate for its low tensile strength concrete is combined with steel to form reinforced concrete in order to work better together. This combination of concrete and steel goes back a very long way, but were disavowed by contradictions and a few misfortunes. From then on, reinforced concrete gradually spread throughout the world, and is now an indispensable part of today's construction.

2. ANALYSIS OF FEA RESULTS

The aim of this research project is to use a finite element calculation code to study the behavior of a reinforced concrete beam, strengthened in shear by FRP (Fiber Reinforced Polymer) composite materials. The question of the reliability of reinforcement of beams with FRP frames is a relevant topic, In an attempt to answer this question, In our work we analysed the behaviour of concrete beam throughout the study of plastic, and fracture parameters such as Von Mises stress Displacement and Stress intensity factor, using Finite Element method implemented in the code Compute Abaqus, for different loads, crack sizes, and different Composite materials used to repair the cracked beam. The geometrical model consist of a rectangular concrete beam discretisized using Abaqus

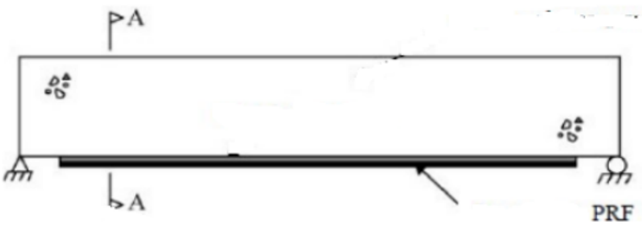
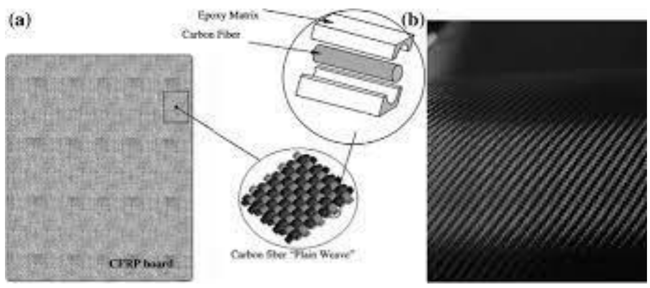


Figure: Concrete beam with PRF reinforcement technique



Carbon Fiber Reinforced Polymer (CFRP) Composite Materials (Dervis Ozkan et al.)

Table: Geometries and Dimensions

Dimensions	L(MM)	B(mm)	T(mm)
Beam	3000	200	300
Patch	300	200	10
ADHESIVE	300	200	0.2

Table: Material Properties

	YOUNG modulus	Poisson ratio
beam	30 GPA	0.18
adhesive	2 GPA	0.35

Adhesive properties E = 2GPA Nu=0,35

Patch properties (T 300/934)

E1	E2	G	NU
148	9.65	4.55	0.33

First, it is necessary to make sure that yielding is absent (or appropriate). Verify if plastic stresses are acceptable if your model yields. Check to see if you have any stability problems (buckling analysis, for example). Remember to check if the model deformations are minimal enough.

The findings of Von Misses Stress are displayed in the following figures. for a concrete beam, under Tensil loads, for tensile values 50 MPa, and 100 MPa. Note that S,Mises for 100MPa is two times higher than S,Mises for 50 MPa

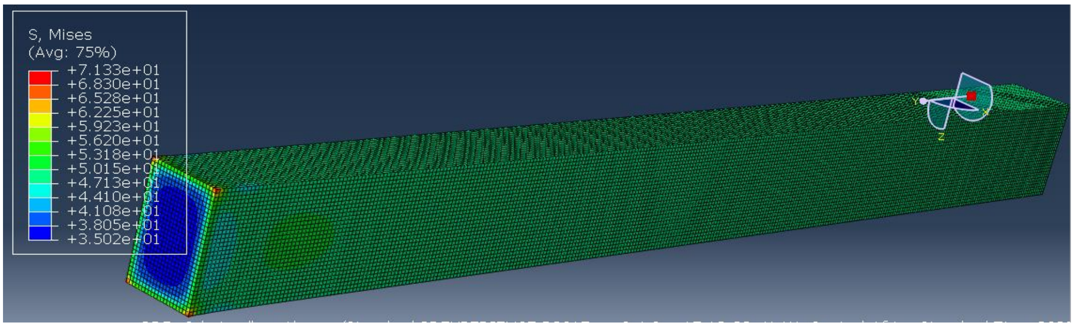


Figure: Von Mises Stress-load plot for concrete beam under tensile load (50 MPa)

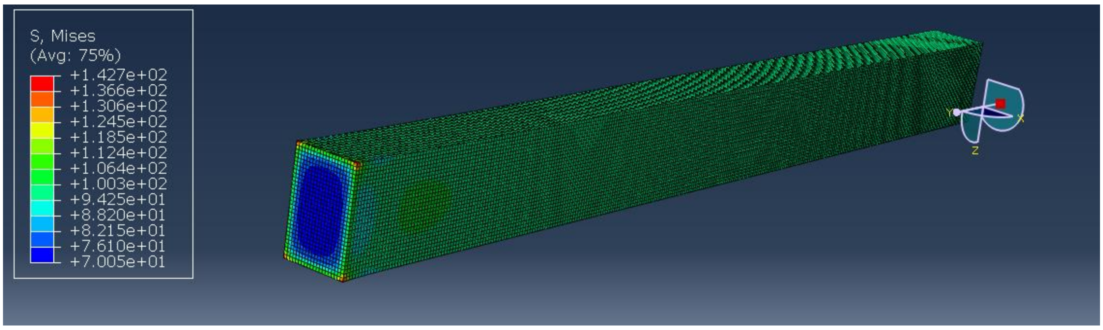


Figure: Von Mises Stress-load plot for concrete beam under tensile load (100 MPa)

The following two **figures alfa and beta** show respectively the variation of Von Misses stress, and variation of displacement under tensile load, and flexion Load, it is noticeable that flexion has a higher impact on Von Misses values for both plots, which may indicate that flexion loads is significantly more affecting the concrete beam structure than tensile loads, however it does not mean that tensile load is to be neglected.

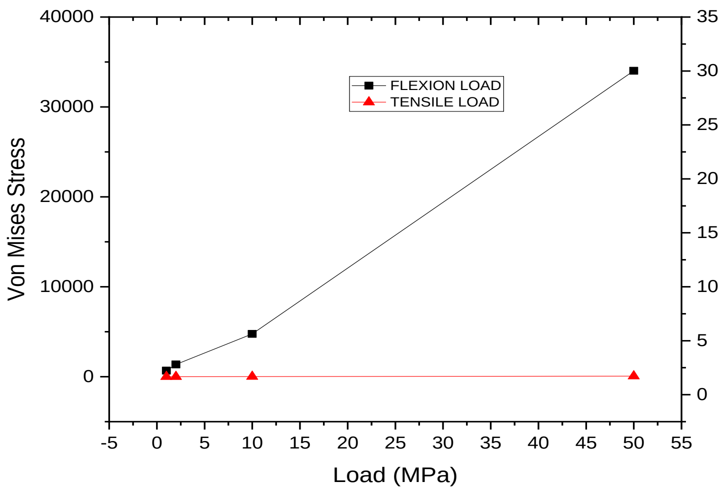


Figure alfa: Von Misses Stress-Load plot for concrete beam

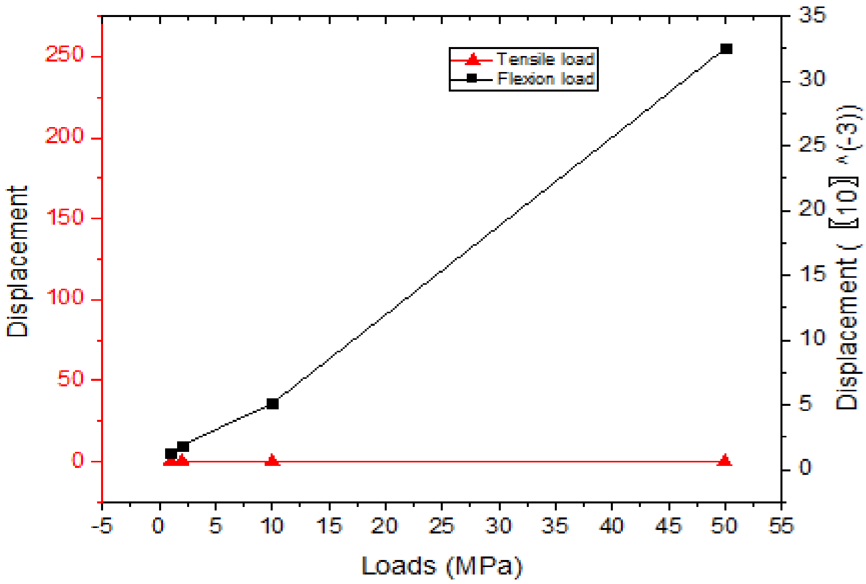


Figure beta: Displacement-Load plot for concrete beam

In the design of reinforced concrete members, the tensile strength of the concrete is generally ignored. However, the tensile strength of concrete still has significance in terms of durability and serviceability. For example, the propagation and control of cracks are highly related to the tensile strength of concrete. Ignorance towards the tensile strength of concrete may lead to the problems of serviceability and durability and it makes tensile strength an important parameter of design. [Wen-Cheng Liao, et al. « An Innovative Test Method for Tensile Strength of Concrete by Applying the Strut-and-Tie Methodology » journal Materials Basel]

Tensile Strength of Concrete

Any concrete structure that may undergo tensile stress must first be reinforced with high tensile strength materials like steel. The knowledge about the tensile strength of concrete is increasingly getting vast due to its significance in managing potential cracking.

Studies indicate that traditional concrete's tensile strength varies between 300 and 700 psi, i.e., around 2 to 5 MPa. This means, on average, the tension averages about 10% of the compressive strength. [https://www.bigdreadymix.com/]

Cracked Beam

In our work we modeled different sizes of cracks existing in the beam, in order to analyse it's behavour and failure Crack's dimensions: Length of 100mm, Width of 2mm, and depth of 30mm Plastic behaviour of concrete (cracking behaviour):

The major processes that influence and constitute the plastic cracking behaviour of concrete include bleeding, evaporation, settlement, shrinkage, and capillary pressure. These underlying processes mainly occur during the plastic phase of concrete, during which time concrete has considerable rheological properties. [John Temitope Kolawole and al']

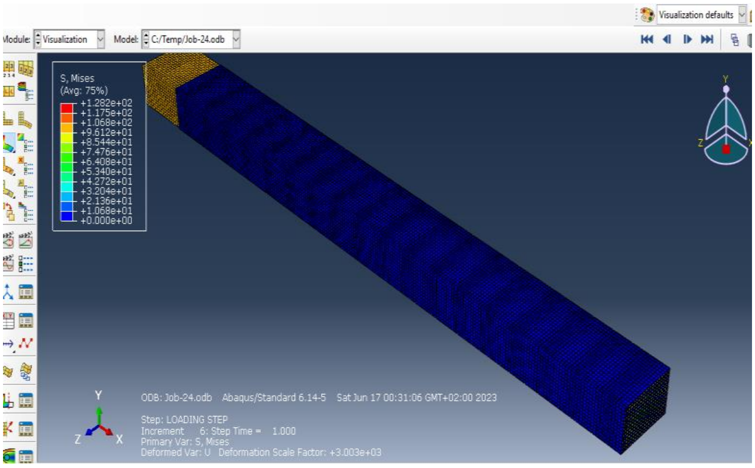


Figure A: FEM Results of Von Mises Stress for a crack size of 100mm

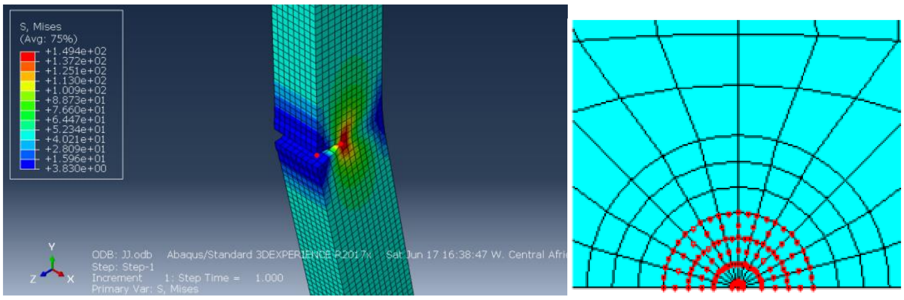


Figure B: FEM Mesh, and Results of Von Mises Stress near the crack size

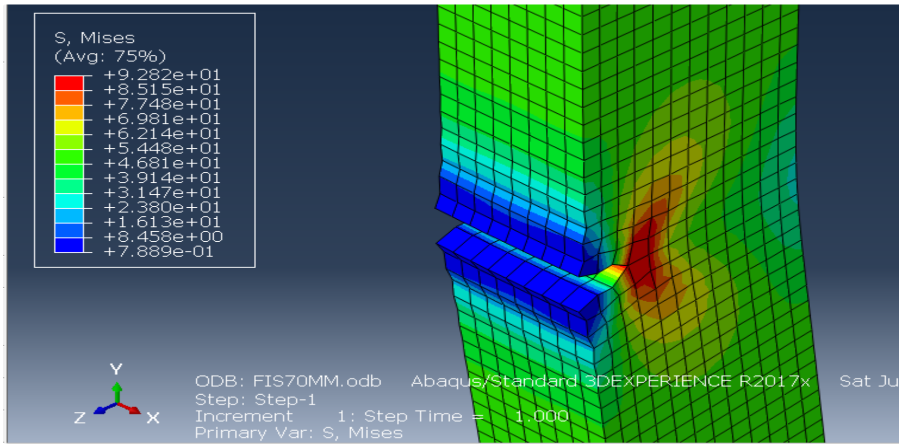


Figure: FEM Results of Von Mises Stress for a crack size of 70mm

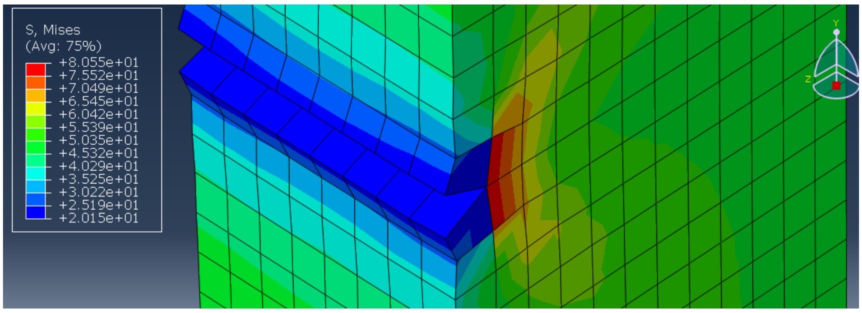


Figure: FEM Results Von Mises Stress for a crack size of 30mm

The region where the micro-cracks distribute and the 49 damages accumulate as fracture proceeds is called the fracture process zone (FPZ), which 50 reflects the nonlinear characteristic of concrete as a quasi-brittle material. Due to the 51 existence of FPZ ahead of the crack tip, the whole fracture process in concrete can be 52 divided into three stages, i.e., crack initiation, stable and unstable crack propagation. The following figure represents Von Mises Stress, and Stress Intensity factor variation along the concrete beam, in the presence of a crack. It is clear that SIF variation are highly more remarquably increasing toward a critical value, however S, Von Mises increases gradually, but we can assert that this parameters are both used to characterise the structure behaviour in the presence , and propagation of cracks.

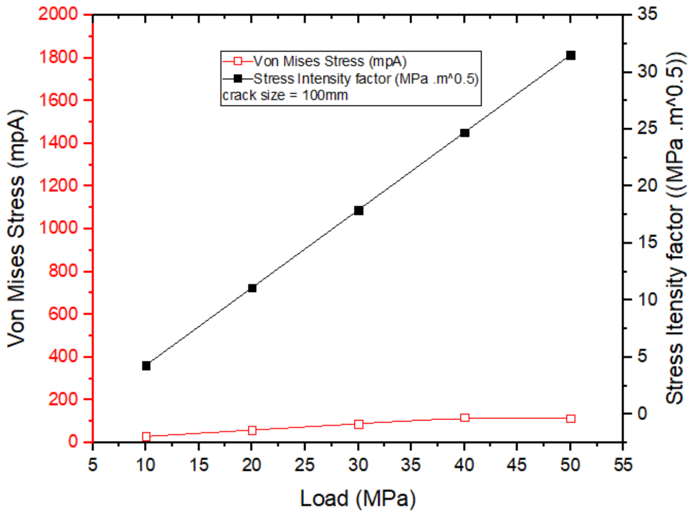


Figure: Von Misses stress-load plot for cracked beam

Repaired structure

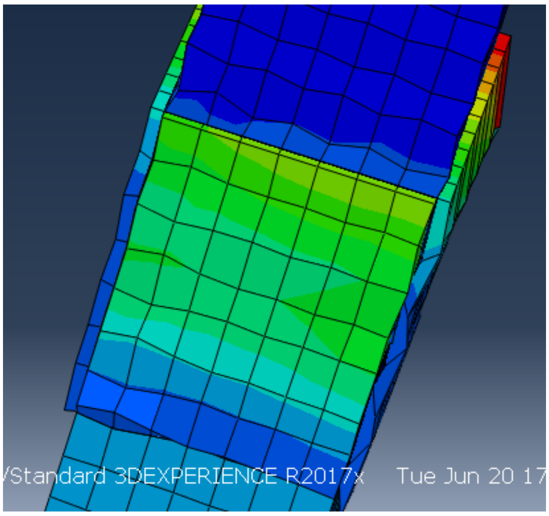


Figure B: FEM Results of Von Mises Stress for a repaired beam (crack size of 110mm)

The figure représentes thé variation of Sif values for both cases of repaired and unrepaired structure along thé variation of the crack's size, it IS clear tha Sif values of the repaired structure are significantly reduced compared to thé unrepaired structure (almost 3 Times less) which prooves the capacity of thé composite patch to atenuate Sif values, and this to reinforce thé structure, which asserts thé efficiency of this method of repair.

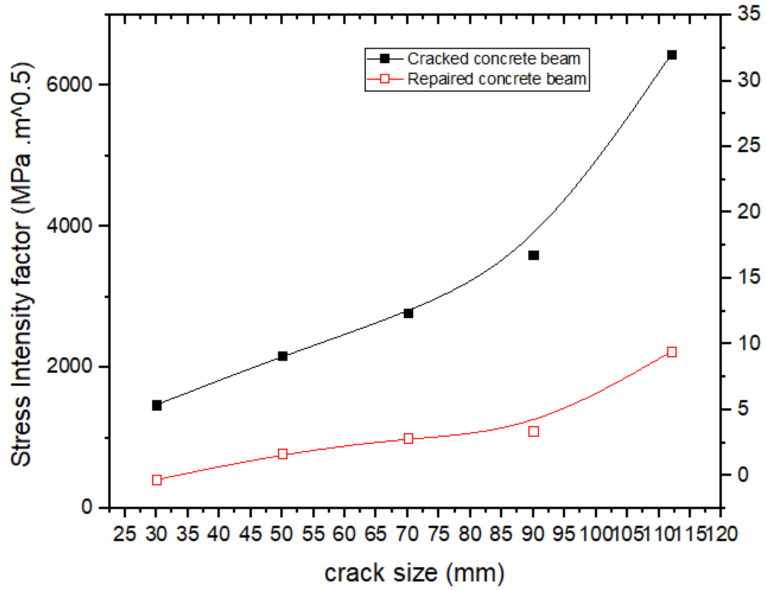


Figure: Stress intensity factor-crack size plot for repaired and unrepaired beam

CONCLUSION

The analysis allowed us to assert that crack propagation is a phenomenon that threat the structure, and lead it to failure, since it minimizes it's strentgh and degradate the mechanical properties of material used in this structure Von Mises Stress is a value used to determine if a given material will yield or not, if tgis value of a material under load is equal to or greater than the yield limit of the same material under simple tension the materiel will yield.

Cracked beam repaired with patch is a method that allows us to highly reduce stress intensity factor, because it transmit the charges from the concrete beam to the Patch on both sides, SIF is then minimized, since crack propagation on the front tip of the crack is reduced

References

1) M. Bill Wong, in Plastic Analysis and Design of Steel Structures, 2009
2) Dervis Ozkan, Mustafa Sabri Gok & Abdullah, Cahit Karaoglanli Carbon Fiber Reinforced Polymer (CFRP) Composite Materials, Their Characteristic Properties, Industrial Application Areas and Their Machinability,
3) Wen-Cheng Liao, et al. « An Innovative Test Method for Tensile Strength of Concrete by Applying the Strut-and-Tie Methodology » journal Materials Basel
4) https://www.bigdreadymix.com/]
5) Abaqus Simulia code compute 2018
6) John Temitope Kolawole and al. 'Plastic cracking behaviour of concrete and its interdependence on rheo-physical properties', Journal of Composites Part B: Engineering, Volume 230, 1 February 2022