SSRG International Journal of Civil Engineering Volume 7 Issue 7, 123-127, July 2020
ISSN: 2348 – 8352 /doi:10.14445/23488352/IJCE-V7I7P115 ©2020 Seventh Sense Research Group®

Modeling and Analysis Of Reinforced Concrete Beam Without Transverse Reinforcement And Strengthened With CFRP Lamellas: A parametric Study

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Received Date: 10 June 2020
Revised Date: 24 July 2020
Accepted Date: 30 July 2020

Abstract

The main objective of this paper is to study analytically, numerically modeled and analysis of reinforced concrete beam without transverse reinforcement and strengthened with cfrp lamellas by using a finite element based software Atena-Gid. A parametric study has been performed for the reinforced beam. A C25/30 grade reinforced concrete beam without transverse reinforcement is modeled and analyzed. Due to the missing of stirrups cfrp lamellas are modeled as reinforcement bars, it is sufficient to define just lines in the location where we want to use these cfrp-Sika CarboDur S[14] lamellas to reduce the deflections and increase the load-carrying capacity of the beam. Comparing the results with a reinforced beam without strengthening and with strengthening with cfrp lamellas. It is concluded that the strengthened beam with cfrp lamellas increases the load-bearing capacity, different crack patterns, delay the failure in the form of ductility, reduces the deflections and crack width. Calculating the load-bearing capacity percentage from the load-displacement diagram with lamellas and without cfrp lamellas.

Key Words: *ATENA-GID, FRP, CFRP, FE, Sika Carbodur S[14], Numerical Modelling.*

I. INTRODUCTION

ATENA-GID is a finite element based software specifically developed for the nonlinear analysis of reinforced concrete structures. ATENA stands for Advanced Tool for Engineering Nonlinear Analysis, Simulates real behavior of concrete and reinforced concrete structures. ATENA is used for the analysis itself and the program GID is used for the data preparation and finite element non-linear analysis for the mesh generation. By using the Atena studio interface the actual behavior of reinforced concrete structures such as concrete crushing, different crack patterns, stress & strain values, crack width values, and yielding of reinforcing steel bar, the load-displacement diagram can be analyzed and it is a user-friendly tool for modeling reinforced concrete elements. GID is an interactive graphical user interface program used for the preparation of input data for the geometrical model, material parameters, boundary conditions, interval-loading history, and generates the mesh.

Fiber-reinforced polymer (FRP) is also called fiber-reinforced plastic, is a composite material made of a polymer matrix reinforced with fibers. The fibers are usually glass, carbon, or aramid. Sika CarboDur S[14] are CFRP lamellas for the strengthening of concrete, timber, masonry, and steel structures. CFRP is used to allow concrete beams and floors to carry much higher loads. Sika CarboDur makes it easy to strengthen concrete beams and floors to make new design loading or take heavier loadings. Sika CarboDur S512 is taken for modeling and its thickness, width, and cross-sectional area is 1.2mm,50mm,60mm^2. It's cost-effective, so thin and it can be installed very quickly, disruption is minimum, material parameters can see in Table 1.

Parameter	FRP Lamella
Young´s modulus [MPa]	165000
Area [m^2]	0.000060
Tensile strength [MPa]	3100
Elongation at rupture	0.0188
Density [kg/m^3]	1600
Thermal expansion coefficient [c^{-1}]	0.000045

Table1:Material parameters of Sika CarboDur S512

II. FINITE ELEMENT MODELLING

ATENA-GID is a finite element based software specifically developed for the non-linear analysis of reinforced concrete structures. Taking a model of the simply supported beam which is supported with two steel plates at the bottom on pin supports and two steel plates which was loaded by two loads on top, three reinforcing bars as it is shown in Figure 3 with complete dimensions.

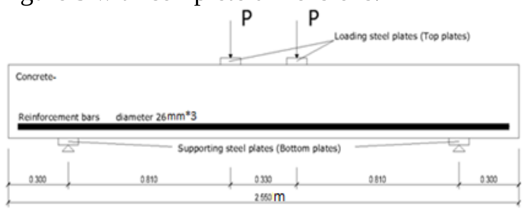

Fig.1: The geometry of the structure.

The model is symmetric around its vertical axis, therefore only one symmetric half of the beam is analyzed with the symmetric condition is applied at the middle of the beam as can be seen in below Figure 2. The cross-section of the beam with 50mm effective cover,1.275*0.19*0.30m, and 3*26mm bars.

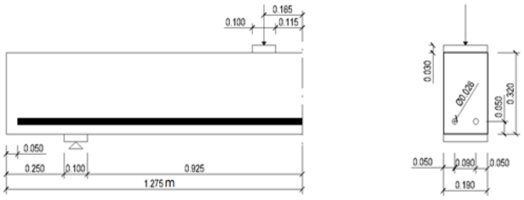

Fig. 2: The front and side view of the structure.

The geometry of the beam will be created by the extrusion of a rectangular surface. Each point is defined by three coordinates(x,y,z). To create a rectangle four points are needed, creating the first point by using the command **Geometry| Create| Point** in the main menu the coordinates are 1(0,0,0), 2(1.275,0,0), 3(1.275,0.19,0), 4(0,0.19,0). And it is connected by straight line command. The boundary line is created and creates the surface with the nurbs surface command and extrudes the surface to volume, second point 0.32m Z-axis and the volume is created and later creates the top steel plate and fixed support steel plate at the bottom. And define the three reinforcing longitudinal bars, create beam layer and assign to the volume of the beam and create bars layers and assigned to the three bars and press ESC button, create plate layer and select the top and bottom plates and select the volumes of the plate and press ESC button for complete assigning. Material parameters for concrete beam, loading and supporting steel plate, reinforcement bars are defined. Concrete beam C25/30 is selected and young's modulus E:33345Mpa, Tension strength F_t:2.027Mpa, Compression strength F_c:-40Mpa is calculated to eurocode2 and select the volume for assigning the material properties for the concrete beam. Material properties as solid elastic for plates and default values for the plates and assigned to the volume of plates. Material properties of bars as 1D reinforcement, take yield strength as 560Mpa, class A, bar diameter as 26mm for the reinforcement of the bar. Select the lines to option for assigning the parameters of the bar. The bottom plate surface is dividing into two divisions and add the fixed supporting condition. The top plate surface is divided into two halves and the line is divided into two, at the midpoint of the line the displacement condition -0.1mm is applied in Z-direction for a better understanding of load variation in the graph. The symmetry condition is applied at the middle of the beam, two monitors are applied at two various points. The first monitor point at the midpoint of the top plate will monitor the load, the second monitor point at the bottom of the middle surface will monitor the displacement. The master, slave top beam condition on the top surface of the beam and the bottom surface of the plate. The master, slave bottom beam condition is applied on the bottom surface of the beam. Later the mesh is generated. Finite element analysis ATENA dialog window is opened automatically to get the results.

Due to the shear failure of the beam, strengthening should be applied in the vertical direction in the area between the top-loading plate and bottom supporting plate to supply missing stirrups. As the FRP lamellas are modeled as reinforcement bars, it is sufficient to define just lines in the location where we want to use these lamellas. Two vertical FRP lamellas are used on each side of the beam. The coordinates of the first point into the command **Geometry| create| point** and its coordinates are [0.605,0.005,0.0025]. After the definition of the first point is completed, it can be translated vertically by 0.315m together with the extrusion to the line. The created line is copied in the Y-direction by 0.18m without any extrusion, then the created lines are copied in the X-direction by 0.2m. The material model is created according to the parameters of FRP lamellas Sika CarboDur S[14] which was in the table1.i.e, Young's modulus, Area, Yield strength, Failure parameters, and density values. The connection between beam and cfrp lamellas is modeled by a bond with none fixed end. After the definition, this model should be assigned to 4 cfrp lamellas by selecting the assign/lines in the material model definition. There are two intervals one is for reinforcement bars, other is for the lamellas. After that Generate the mesh and we will get the mesh elements, 8 linear elements correspond to reinforcement bars, tetrahedra elements 128, hexahedra elements 160, number of nodes are 308. There are the following results given below:

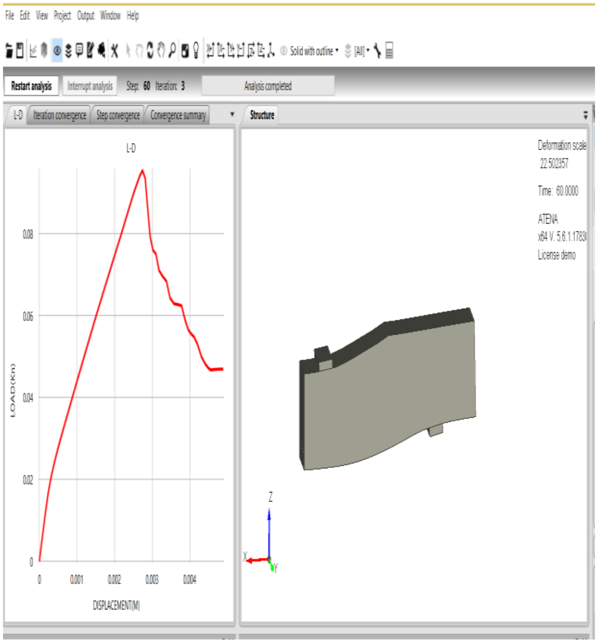

Fig.3: Deformed beam(without cfrp lamellas)

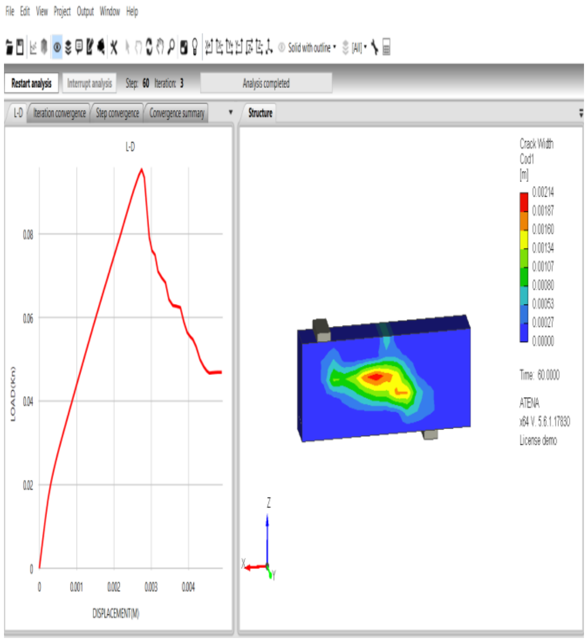

Fig.5: The crack width values (without cfrp).

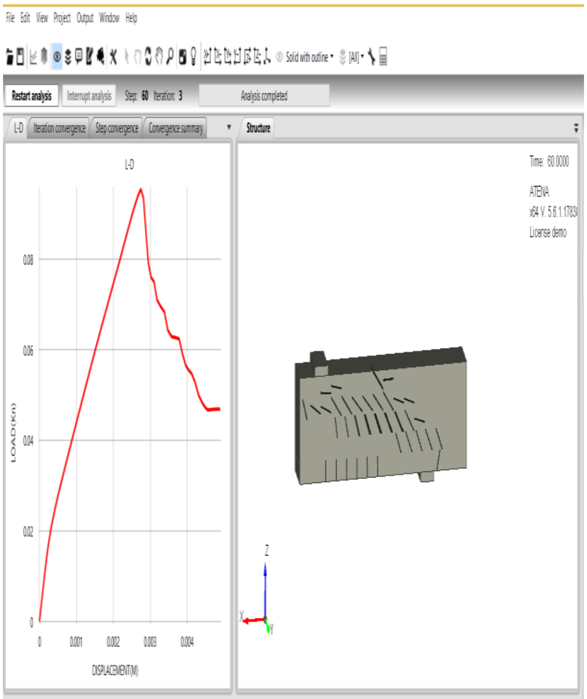

Fig.4: The cracks in the beam(without cfrp).

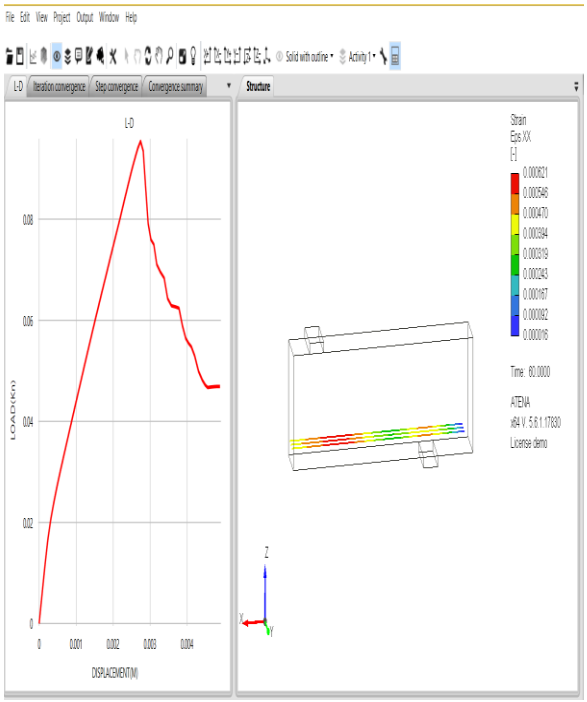

Fig.6: Strain Values(without cfrp lamellas)

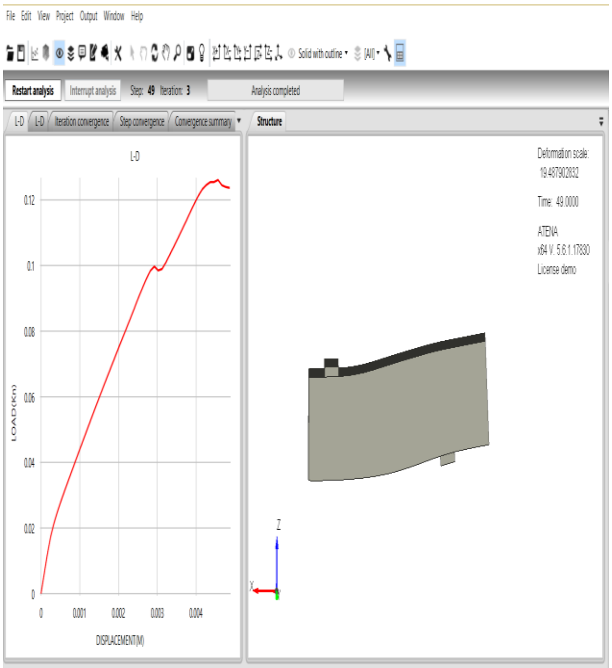

Fig.7: Deformed beam with cfrp lamellas

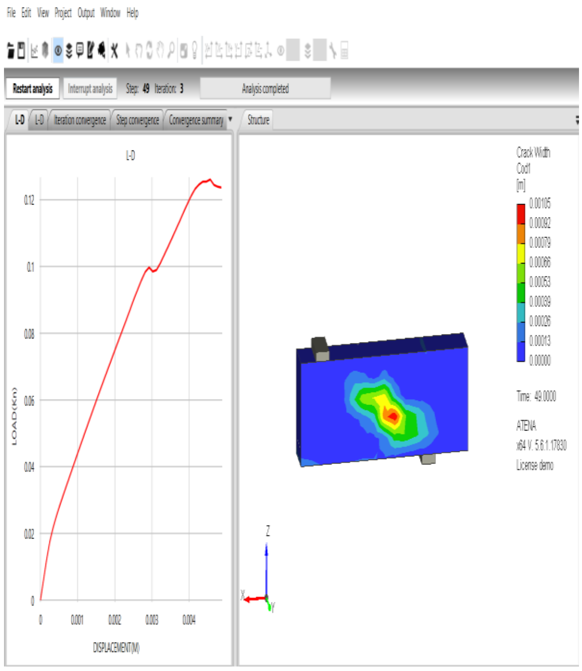

Fig.9: Crack width values with cfrp lamellas.

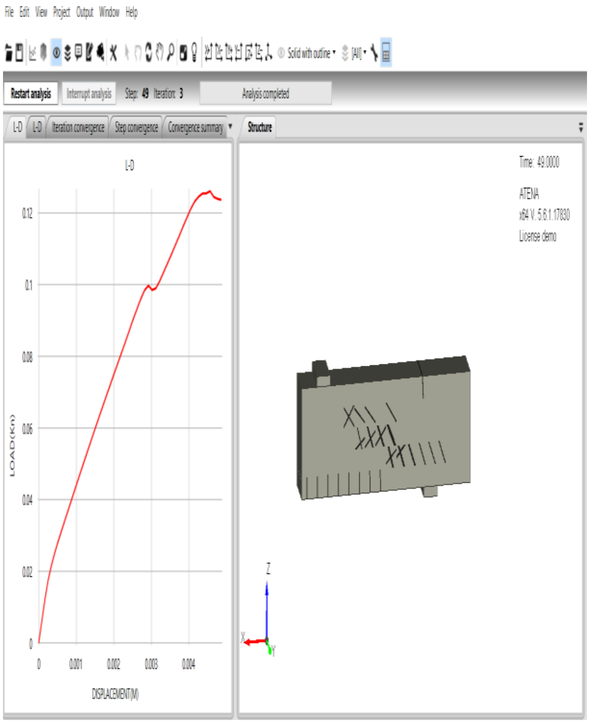

Fig.8: Cracks in beam with cfrp lamellas.

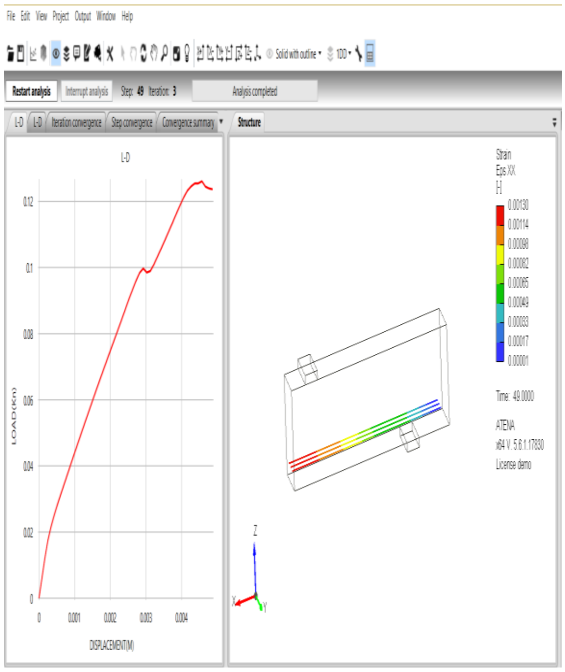

Fig.10: Strain Values with cfrp lamellas.

III. CONCLUSIONS

In this thesis, the design and analysis of reinforced concrete beam without transverse reinforcement and strengthening with cfrp lamellas. The vertical cfrp layers can help to further reduce the deflections and increase the ultimate load-bearing capacity.

1. Due to the missing transverse reinforcement the beam fails by sheer diagonal crack.
2. Failure of the beam is brittle due to missing transverse reinforcement.
3. Failure of the beam is not brittle, ductility of the beam is higher now with frp lamellas.
4. By using frp lamellas, the beam fails by shear but two diagonal cracks.
5. Comparsion of the unstrengthened beam and strengthened beam with four frp lamellas increases the load-bearing capacity by 30%.

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