Journal of Structural Engineering and Geotechnics,

6 (2), 25-29, Summer 2016

Effects of Using Multilayers of High Resistance AFRP on Loading Capacity of Reinforced Concrete Beams in Comparison with Low Resistance AFRP Considering EBROG Method

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Received 15 April 2016, Accepted 18 June 2016

Abstract

Externally Bonded Reinforcement on Grooves (EBROG) is a new method that has been introduced to postpone or eliminate debonding of FRP sheets from concrete surface in concrete beams strengthened for flexure and increase loading capacity. For strengthening reinforced conceret beams in strructure, use of different types of FRP like: laminate, AFRP, CFRP, and GFRP. By there is some differences between these kinds related to sensitivity to temperature, shear sterength, The aim of the current study is to examine the efficiency of Externally Bonded Reinforcement on Grooves method on Concrete beams' loading capacity when used under multilayers of high resistance AFRP sheet and comparing it with the results of multilayers of low resistance AFRP. For this purpose , beam specimens with dimension 120*140*1000 mm were modeled in ABAQUS program. According to the analysis, loading capacity is increased when used multilayers of high resistance AFRP instead of using multilayers of low resistance AFRP. Finally, diagram shown that use of multilayers of AFRP has better results than use of one layer of AFRP.

Keywords: High Resistance, Low Resistance, Aramid Fiber Reinforced Polymer (AFRP); strengthening, Externally Bonded Reinforcement on Grooves (EBROG), loading capacity, ABAQUS program

1. Introduction

One the most important problems in structures, regarding to the earthquake, is related to retrofitting and rehabilitation. Several methods were created around 2011 for retrofitting and has been used nowadays. There are 4 different methods that used for retrofitting concrete beams in structure. Methods divided into 4 techniques like: NSM (Near Surface mounted), EBR (Externally Bonded Reinforcement), EBROG (Externally Bonded Reinforcement on Grooves), and EBRIG (Externally Bonded Reinforcement in Grooves). All of these methods can increase loading capacity, and postpone or eliminate debonding in concrete beams. EBROG method could postpone and eliminate debonding in some experiments which was done by Mostofinejad and Shameli in 2011. They used this method for testing Multilayer FRP (Fiber Reinforced Polymer) sheets for flexural strengthening [1].

Figure1-Grooves at EBROG method [1] & [5]

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Figure2-EBR and EBROG methods [1] & [5]

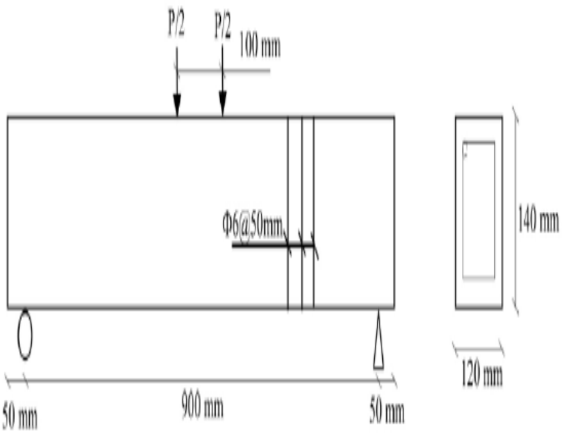

Figure3-Concrete specimen [1]

Figure4-Testing device [1]

In 2013, Hosseini and Mostofinejad investigated bond behavior on CFRP (Carbon Fiber Reinforced Polymer) sheets [2]. They had used both EBR and EBROG to evaluate effect of bond behavior on CFRP sheets when attached to RC (Reinforced Concrete) beams and comparing results of these two methods.

Differences between four methods that used for retrofitting, highly related to kinds of resin epoxy. For example, in EBROG method and EBRIG method different results was shown only for two different kinds of epoxy. In NSM, at first make grooves under beams. Then, fill the grooves by epoxy.
In 2013, Mostofinejad and Kashani used EBR and EBROG method to examine results for shear strengthening of RC beams [3]. In EBR, EBROG, and EBRIG cut bottom of concrete beams and finally fill it by resin epoxy and attached FRP layers to bottom of the beam. In 2013, Mostofinejad and Shameli used EBRIG by FRP sheets to evaluate the results for debonding [4].

Figure5-Specimens strengthened with EBROG technique [4]

Mostofinejad and Moghaddas in 2014 had done a research about bond efficiency of EBR and EBROG methods in different flexural failure mechanisms of FRP strengthened RC beams [5]. It is clear that some gap in research there is. One of this gap is related to ductility. In 2015, a research was provided about ductility of RC beams that strengthened with FRP by EBR and EBROG method [6]. This research was presented effect of GM (Grooving Method) patterns on ductility.
One of concerns about using CFRP related to temperature and function of CFRP or other kinds of FRP against high or low temperature. So that, Firmo et al, did a research about effect of temperature on RC beams that strengthened by CFRP [7]. In conclusion, FRP is a reasonable material for strengthening concrete beams.

On the other hand, there are some differences between FRP, CFRP, AFRP (Aramid Fiber Reinforced Polymer), and GFRP (Glass Fiber Reinforced Polymer). It is needless to say that use of FRP and other kinds of FRP increase loading capacity of RC beams. Consequently, this way of strengthening concrete beams is much more valuable and reasonable way against other kinds of retrofitting or strengthening.

So far, the performance of the EBROG method is examined only with single layer of fiber and there is no research when multilayer fibers are used to strengthen beams with EBROG method. The aim of the current study is to carry out some analytical data for improving loading capacity when we used multilayers of high resistance AFRP instead of FRP laminates and comparing it with the results that carried out when we had used multilayers of low resistance AFRP before.

2. Modeling

Model is created by following characteristics: a concrete beam with 120*1000 mm dimension, AFRP with 100*800 mm dimension, length of grooves with 850 mm, width of grooves with 8 mm and depth of grooves with 10 mm in ABAQUS program. Assumption for distance between grooves with 15 mm. Finally, for preventing any undesired shear failure, creating mesh bar with 120*140 mm dimension and distance between grooves with 5 mm.

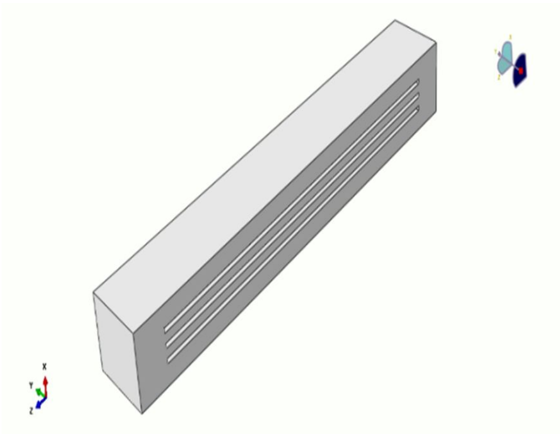

Figure6-Concrete beams with grooves

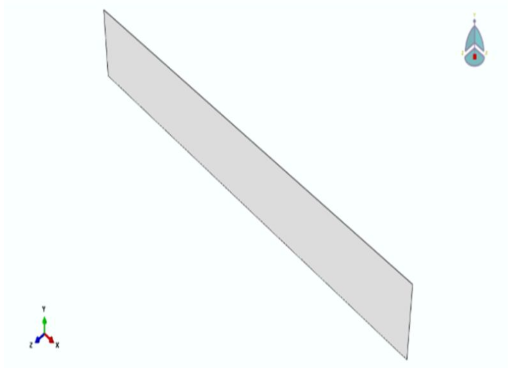

Figure7-AFRP layer

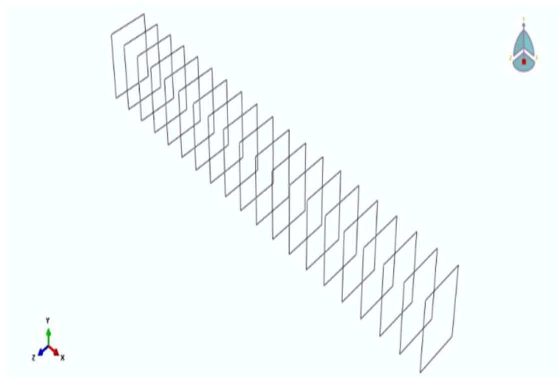

Figure8-Mesh bar

3. Materials are USED

Definition for running data in ABAQUS program is divided to 4 separate behavior. One of them related to concrete beam, another related to AFRP, One behavor for mesh bar, and last behavior for resin epoxy. Definition for concrete is based on elasto-plastic behavior. For plastic behavior, we used concrete damage plasticity for both compression and tension region. The behavior for AFRP, mesh bar, and resin epoxy was fully elasto-plastic.

Table1-Values for inelastic behavior (concrete)

Material	**f'c (N/m2)**	**Ec (N/m2)**	**fr (N/m2)**	**ε'c (εc in σc = f'c)**
Concrete	**2.50E+07**	**2.00E+10**	**2.50E+06**	**0.002**

4. Interaction and loading

In this level, create definition 4 behavior in interaction property part: 1-normal behavior, 2-tangential behavior, 3-cohesive behavior, and 4-damage. In constraint menu, we embedded mesh bar in concrete and tied AFRP to bottom of concrete beam.

Load definition is based on maximum displacement. We created 2 surface on the top of concrete beam and allocated maximum displacement on that surface.

We created 2 type for boundry condition:1-fixed support, and 2-hinged support and assigned them to left and right side of the concrete beam.

5. MESH AND ANALYSIS

At this step, we assembled 4 separate parts (concrete beam, AFRP, mesh bar, and resin epoxy). In this step, at first concrete beam is selected. After that, using data for resin epoxy at bottom of concrete beam and in grooves. In the 3rd stage, attached AFRP to the bottom of concrete beam. Finally, embedded the mesh rebar in concrete beam.

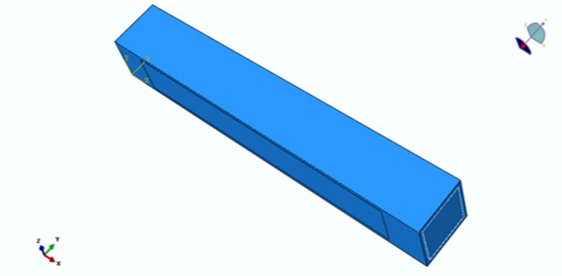

Figure9-Fibal Model

Mesh for concrete beam was hexagonal and technique of the mesh was structured. The name of mesh was C3D8R and the size of mesh was 0.02 m.

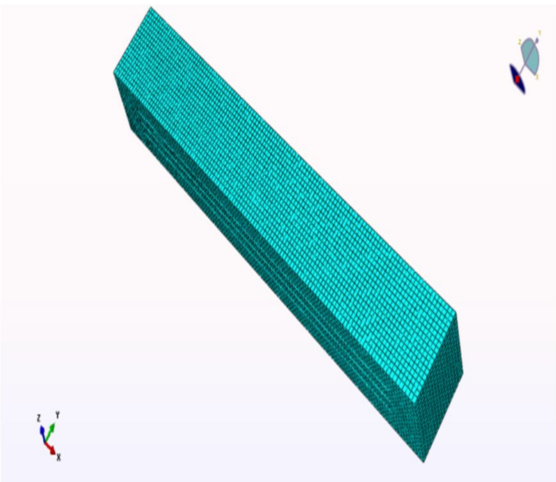

Figure10-Mesh for concrete beam

Mesh for AFRP was Quadratic and technique of the mesh was structured. The name of mesh was S4R and the size of mesh was 0.02 m.

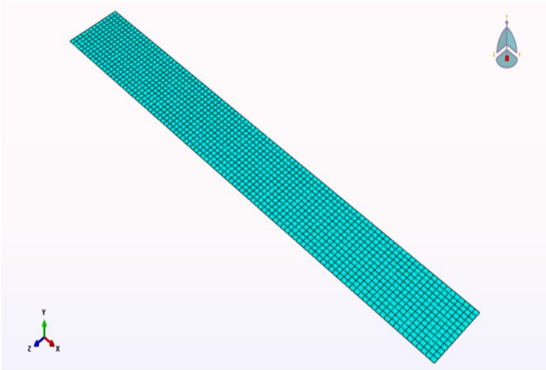

Figure11-Mesh for AFRP

The name of mesh for mesh bar was B31 and the size of mesh was 0.02 m.

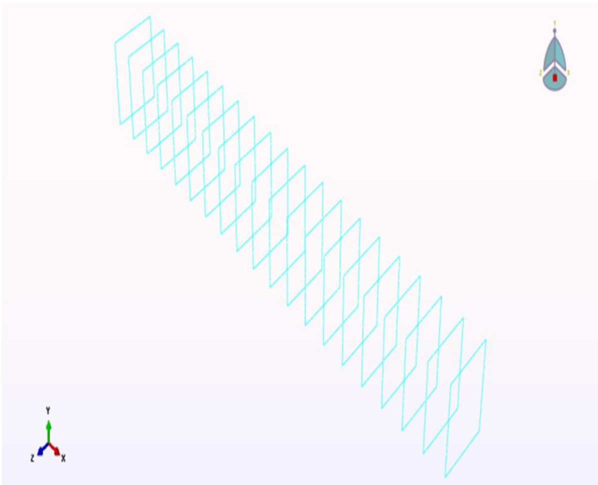

Figure12-Mesh for mesh bar

Before analyzing model, set characteristicts for final step. For this sample we are using Dynamic, Explicit method and we assigned time period=3.

6. Results

After analysis, results were shown in diagram1. There is a breaking point is some parts of diagram. This points mainly related to epoxy and its' function. Better results related to multilayers of FRP due to strength of multilayers.

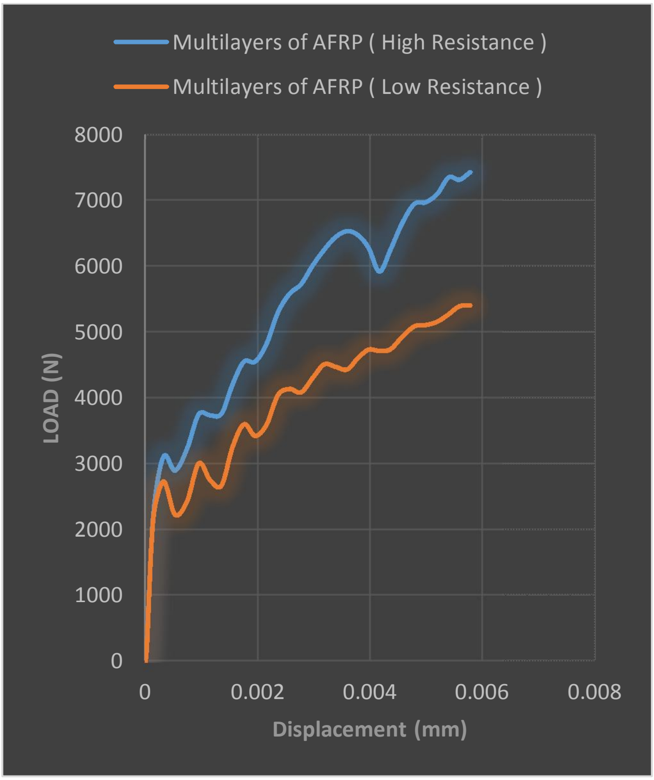

Diagram1-Load-displacement diagram

7. Conclusion

1- The less differences and the most differences between multilayers of high resistance AFRP and multilayers of Low resistance AFRP respectively was: 1.96% and 32.15%.
2- It is clear that the size of mesh between 0.005, 0.008, and 0.02 m not differences widely.
3- allocating separate behavior to grooves can improve the loading capacity. It means do not tie AFRP to concrete, and instead of doing that, create contact behavior (surface to surface).
4- It is clear that loading capacity has increased when used high resistance AFRP instead of using low resistance AFRP.
5- Moreover, creating mesh bar has important role for increasing loading capacity. Removing mesh bar can decrease loading capacity.
6- Finally, EBROG is one of the method for eliminating debonding and increasing the loading capacity. It is better to use this method when we use multilayers of high resistance AFRP.

8- References

[1] Mostofinejad, D., Shameli, M. (2011). "Performance of EBROG Method under Multilayer FRP Sheets for Flexural Strengthening of Concrete Beams". Procedia Engineering, 14, 3176-3182.
[2] Hosseini, A., Mostofinejad, D. (2013). "Experimental investigation into bond behavior of CFRP sheets attached to concrete using EBR and EBROG techniques". Composites: Part B, 51, 130-139.
[3] Mostofinejad, D., Tabatabaei Kashani, A. (2013). "Experimental study on effect of EBR and EBROG methods on debonding of FRP sheets used for shear strengthening of RC beams". Composites: Part B, 45, 1704-1713.
[4] Mostofinejad, D., Shameli, S, M. (2013). "Externally bonded reinforcement in grooves (EBRIG) technique to postpone debonding of FRP sheets in strengthened concrete beams". Construction and Building Materials, 38, 751-758.
[5] Mostofinejad, D., Moghaddas, A. (2014). "Bond efficiency of EBR and EBROG methods in different flexural failure mechanisms of FRP strengthened RC beams". Construction and Building Materials, 54, 605-614.
[6] Mostofinejad, D., Khozaei, K. (2015). "Effect of GM patterns on ductility and debonding control of FRP sheets in RC strengthened beams". Construction and Building Materials, 93, 110-120.
[7] Firmo, J. P., Correia, J. R., Pitta, D., Tiago, C., Arruda, M. R. T. (2015). "Experimental characterization of the bond between externally bonded reinforcement (EBR) CFRP strips and concrete at elevated temperatures". Cement & Concrete Composites, 60, 44-54.