© 2019 IJSRST | Volume 6 | Issue 3 | Print ISSN: 2395-6011 | Online ISSN: 2395-602X
Themed Section: Science and Technology
doi : https://doi.org/10.32628/IJSRST2182909

Experimental Investigation on Pull-Out Test of FRP Headed Bars to Determine Bond Strength of Concrete in Exterior Beam-Column Joint

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ABSTRACT

A total of 32 pullout tests were performed for the multiple headed bars relatively deeply embedded in reinforced concrete column-like members. The objective was to determine the minimum embedment depth that was necessary to safely design exterior beam-column joints using headed bars. The variables for the experiment were embedment depth of headed bar, variation in diameter of bars. The results of the test indicated that a headed bar embedment depth of 10d_b was not sufficient to have relatively closely installed headed bars develop the pullout strength corresponding to the yield strength. All the experimental variables influenced the pullout strength. The pullout strength increased with increasing embedment depth. The purpose behind this is to study is to find bond behavior of headed reinforcement bar in concrete with variation in embedment length as well as to study bond behavior of headed reinforcement bar in concrete with variation in size of bars and shape of head. For 16 mm and 20 mm bar the result shows that the bond strength increases with respect to increase in embedment depth. Square head has maximum bond strength in comparison of Rectangular and Circular head. Circular headed bar has minimum bond strength in all specimens. There were no FRP headed bar used in the any of literatures.

Keywords : Pull out test, bond strength, FRP headed bars, exterior beam column joint

I. INTRODUCTION

Research carried out in the past has enabled the development of design standards that provide seismic requirements and reinforcement detailing that result in better seismic performance of newly designed structures and minimize the probability of damage and/or collapse. As pointed out by Pantaildes et al. this can be achieved by preventing the brittle failure of joints in reinforced concrete (RC) frame structures, maintaining its integrity, and reducing its stiffness degradation. However, there is a considerable number of buildings worldwide that have been designed, detailed, and built without specific seismic requirements that may be vulnerable to seismic events, as demonstrated by recent earthquake on an existing RC structure, several strengthening techniques have been developed, studied, and applied in previous decades. Traditional techniques include concrete and steel jacketing of the frame elements; however, these techniques are complex, intrusive, and labour-intensive. More modern techniques such as base isolation and supplemental damping devices have also been developed, but some challenging aspects still need to be addressed such as cost, invasiveness, and practical implementation. Anchor plates or heads, either welded or threaded to the longitudinal bar, can be used as an alternative to the use of hooked bars in exterior beam-column joints. The use of headed bars offers a potential solution to the problems posed by hooked bars and may ease fabrication, construction, and concrete placement. ACI 352:2002 was revised to allow the use of headed bars with a development length Ldh equal to 75 percent of the development length of a standard 90o hooked bar. The head of bar should be located within 50 mm from the back of confined core, as per ACI 352:2002.

II. METHODOLOGIES

In the pullout study, the different embedment depth Ld of 10db,12db,14db (db = diameter of bar) for different diameter 16mm, 20mm were used for all tests to examine bond strength and maximum load with different FRP heads like rectangular and square in shape. Two different materials of head metal and FRP was used with different diameter of bars. The headed bar specimens maintained the anchorage strength (by head bearing) even after significant bond deterioration, leading to ductile failure. The bond deterioration was evidenced by a reduction in stiffness of the load-slip relations, and by the observation that the stiffness softening had occurred when splitting cracks began to form. Headed deformed bars with a bar diameter of 16mm, 20mm were used in this study. Three types of head geometries used for pullout test. For reversed cyclic tests of the beam-column joint, square, rectangular, circular heads were chosen based on the pullout test results. Measured material properties of steel and concrete are summarized in Headed for pullout test. Different concrete mixes M_{20}, M_{30} and M_{40}were used for pullout tests.

In the specimen preparation, the rebar was cut to segments of 300 mm in length, and the segment was cast into a 150 mm,200mm,300mm cubical concrete block with 10db,12db,14db embedment length. After casting, the specimens were cured in water tank for 28 days.

The tested some beam column junctions with headed bars and found that headed bar has enough anchorage capacity in the exterior beam column joints this study attempts to investigate the pull-out behaviors such as strength, failure mode, and crack patterns of different arrangements of reinforcement in exterior beam column from the inner face of column. The materials required for the experimental work were tested in the laboratory to get necessary data for mix design. To evaluate the effect of headed bars, various types were manufactured, and each was tested monotonically in pull-out tension until failure. The load–displacement curves, failure modes and failure strengths were investigated. A total of 32 pull-out tests were conducted.

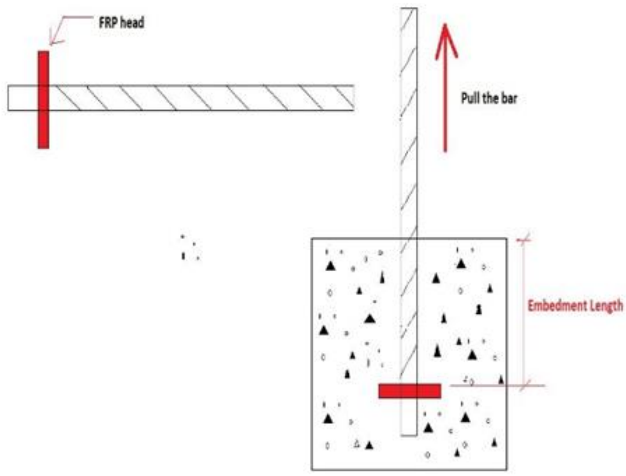


Fig. 1 Headed bar and Cube with Embedment Length

Fig. 2 Pull out

Fig.3 FRP headed bars

Fig.4 FRP headed cubes

Fig.5 Cone failure

2.1 Evaluation of pull-out test on concrete cube with FRP headed bars and metal headed bars.

In structural concrete the addition of anchorage of normal bars and hooks sometimes may occur detailing problems because of long development length and large bend diameters that are required, especially when big diameter reinforcing bars are used. The requirements for normal bar anchorage and lap splices cannot be provided within the available sizes of members. Hooked bars are used to decrease the anchorage length, but in many cases, the bend of the hook will not fix within the sizes of a member, or the hooks create congestion and make a member difficult to construct.

Table 1 Embedment length and thickness of head

Dia. of bar d_b in mm	Embedment length, mm			Thickness of Head (0.5 d_b) mm
	10 d_b	12 d_b	14 d_b	
16	160	192	244	8
20	200	240	280	10

Table 2 Shape and Size of head

Diameter of bar	16 mm			20 mm		
Shape of head	Square	Circular	Rectangular	Square	Circular	Rectangular
Size of head in mm	45 x 45 x	46 in dia.	50 x 36 x 8	50 x 50 x	56 in dia.	64 x 40 x 10

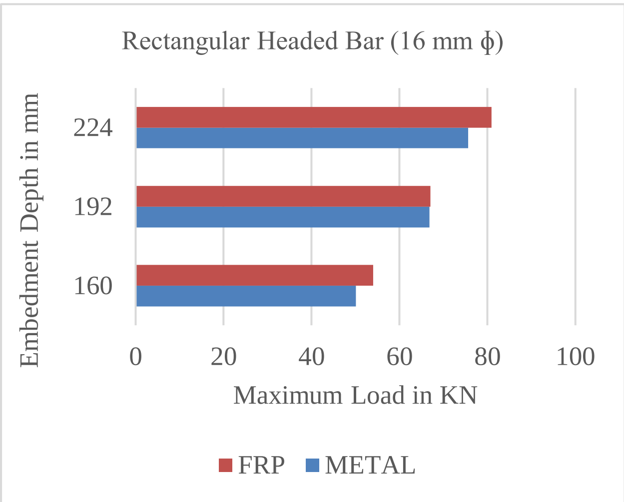
	8			**10**		

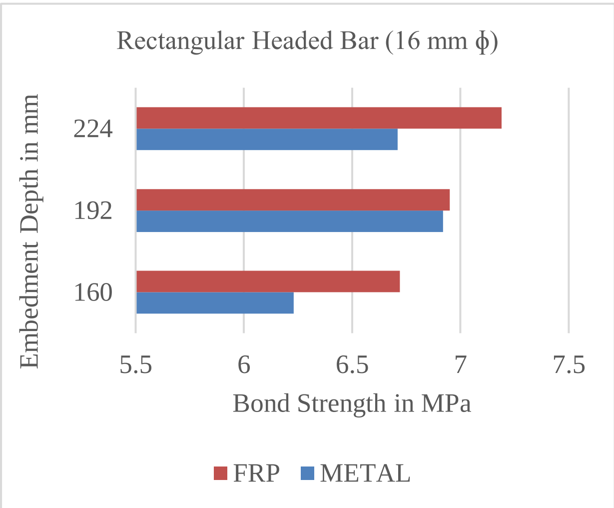
Table 3 No. of Specimens

Grade of Concrete	Shape of heads			Total no of specimens
	Square	Rectangular	Circular	
M20	9	9	9	81
M30	9	9	9	
M40	9	9	9	

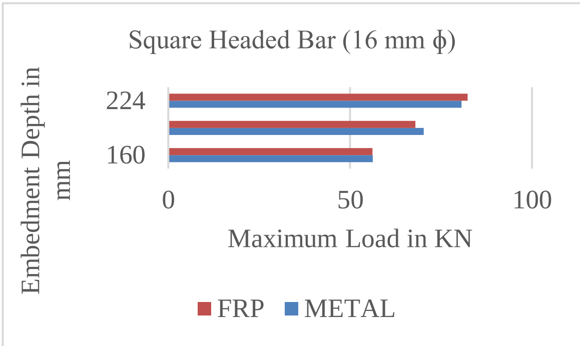
III. RESULTS & DISCUSSION

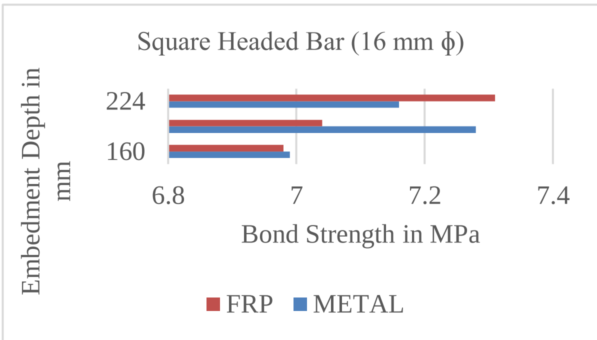
Graph 1 Results of Metal & FRP Rectangular Headed Bars for 16mm dia. Bars





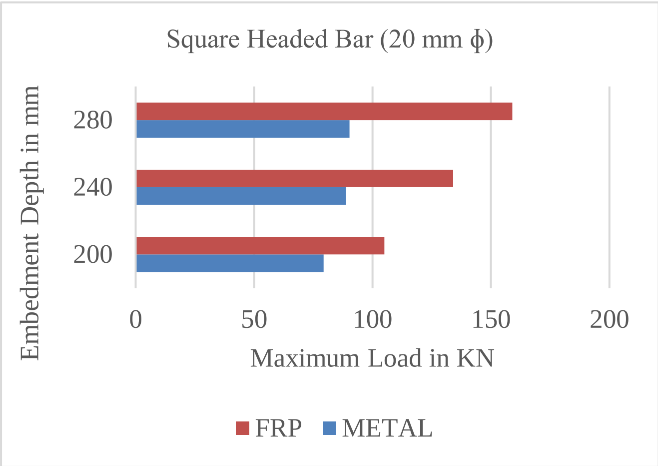
Graph 2 Results of Metal & FRP Square Headed Bars for 16 mm dia. Bars

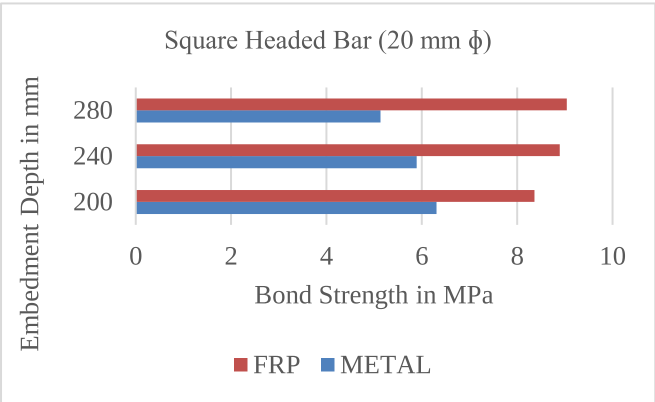




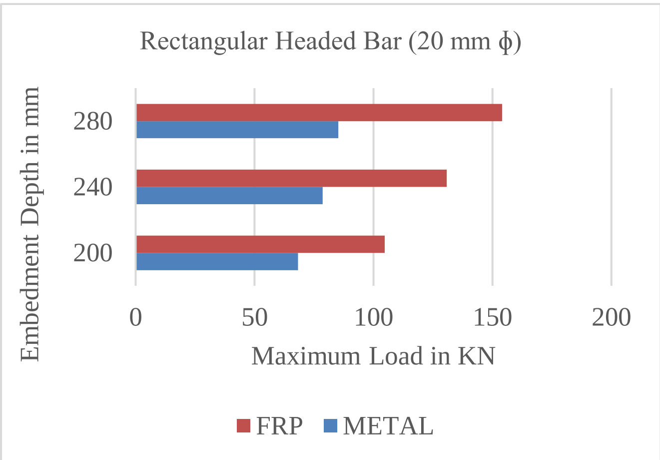
For 16mm bar the result shows that the bond strength increases with respect to increase in embedment depth, grade of concrete as well as square head has maximum bond strength in comparison of Rectangular and Circular head. Circular headed bar has minimum bond strength in all specimens.

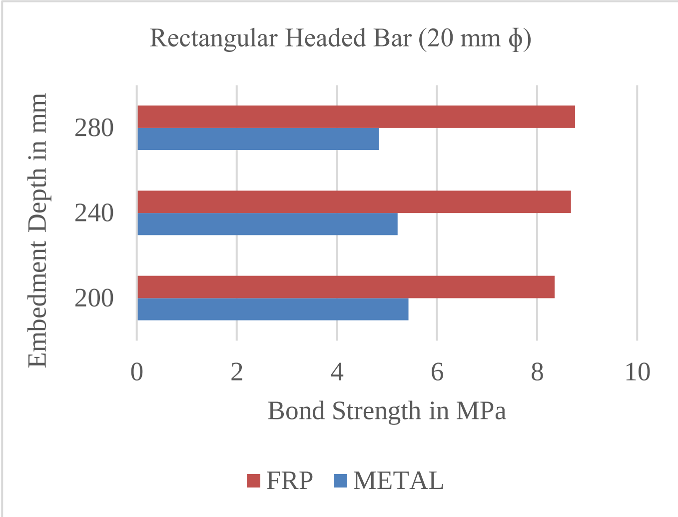
Graph 3 Results of Metal & FRP Square Headed Bars for 20mm dia. Bars





Graph 4 Results of Metal & FRP Rectangular Headed Bars for 20mm dia. Bars





• For 20mm bar the result shows that the bond strength increases with respect to increase in embedment depth, grade of concrete as well as square head has maximum bond strength in comparison of Rectangular and Circular head. Circular headed bar has minimum bond strength in all specimens.

IV. CONCLUSIONS

For 16mm dia. bars:

• In square headed bar, the pull-out load results for metal and FRP headed bars are nearly same, but the bond strength of FRP bars increases with the increase in the embedded length, which is not the case for the metal headed bars. It shows good result for only 14-time dia. embedded length.

• In circular headed bar, the pull-out load as well as the bond strength results for metal headed bars are more as compared to FRP headed bars. In rectangular headed bar, the pull-out load results for metal and FRP headed bars are nearly same, but the bond strength of FRP bars increases with the increase in the embedded length, which is not the case for the metal headed bars.

For 20mm dia. bars:

• In square headed bar, the pull-out load results of FRP bars increases with the increase in the embedded length, however this is not the case in metal headed bars. They show the same results for all embedded length.

• The bond strength of FRP bars increases with the increase in the embedded length, which is not the case for the metal headed bars. It shows good result for only 12-time dia. embedded length. In circular headed bar, the pull-out load of FRP headed bar having more value compared to metal headed bar.

• In rectangular headed bar, the pull-out load results for metal headed bars are nearly same for all case, however the FRP headed bar having pull out load increases with the increase in the embedded length, but for bond strength for FRP headed bars nearly same for all embedded length but also more compare to metal bar in all embedded length.

• This is the good application for beam-column joint in high rise building construction.

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Cite this Article

Vrajesh M Patel, Dr. Suhasini M Kulkarni, "Experimental Investigation on Pull-Out Test of FRP Headed Bars to Determine Bond Strength of Concrete in Exterior Beam-Column Joint", International Journal of Scientific Research in Science and Technology (IJSRST), Online ISSN : 2395-602X, Print ISSN : 2395-6011, Volume 6 Issue 3, pp. 504-509, May-June 2019. Available at doi : https://doi.org/10.32628/IJSRST2182909

Journal URL : https://ijsrst.com/IJSRST2182909