Research Proposal II.1

UMR Node

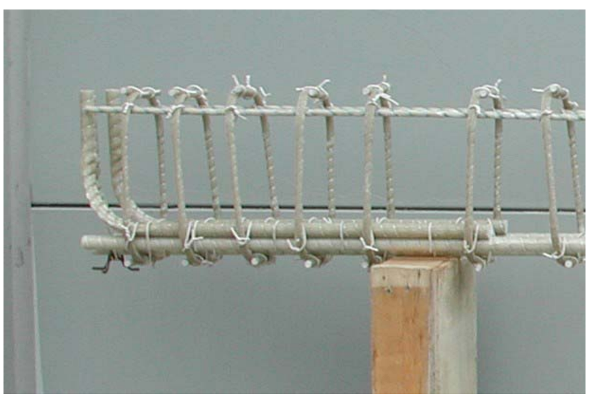
Fiscal Year 2006

repair of buildings & bridges with composites

DEVELOPMENT LENGTH AND CHARACTERIZATION OF GFRP BARS WITH END ANCHORAGES

SUMMARY

One of the issues concerning the construction of reinforced concrete beams using GFRP bars is the detail in the end regions. According to Figure 1a, the main longitudinal bars are terminated straight and additional L-shape GFRP bars are spliced to these bars for end anchorage. Although this detail is adequate to provide for end anchorage it leads to reinforcement congestion in the end regions and additional costs. In order to simplify this design detail this research program will propose and conduct research to substantiate a new design detail consisting of headed reinforcement (see Figure 1b). As such, it is the main objective of this research program to conduct experimental studies that can lead to the development of design recommendations and subsequently to the implementation in the field of this simpler headed reinforcement detail. This research program will consist of two tasks composed of experimental and analytical studies.



(a) Lap Splice at Bar Ends

(b) Headed Reinforcement at Bar Ends

Figure 1 GFRP Bar Details

BACKGROUND

ACI 440 stipulates that the minimum length required to achieve a proper development length for the internal reinforcement is given by:

$$l_d = \frac{d_b f_{fu}}{2700} \qquad \text{Eq. 1}$$

Eq. 1 was developed based on a conservative estimate of the development length of FRP bars controlled by pull out failure. In Eq. 1, l_d is the bar development length, d_b is the diameter of one FRP bar, and f_{fu} is the ultimate stress value for the bar.

In addition, available research has indicated that a lap splice length of $1.6l_d$ is necessary to reach 100% of ultimate stress in these bars (Class B). ACI Committee 440 assumed that a value of $1.3l_d$ would be sufficient for a Class A splice using FRP. Since the stress level for Class A splices, is not to exceed 50% of the tensile strength of the bar, using a value of $1.3l_d$ should be conservative.

This research program will lead to design specifications that will be introduced at the ACI 440 level to serve as a design guide for the end anchorage of GFRP bars using headed reinforcement.

OBJECTIVE

To obtain substantial experimental and analytical research data that can substantiate specifications for the usage of headed reinforcement in GFRP bars as a means to alleviate congestion of reinforcement at beam ends.

WORK PLAN

This research program consists of experimental and analytical tasks. In the experimental tasks characterization of the anchor end will be carried out at both the coupon and at the element levels.

<u>Task 1: Experimental characterization of the end anchors</u>. The experimental characterization of the anchor will consist of three series of tests as discussed below.

Series I: Stand-alone pull-off tests for three different bar sizes. In order to correlate the anchor performance to bar size, pull-off tests will be conducted on different bar terminations. A schematic of the test is shown in Figure 2. Three bar diameters will be investigated, namely: #4 (12.7 mm), #6 (19.1 mm) and #8 (25.4 mm). With a minimum of four repetitions per diameter, a total of 12 specimens will be tested. Tests will be conducted in the university laboratories using the universal MTS8000 testing machine at UMR.

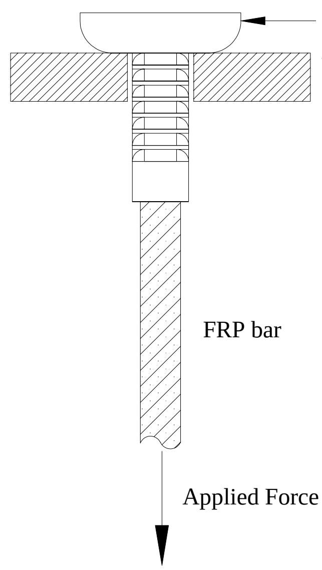


Figure 2 - Schematic of the pull-off test

Series II: Concrete embedded termination pull-off test. Pull-off tests will be conducted on the end-anchored bars at various concrete cover depths and concrete strengths. The concrete cover over the anchor will be set at three different values as shown in Figure 3. For each cover, three repetitions will be undertaken. In addition, for the deepest cover, the anchorage of conventional L-shaped bent bars will be investigated (Figure 3). This set of tests will be repeated for two different concrete strengths: 4,000 psi (27.6 MPa) and 8,000 psi (55.2 MPa). The diameter of the GFRP bar will be kept constant to a #6(19 mm) for all tests. A total of 24 pull-off tests will be conducted in this series.

It should be noted that the distance between the bars is chosen in order to avoid interference among the potential concrete failure cones traceable from each anchor.

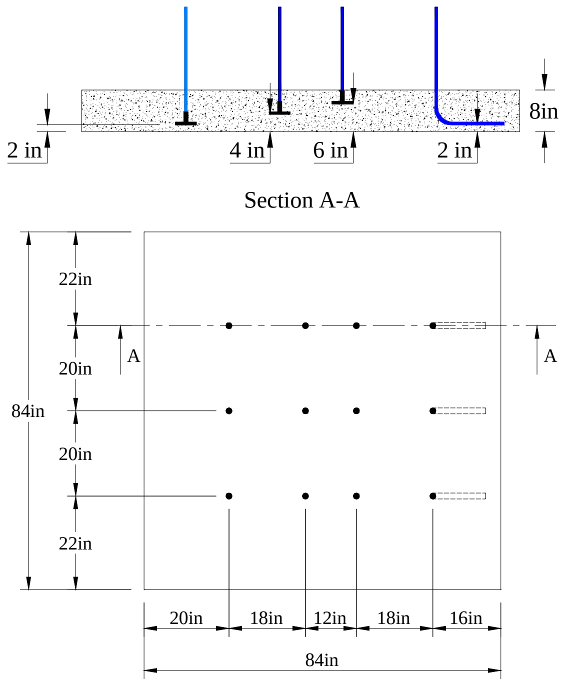


Figure 3 - Bar termination layout
(1 in.= 25.4 mm)

Figure 4 depicts a schematic of the test setup. The load will be applied in a close loop fashion by means of a hydraulic jack reacting against a steel plate anchored to the FRP bar. The load will be measured using a load cell placed between the hydraulic jack and the steel plate. It should be noted that the steel spreader beam will be long enough to react along the borders of the concrete slab in order to avoid a compression field around the anchor being tested.

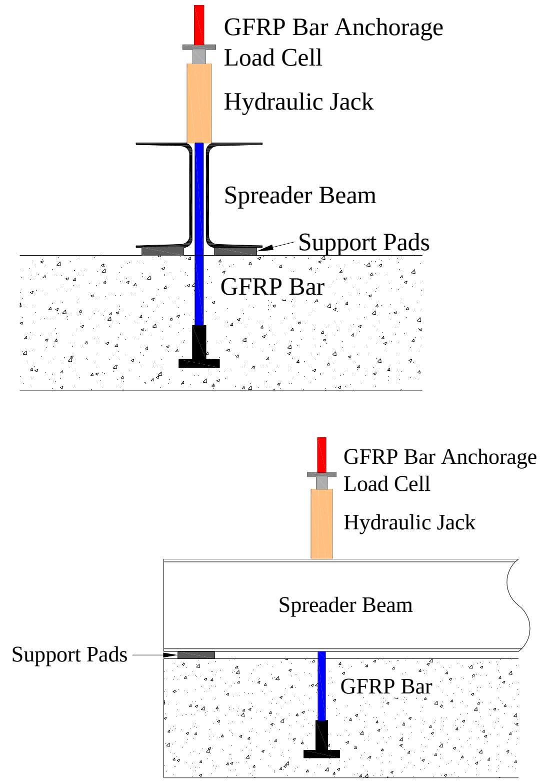


Figure 4 - Concrete embedded termination pull-off test

Series III: Beam-end tests. The anchoring technique will be tested at the component level on four simply supported beams subjected to 4-point bending load. As summarized in Figure 5, two types of test will be conducted: Type A on beams in which the flexural reinforcement is anchored with a conventional L-shaped splice, and Type B using the new anchor system. Two specimens per type having concrete strength of 4,000 psi (27.6 MPa) and 8,000 psi (55.2 MPa), respectively, will be used. A total of 8 specimens will be tested.

All specimens are designed to induce failure in the FRP bars, allowing the determination of the performance of both conventional and new anchoring systems.

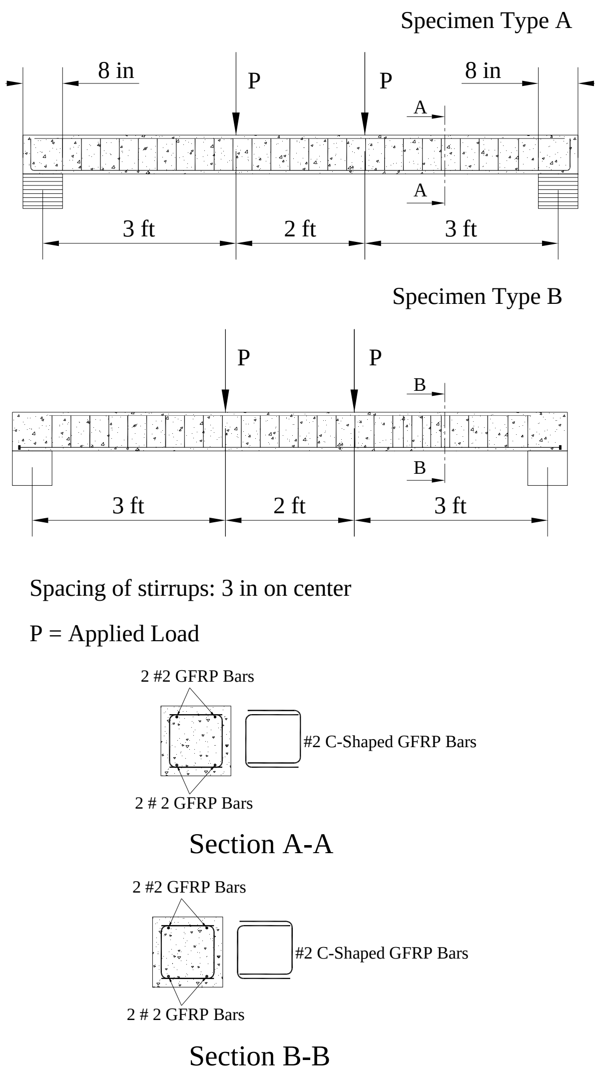


Figure 5 - Test Set-up for beam-end tests
(1 in = 25.4 mm; 1 ft = 304.8 mm)

Task 2: Analytical modeling. The analytical task will consist of simulations that will be calibrated using the experimental results from Task 1. The objective of this modeling will be to develop a design chart that relates anchor performance to bar size, concrete strength and embedment depth.

BUDGET

Budget for this project will cover support for one graduate student and adequate funds to conduct the experimental and analytical studies over a period of one year for a total budget of $15,000.

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