# Pullout Test on Barrier Reinforcing

**March 2002**

**Submitted by: Marc Ansley**

# Table of Contents

# Disclaimer

The opinions, findings and conclusions expressed in this publication are those of the authors and not necessarily those of the Florida Department of Transportation (FDOT).

# Acknowledgements

This report is the result of the work by a number of individuals none of whom can be blamed for any omissions or inadequacies, which are solely the responsibility of the author.

Dr. Dongzhou Huang checked the report and made a number of suggestions.  Tony Johnston developed the pullout-testing device and constructed it with the help of Paul Tighe.  Tony and Paul along with David Allen setup the specimen for testing.  Steve Eudy setup and ran the data acquisition equipment.  Jack Evans requested this test based on concerns his section had about the present FDOT standard.

## Technical Summary

According to the current and previous codes the development of the primary vertical tension reinforcing in the Florida Department of Transportation (FDOT) standard barrier is insufficient. The Standard Code (Article 8.29.2) requires a hook development length of 11.2 inches for a number 5 bar and f`c = 4500 psi. Using the reduction factor of Article 8.29.3.2, this development length reduces to 7.8 inches. For an 8 inch slab with 2 inches of cover the available concrete depth for bar development is only 6 inches, which is less than required in the Standard Code. The code equations are conservative in that they address the general condition and do not include a number of beneficial factors. These factors, in the case of this reinforcing, are the confinement provide by the surrounding reinforcing, the longitudinal bar that the reinforcing is hooked around and the bar bend diameter for the hook of the bar, which has a bend diameter smaller than the standard hook.

It was found by testing that this reinforcing is sufficiently developed. All tests indicated capacity well beyond the prescribed yield of the reinforcing.

## Test Setup

The bar of concern is labeled 5V in Figure 1. The test setup, shown in section in Figure 2, duplicated the reinforcing of the barrier and included as well the typical slab reinforcing. The spacing on the barrier bars in the test setup was 18 inches on center. The bar spacing for the actual barrier reinforcing is 8 inches on center as shown in Figure 1.

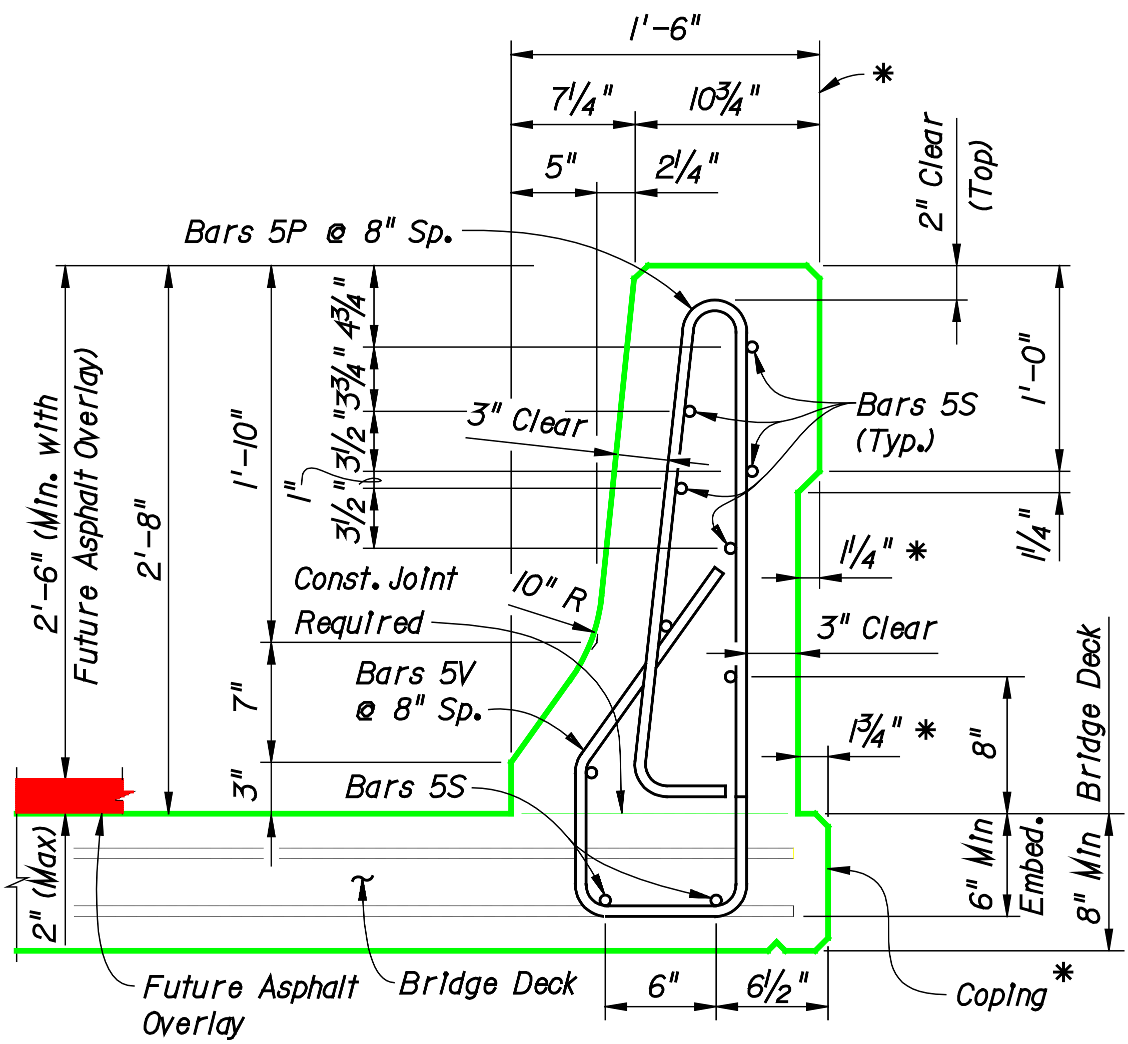


**Figure 1**

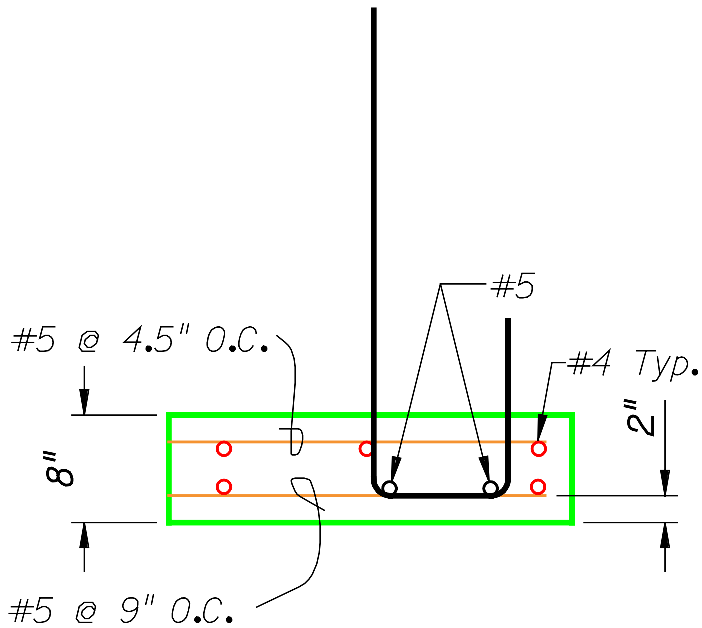


**Figure 2**

In addition to the bar that duplicated the 5V barrier bar (as shown in Figure 2) at the request of the Structures Design Office additional standard hook bars were added (as shown in Figure 3) between the 5V bars to allow for additional testing if testing of the 5V bars did not damage the surrounding concrete. This bar was also a number 5.

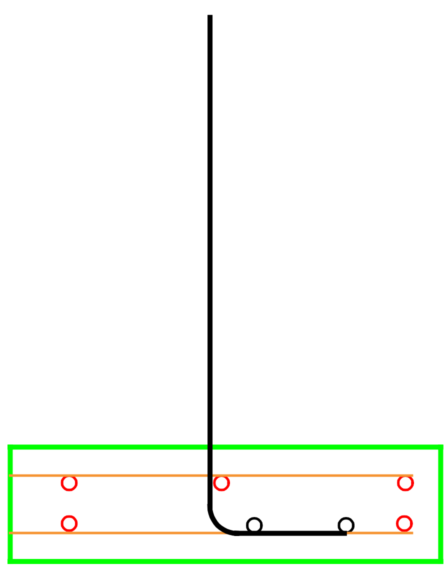

**Figure 3**

Figure 4 shows a plan view of the test setup.

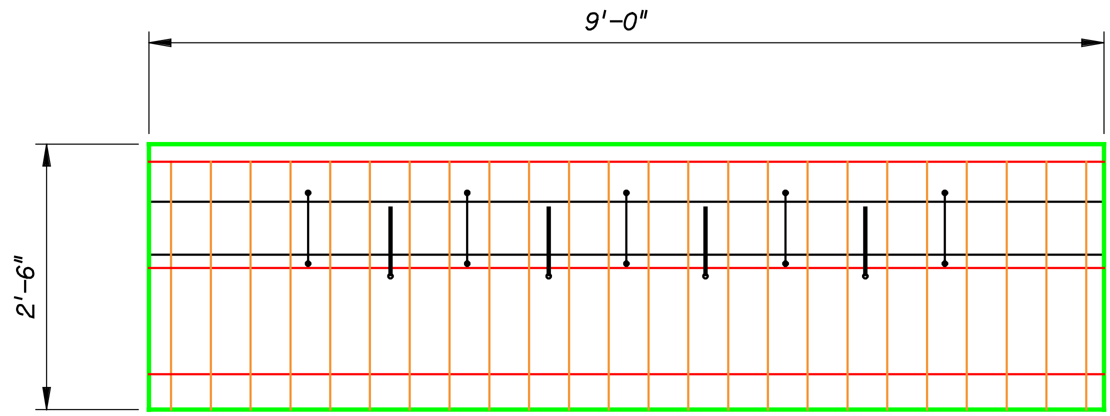


**Figure 4**

As can be seen from Figure 4 five 5V bars were provided for testing and 4 standard hook bars. Figures 5 and 6 show the specimen prior to casting concrete.

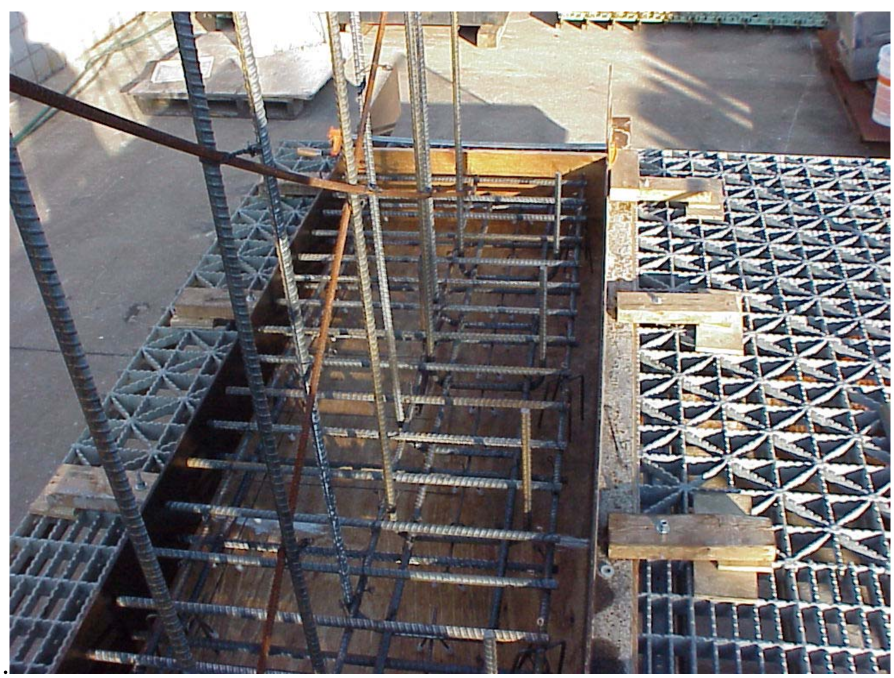

**Figure 5**

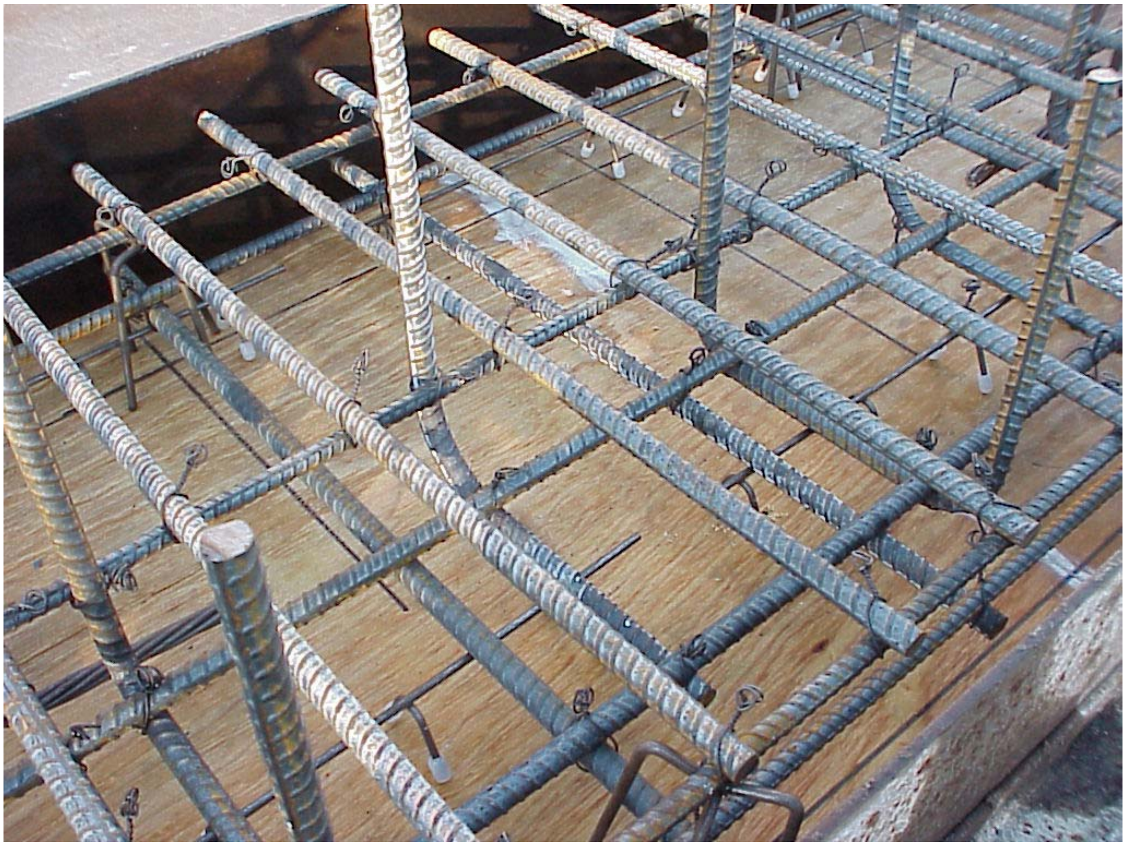

**Figure 6**

The reinforcing was Grade 60.  No material tests were conducted on the reinforcing since the pullout tests would indicated the yield stress if the bars were able to reach that capacity.

The concrete requested was a FDOT Class II (Bridge Deck) however, there was a mix up and the concrete delivered was a regular Class II.  The concrete was cast on November 30, 2001 and the cylinders were tested the day of the test January 3, 2002.  The 6 inch cylinders had breaks of 135.2 and 137.7 kips.  Based on this, the concrete strength for the pullout tests was assumed to be 4826 psi.


**Figure 7**

To provide for an unconfined condition the jacking load supports were placed 10 inches or more from the bar being tested. As can be seen from Figure 7 the support in the compression zone, for the barrier in bending, was placed adjacent to the projecting end of the U bar. This made the closest edge of that support 10 3/8 inches from the centerline of the bar while the other support edge was 12 1/8 inches from the center. The device was equipped with an inline load cell and deflection was measured at the end of the bar. The load cell and the deflection gage can be seen in Figure 7.

## Test Results

Seven pullout tests were conducted. The last two tests on the barrier bars (type 5V) disturbed the concrete area around them to the extent that the adjacent standard hook bars could not be tested. Looking at the specimen from a position that would view the outside of the barrier, the bar locations were numbered 1 to 9 from left to right. Based on this number scheme the testing sequence is given in Table 1.

**Table 1**

| Test Number | Bar Number | Bar Type |
|---|---|---|
| 1 | 1 | Barrier bar |
| 2 | 3 | Barrier bar |
| 3 | 2 | Standard Hook Bar |
| 4 | 5 | Barrier bar |
| 5 | 4 | Standard Hook Bar |
| 6 | 7 | Barrier bar |
| 7 | 9 | Barrier bar |

Load and deflection data was gathered for each test. The results of which are presented in Figures 8 through 14.

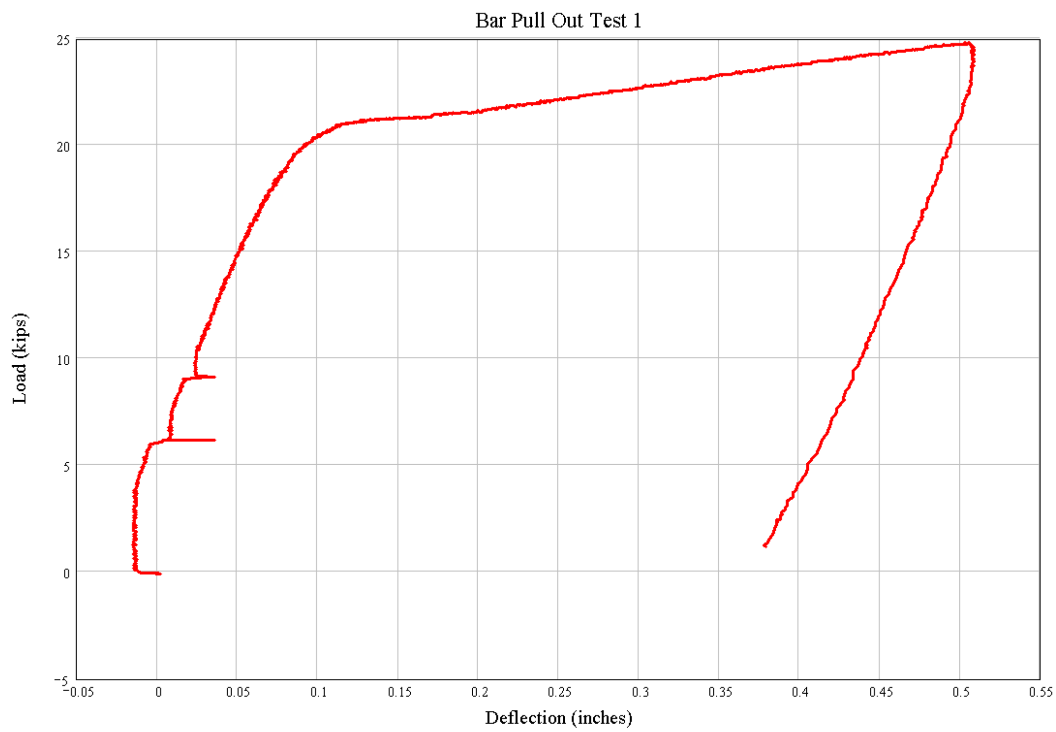


**Figure 8**

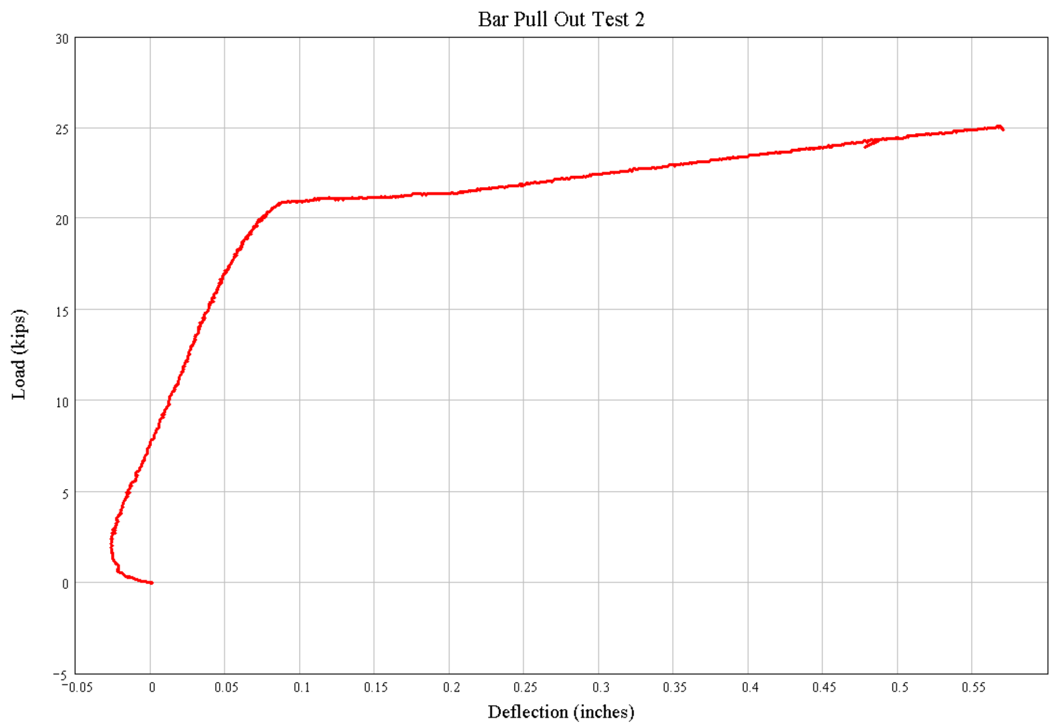


**Figure 9**

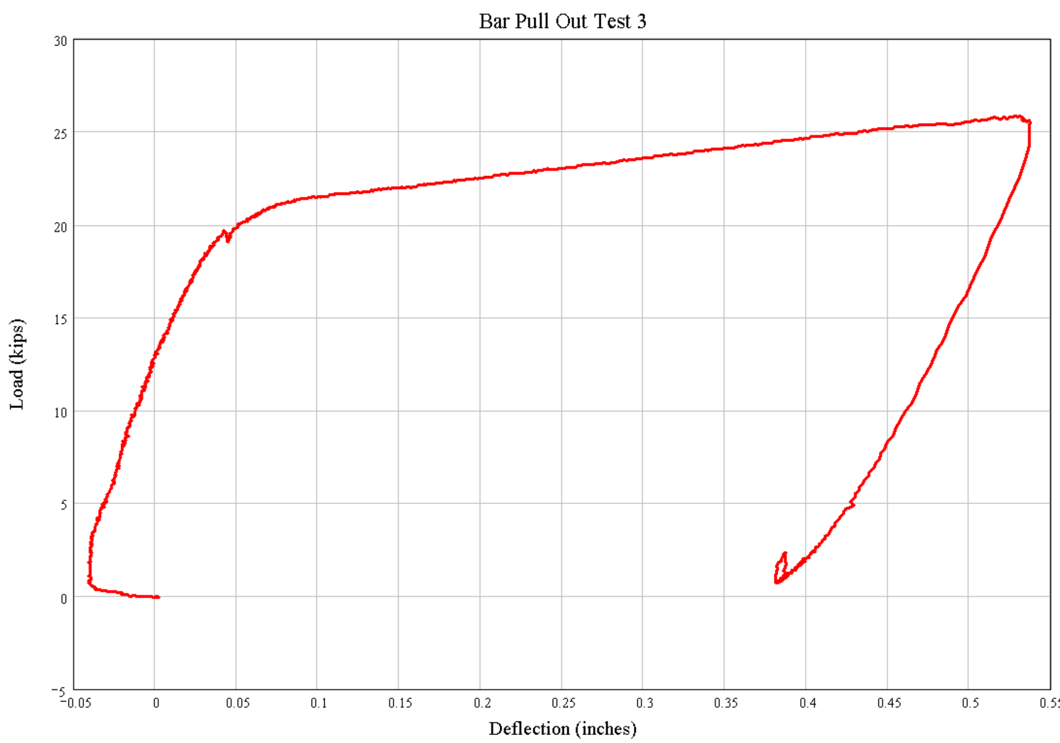


**Figure 10**

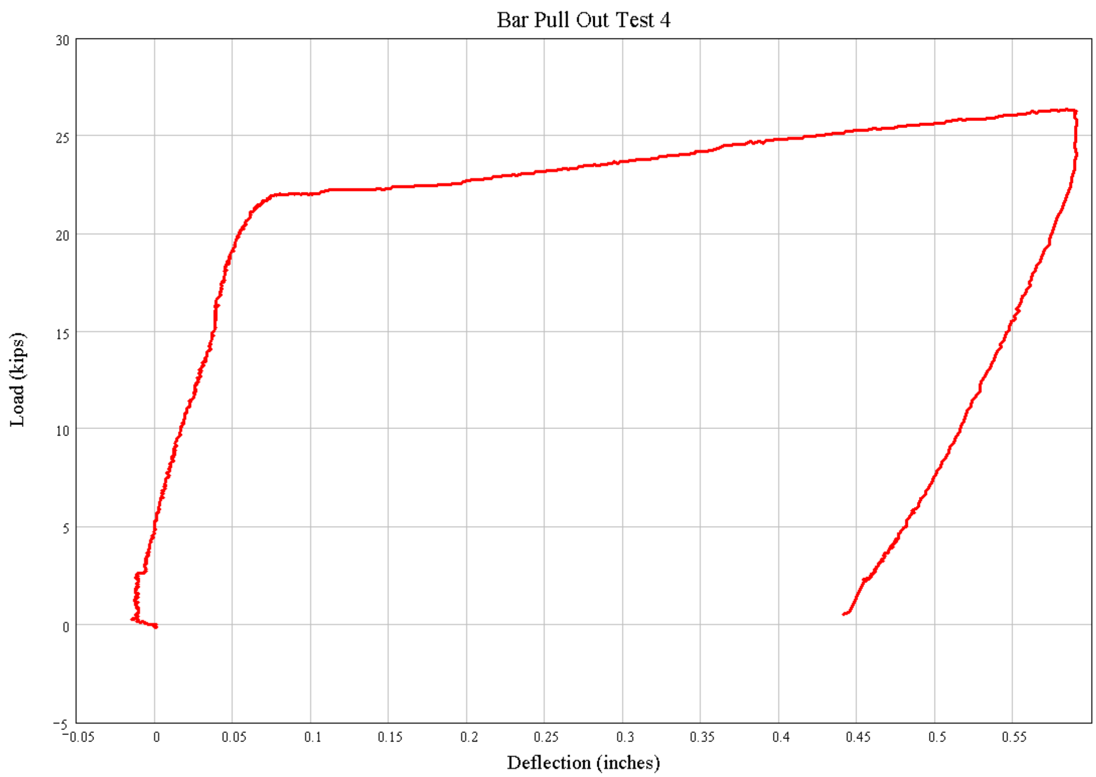


**Figure 11**

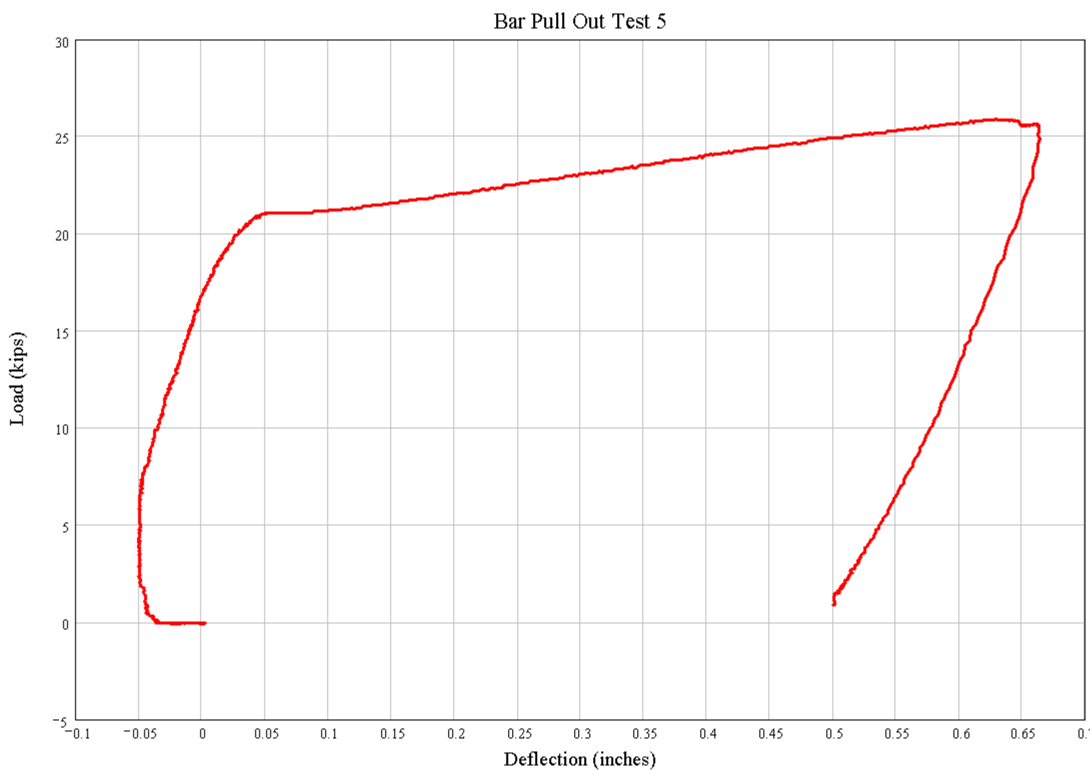


**Figure 12**

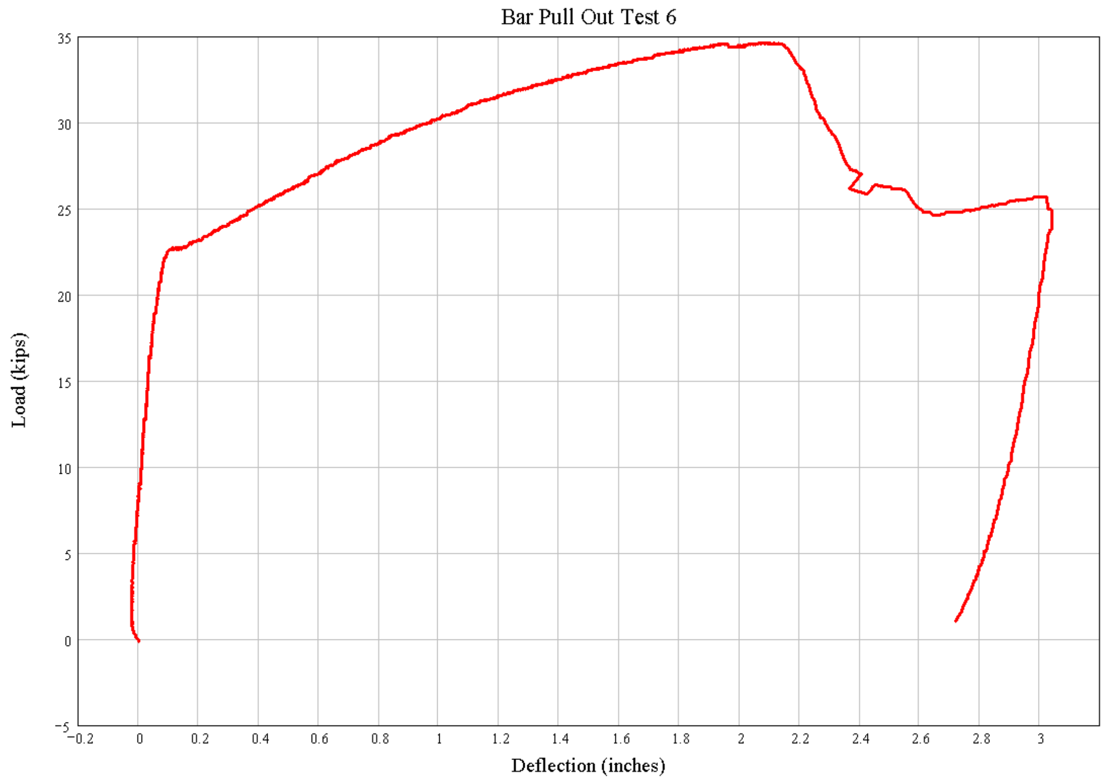


**Figure 13**

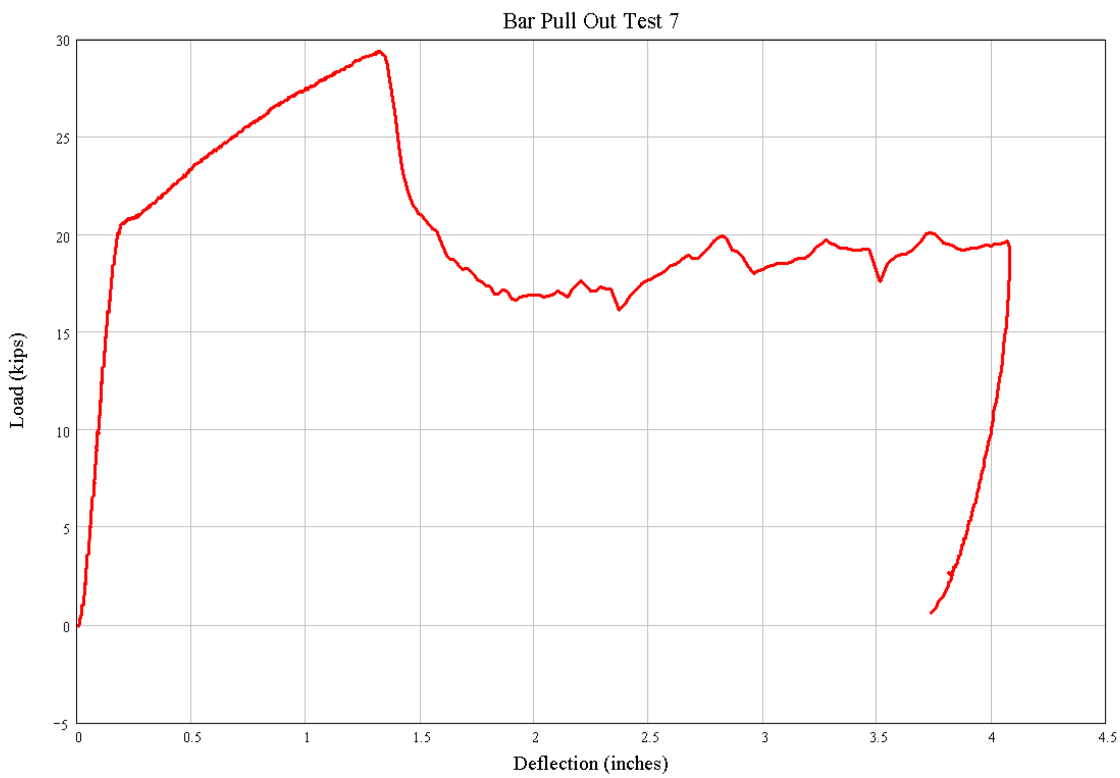


**Figure 14**

Tests 1 through 5 were halted before failure of either the bar or the concrete, although some concrete cracking had initiated. The nominal yield force for 60 ksi #5 bars is 18.6 kips and 125% of that value is 23.25 kips. It was decided that if the bars reached a value exceeding 23.25 kips they had demonstrated sufficient capacity for their intended use. Tests 6 and 7 were loaded until the capacity of the system was exceeded. In both of these cases the bars did not fail; the concrete in a radius of approximately 10 inches around the bar delaminated. Table 2 provides a summary of the results. (Yield loads were determined by visual inspection of the load deflection graphs)

**Table 2**

| Test | Type | Yield Load (kips) | Maximum Load (kips) | Reason for Halting |
|---|---|---|---|---|
| 1 | Barrier | 21.2 | 24.8 | Sufficient |
| 2 | Barrier | 20.9 | 25.1 | Sufficient |
| 3 | Std. Hook | 21.6 | 25.8 | Sufficient |
| 4 | Barrier | 22.0 | 26.4 | Sufficient |
| 5 | Std. Hook | 21.1 | 25.9 | Sufficient |
| 6 | Barrier | 22.7 | 34.6 | Concrete Failure |
| 7 | Barrier | 20.9 | 29.4 | Concrete Failure |

In examining the failure for test 6 it was apparent that the longitudinal reinforcing bar placed inside the hook at the bottom played a significant role in its capacity. This can be seen in Figure 15.

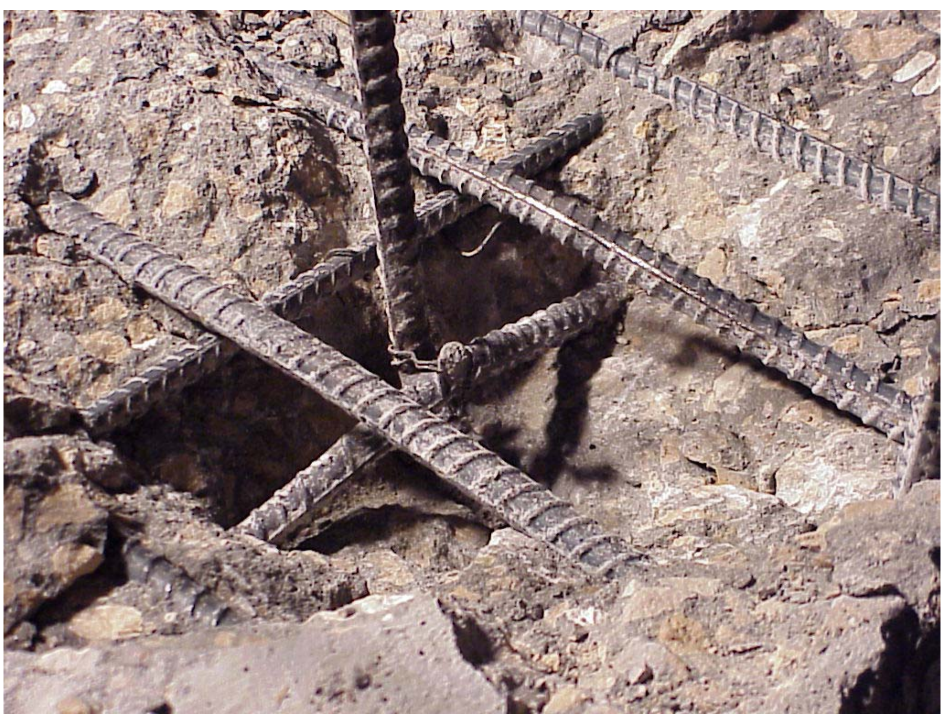

**Figure 15**

## Conclusions

The present barrier-reinforcing configuration, based on the results of these tests, is completely developed. From an examination of the two tests to failure (Tests 6 and 7), it is apparent that the greatest contributor to the additional capacity, beyond what would be expected, is the longitudinal bar the reinforcing was hooked around. For both tests these longitudinal bars at the hook are the focal point of the concrete failure. In can be speculated that this condition causes these bars to act more like a headed anchor than a hook. Other possible contributors were the top transverse bars, adjacent to the test specimens, which were bowed up from resisting the concrete delamination. It can also be surmised that for the extent they were tested (only two) the standard hooked bars perform as well as the barrier bars with the smaller radius hooks. Their performance also lends credence to the importance of the longitudinal bars at the hook location since the standard hooked bars lacked the complete U shape. The U shape of the barrier bars from examination of the tests did little to contribute to the additional capacity.

There are a number of items apparent from this testing that might warrant further investigation.

- The quality of the workmanship needed to achieve these results. Does the longitudinal bar have to be in contact at the hook location. Could the bar be in contact on the flat part of the bar some distance from the bend. Could it be separated from bend by say a half-inch of concrete and still function.
- How much does the adjacent reinforcing contribute.
- How much embedment is required, as a minimum, to develop the reinforcing with these conditions.
- Since the bars are spaced at 8 inches on center would group effects reduce their capacity.
- Would it be appropriate to use headed anchor equations to calculate the capacity of these bars. Using the ACI 318-02 Appendix D method for headed anchors:

$$N_b = k \cdot \sqrt{f'_c} \cdot h_{ef}^{1.5}$$

$N_b$ = basic breakout strength
$k$ = 40 (code value is 24 with 1.25 increase allowed but mean of test data is 40) (ref. 3)
$f'_c$ = 4826 psi
$h_{ef}$ = 4.75 inches

$N_b$ = 28.8 kips

This value is only slightly less than test 7 and about 20% less than test 6. This brings into question the amount of additional capacity provided by the adjacent reinforcing.

## References


1) AASHTO Standard Specifications for Highway Bridges, Sixteenth Edition 1996
2) ACI 318-02, Appendix D
3) Private communication with Dr. Ron Cook of the University of Florida