BOND STRENGTH OF 15 mm (#5) MST-BAR® GFRP REBAR AS PER ASTM D7913/D7913M

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1) INTRODUCTION

This report presents the test results of the bond strength of 15 mm (#5) MST-BAR® manufactured by B&B FRP Manufacturing Inc. as per ASTM D7913/D7913M *"Standard Test Method for Bond Strength of Fiber-Reinforced Polymer Matrix Composite Bars to Concrete by Pullout Testing"*. A total of 5 samples from 1 production lot of 15 mm (#5) MST-BAR® GFRP rebar, having a cross-sectional area of 199 mm^2 (as provided by B&B FRP Manufacturing Inc.), were tested at the Structures Laboratory of Concordia University.

2) FRP BAR SAMPLE

Visual inspections showed no apparent signs of damage to the GFRP rebars. Figure 1 shows the surface deformation of the MST-BAR®. The samples were cut using a grinder in the Structures laboratory of Concordia University to meet the dimensional requirements of ASTM D7913/D7913M and were cast in a 200 mm concrete cube. The length of the test bar in contact with concrete was $5d_b = 80\ mm$.

Figure 1: *15 mm (#5) MST-BAR® GFRP rebar.*

All five samples were cast using the same batch of ready-mix concrete. Figure 2 shows the five specimens after the concrete pour.

Figure 2: *15 mm (#5) MST-BAR GFRP rebars samples after the concrete pour.*

3) TEST SETUP

The tests were performed using a 534 *kN* (120 *kips*) Tinius-Olsen Super "L" Universal Testing Machine with a loading rate of 0.15 *kN/sec*. The specimens were aligned into the test frame of the universal testing machine. The bar's loaded end was anchored in a steel tube, gripped in the machine, and loaded in tension until failure. Figure 3 shows the test setup.

Figure 3: *Test setup.*

4) TEST OBSERVATIONS

The failure mode of three out of five specimens was splitting of concrete. In two out of five specimens, the test was stopped just before failure at the load around 105 kN due to safety concerns to avoid brittle concrete splitting failure. Figure 4 shows the failure mode of the five specimens.

Figure 4: *The failure mode of the 15 mm (#5) MST-BAR® GFRP rebar.*

5) CALCULATIONS AND RESULTS

The average bond stress is calculated as the maximum force observed during the test divided by the bar's surface area bonded to the concrete.

$$\tau = \frac{F}{C_b l}$$

where τ is average bond stress, F is the maximum tensile force, C_b is the effective circumference of FRP bar, and l is the bonded length ($5d_b = 80\ mm$). The average, standard deviation, and coefficient of variation of the bond strength of the straight portion of 15 mm (#5) MST-BAR® GFRP rebar are listed in **Table 1**.

***Table 1**: Summary of experimental results of 15 mm (#5) MST-BAR® rebars*

Specimen	Failure Load kN	Bond Strength MPa	Failure Mode
1	113	29	**Concrete Splitting**
2	103	26	**Concrete Splitting**
3	105	26	**Concrete Splitting**
4	106	27	**Test Stopped**
5	105	26	**Test Stopped**
Average	**106.5**	**27**	
Standard Deviation	3.93	1.0	
Coefficient of Variation (%)	3.7	3.7	

6) CONCLUSIONS:

This report presents the bond strength of the straight portion of 15 mm (#5) MST-BAR® rebars manufactured by B&B FRP Manufacturing Inc. as per ASTM D7913/D7913M "*Standard Test Method for Bond Strength of Fiber-Reinforced Polymer Matrix Composite Bars to Concrete by Pullout Testing*". Based on experimental observations, the splitting strength of concrete cubes controlled the failure of specimens, and thus the full pullout capacity of the GFRP samples was not achieved. Based on test results, it can be concluded that 80 mm ($5d_b$) embedment length of 15 mm (#5) MST-BAR® has, more than 106 kN pullout capacity. Moreover, since the average bond strength is greater than 10 MPa, it can also be concluded that the 15 mm (#5) MST-BAR® rebar meets the requirements of CSA S807-19.

It should be noted that since the observed failure mode of the specimens was splitting of concrete, the 200 mm cube size provided by ASTM D7913/D7913M is not sufficient to develop the full pullout capacity of MST-BAR® GFRP rebars. Tests with larger concrete cubes are required to achieve the actual pullout capacity of 15 mm (#5) MST-BAR® GFRP rebars.

REFERENCES

ASTM, ASTM D7913/D7913M-14: Standard test method for bond strength of fiber-reinforced polymer matrix composite bars to concrete by pullout testing, ASTM Standards. (2014) 1–9. https://doi.org/10.1520/D7913.

CSA S807-19: Canadian Standards Association, Specification for fibre-reinforced polymers (CSA S807-19), (2019).