FORTEC STABILIZATION

Test Report & Case Study

University of Miami College of Engineering Structures and Materials Laboratory

IAS ACCREDITED

CERTIFIED TEST REPORT

EVALUATION OF ANCHORING SOLUTION FOR EXTENALLY BONDED FIBER REINFORCED POLYMER (FRP) SYSTEMS

Report Number: R-5.10_161206_FSS
Date: December 16, 2015

INTERNATIONAL CONCRETE REPAIR INSTITUTE 2017 Spring Convention | March 15-17 | Montreal, Canada

EXECUTIVE SUMMARY

This certified test report, evaluates the performance of a unique anchor solution for externally bonded fiber reinforced polymer (FRP) systems on concrete substrate.

The anchor solution is a development composed of two components: i) a 'flat staple' composed of a pre-cured carbon FRP piece and; ii) a saturated fiber sheet piece that wraps around the flat staple anchor and is placed onto the externally bonded FRP sheet or laminate, here in referred to as anchor 'Type Z'.

Based on double shear load tests of FRP laminates bonded to concrete per the results reported here, the following can be concluded:

- When comparing type Z anchor system to an un-anchored FRP laminate bonded to concrete, under the same conditions it improves the load carrying capacity of the FRP laminate by 156%.
- When comparing type Z anchor system to an FRP laminate bonded to concrete anchored only with the 'flat staple' only component, under the same conditions it improves the load carrying capacity of the FRP laminate by over 115%.

The anchor type Z translates the failure to the concrete substrate, fully engaging the FRP laminate system bonded to the concrete. Neither laceration nor debonding of the FRP laminate occurs with anchor type Z, which are unwanted failure modes since they do not fully engage the FRP laminate.

In summary the anchor behaves as a single element (coupling both the staple and wrapped piece), and results in an effective anchoring solution as presented herein.

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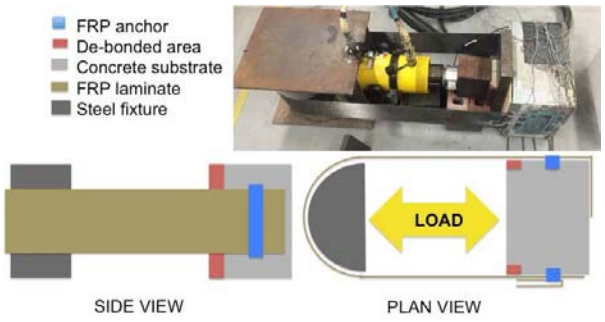

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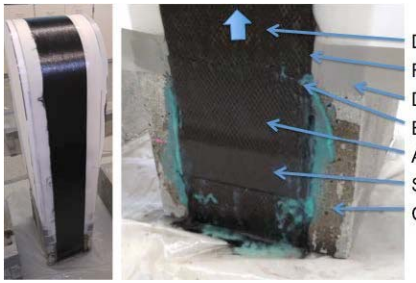


Direction of tensile load
FRP Laminate
De-bonded concrete area
End of anchor wrapped piece
Anchor wrapped piece
Staple anchor
Concrete block test side

5. TEST INFORMATION

Specimen preparation: All specimens were prepared by Structures and Materials Laboratory personnel, following manufactures instructions. All concrete blocks used in testing were cast in a single batch conforming to ASTM C192/C192M-13a, to ensure validity on the comparison of the test results. Concrete substrate surface was prepared via sandblasted to ensure a minimum surface roughness of CPS 3, as defined by ICRI was achieved. The FRP laminate and anchors were installed on the substrate simultaneously.

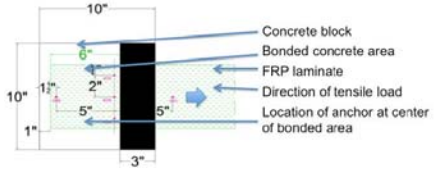
Specimen geometry: Geometry of test area is provided in Figure 3. All geometry was kept consistent to ensure validity on the comparison of the test results.

Test Location: Structures and Materials Laboratory, SML, University of Miami, 1251 Memorial Dr., MEB108 Coral Gables, FL, 33146

Test setup: Load was applied via hydraulic jack manually to a quasi-constant rate. All load measurements were recorded with a load cell conforming to ASTM E4-16.

Specimen Conditioning: After installation of the FRP laminate and anchor on the concrete substrate, the specimens were left to cure for a minimum period of 5 days. Following that, specimens were brought into the laboratory to become temperature balanced for a minimum period of 24 hours at 23 ± 1°C (73 ± 3°F) and 60 ± 5% RH.

Specimen ID: Specimens are labeled and uniquely identified for quality and traceability using the format T_XX, where T is the specimen type (B for benchmark, S for staple only, and Z for staple and wrapped piece specimen) product, and X is the sample number.



6. TEST RESULTS

Table 1- Test Results for FRP Staple Anchor Solution

SPECIMEN ID	Total peak load (P_{max})		Total load sustained by anchor ($P_{max}/2$)		Increase in performance	Failure Mode
	lbf	kips	lbf	kips	%	
B_01	13041	13.04	6521	6.52	-19.7	FRP de-bonding
B_02	17034	17.03	8517	8.52	4.9	FRP de-bonding
B_03	18635	18.63	9317	9.32	14.8	FRP de-bonding
Average	16237	16.24	8118	8.12		
Stand. Dev.	2352	2.35	1176	1.18	0.0	
Coef. of Var. (%)	14.5	14.5	14.5	14.5		
S_01	24628	24.63	12314	12.31	51.7	FRP de-bonding and slippage beneath the anchor
S_02	30118	30.12	15059	15.06	85.5	FRP de-bonding and slippage beneath the anchor/FRP rupture
S_03	29170	29.17	14585	14.58	79.7	FRP de-bonding and slippage beneath the anchor/FRP rupture
Average	27972	27.97	13986	13.99		
Stand. Dev.	2396	2.40	1198	1.20	72.3	
Coef. of Var. (%)	8.6	8.6	8.6	8.6		
Z_01	34480	34.48	17240	17.24	112.4	Failure in concrete substrate
Z_02	43131	43.13	21566	21.57	165.6	Anchor failure and FRP de-bonding
Z_03	45927	45.93	22964	22.96	182.9	Failure in concrete substrate
Z_04	41412	41.41	20706	20.71	155.1	Failure in concrete substrate
Z_05	42833	42.83	21417	21.42		Anchor failure and FRP de-bonding
Average	41556	41.56	20778	20.78		
Stand. Dev.	3829	3.83	1915	1.91	155.9	
Coef. of Var. (%)	9.2	9.2	9.2	9.2		

GEORGIA BRIDGE CASE STUDY

Date: July 24, 2016
Location: Columbus Georgia
Contractor: Engineered Solutions

Project Scope: Concrete Bridge to be reinforced for traffic. Small concrete beams were under designed.

Solution: One layer 600 gsm carbon fiber with carbon anchors were installed to achieve this.

GEORGIA BRIDGE CASE STUDY

Conclusion: Testing of Anchors prove to dramatically increase long term creep of the surface mounted carbon fiber under the flexural load. Project was completed in 2 days.