FRP Anchorage Systems for the Strengthening of Infill Masonry Structures

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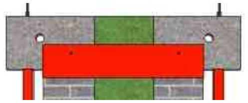
ABSTRACT

A previous study conducted at North Carolina State University on the strengthening of infill masonry walls with FRP clearly indicated that the type of anchorage system has a strong influence on the overall performance of the FRP strengthening system. This study will explore the performance of several innovative FRP anchorage systems for strengthening of masonry infill walls. A new type of FRP with high fracturing strain, PET, is proposed for the experimental program in which the FRP is anchored to the supporting members using four different types of anchorage: overlap, mechanical anchorage, wrapping around an embedded FRP bar, and FRP anchor bolts.
The primary objective of this study is to explore the performance of innovative FRP anchorage systems for strengthening of infill masonry walls. Previous studies have shown that FRP strengthening of masonry can lead to a substantial increase in load carrying capacity when proper anchorage of the FRP to supporting elements is provided. In cases where inadequate anchorage is used, the mode of failure can shift from a ductile flexural failure to a brittle and premature shear sliding failure. This study intends to explore different anchorage systems to determine which are effective in preventing or delaying the shear sliding mode of failure and to quantify the effectiveness in terms of increased load carrying capacity and ductility.

FRP ANCHORAGE TYPES



"shear restraint" (SR), consists of steel plates bolted to the RC caps. The plates were clamped over the FRP sheet to provide mechanical anchorage and extend two inches beyond the masonry/RC cap interface to resist sliding shear along this interface.

Figure 1: FRP Reinforcement with Shear Restraint anchor

"fiber bolt" (FB), consists of a bundle of fibers embedded perpendicular to the face of the RC cap and flayed outward at the surface to resist pullout of the FRP sheets.

Figure 2: FRP Reinforcement with Fiber Bolts anchor

"embedded bar" (EB), consists of wrapping the FRP sheets around an FRP bar embedded near in the surface of the RC cap and running parallel to the masonry/RC cap interface.

Figure 3: FRP Reinforcement with Embedded Bar anchor

"shear keys" (SK), consists of short near surface mounted CFRP strips embedded perpendicular to the masonry/RC cap. These are intended to resist sliding shear along the interface. The FRP sheet will then be placed with the "overlap" configuration above these shear keys.

Figure 4: FRP Reinforcement with CFRP Shear Key anchor

"Near Surface Mounted " (NSM), consists of short surface mounted CFRP strand sheet embedded perpendicular to the masonry/RC cap. These are intended to resist sliding shear along the interface and resist flexural failure.

Figure 5: Reinforcement with Near Surface Mounted Bar anchor

Test Specimen and set up

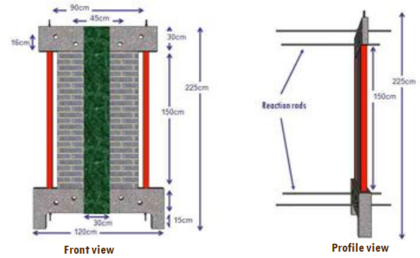


Figure 6: Details of Test Specimen

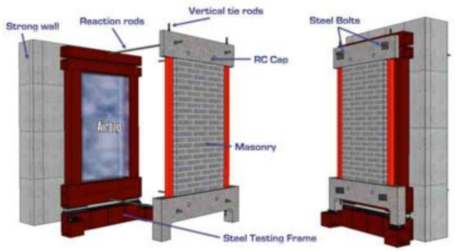


Figure 7: Profile of Test Setup

Testing Condition

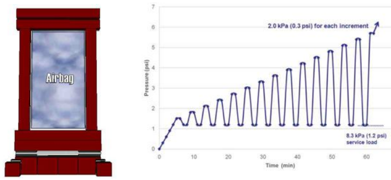


Figure 8: Typical cyclic loading sequence from Airbag

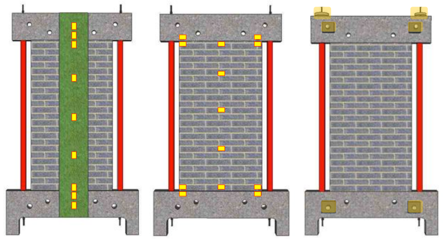


Figure 9: Basic location of Strain Gages (Left)
Figure 10: Basic location of String Potentiometers (Center)
Figure 11: Location of Load Cells (Right)

Comparison of Results

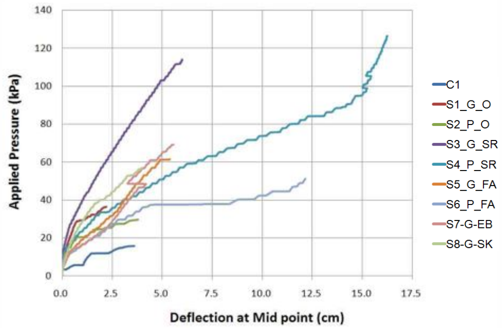


Figure 12: Comparison of Load – Deflection behavior

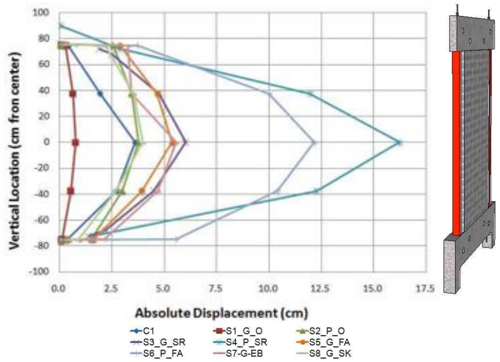


Figure 13: Comparison of Out-of-plane displacement profile along vertical line

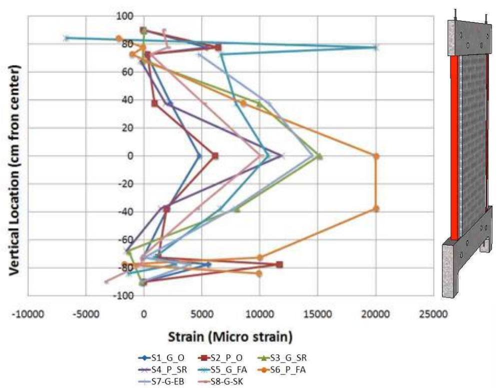


Figure 14: Comparison of Measured Strain profile in FRP Sheet

FAILURE MODES

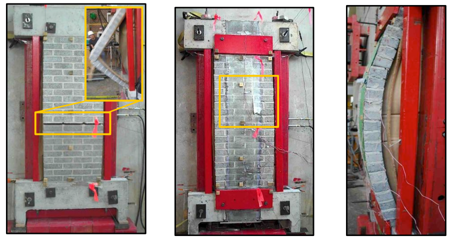


Figure 15: Flexural Failure of Control Specimen (Left)
Figure 16: FRP Rupture Failure of S3-G-SR Specimen (Center)
Figure 17: Displaced Shape of S4-P-SR Specimen (Right) -No Failure

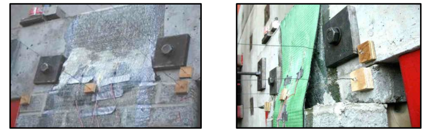


Figure 18: Debonding at top interface up to fiber anchors of S5-G-FA Specimen (Left)
Figure 19: Debonding at top interface up to fiber anchors of S6-P-FA Specimen (Right)

Figure 20: Top fiber anchor pull out (left) and Bottom fiber anchor rupture (right) of S6-P-FA Specimen

SUMMARY OF TEST RESULTS

Specimen ID	FRP Type	Anchorage Type	Elastic limit (kPa)	Max Load (kPa)	Max Displ (cm)	Failure Mode
C1	—	—	3.5	15.5	3.6	FB
S1-G-O	GFRP	Overlap	28.3	36.1	2.2	DB
S2-P-O	PET		19.3	29.0	3.8	DB
S3-G-SR	GFRP	Shear Restraint	28.3	112.3	6.0	FR
S4-P-SR	PET		33.1	124.6	16.2	NF
S5-G-FB	GFRP	Fiber Bolt	11.7	60.7	5.4	AR&AP
S6-P-FB	PET		36.5	50.4	12.2	AR&AP
S7-G-EB	GFRP	Embedded Bar	47.6	68.3	5.4	AP
S8-G-SK	GFRP	CFRP Shear Key	39.3	56.1	4.0	AP
S9-P-SK	PET		16.5	38.3	3.3	AP
S10-G-NSM	Grancrete	Near Surface Mounted	17.9	25.0	2.5	AP
S11-E-NSM	Epoxy		16.5	36.6	3.1	AP

† Failure modes: FB – Flexural Bending; DB – FRP Debonding; FR – FRP Rupture; NF – No Failure (stop testing); AR- Anchor Rupture; AP – Anchor Pull out

Experiment of this study was conducted at NC STATE UNIVERSITY