Direct Service Temperature Exposure Effect on Bond Behaviour between NSM Composites and Concrete Masonry Units

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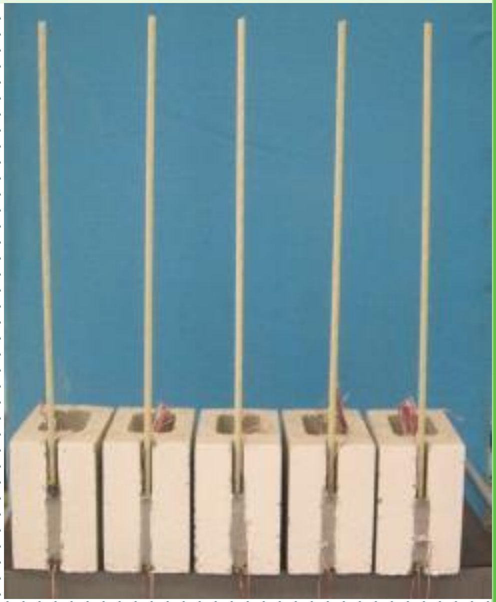

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Presentation Outline

- Objectives
- Introduction
- Motivation
- Experimental Program
- Test Results and Discussion
- Conclusions

Objectives

> This study will help to investigate **<u>for the first time</u>** the bond behavior when the advanced composite is subjected to tension force simultaneously with applying temperature.

> The key parameters investigated include different levels of temperature applied to the specimen at:

- freezing temperature of −18°C (0°F),
- ambient temperature of 21°C (70°F), and
- elevated temperature of 49°C (120°F).

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Objectives

- An additional objective was to compare the performance of specimens exposed to temperature and load concurrently with the performance of specimens subjected to cycles of the same temperature before loading.

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Motivation

> Previous durability research on bond behavior has primarily focused on exposure to harsh environmental conditions and testing the specimens **after** exposure to same conditions, which enables the adhesive material to reset before performing the bond test.

> However, this research focused on studying the bond behavior when composite is subjected to tension force **simultaneous** with the direct application of different temperature (freeze, ambient, and high temperature), which is more representative of structural elements in the field.

Introduction

The interest in advanced composites in repairing and strengthening infrastructure systems has considerably increased, especially when the application of fiber reinforced polymer (FRP) has become more established.

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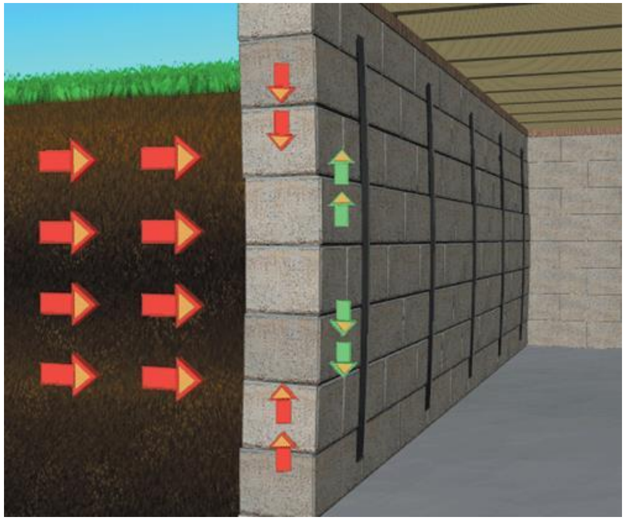
Introduction

- **Why Composites?**
  - High longitudinal tensile strength.
  - Lightweight (about 1/5 steel density).
  - Corrosion resistance.
  - High fatigue endurance.
  - Extended service life
  - Design flexibility



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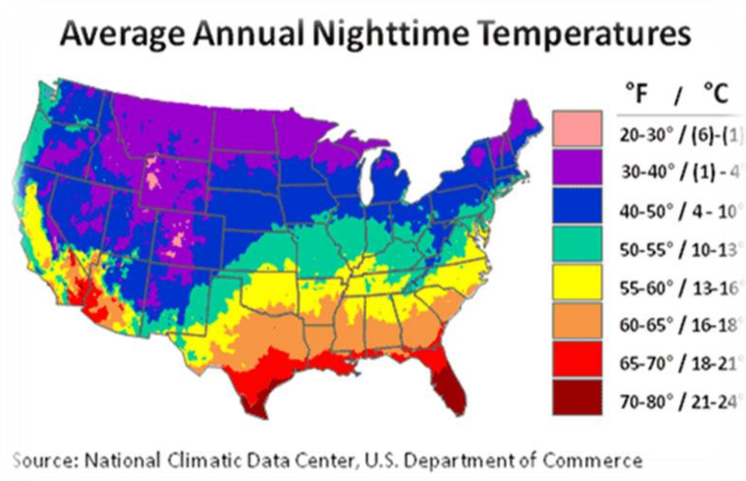
Introduction

> The main environmental degradation factors that can affect the behavior of strengthened walls are:

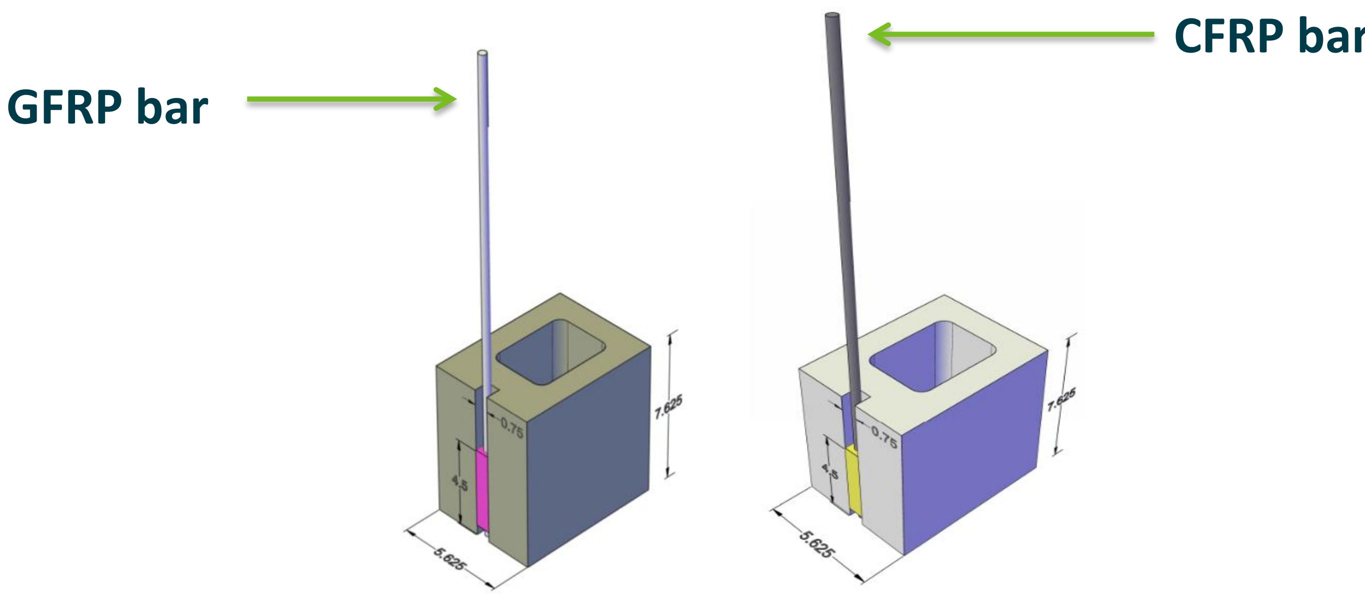
- Freeze and thaw,
- Temperature, and
- Moisture



Experimental Program

❖ Materials and Strengthening Procedure

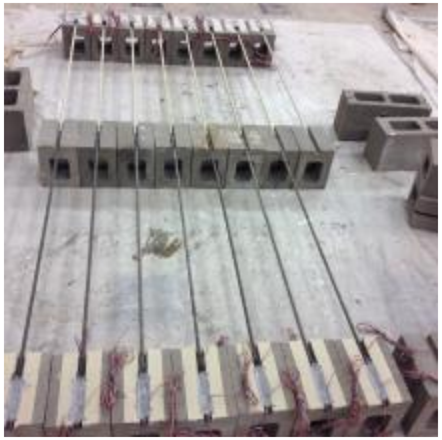
- Hollow concrete masonry units with nominal dimensions 200 x 200 x 152 mm (8 x 8 x 6 in.) were used in this study.
- FRP carbon or glass fiber in addition to the epoxy resin were considered.

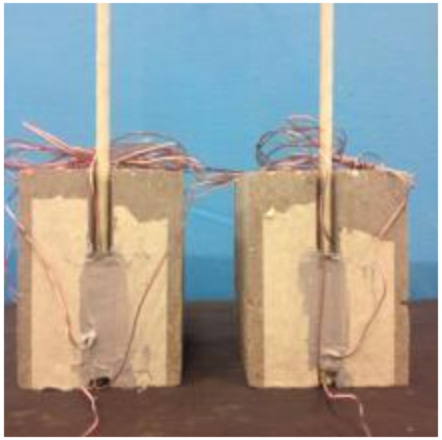


Experimental Program

❖ Strengthening Procedure

No surface preparation was needed for the NSM system, and the strengthening procedure involved inserting FRP bar into a groove cut at the surface of the specimen. A grinder with a diamond concrete blade was used to cut the groove with a dimension double the diameter of the bar to avoid splitting failure of the adhesive cover.





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Experimental Program

❖Preparing the Specimens

Specimens were preconditioned, heated up to 49°C (120°F) in a furnace or cooled down to −18°C (0°F) in a refrigerator, and then the specimens were immediately brought to the chamber that was attached to the MTS universal testing machine to ensure that the specimens were at temporal with desired temperature.

Specimen in furnace

Specimen in refrigerator

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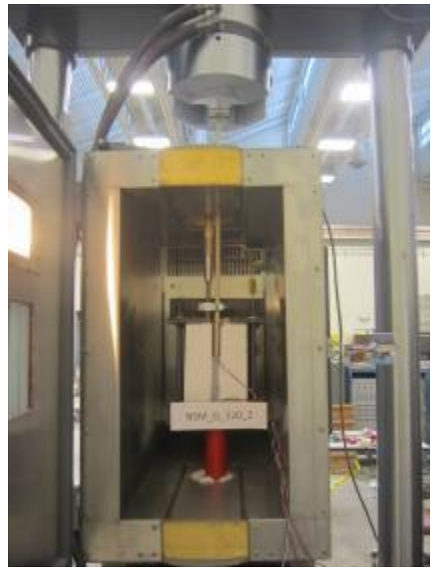
Experimental Program

❖Test Setup

MTS universal testing machine

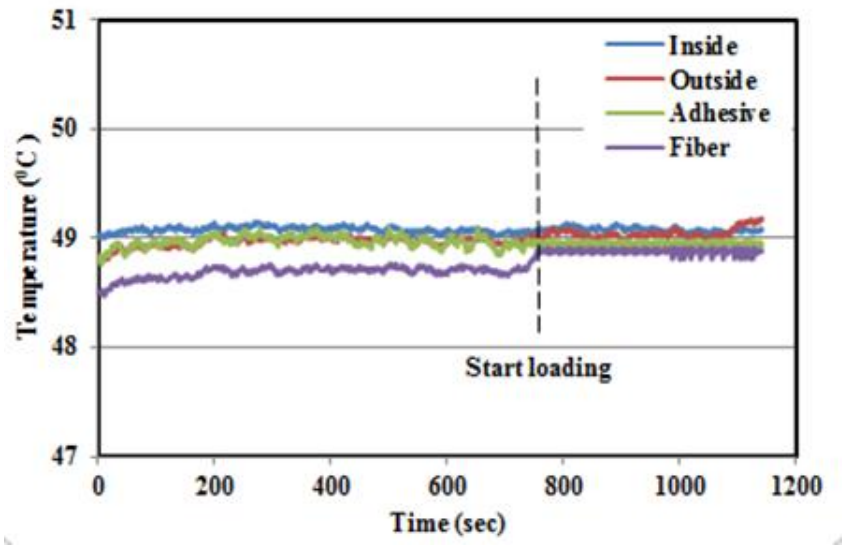


Chamber attached to the MTS machine

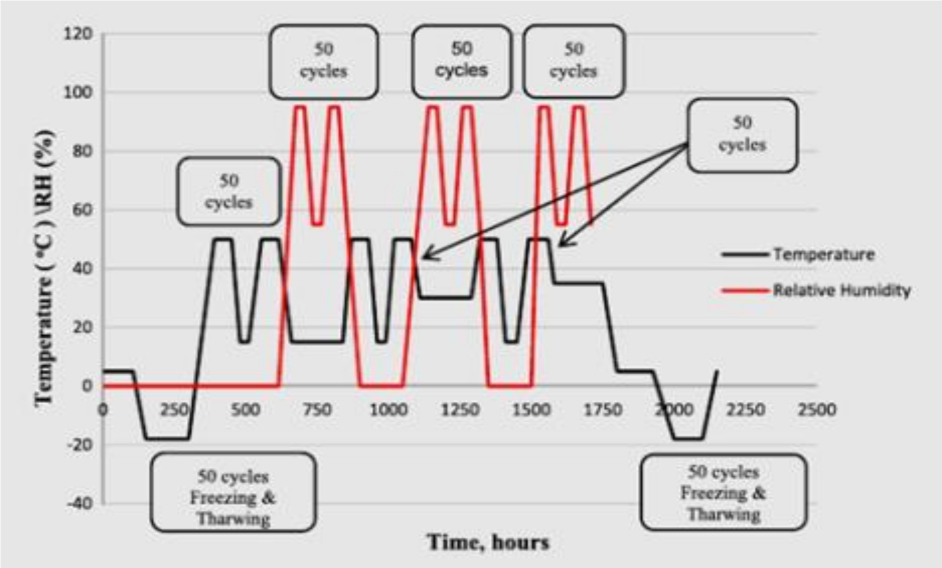
Environmental chamber

Experimental Program

❖Direct and Cyclic Temperature



Four thermocouples reading



Cyclic exposure regime

Test Results

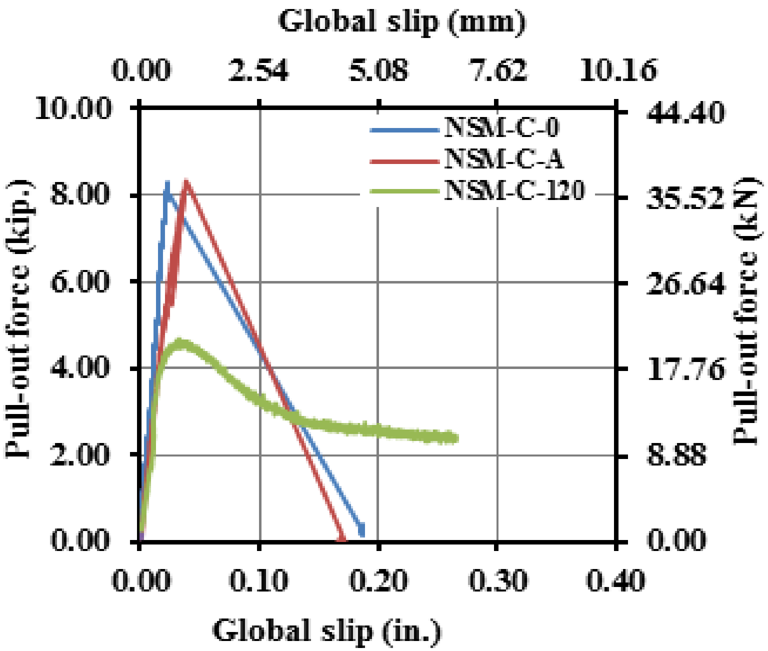
❖Summary of Test Results

specimen	Phase	Specimen ID	Ultimate force P_u (kN)	Effectivity index $P_u/P_{u,A}$	Mode of failure*
1	Phase 1	NSM-G-A	37.36	1.00	D-C/SP
2		NSM-G-120	19.60	0.52	S-F/E
3		NSM-G-0	37.05	0.99	D-SP
4		NSM-C-A	37.10	1.00	D-C/SP
5		NSM-C-120	20.56	0.55	S-F/E
6		NSM-C-0	36.94	0.99	D-SP
7	Phase 2	NSM-G-A-Cy	35.05	0.94	D-SP
8		NSM-C-A-Cy	33.50	0.90	D-SP
Note : 1.0 kN = 0.224 kip; 1.0 mm/mm = 1.0 in./in.					

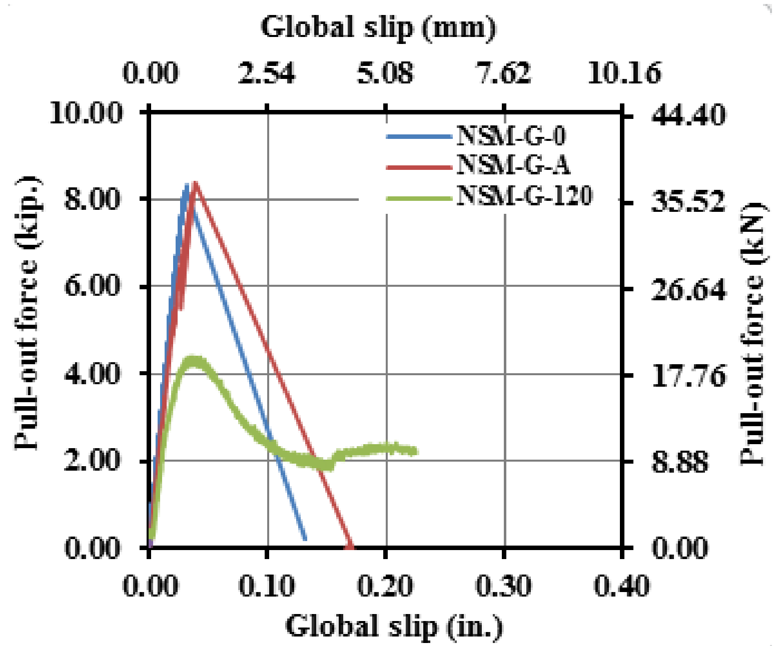
*D-C/SP: debonding due to concrete splitting,
D-Sp: debonding due to splitting of the epoxy cover,
D-F/E: debonding at fiber- epoxy interface, and
S-F/E: slipping at fiber- epoxy interface.

Test Results

❖ Pull-out Force-global Slip Relationship



(A)



(B)

Pull-out force vs. global slip relationship for (a) NSM-CFRP, (b) NSM-GFRP

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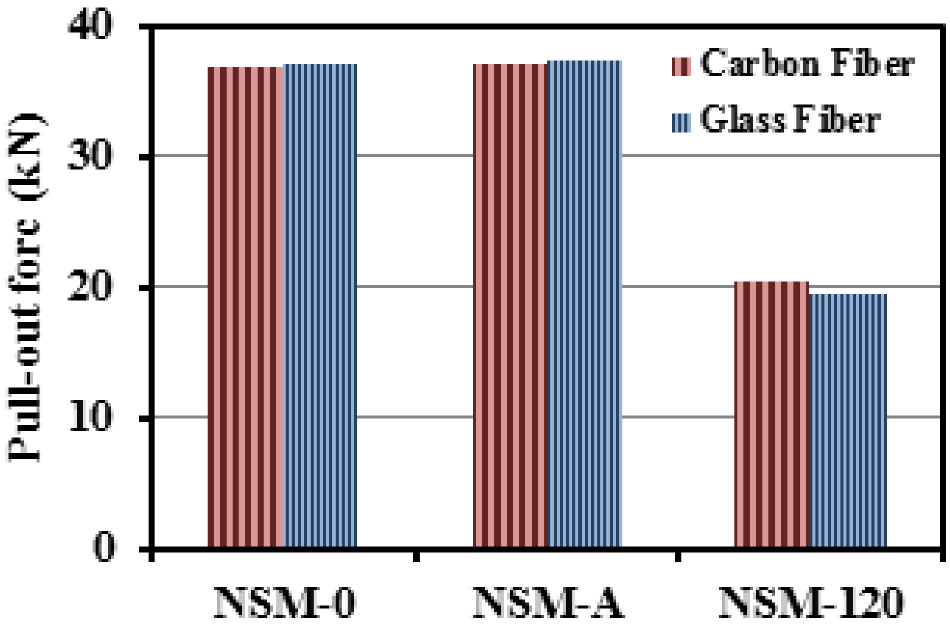
Test Results

❖ The Effect of Temperature

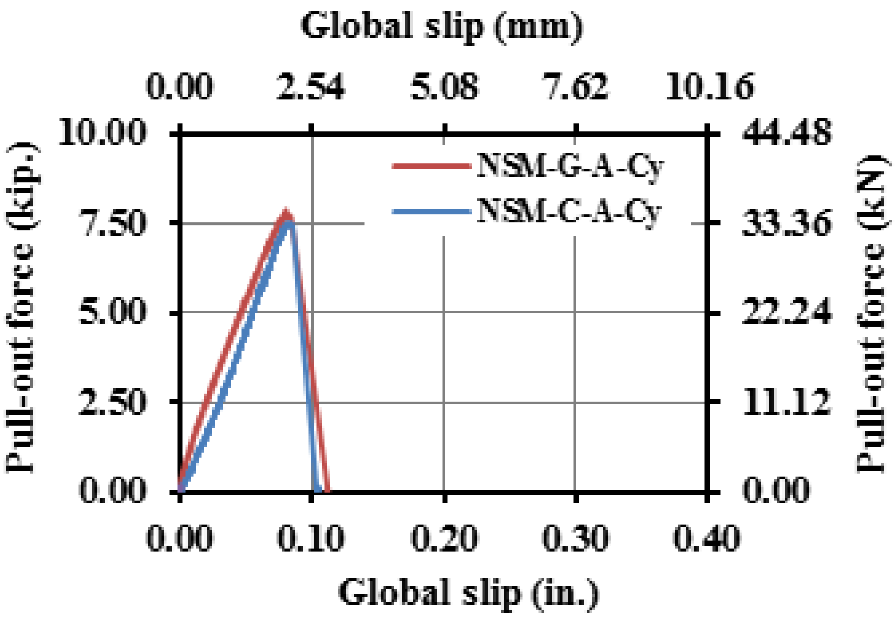
The decrease of the ultimate pull-out force can be observed for temperatures close to the heat distortion temperature (HDT).



Test Results

❖ The Effect of Exposure Condition

For the epoxy strengthening systems exposed to cycles of heating followed by cooling, microcracks that generated in the adhesive material changed the mode of failure from debonding due to concrete splitting to debonding due to epoxy splitting.



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Test Results

❖Modes of Failure


NSM-G-0

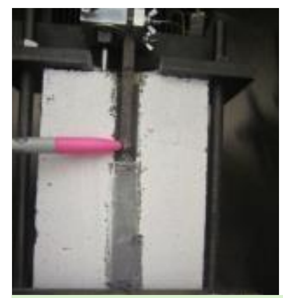

NSM-G-A


NSM-G-120


NSM-G-A-Cy


NSM-C-0


NSM-C-A


NSM-C-120


NSM-C-A-Cy

(D-SP) | D-C/SP | S-F/E | D-SP

Conclusions

- The relation of pull-out force and global slip was linear up to the ultimate and then the capacity dropped either suddenly due to complete debonding (in case of low and ambient temperature) or gradually due to softening of the concrete-resin interface (in case of high temperature).
- The debonding mode of failure was identified from this study as follows: debonding due to concrete or epoxy cover splitting, debonding at the fiber- matrix interface, debonding at the fiber-epoxy interface, and slipping at the fiber-epoxy interface.
- Comparing with reference specimen strengthened with FRP-epoxy, the reduction of FRP-epoxy bond properties was up to 48% when exposed to high service temperatures.

Conclusions

- The high service temperature, 49 ^{o}C (120 ^{o}F), affected mode of failure by changing from mixed cohesive-adhesive with concrete detached to perfect adhesive.
- The performance of CFRP and GFRP in NSM system was the same due to identical surface of bars and epoxy used in this system.
- For the epoxy strengthening systems exposed to cycles of heating and cooling, microcracks generated in adhesive material that changed the mode of failure from debonding due to concrete splitting to the debonding due to epoxy splitting associated with pull-out force reduction by 10%.

Acknowledgment

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