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What About Adhesive Anchors? Part 2(B)

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Effect of Environmental Exposure on the Creep Behavior of Adhesive Anchors

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INTRODUCTION

- Anchoring systems for concrete are comprised of: cast-in-place, and post-installed anchors.
- Post-installed anchors:
  - Mechanical systems (expansion and undercut)
  - Bonded (adhesive and grouted) systems.
    - Load transfer is ensured by bond stresses between the anchor, adhesive and concrete along embedment length.
    - Adhesive anchors can be a threaded rod or deformed steel rebar.
    - Different products are used to install adhesive anchors including polymers (epoxies, polyesters, or vinylesters).

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INTRODUCTION

- Tu and Kruger, (1996) reported that water is a harmful factor for epoxy adhesives and noted severe bond strength deterioration of joints subjected to water immersion.
- Higgins and Klingner, (1998) tested the effect of UV exposure and acid rain wetting and drying on the bond strength of a single adhesive anchor, and found no significant impact on the tensile behavior of the anchor to such exposure.

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INTRODUCTION

- Cook and Konz, (2001) experimentally investigated the sensitivity of 20 adhesive products to various installation and service conditions through confined tension tests. Findings showed some general trends for products with similarities in chemical composition. However, responses to various conditions and factors varied significantly making it unreliable to make prediction based on chemical formulation.
- Meline et al., (2006) evaluated the creep performance of epoxy adhesive anchor systems with epoxy-coated steel rebars at elevated temperature on three types of adhesives. Two out three failed to satisfy the ICBO-AC-058 requirements

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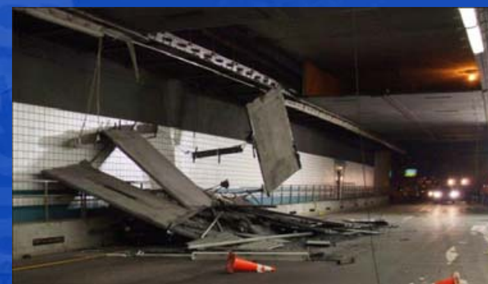
INTRODUCTION

On July 10th 2006, in Interstate 90 (I-90) connector tunnel in Boston, Massachusetts. As the car approached the end of the tunnel, a section of the suspended concrete ceiling detached from the tunnel roof and fell onto the vehicle. 26 tons of concrete fell onto the vehicle and the roadway.

The National Transportation Safety Board determined that the probable cause of the collapse was the use of an epoxy anchor adhesive with poor creep resistance.

INTRODUCTION



(Highway Accident Report NSTB/HAR-07/02, 2007)

INTRODUCTION

Limited research on the long-term performance of adhesive anchors was reported in the literature.

Prompted by concerns with long term durability of adhesive anchors in view of the US experience, and a desire to develop effective material prequalification requirements.

The University of Waterloo, in collaboration with the Ministry of Transportation of Ontario, conducted this research study to investigate the long-term creep behavior of adhesive anchors under sustained tensile loads.

OBJECTIVES OF STUDY

The main objective of this research study is to evaluate the performance of epoxy and acrylic-based adhesive anchor systems.

The study focuses on the creep performance of these anchor systems under sustained tensile loads combined with different exposure condition, and on the tensile capacity after exposure to different environmental conditions.

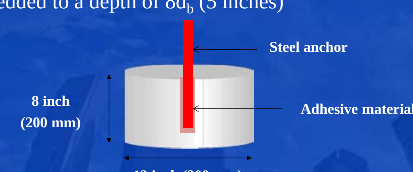
EXPERIMENTAL PROGRAM

PHASE		Type A	Type B	Type C
Phase I : Static testing at room temperature	Sustained load = 0% ultimate	3	3	3
Phase II : Creep test at room temperature	Sustained load = 40% ultimate	3	3	3
Phase III : Creep test under moisture exposure	Sustained load = 40% ultimate	3	3	3
Phase IV : Creep test under freeze-thaw cycles	Sustained load = 40% ultimate	3	3	3
Total number of specimens		18	18	18

EXPERIMENTAL PROGRAM, Cont.

Test specimens

- Cylindrical concrete block 12 inch in diameter and 8 inch in height.
- Anchors are 15 M deformed steel reinforcing bar, embedded to a depth of $8d_b$ (5 inches)



Typical test specimen

EXPERIMENTAL PROGRAM Cont.
Anchor installation

Three adhesive materials were used for anchors installation:

- Type A - Fast setting two component methyl methacrylate
- Type B - Fast setting two part epoxy adhesive
- Type C - Standard set two part epoxy adhesive
- witnessed by a representative for each manufacturer.

EXPERIMENTAL PROGRAM Cont.
Creep Test Setup - ambient temperature & moisture exposure

Specimens are tested in a steel frame that is designed to magnify a dead load through a series of lever arms.

Axial tension load on the anchors was approximately 32 kN (40% of the yield strength of the anchor).

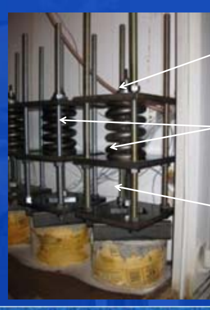
All steel frames were pre-calibrated.

Magnification factor: **1:115**

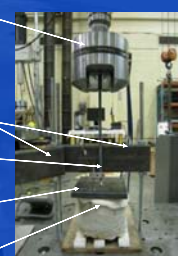
EXPERIMENTAL PROGRAM Cont.
Creep Testing Setup for Freeze/Thaw cycling

The second testing frame relied on compression coil springs and rod assembly to apply the load.

The coil springs used had a capacity of 40kN at 1.5 inch of compression displacement.



EXPERIMENTAL PROGRAM Cont.
Static Pullout Testing Setup



STATIC PULLOUT RESULTS

- Specimens with all 3 adhesives behaved in a similar manner up to yielding of the anchor.
- Specimens with Type B and Type C adhesives exhibited stronger ultimate capacities, forcing the anchor to fail by rupture prior to bond failure.
- All three specimens with Type A adhesive failed by bond.

STATIC PULLOUT RESULTS

Specimen	Ultimate Load (kN)		Failure Mode
		Average	
A-R-1	132	120.7	Yielding of the anchor followed by bond failure
A-R-2	122		Yielding of the anchor followed by bond failure
A-R-3	108		Yielding of the anchor followed by bond failure
B-R-1	133	133.3	Yielding of the anchor followed by anchor rupture
B-R-2	133		Yielding of the anchor followed by anchor rupture
B-R-3	134		Yielding of the anchor followed by concrete splitting
C-R-1	129	131.7	Yielding of the anchor followed by anchor rupture
C-R-2	133		Yielding of the anchor followed by anchor rupture
C-R-3	133		Yielding of the anchor followed by anchor rupture

CREEP TEST RESULTS

- The creep tests were carried out under a sustained load of 32kN or 40% of the yield strength of the anchor for a minimum period of 90 days.
- Specimens with each type of adhesive were subjected to three types of exposure:
  1. Ambient temperature
  2. Moisture exposure (by ponding)
  3. Freeze/thaw cycles with the presence of moisture (16hrs freezing @ -20C, 8hrs thawing @ +20C)

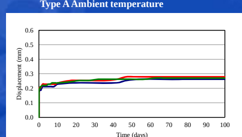
CREEP TEST RESULTS, Cont.
Specimens with Type A adhesive

Environmental exposure caused significant variation in the measured creep displacement:

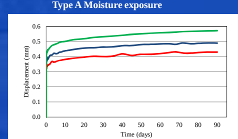
- Ambient temperature - consistent response with decreasing creep displacement rate over time.
- Moisture exposure - significant increase in initial elastic displacement and in the overall creep displacement.
- Freeze/thaw cycling - increased creep displacement and an increasing rate of creep displacement over time.

CREEP TEST RESULTS, Cont.
Specimens with Type A adhesive

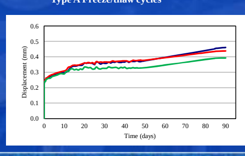
Type A Ambient temperature



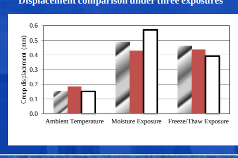
Type A Moisture exposure



Type A Freeze/thaw cycles



Displacement comparison under three exposures



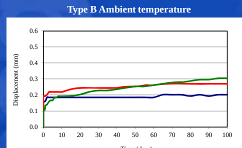
CREEP TEST RESULTS , Cont.
Specimens with Type B adhesive

Environmental exposure led to inconsistent behavior significant variation in the measured creep displacement:

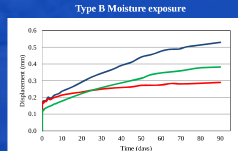
- Moisture exposure - higher average overall creep displacement with an increasing rate with time, with a widely variable response within the three specimens.
- Freeze/thaw cycles in presence of moisture – slightly higher overall average creep displacement.

CREEP TEST RESULTS, Cont.
Specimens with Type B adhesive

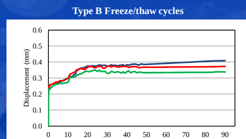
Type B Ambient temperature



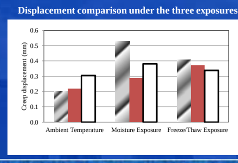
Type B Moisture exposure



Type B Freeze/thaw cycles



Displacement comparison under the three exposures



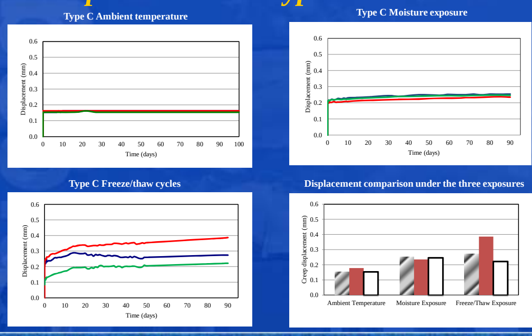
CREEP TEST RESULTS, Cont.
Specimens with Type C adhesive

Environmental exposure caused insignificant variation in the measured creep displacement

- Ambient temperature - Insignificant creep displacement was recorded.
- Moisture exposure - Slight increase in displacement.
- Freeze/thaw cycles in the presence of moisture- Significant variation in response, along with substantial increase in creep displacement.

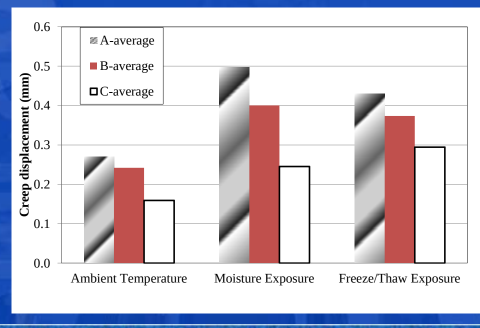
CREEP TEST RESULTS, Cont.

Specimens with Type C adhesive



CREEP TEST RESULTS, Cont.

Overall comparison



CONCLUSION

- All adhesive types had lower creep displacements under ambient exposure than moisture or freeze-thaw exposure
- Types A and B showed a significant increase in creep displacement when exposed to moisture.
- Freeze/thaw cycles did not have much of an effect on Type B, slightly affected Type C but significantly affected creep response for Type A.
- Type C (Standard set two part epoxy) adhesive appears to be superior in terms of creep behavior over both the fast setting Types A and B adhesives.
- Types B and C adhesives exhibit higher capacity compared to the acrylic based Type A.

CONCLUSION, Cont.

- Further extrapolation and analysis of the test data is required to assess the effect of such conditions on the anchor system within their intended service life.
- Additional testing on a wider range of adhesives should be done to incorporate these environmental impacts in a design model.

ACKNOWLEDGMENT

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Related Documents

Anchorage to Concrete

- 355.2-07: Qualification of Post-Installed Mechanical Anchors in Concrete & Commentary
- 349.2R-07: Guide to the Concrete Capacity Design (CCD) Method - Embedment Design Examples
- 503.5R-92: Guide for the Selection of Polymer Adhesives in Concrete (Reapproved 2003)
- SP-103: Anchorage to Concrete
- SP-130: Anchors in Concrete--Design and Behavior
- 318-08: Building Code Requirements for Structural Concrete and Commentary

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