

Thursday, October 14, 2021

2021 TMS Annual Meeting



Nashville, TN

General Session 2 - Research

Performance of Post-Installed Anchors in Grouted Concrete Block Masonry

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PERFORMANCE OF POST-INSTALLED ANCHORS IN GROUTED CONCRETE BLOCK MASONRY

Outline

- 1) Survey of Masonry Construction Practices for PI Anchors
- 2) New Methodology for PI Anchors in Masonry
- 3) Tests on Breakout Capacity of PI Anchors in Grouted Concrete Masonry

PERFORMANCE OF POST-INSTALLED ANCHORS IN GROUTED CONCRETE BLOCK MASONRY

1) Survey of Masonry Construction Practices for Post-Installed Anchors

Summary

- Developed and conducted a survey in 2020 for the Concrete and Concrete Masonry Anchor Manufacturers Association (CAMA)
- Acquired information on anchors in US masonry construction
- Sought information from design professionals regarding
 - use,
 - experience, and
 - opinions on post-installed anchors in masonry
- Identified trends in masonry construction
- Gained perspectives on the use of anchors for masonry

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PERFORMANCE OF POST-INSTALLED ANCHORS IN GROUTED CONCRETE BLOCK MASONRY

Regional Subdivision

| No. | Region | States | Population |
|------|-------------------|--|------------|
| I | Northeast | Connecticut, Maine, Massachusetts, New Hampshire, New York, Rhode Island, Vermont | 33,822,967 |
| II | Mid-Atlantic | Delaware, Maryland, New Jersey, Pennsylvania, Virginia, Washington DC, West Virginia, | 38,621,500 |
| III | Southeast | Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, South Carolina, Tennessee | 68,531,605 |
| IV | Midwest | Illinois, Indiana, Michigan, Missouri, Ohio, Wisconsin | 52,410,491 |
| V | Great Plains | Iowa, Kansas, Minnesota, Nebraska, North Dakota, South Dakota | 14,516,510 |
| VI | Southwest | Arizona, New Mexico, Oklahoma, Texas | 37,348,108 |
| VII | Mountain | Colorado, Idaho, Montana, Utah, Wyoming | 10,913,704 |
| VIII | Pacific South | California, Nevada | 39,955,074 |
| IX | Pacific Northwest | Alaska, Oregon, Washington, | 11,265,845 |
| X | Island | Guam, Hawaii, Puerto Rico | 5,245,448 |

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PERFORMANCE OF POST-INSTALLED ANCHORS IN GROUTED CONCRETE BLOCK MASONRY

Observations

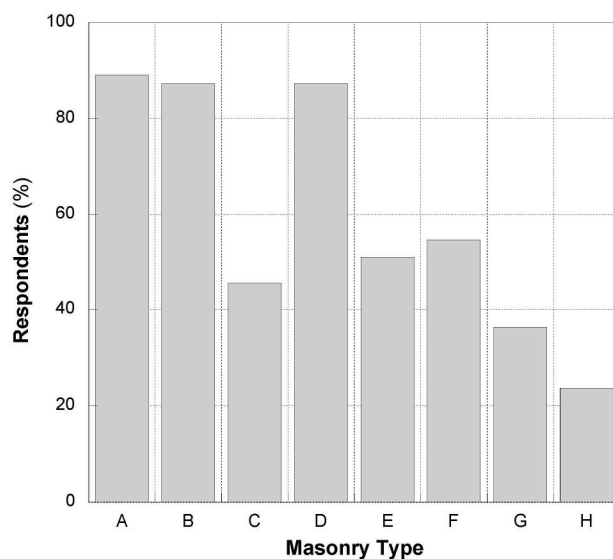
- 3 types of masonry dominate construction across US:
 - fully grouted and reinforced concrete block masonry,
 - partially grouted and reinforced concrete block masonry, and
 - brick veneer
- Unreinforced concrete block masonry use:
 - persists in eastern & central US
 - exception in some southeastern states (hurricanes)
- On masonry use:
 - unreinforced loadbearing masonry appears to be decreasing
 - reinforced masonry and masonry veneers appear to be increasing
- Mechanical & adhesive anchors more common than grouted ones

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PERFORMANCE OF POST-INSTALLED ANCHORS IN GROUTED CONCRETE BLOCK MASONRY

Masonry Types

| Code | Masonry Type |
|------|--------------------------------------|
| A | Fully grouted & reinforced CMU |
| B | Partially grouted and reinforced CMU |
| C | UngROUTED and unreinforced CMU |
| D | Brick veneer construction |
| E | Unreinforced solid brick |
| F | Grouted and reinforced hollow brick |
| G | UngROUTED and unreinforced clay tile |
| H | Other |

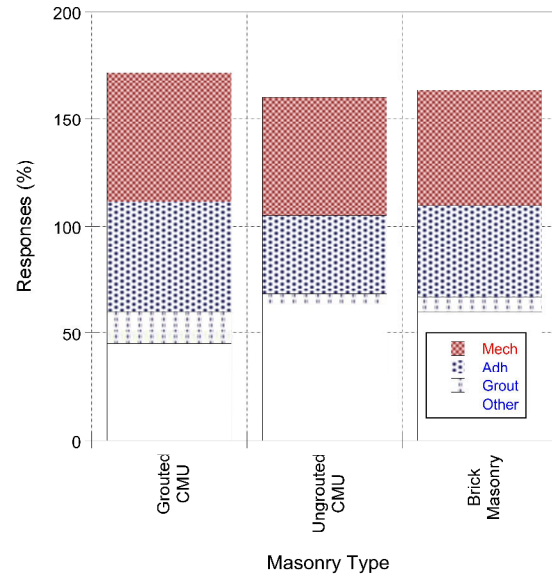


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PERFORMANCE OF POST-INSTALLED ANCHORS IN GROUTED CONCRETE BLOCK MASONRY

Anchor Systems for Masonry

| Type of Masonry | Responses per Anchor Category (%) | | | |
|-----------------|-----------------------------------|------|-------|-------|
| | Mech | Adh | Grout | Other |
| Grouted CMU | 60.0 | 51.7 | 15.0 | 45.0 |
| Ungrooved CMU | 55.0 | 36.7 | 5.0 | 63.3 |
| Brick Masonry | 53.3 | 43.3 | 6.7 | 60.0 |



PERFORMANCE OF POST-INSTALLED ANCHORS IN GROUTED CONCRETE BLOCK MASONRY

2) New Methodology for PI Anchors in Masonry Post-Installed Anchor Acceptance Criteria in Masonry

ICC EVALUATION SERVICE
Most Widely Accepted and Trusted

ACCEPTANCE CRITERIA FOR MECHANICAL ANCHORS IN CRACKED & UNCRACKED MASONRY ELEMENTS

EXPANSIVE AC01

Approved November 2015

Previously revised May 2012, December 2009, December 2006, June 2005, October 2004, April 2002, November 2001, January 2001, January 1999, September 1997, January 1993
(Previously editorially revised May 2014 and August 2013)

PREFACE

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The provisions of this code are not intended to prohibit the installation of an individual or to restrict any design or method of construction not specifically prohibited by this code, provided that any such alternative has been approved by the authority having jurisdiction. Any alternative method, design or method of construction shall be approved where the building official finds that the proposed design is substantiated and complies with the intent of the provisions of this code, and that the material, method or work offered is, for the purpose intended, at least the equivalent of that prescribed in this code in quality, strength, effectiveness, fire resistance, durability and safety.

This acceptance criteria has been created to provide interested parties with guidelines for demonstrating compliance with performance features of the code referenced in the criteria. This criteria was developed through a transparent process involving public hearings of the ICC-ES Evaluation Committee, and/or online hearings where public comment was solicited.

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NOTE: The references to all evaluation reports are subject to what appears on the report.

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ACCEPTANCE CRITERIA FOR ADHESIVE ANCHORS IN CRACKED AND UNCRACKED MASONRY ELEMENTS

AC58

Approved November 2015

Compliance date - November 15, 2022

Previously approved March 2018, November 2015, May 2012, October 2011, June 2011, December 2009, December 2006, June 2005, February 2005, November 2001, January 2001, July 2000, January 1999, January 1996, September 1997, April 1995, January 1995
(Previously editorially revised August 2013)

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PERFORMANCE OF POST-INSTALLED ANCHORS IN GROUTED CONCRETE BLOCK MASONRY

Background of AC01 (Mechanical) and AC58 (Adhesive) Anchors

- AC01 originally developed by ICBO in the 1970s for all post-installed anchors in concrete. No specific tests distinguishing between anchor types.
- When three model code agencies (SBC, ICBO, UBC) joined, ICC-ES began building the AC model as we know it today.
- **Post-installed anchors in masonry** as an “add-on” feature to a test program for anchors in concrete.
- Test program – “you get what you test”. **No design model** (ASD, FS = 5)
- Replaced by AC193 (2002) and AC308 (2005) for concrete. **AC01 and AC58 limited to adhesive anchors in masonry** despite previous status as “add-on” features.
- No provision for cracked masonry. Seismic recognition in uncracked masonry.
- Several tests and methods were retained unrevised.



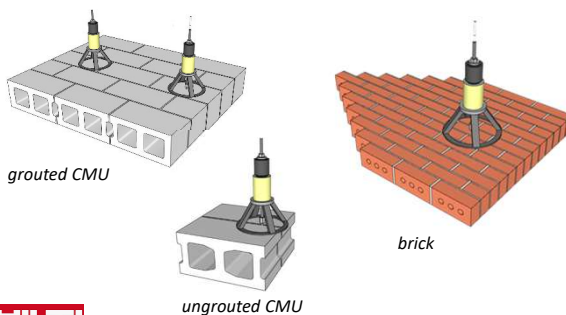
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PERFORMANCE OF POST-INSTALLED ANCHORS IN GROUTED CONCRETE BLOCK MASONRY

Testing Changes

Existing

- uncracked only
- significant edge and spacing testing effort/cost
- oblique (45 degree) tests
- execution of tests and conditions left to manufacturer



New

- uncracked and cracked masonry
- no edge or group testing – handled through calculation
- primary testing at Independent Testing and Evaluation Agency (ITEA)
- specific guidance for testing in grouted CMU, ungrouted CMU, and brick



testing in cracked masonry



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PERFORMANCE OF POST-INSTALLED ANCHORS IN GROUTED CONCRETE BLOCK MASONRY

Design Changes

Existing

- Scope:
 - Loosely defined
 - Uncracked masonry only
- Design capacities based on tabulated/interpolated data only – no overarching design principles

New

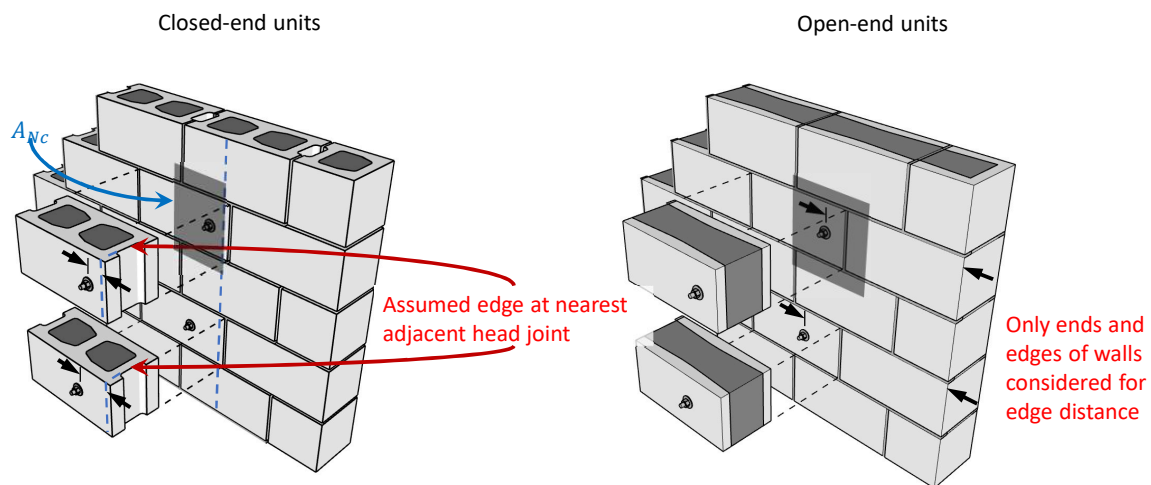
- Scope
 - Fully grouted, partially grouted, ungrouted CMU, and brick
 - Uncracked and cracked masonry
- Tension Failure modes
 - Steel
 - Breakout
 - Bond (adhesive anchors only)
- Shear Failure modes
 - Masonry breakout
 - Pryout
 - Crushing (from TMS)



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PERFORMANCE OF POST-INSTALLED ANCHORS IN GROUTED CONCRETE BLOCK MASONRY

Breakout Calculation Assumptions

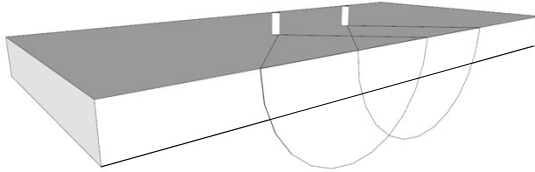


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PERFORMANCE OF POST-INSTALLED ANCHORS IN GROUTED CONCRETE BLOCK MASONRY

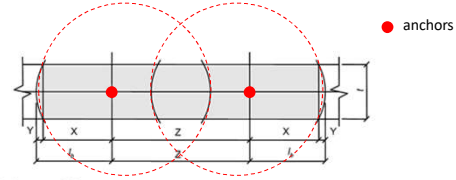
Shear Breakout: TMS vs. New Methodology

45-degree cone approach for shear loading: projected areas from cones in thin members



- to calculate projected area,**
- calculate area of two semicircles
 - subtract circular segments from below wall
 - subtract overlapping area

similar illustration: projected area calculation overlapping cones for top-of-wall installation from TMS 402-13 p. C-75



For $l_b \leq z \leq 2X$

$$X = \frac{1}{2} \sqrt{4(l_b)^2 - t^2}$$

$$Y = l_b - X = l_b - \frac{1}{2} \sqrt{4(l_b)^2 - t^2}$$

$$\therefore A_{pt} = (2X + Z)t + l_b^2 \left(\frac{\pi\theta}{180} - \sin\theta \right) \quad \text{where } \theta = 2\arcsin\left(\frac{t/2}{l_b}\right) \text{ in degrees}$$

expanded TMS calc \Rightarrow

$$A_{pt} = \left(\sqrt{4(l_b)^2 - t^2} + Z \right) \cdot t + l_b^2 \left(\frac{2\arcsin\left(\frac{t/2}{l_b}\right)}{180} - \sin\left(2\arcsin\left(\frac{t/2}{l_b}\right)\right) \right)$$

equivalent calculation using new methodology:
(nomenclature maintained for comparison)

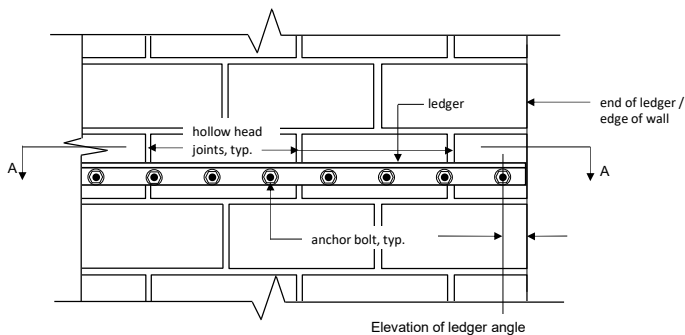
$$A_{pt} = (3l_b + Z) \cdot t$$



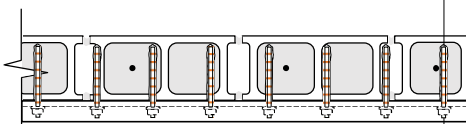
PERFORMANCE OF POST-INSTALLED ANCHORS IN GROUTED CONCRETE BLOCK MASONRY

Special Case: Design of Ledger Anchors

Regularly spaced anchors in ledger applications permit simplified design assumptions



Elevation of ledger angle



Section A-A

Horizontal capacity (plf)

$$v_{mb,horiz} = 0.75 \cdot V_{gov} \cdot \frac{12}{S_{horiz}}$$

Vertical capacity (plf)

$$v_{mb,vert} = 2 \cdot v_{mb,horiz}$$



PERFORMANCE OF POST-INSTALLED ANCHORS IN GROUTED CONCRETE BLOCK MASONRY

2) Tests on Breakout Capacity of PI Anchors in Grouted Concrete Masonry

- Generate data on breakout capacity of anchors in masonry
- Determine effectiveness factor k_m from unconfined tests
- Determine test setup ratio α_{setup} from confined and unconfined tests
- Evaluate influence on breakout capacity of:
 - Grouted concrete masonry (open end units)
 - Test type (confined, unconfined)
 - Anchor diameter (1/2", 5/8")
 - Anchor type (adhesive, cementitious grout, cast-in-place)
 - Anchor location (cell, bed joint, web)
 - Embedment depth (3", 4.5")
 - Masonry grout strength (Low, High)

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PERFORMANCE OF POST-INSTALLED ANCHORS IN GROUTED CONCRETE BLOCK MASONRY

Background From AC58

- For unconfined anchor tests in cracked masonry

$$N_{u,m} = k \sqrt{f'_m} h_{ef}^{1.5}$$



where $k = 12$

- For unconfined anchor tests in uncracked masonry



ψk is the product of important parameters

where $\psi = 1.4$

- Ratio of breakout capacity from unconfined () to confined () tests

$$\alpha_{setup} = N_{u,m} / \bar{N}_{u,m}$$

- where $\alpha_{setup} = 0.75$ for uncracked masonry and 0.70 for cracked masonry

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PERFORMANCE OF POST-INSTALLED ANCHORS IN GROUTED CONCRETE BLOCK MASONRY

Masonry Material Properties

| Masonry Material | Description | Compressive Strength | |
|------------------|--|----------------------|-------|
| | | mean (psi) | COV |
| Block | Amcon NW, 8" concrete block w/ 1-3/8" face-shells and 1-3/16" webs | 6,670 | 0.091 |
| Mortar | Spec-Mix Type S, Portland Cement-Lime | | |
| Grout | Spec-Mix Small Aggregate | 2,160 | 0.073 |
| Grouted Masonry | Fully grouted units | 3,860 | 0.092 |

Concrete Block



Grout Prism



Grouted Unit



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PERFORMANCE OF POST-INSTALLED ANCHORS IN GROUTED CONCRETE BLOCK MASONRY

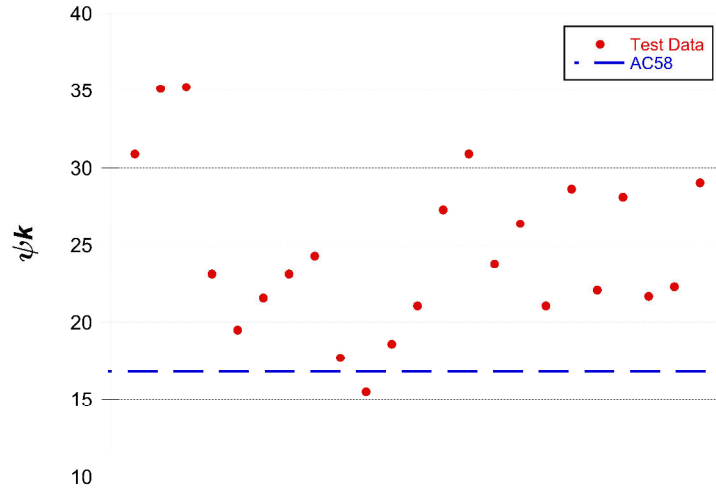
Tested Panels



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PERFORMANCE OF POST-INSTALLED ANCHORS IN GROUTED CONCRETE BLOCK MASONRY

Breakout Test Data for ψk

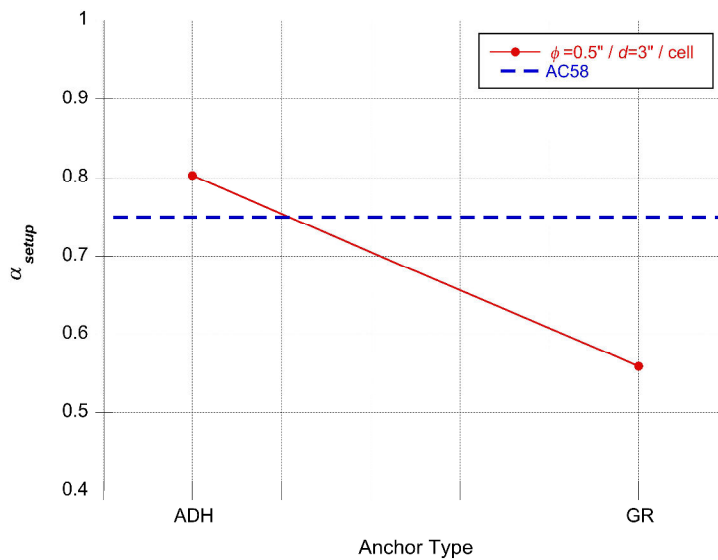


$\psi k_{AC58} = 1.4 \times 12 = 16.8$

1 of 23 test values (3.4%) below ψk_{AC58}

PERFORMANCE OF POST-INSTALLED ANCHORS IN GROUTED CONCRETE BLOCK MASONRY

Influence of Anchor Location on α_{setup}



Thank you! Questions?

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