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2021 TMS Annual Meeting THE MASONRY SOCIETY General Session 2 - Research

Performance of Post-Installed Anchors in Grouted Concrete Block Masonry

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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

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

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

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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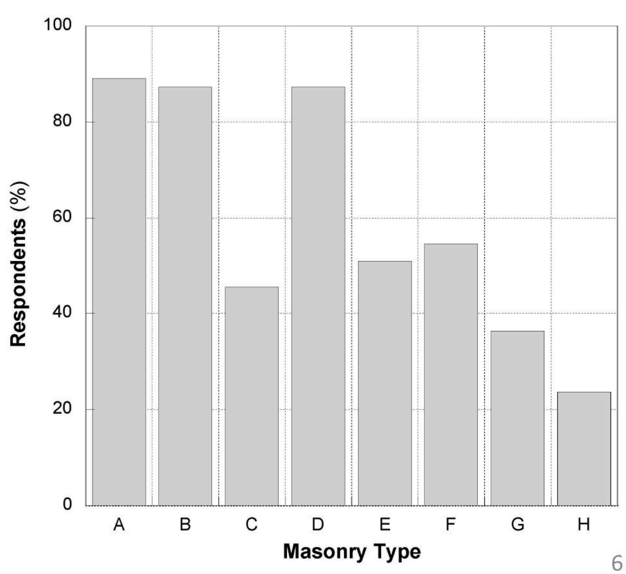
PERFORMANCE OF POST-INSTALLED ANCHORS IN GROUTED CONCRETE BLOCK MASONRY

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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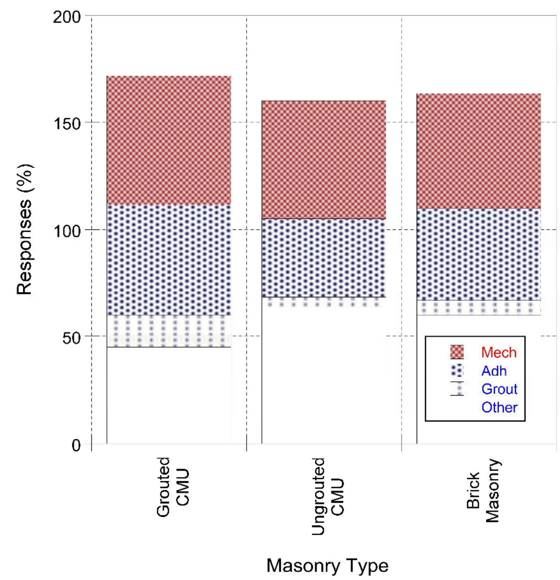
Performance of Post-Installed Anchors in Grouted Concrete Block Masonry

Anchor Systems for Masonry

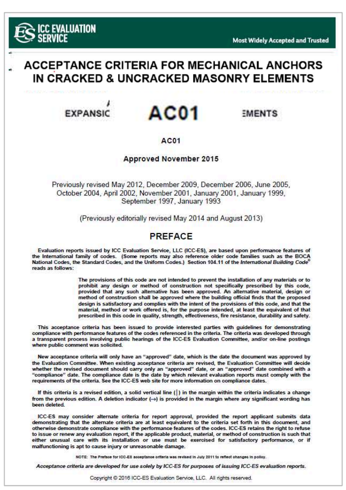
Type of Masonry	Responses per Anchor Category (%)			
	Mech	Adh	Grout	Other
Grouted CMU	60.0	51.7	15.0	45.0
Ungrouted CMU	55.0	36.7	5.0	63.3
Brick Masonry	53.3	43.3	6.7	60.0



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

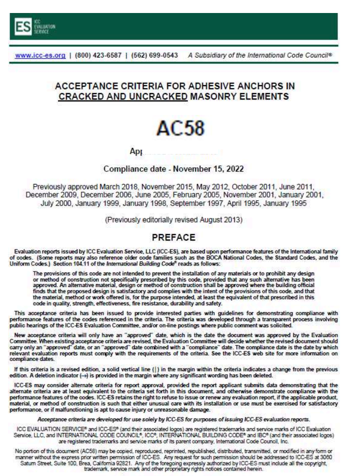
Most Widely Accepted and Trusted

ACCEPTANCE CRITERIA FOR MECHANICAL ANCHORS IN CRACKED & UNCRACKED MASONRY ELEMENTS

AC01

Approved November 2015

PREFACE


ACCEPTANCE CRITERIA FOR ADHESIVE ANCHORS IN CRACKED AND UNCRACKED MASONRY ELEMENTS

AC58

Compliance date - November 15, 2022

PREFACE

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.

Performance of Post-Installed Anchors in Grouted Concrete Block Masonry

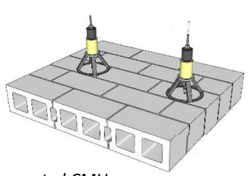
Testing Changes

Existing

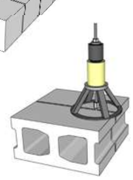
- uncracked only
- significant edge and spacing testing effort/cost
- oblique (45 degree) tests
- execution of tests and conditions left to manufacturer

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



grouted CMU



ungrouted CMU

brick

testing in cracked masonry

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

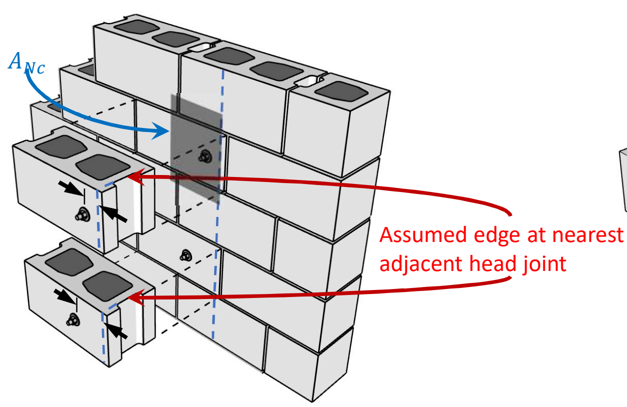
New

- 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)

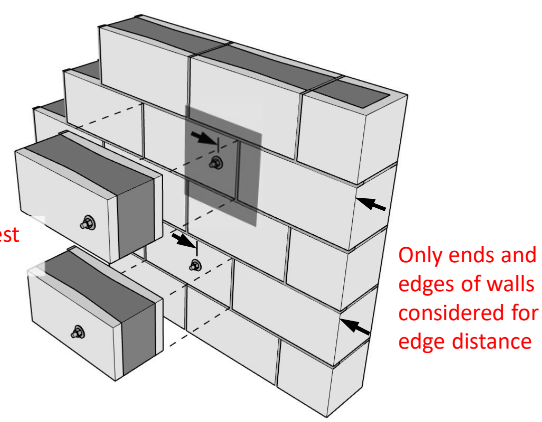
Performance of Post-Installed Anchors in Grouted Concrete Block Masonry

Breakout Calculation Assumptions

Closed-end units



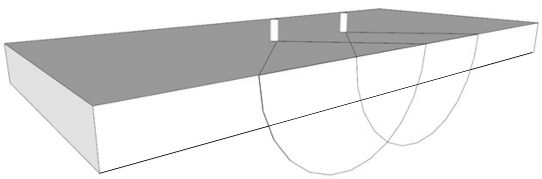
Open-end units



Performance of Post-Installed Anchors in Grouted Concrete Block Masonry

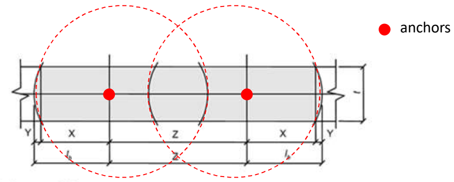
Shear Breakout: TMS vs. New Methodology

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 $l_b \le z \le 2X$

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

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

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

expanded TMS calc ⇒

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

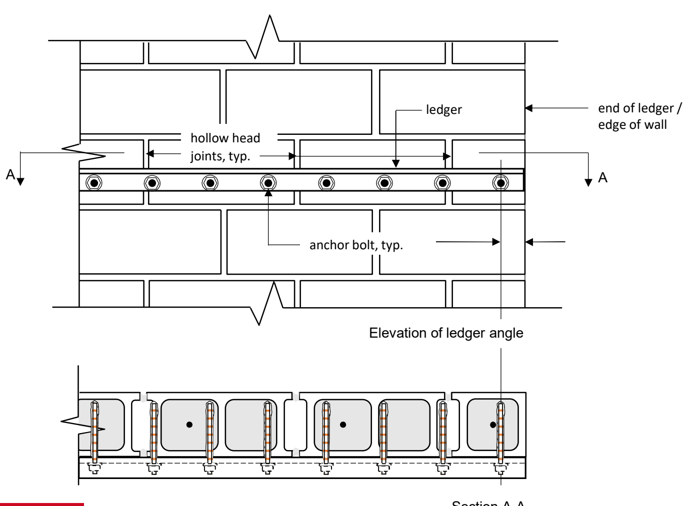
equivalent calculation using new methodology:
(nomenclature maintained for comparison)

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

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



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 a_{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

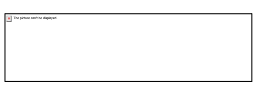
Background From AC58

- For unconfined anchor tests in cracked masonry

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

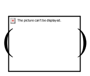
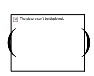
where $k = 12$

- 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 α_{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

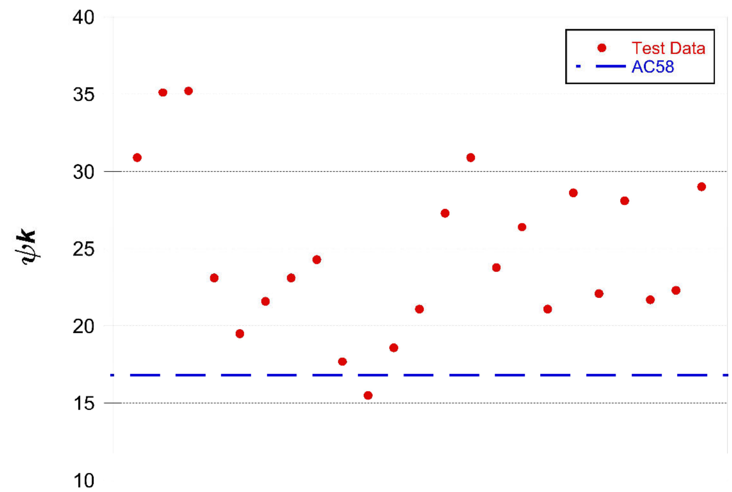
Grouted Unit

PERFORMANCE OF POST-INSTALLED ANCHORS IN GROUTED CONCRETE BLOCK MASONRY

Tested Panels

PERFORMANCE OF POST-INSTALLED ANCHORS IN GROUTED CONCRETE BLOCK MASONRY

Breakout Test Data for ψk

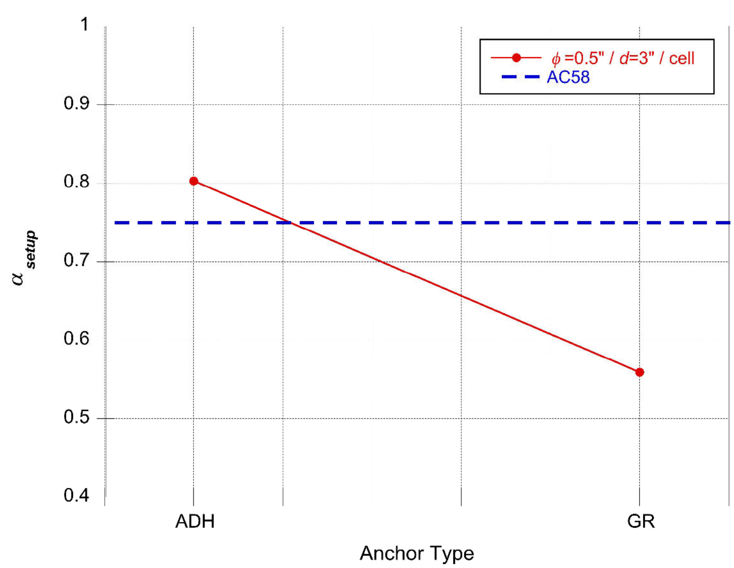


ψk_{AC58} = 1.4 x 12 = 16.8

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?