*This article originally appeared in MasonryEdge/theStoryPole Vol 7 No 1.*

# What's the Magic with 6t?

## Rethinking Sustainability & Economy of Reinforced Masonry

by David T Biggs, PE, SE, Dist M ASCE, HTMS, and
Daniel Zechmeister, PE, AIA Detroit Honorary Affiliate

Reinforced masonry was introduced after the 1933 Longbeach CA earthquake following the collapse of numerous unreinforced brick buildings. That makes reinforced masonry, as an industry, just old enough to have lost many of the pioneers and young enough to still be evolving.

In the development of standards, decisions are made that take on a life of their own. This leads to empirical and prescriptive criteria that are often difficult to change even though there is little technical information to support those criteria.

In an era where efficiency of design and material is essential, some early decisions require reexamination to gain optimum performance. One such decision included the use of 6t in reinforced masonry. **6t represents six times the nominal wall thickness** and is used in the Masonry Standards Joint Committee's *Building Code Requirements for Masonry Structures* (Section 1.9.6)[1]. Most notably it represents the effective compressive width of wall per bar for masonry constructed in running bond or constructed in other than running bond with bond beams at 48". The effective wall width is limited to the lesser of the bar spacing, 72", or 6t. For masonry not in running bond with bond beams spaced greater than 48", the effective width is the length of the unit. For running bond 8" CMU, 6t is 48". For stack bonded 8" walls without bond beams, the effective width is 16".

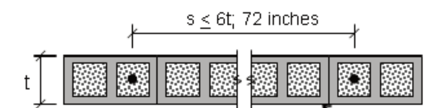


**Figure 1**
**Fully grouted, fully reinforced wall**

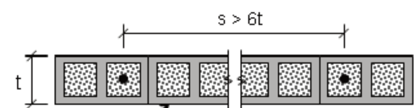


**Figure 2**
**Fully grouted, partially reinforced wall**

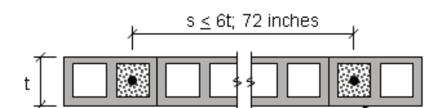


**Figure 3**
**Partially grouted, fully reinforced wall**

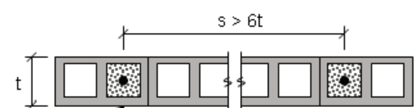


**Figure 4**
**Partially grouted, partially reinforced wall**

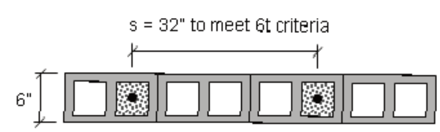


**Figure 5a**
**s = 32" based upon modular spacing**

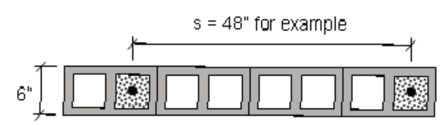


**Figure 5b**
**s = 48" for this example**

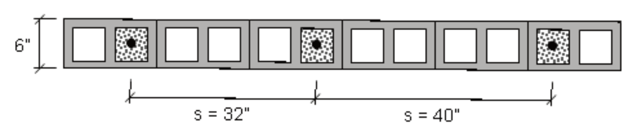


**Figure 6**
**Staggered horizontal spacing**

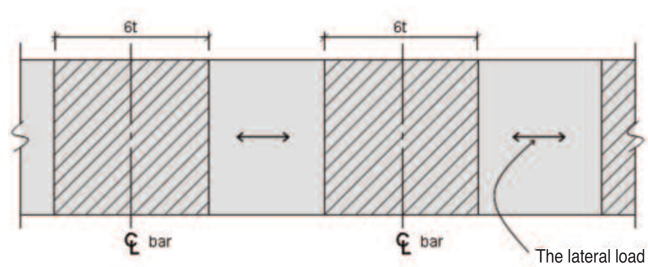


**Figure 7**
**Elevation with wall spanning to 6t using joint reinforcement**

Unfortunately, many designers use a maximum spacing for vertical bars as 48" on center (oc). That comes from 6t for 8" CMU (6 x 8 = 48"). It is not appropriate for all CMU sizes.

## Arriving Here

How did we arrive at 6t as a limitation?

In 1971, research by Dickey and MacIntosh[2] for the Masonry Institute of America actually determined that the effective width for masonry in running bond was at least 13t and was 6t for stack bonded walls with horizontal joint reinforcement.

Schneider and Dickey[3] cite this research. "In 1971, the Masonry Institute of America carried out a test program which attempted to determine the effective width, b, in flexure for concrete block wall panels (8' 8" wide x 20' 0" high). They concluded that in both the 6" and 8" thick panels, laid in running bond, the vertical steel functioned as effectively at an 8' spacing as it did for a 2' spacing. This would represent an effective b for a spacing-to-thickness ratio of 96 to 8 = 12. Further, they found that the 8" thick stack bond panels functioned as if the effective width were about one-half that of the running bond panels. These results would certainly suggest that taking the effective width, in running bond, at six times the block thickness, provides an extremely conservative structural design."

A report by McGinley[4] for the NCMA Foundation has studied this further. Testing done by Andresen[5] at North Carolina A & T confirmed the conservativeness of the 6t criteria.

Using the initial research, we see that for an 8" CMU wall, 13t is more than 8' oc. Take the example of #5 at 48" (6t) oc for a design. Based upon the research, the design could be replaced by #6 at 64" (8t) or #7 at 80" (10t). Excluding lap splices, the steel is about the same for all three, but the amount of grout is reduced, creating a net savings in wall construction. Reduced grouting makes cells available for more insulation.

## Current Practice

**Can engineers design walls with reinforcement spaced greater than 6t? Yes!** Let's review some terminology.

Fully grouted and partially grouted masonry are commonly understood terms. They are based upon the number of grouted cells in masonry.

Fully reinforced and partially reinforced masonry walls are not commonly used terms. Fully reinforced means the reinforcement is placed equal to or less than 6t apart, making the entire wall length effective in resisting compression due to out-of-plane flexure. Partially reinforced means the vertical reinforcement is placed with a horizontal spacing greater than 6t and only the 6t width of wall centered on the reinforcement is effective in supporting compressive stresses due to flexure. The amount of the wall thickness effective (face shells and grout) in supporting the compressive stresses is dependent upon design loadings and the amount of grouting. In many cases, compressive stresses are confined to face shells only.

Thus, the possible variations of walls become:

- Fully grouted, fully reinforced wall (**Figure 1**).
- Fully grouted, partially reinforced wall (**Figure 2**).
- Partially grouted, fully reinforced wall (**Figure 3**).
- Partially grouted, partially reinforced wall (**Figure 4**).

As defined for partially reinforced walls, the out-of-plane lateral wall load is concentrated within only a strip of wall 6t wide. For example, assume the wind load on a wall constructed in running bond is 24 psf. If the wall is 6" CMU, the 6t is 36". However using 8" modular spacing, the horizontal spacing must be reduced to 32" which is even less than 6t (**Figure 5a**). Another option could be to use a staggered horizontal spacing of 32" and 40" (average 36") (**Figure 6**). However, if the bars are spaced 48" oc (**Figure 5b**), the effective load on the reinforcement and the 6t of masonry is (48/36) x 24 psf = 32 psf. If the $b_{effective}$ = 36" can support this effective lateral load, the section is adequate. That results in a 25% reduction in grout compared to the 6t spacing. Rather than stagger bars to achieve exactly the 6t spacing of 36", it is more likely that engineers would select a uniform spacing of 32" as was shown in **Figure 5a**. If the partial reinforcement is extended to 48", the grout savings would be even greater at about 33%.

For partial reinforcement, the size of the reinforcement will likely be larger than were the bars spaced at b = 6t =36". Accordingly, the area of reinforcement per square foot of wall is likely to increase. Each case needs to be evaluated independently. While there would be some savings from installing fewer but bigger bars, the grout savings alone improves the economy of the system.

What about the zone between the 6t strips for partially reinforced walls? Lateral load must be transferred to the 6t strips to be effective. McGinley[4] reports that wall arching can make that transfer without reinforcement. However, to be considered a reinforced masonry wall, it is rather simple to use joint reinforcement for crack control and to also use it as reinforcement to distribute the lateral load to the 6t strips (**Figure 7**, wall elevation).

## Prescriptive Reinforcement

Partial reinforcement offers an option for making wall designs more economical excluding those walls in areas with high seismicity or high winds. Economy is less likely in higher seismic design categories (SDC) because prescriptive requirements often mandate closer spacing of reinforcement in walls. For example, TMS 402[1] lists the following for elements that are not part of the seismic force-resisting system:

1.17.4.3 *Seismic Design Category C requirements*, 1.17.4.3.1(b) *Vertical reinforcement* – Vertical reinforcement shall consist of at least one No. 4 (M #13) bar spaced not more than 120" (3048 mm).

1.17.4.4 *Seismic Design Category D requirements*, 1.17.4.4.1(b) *Vertical reinforcement* – Vertical reinforcement shall consist of at least one No. 4 (M #13) bar spaced not more than 48" (1219 mm).

1.17.4.5 *Seismic Design Categories E and F requirements* – Masonry elements in structures assigned to Seismic Design Category E or F shall comply with the requirements of Seismic Design Category D and with the additional requirements of Section 1.17.4.5. Section 1.17.4.5 *primarily* affects the horizontal reinforcement.

**Excluding lap splices, steel is about the same for all three, but grout is reduced, creating a net savings in wall construction. Reduced grouting makes the cells available for more insulation.**


[1] *Building Code Requirements for Masonry Structures, TMS 402-08/ ACI 530-08/ ASCE 5-08, Masonry Standards Joint Committee,* The Masonry Society, Boulder, CO.

[2] Dickey, WL and Mackintosh, A, 1971. *Test Report Results of Variation of b or Effective Width in Flexure in Concrete Block Panels;* Masonry Institute of America, Los Angeles CA.

[3] Schneider, RR and Dickey, WL, 1994. *Reinforced Masonry Design*. 3rd ed. Englewood Cliffs, NJ: Prentice Hall.

[4] McGinley, WM, 2007. *Spacing Of Reinforcing Bars In Partially Grouted Masonry,* NCMA Education and Research Foundation, National Concrete Masonry Association Publication Number FR01, Herndon VA.

[5] Andresen, N, 2006. *Effective Width of Vertical Reinforcement in Concrete Masonry Walls Subjected to Out-of-Plane Loads. Master Thesis,* North Carolina A&T State University, Greensboro NC.

Table 1 - Maximum Reinforcement Spacing for Elements that are not Part of the Seismic Force-Resisting System

| Nominal CMU Size (inches) | 6t (inches) | Maximum allowable spacing for SDC A, B and C (inches) | Maximum allowable spacing for SDC D, E and F (inches) |
|---|---|---|---|
| 6 | 36 | 120 | 48 |
| 8 | 48 | 120 | 48 |
| 10 | 60 | 120 | 48 |
| 12 | 72 | 120 | 48 |
| 14 | 84 | 120 | 48 |

While SDC A and SDC B are not specifically included, it is also practical to limit the bar spacing in those categories to 120".

**Until 6t criteria is re-evaluated by code, engineers can effectively use the economy of partial reinforcement.**

These prescriptive spacings might be reduced further if the walls are also part of the seismic force-resisting system. Thus, it is important to distinguish walls that are part of the seismic force-resisting system.

Based upon the prescriptive requirements just described, partial reinforcement is acceptable in SDC A, B and C for 6", 8", 10", 12" and 14" CMU. For SDC D, E and F, partial reinforcement is possible only for 6" CMU since the maximum spacing exceeds 6t. This is shown in **Table 1**. Whenever the maximum allowable spacing exceeds 6t, the wall may be partially reinforced.

Based upon **Table 1**, there are many opportunities for using partial reinforcement, particularly in low seismic categories.

**Examples** Using the NCMA Structural Masonry Design Software[6], several examples were developed to illustrate the possible savings to wall designs by using partial reinforcement rather than full reinforcement. The examples in **Table 2** are based upon Allowable Stress Design (ASD) methods and were prepared using IBC 2009 and TMS 402[1]. CMU is 8" with a density of 115 pcf.

**Wall 1** first assumes #4 bars at the 6t fully-reinforced spacing of 48". Then, six variations of partially reinforced masonry are calculated to obtain maximum bar spacings if #5, #6, #7 and #8 bars are used. Resulting percentage reduction in grout spacing and increase in reinforcement area per foot are calculated for each case. Finally, unit prices were applied to the reduced grout and increased reinforcement to determine the

[6]NCMA Design Software, Structural Masonry Design System, Masonry 5.0, National Concrete Masonry Association, Herndon VA.

Specialized protection. Exclusive discount.

Count on SECURA for protection designed specifically for Masonry Institute of Michigan Members. You'll have fewer worries when you are covered by this insurance program — the only one endorsed by the MIM Board of Trustees.

"I use this SECURA program through Van Wyk to insure my business and personal assets. I've been pleased with the significant savings, expanded coverage, and exceptional service they deliver. I also feel good knowing that the program provides valuable benefits and support to the MIM, our members, and our industry."

**- Kevin Ryan, Owner - Masonry Developers**

As a MIM member, you can take advantage of an exclusive insurance discount on your policy. Call today to get the specialized protection you need and the discount you deserve!

VanWyk RISK & FINANCIAL MANAGEMENT

800-7VANWYK

vanwykcorp.com

SECURA INSURANCE COMPANIES

secura.net

**Allowable Stress Design (IBC 2009) 8" CMU, $f'_m$ = 2000 psi, fy = 60,000 psi**

| | | | fully reinf. with bars ≤6t | | | partially reinf. with bars >6t | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| wall no. | height ft | wind psf | 6t in. | bar spacing in. | bar # | wind on 6t strip psf | bar spacing in. | bar# | reduction in grout spacing % | increase in reinforcement area per foot of wall % | grout cost savings $/ wall sf | reinforcement cost savings $/ wall sf | total savings $/wall sf |
| 1 | 10 | 24 | 48 | 48 | 4 | 28 | 56 | 5 | 14.3 | 32.9 | 0.070 | -0.010 | 0.060 |
| 1 | 10 | 24 | 48 | 48 | 4 | 32 | 64 | 5 | 25.0 | 16.3 | 0.116 | 0.018 | 0.134 |
| 1 | 10 | 24 | 48 | 48 | 4 | 36 | 72 | 6 | 33.3 | 46.7 | 0.155 | 0.005 | 0.160 |
| 1 | 10 | 24 | 48 | 48 | 4 | 40 | 80 | 7 | 40.0 | 80.0 | 0.186 | -0.008 | 0.178 |
| 1 | 10 | 24 | 48 | 48 | 4 | 44 | 88 | 7 | 45.5 | 63.6 | 0.217 | 0.012 | 0.229 |
| 1 | 10 | 24 | 48 | 48 | 4 | 48 | 96 | 8 | 50.0 | 97.5 | 0.233 | -0.029 | 0.204 |
| 2 | 14 | 24 | 48 | 48 | 5 | 28 | 56 | 6 | 14.3 | 21.7 | 0.070 | -0.007 | 0.062 |
| 2 | 14 | 24 | 48 | 48 | 5 | 32 | 64 | 7 | 25.0 | 45.2 | 0.116 | -0.017 | 0.099 |
| 2 | 14 | 24 | 48 | 48 | 5 | 36 | 72 | 8 | 33.3 | 69.9 | 0.155 | -0.063 | 0.093 |
| 2 | 14 | 24 | 48 | 48 | 5 | 40 | 80 | 11 | 40.0 | 201.9 | 0.186 | -0.218 | -0.032 |
| 3 | 18 | 24 | 48 | 48 | 7 | 28 | 56 | 8 | 14.3 | 12.9 | 0.070 | -0.045 | 0.024 |
| 4 | 18.67 | 24 | 48 | 48 | 7 | 28 | 56 | 9 | 14.3 | 42.9 | 0.070 | -0.118 | -0.048 |
| 5 | 19.33 | 24 | 48 | 48 | 8 | 28 | 56 | 10 | 14.3 | 37.8 | 0.070 | -0.095 | -0.026 |
| 6 | 20 | 24 | 48 | 48 | 8 | 28 | 56 | 11 | 14.3 | 69.3 | 0.070 | -0.198 | -0.128 |
| 7 | 22 | 24 | 48 | 48 | 9 | | | | | | | | |

**Table 2 – Design Examples**


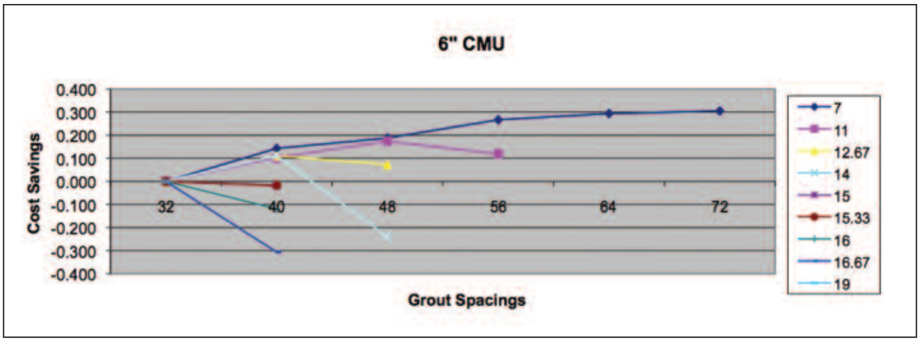


Chart 1 – 6" CMU

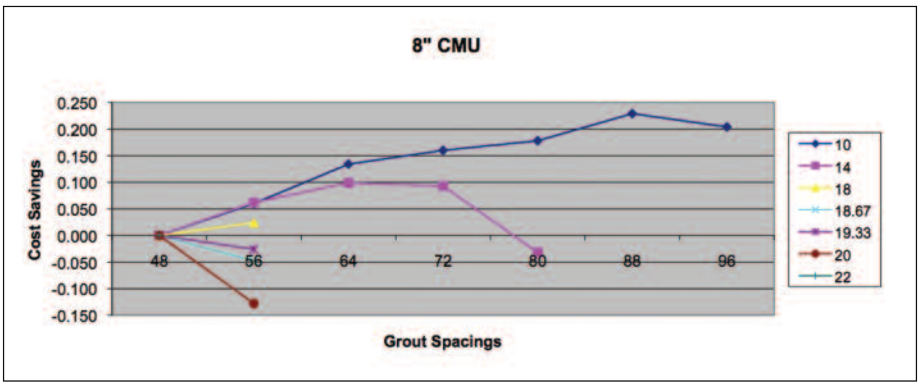


Chart 2 – 8" CMU

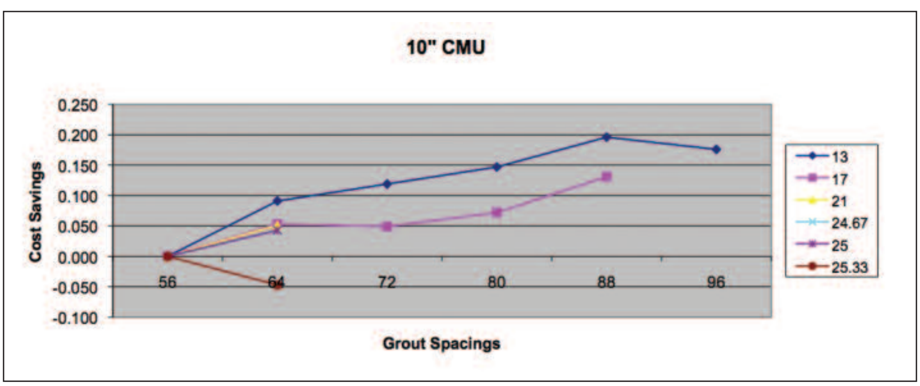


Chart 3 – 10" CMU

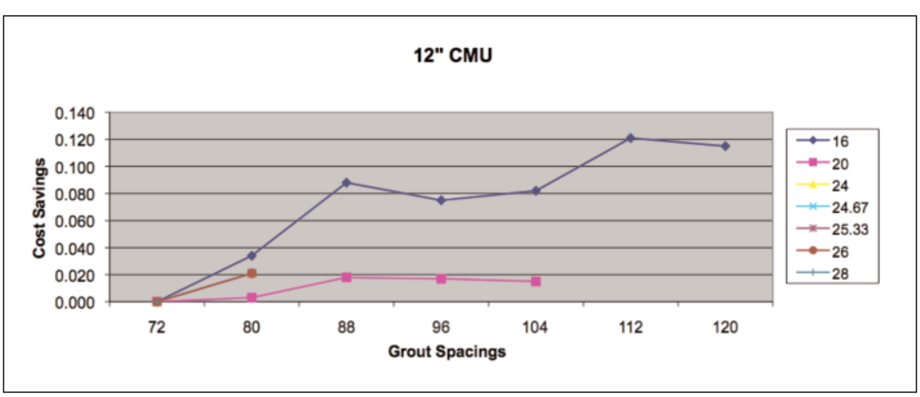


Chart 4 – 12" CMU

associated costs compared to the fully reinforced masonry. Furnished and installed unit prices for grout per cubic foot and reinforcing steel per lineal foot were provided by a prominent Michigan mason contractor, Davenport Masonry. Prices are based on Lansing MI wages. Using this methodology, different unit prices can be applied regionally anywhere in the US.

For all six variations of partially reinforced masonry, the calculations resulted in a reduced wall construction cost. However, the variation with #7 bars at 88" gave maximum savings at $0.23 per square foot of wall. Thus, each wall has an optimized design for partial reinforcement.

**Results of Wall 2** show another example with a similar result. One of the partially reinforced variations provides an optimum design based upon initial construction cost. Variation with #7 bars at 64" gave the maximum savings at $0.10 per square foot of wall.

**Results of Wall 3** illustrate that as walls become taller, the size of the reinforcement required for the fully reinforced design increases. Thus, there are fewer possible variations using larger bar sizes for partial reinforcement. By limiting bar sizes to a maximum of #8, Wall 3 has only one possible variation, yet it still produces a slight savings of $0.02 per square foot of wall. The #8 limitation is a personal preference of the authors since TMS 402 actually limits bar sizes to #11 and smaller when using ASD methods.

Finally, results of **Walls 4 to 6** indicate that for tall walls there are no partial reinforcement option savings. If the design examples were continued beyond 22' high, the fully reinforced design would begin to require bar spacings less than 6t. **Wall 7** illustrates that bars larger than #8 are required.

Similar examples can be developed for 6", 10", 12" and 14" walls. Each would show the economy of partial reinforcement. **Charts 1-4** show results for each wall thickness, except 14" wall, for various wall heights.

| Wall Thickness | Approximate Wall Height for Partial Reinforcement for the Example Given |
|---|---|
| 6" | 14'-0" |
| 8" | 18'-0" |
| 10" | 25'-0" |
| 12" | 26'-0" |
| 14" | 29'-0" |

**Table 3 Partial reinforcement may offer greater economy below these heights**

For our example and given loadings, the results indicate partial reinforcement offers an economical alternative to 6t spacing for walls shorter than the listed heights in **Table 3**. For mason contractors not in high seismic or high wind areas, Table 3 could be used as a point of discussion with project engineers as to whether they considered partial reinforcement.

For any project with its own specific loading conditions, a similar table can be developed. These are worth developing and examining to determine if the economy of the wall design can benefit from partial reinforcement.

**Economy of Partial Reinforcement** Design examples illustrate that under certain conditions (low seismicity and not in high wind areas), partially reinforced masonry walls provide greater economy compared to fully reinforced masonry because the partially reinforced system can:

- Decrease amount of grout required in a wall.
- Reduce number of bars, lap splices and rebar positioners installed.
- Reduce amount of mechanical consolidation and reconsolidation required.
- Reduce number of cleanouts required for high-lift grouting.

These benefits can be compounded by effecting other aspects of the wall that affect economy:

- Increase possible insulation so that overall R-value of the wall increases.
- Decrease amount of grout which can reduce thermal bridging.
- Increase mason's productivity by installing fewer bars.
- Decrease wall weight and footing sizes.

While there has been limited research on 6t, the available work indicates our standards are possibly overly conservative for certain conditions. Perhaps it's time for the codes to re-evaluate the 6t criteria to larger values. Until then, engineers can effectively use the economy of partial reinforcement. Saving materials is the best thing we can do for improving the sustainability of our wall designs. ▮▮▮

**David T Biggs**, PE, SE, DIST M ASCE, HTMS, is principal of Biggs Consulting Engineering in Troy, NY. He specializes in structural forensic engineering, masonry design and historic restoration. He lectures, is involved with research projects and provides consulting for the development of new masonry products. Biggs was a member of the Building Assessment Team that investigated the World Trade Center disaster for FEMA and the American Society of Civil Engineers. He is a Distinguished Member of ASCE, an Honorary Member of The Masonry Society and has been a visiting lecturer at the Czech Technical University in Prague and the University of Minho in Portugal for the European Course *Advanced Masters in Structural Analysis of Monuments and Historic Constructions*. He is a member of the Masonry Standards Joint Committee and a board member of both The Masonry Society and the Structural Engineering Institute of ASCE. Biggs is also a Great Mind of the Editorial Advisory Board of *MasonryEdge/theStoryPole, a leading provider of masonry intelligence*, and a partner of Constructive, LLC, prefabricated masonry wall system. **biggsconsulting@att.net | 518.495.5739**

**Dan Zechmeister**, PE, AIA Detroit Honorary Affiliate member, executive director and structural services director of the Masonry Institute of Michigan, sets the pace infusing members with knowledge and confidence to collaborate with A/E/C in designing and constructing higher performance and more efficient masonry buildings using Masonry for All Its Worth. He has been actively involved on *The StoryPole* and *MasonryEdge/theStoryPole* Editorial Advisory Boards since inception. He is an active member of ASTM, MSJC, the MIOSHA Masonry Wall Bracing Advisory Committee and board member of the AIA Building Enclosure Council of Greater Detroit. **dan@mim-online.org 248.663.0415**


MAXIMIZE R-VALUE with SPRAY FOAM and AIR/VAPOR BARRIER in ONE

- Higher R-value 6.8/" with less thickness in the cavity
- Fully Adhered to CMU/ Monolithic
- Conforms to Odd Shapes and Configurations
- Seals Construction Joints
- Quick and Easy Application
- Gold Star Certified Installers
- Increase Productivity, Quality

InsulBloc™ *Call us to find out why architects and masons prefer NCFI InsulBloc*

SCS STONY CREEK SERVICES INC.

SE Michigan 734-326-2222 | Outstate 800-846-6789

stonycreekservices.com

Serving the Great Lakes states and beyond for over 30 years | Specialists in spray foam application