Once the US Government Accountability Office (GAO) found the Army did not monitor goal achievement and thus did not know to what extent the goals had been met or whether changes made to its military building construction program resulted in actual reductions in facility costs, the Department of Defense (DoD) found themselves rethinking the Army’s military construction strategy. Army set goals to reduce building costs by 15% and timelines by 30% to meet challenges associated with a threefold increase in construction between fiscal years 2005 and 2009. In addition to saving money (initial construction costs), they were also challenged to reduce timelines (schedules), while incorporating additional antiterrorism construction standards and meeting sustainable design goals.

The GAO found that the Army did not maintain strong or accurate data to clearly or definitively quantify whether some initial changes would make these four goals achievable. For example, a movement to wood-framed and modular buildings saved on initial cost and schedule in some instances, but not enough to meet the 15% and 30% established targets, respectively. In addition, little data was available to show that use of these materials would result in long-term savings. Other branches of military (Navy and Air Force) typically build for 50-year life expectancy as a result of the 2009 Defense Authorization bill that directed the Department of Defense (DoD) found themselves challenged to reduce timelines (schedules), while incorporating additional antiterrorism construction standards and meeting sustainable design goals.

Results compare brick veneer over 2 1/2" spray foam insulation on 8" block backup to brick veneer over metal stud with 2" rigid and R19 batt insulation.

NCMA has been actively lobbying the DoD on masonry’s behalf for a number of years. The Masonry First Coalition of Washington State and the Mason Contractors Association of America (MCAA) have also been working to regain military market share at local and regional levels. Through local connections in Texas, MCAA organized a group of industry leaders including their own Jeff Buczkiewicz, president/CEO, and Bob Thomas, president of NCMA, to attend a meeting at the Pentagon with Assistant Deputy Under Secretary of Defense (Installations and Environment) John Conger presenting the benefits of structural loadbearing masonry construction as an alternative to other structural exterior wall systems. Because of the limitation of the US Government Accountability Office (GAO) to monitor goal achievement, the Department of Defense (DoD) found themselves rethinking the Army’s military construction strategy. Army set goals to reduce building costs by 15% and timelines by 30% to meet challenges associated with a threefold increase in construction between fiscal years 2005 and 2009. In addition to saving money (initial construction costs), they were also challenged to reduce timelines (schedules), while incorporating additional antiterrorism construction standards and meeting sustainable design goals.

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presentations I give on behalf of the Masonry Institute of Michigan to architects, engineers and owners based on merits of the high performance and most economical structural well insulated thermal cavity wall system, I was invited to become a part of this group.

This was an opportunity to compile years of MIM research and industry data (in particular the Masonry Alternate Design program) into one presentation that would make a far reaching and long term impact. Articles written for MasonryEdge/theStoryPole were referenced, as well as previous presentations spanning economics, efficiency of design and installation, sustainability and durability of loadbearing masonry’s cavity wall system. A new in-depth presentation was created. The life cycle cost analysis information the Army was in need of challenged us to expand our presentation with most efficient operational costs. More importantly, the GAO recommended that the Secretary of Defense direct the Deputy Under Secretary of Defense (Installations and Environment) to commission a tri-service panel that would be responsible for determining and comparing estimated life cycle costs of facilities built with alternative construction materials and methods, including a mix of wood and steel, concrete and masonry construction materials and on-site and modular construction methods.

**Life Cycle Cost Analysis**

Life Cycle Cost Analysis (LCCA) is an economic assessment of an item, system or facility and competing design alternatives considering the time value of money. For this presentation, the Present Worth Method\(^1\) was employed. This method allows conversion of all present and future costs to a single point in time, usually at or around the time of the first expenditure. Considered were Initial Costs, Replacement Cost/Salvage Value and Annual Costs.

Pete Loughney, director of Market Development and Technical Services with the International Masonry Institute (IMI), was consulted. IMI has developed a program\(^2\) to determine the LCCA of a masonry exterior envelope based on the Present Worth Method as determined by impartial, published industry reference material, including NIST 135 Handbook (National Institute of Standards and Technology), ASTM E917 Standard Practice for Measuring Life-Cycle Costs of Buildings and Building Systems, ASTM E1057 Standard Practice for Measuring Internal Rate of Return and Adjusted Internal Rate of Return for Investments in Buildings and Building Systems, RS Mean’s CostWorks 2012, Whitestone Facility Maintenance and Repair Cost Reference 2011-2012 and ASHRAE Energy Analysis.

Data is input and the LCCA is output. To meet the Army’s objective, we selected typical military housing (100 room student dormitory) as built in San Angelo TX on a military base for the Pentagon meeting. Since that DoD meeting in July 2010, more research and data have been collected. For purposes of incorporating the new information for this article, the input data for the IMI’s LCCA model has been modified and rerun:

1. change building location to Detroit
2. change life cycle to 50 years
3. to include a brick veneer with 6” metal stud backup with R19 batt insulation\(^3\) placed between the studs and 2” rigid insulation placed in the cavity (total calculated R-value of 19.5)
4. to include a brick veneer with 8” block backup with 2” of spray foam (total calculated R-value of 20.4)\(^4\)

\(^1\)MasonryEdge/theStoryPole Vol 4 No 3, The High R-Wall Model, page 36, Table 2
\(^2\)MasonryEdge/theStoryPole Vol 4 No 3, The High R-Wall Model, page 37, Table 4
These two wall sections were selected because they are approximately the same total thickness, with the brick veneer and metal studs at 14\(\frac{3}{4}\)" (not including the box out of steel columns) and the brick veneer and block at 15\(\frac{3}{4}\)". Both wall sections meet the minimum prescriptive code requirements for the R-value of the insulation with the brick veneer and metal studs at R19 + R10c > R13 + R7.5c, and the brick veneer and block backup R17 > R 14.4 for climate zone 5.

Brick veneer & block backup was less expensive than brick veneer & metal stud by 13.8%, 39.3%, 4.4% and 15.1%, respectively.

Running the Numbers (Monetary and Non-Monetary) Economic data must be determined and input from the most current and accurate sources available.

- Expected Useful Life, as determined by owner.
- Discount Rate, a rate of interest reflecting the investor’s time value of money, used to determine discount factors for converting benefits and costs occurring at different times to a baseline date.
- Overall Location Factor, which changes automatically by RS Means and is based on materials in the geographic area, whether prevailing wages are relevant, etc.
- Cost Index (time), per RS Means.
- Energy Escalation per year, available on Department of Energy website.
- Maintenance Escalation per year, per client experience.
- Cost of Energy ($/kWh), per local utility.
- Seismic/Wind Premium, based on probability of damage from natural hazards.

Framing premium based on structural system fragility (Fig 1)
- For the brick veneer and metal stud wall, $7.50/sf was included for the cost of the structural steel columns, beams, concrete piers and the concrete spread footings on the exterior.
- For the brick veneer and block backup, $0.55 was included for additional grouting for the reinforced masonry system.

Next, is an input of non-monetary criteria, the weight of which is subjective, based on owner’s preference. IMI states, “This allows the owner to make very deliberate choices as to how much value they want to place on preferences or specific types of requirements.” These non-monetary criteria exemplify how far a dollar can be stretched. The seven criteria are weighted and combine for a total of 100 points. This information is overlaid with a masonry and competing wall system for scoring. For the wall sections under consideration the non-monetary weighted criteria are: Image/Aesthetics 15, Security 25, Environmental Sustainability 20, Obsolescence Avoidance 0, Operational Effectiveness 5, Durability 30 and Future Extendability 5. Scoring of each criterion is an assigned value from 1 to 10 with 10 being highest performance possible by a wall system. The sum of the score values times the weight of each criterion determines the Benefit Total output value used in the LCCA to compare systems. For the wall sections under consideration, the brick veneer and block backup has a Total Benefit of 930, while the brick veneer and metal stud has a Total Benefit of only 670. (Fig 1)

Results of the program compare brick veneer over 2\(\frac{3}{4}\)" spray foam insulation on block backup to brick veneer over metal stud with 2" rigid insulation and R19 batt insulation between metal studs for a 50,000 sf exterior wall model using Detroit labor and material figures. Comparisons were for initial costs, total replacement/salvage value (including cleaning, repointing, resealing and painting), total annual costs (including energy, fuel, maintenance and general repair), and total life cycle costs. (Figs 2 & 3)

Results of the life cycle cost analysis (monetary) show the total cost of ownership over 50 years is less for the brick veneer and block backup wall at $2.02M ($40.46/sf) than the brick veneer and metal stud wall at $2.38M ($47.68/sf).

In reviewing Fig 1 and comparing the costs for 1. total initial construction
2. total replacement/salvage
3. total annual
4. total life cycle it shows the brick veneer and block backup less expensive than the brick veneer and metal stud by 13.8%, 39.3%, 4.4% and 15.1% respectively.

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**Figure 2 | LCCA – Brick Veneer and Block**
Results of the Total Benefit to Cost Ranking (non-monetary) show the brick veneer and block backup at 23.0 is \( 63 \% \) greater than the brick veneer and metal stud at 14.1.

It is clear that time is on masonry's side. The longer a building's useful life, the lower its life cycle costs will be. Masonry has proven it can last hundreds of years and still provide functionally operational building envelope through changing climates. Ultimately, the Army would like its buildings to be attractive to private owners in the future should they no longer be required by the Army. From the Army post at the Presidio in San Francisco to its adoption by the National Park Service, and the Army Air Corp and Air Force Base turned Naval Training Center turned urban neighborhood just outside of downtown Orlando, military bases and some of their buildings have already been adapted and repurposed for a changing society. At least in Seattle WA, the Army has recently turned to a 21st-century building life expectancy.

**Beyond Military** Moving beyond life cycle cost analysis for military housing structures alone, others are finding that results of LCCAs are shining a favorable light on masonry structures and exterior wall systems. The University of Florida (U of F) and Florida Department of Education published an updated report in 2010\(^7\) that compared several systems for all parts of a school building, including exterior materials. The purpose of the study was to provide guidance to local Florida educational agencies and their supporting design teams to use in the selection of the most appropriate and cost-effective materials, products and systems for designing and constructing school and college buildings including life cycle assessment. Table 2.1 on page 26 of that study includes four teen walls. Exterior wall systems included single-wythe CMU and several multi-wythe masonry systems, as well as nine other systems that had at least one non-masonry wythe. Single wythe CMU proved to be the lowest first cost and life cycle choice (the best option) as compared to other single systems. The single wythe exterior brick facing over CMU first cost and life cycle cost was lower than the single wythe brick facing over steel stud. The useful life of a building for the Florida LCCA was 50 years.

NCMA, MCAA and MIM have continued to research and refine their materials on masonry life cycle cost analysis. There is current discussion amongst the associations to talk with the UofF about a potential study, similar to the UofF 2010 publication, for the entire country.

**Continuous Progress** Considerations beyond LCCA and taking a look at hygrothermal evaluation, there are tools, methods and software programs available to aid designers in determining if water accumulation can occur in exterior walls\(^3\). The brick veneer and metal stud wall in the example above where steel studs are filled with batt insulation and used in facilities that contain higher levels of interior relative humidity could have unintended consequences of material and property damage.

In the example above, R-value for the brick veneer and block backup was a calculated (steady state) value of 20.4. This value did not take into consideration the thermal mass benefits of the masonry. Thermal mass can significantly improve energy efficient performance above that predicted by the steady state R-value\(^9\).

Masonry may be our oldest building system, but it is continually reinventing itself. As more research and understanding has come to light in regard to greenhouse gas emissions, cement production has come under scrutiny. In producing one pound of cement, one pound of greenhouse gas (\( \text{CO}_2 \)) is produced as well. This adds to the embodied energy of CMU, mortar and grout products which contain cement. In the last decade, however, endless innovation has been underway by producers. Inclusion of recycled content and supplemental cementitious materials (fly ash, slag) has reduced the amount of cement needed in production. Unsealed, grey CMU actually absorbs \( \text{CO}_2 \) over time and now there is a new CMU manufacturing process in place that actually adds waste \( \text{CO}_2 \) to block as a means of disposal. Additionally, manufacturing plants are making efforts to scrub-clean waste emissions and capture water and heat for reuse in the process. These efforts combine to lower embodied energy. As manufacturing continues to streamline and become more efficient, affiliated life cycle costs will also continue to decline.
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MILITARY CONSTRUCTION
Single wythe concrete masonry construction is a durable, cost effective and aesthetically versatile form of masonry construction that is used successfully all over the world. Single wythe walls, unlike cavity walls and veneered walls, require additional special attention regarding moisture penetration prevention. The following four items make up what is the industry standard for how to properly use concrete masonry for single wythe walls.

1. **Use Water Repellent Materials** Concrete masonry units are not all created equal. Specify and insist on concrete masonry units which contain integral water repellent (IWR), greatly limiting the amount of water absorbed by the unit. Specify and insist on the use of compatible integral water repellent additives in mortar as well.

2. **Use Rigid, Not Batt Insulation** Batt insulation absorbs and holds on to moisture, creating an environment for mold to grow. Simply substituting rigid extruded polystyrene or polyisocyanurate insulation will go a long way toward preventing mold. Tape the joints or set panels onto a bead of sealant at all joints.

3. **Design/Detailing** Design and detailing of single wythe walls to minimize moisture problems require that proper flashing details serve as a line of defense against water penetration at parapets, windows, doors, structural floor connections and at the base of the wall.

4. **Post Applied Water Repellent** Post applied water repellent must be used on all single wythe CMU walls. Adding a water repellent that is specifically made for concrete masonry units will reduce capillary action and limit staining while maintaining the appearance and vapor permeability of the wall. It is important to note that water repellents cannot bridge cracks or voids of certain sizes, or eliminate the effects of excessively harsh cleaning.

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