Deputy Under Secretary of Defense
Installation and Environment

Military Construction

MCAA
MASON CONTRACTORS ASSOCIATION OF AMERICA

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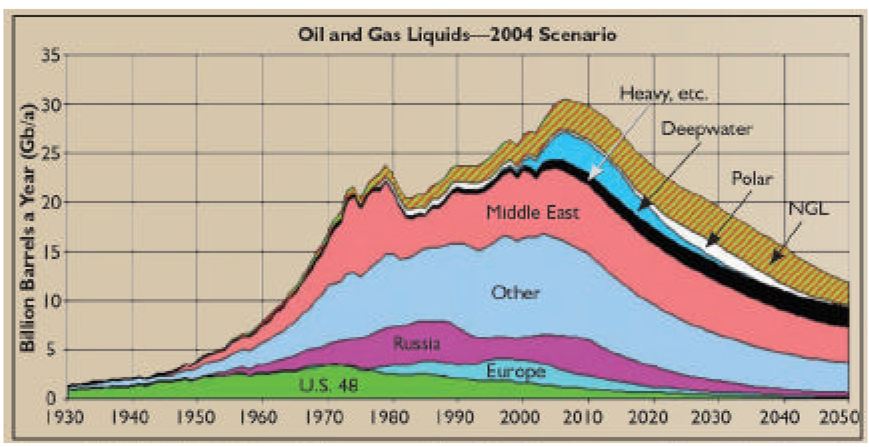
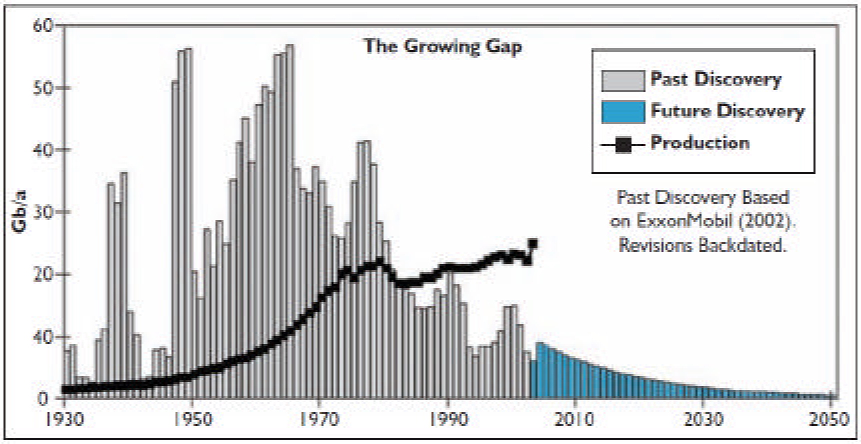
Energy



World Oil Production

Graph is from the Uppsala Hydrocarbon Depletion Study Group
Energy Security and Saving the Planet, Joseph W. Lstiburek, Ph.D, P.Eng., Fellow ASHRAE

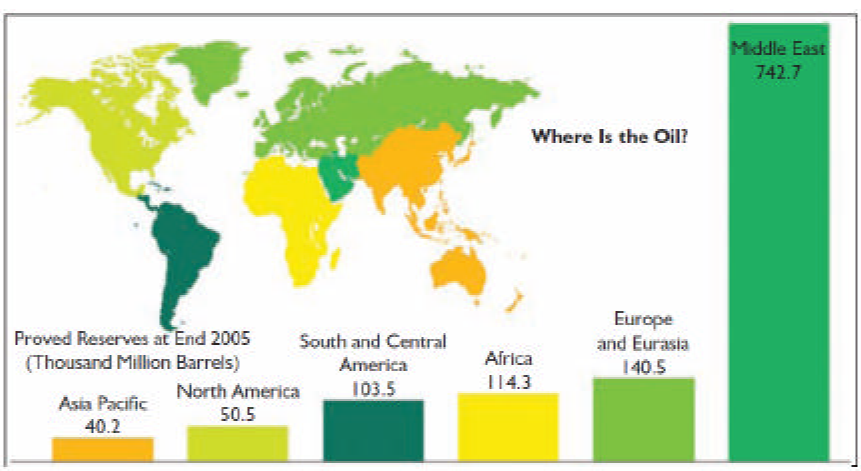
Energy



<u>Using Twice as Much Oil as What's Being Found</u>

Graph courtesy of Chevron Oil
Energy Security and Saving the Planet, Joseph W. Lstiburek, Ph.D, P.Eng., Fellow ASHRAE

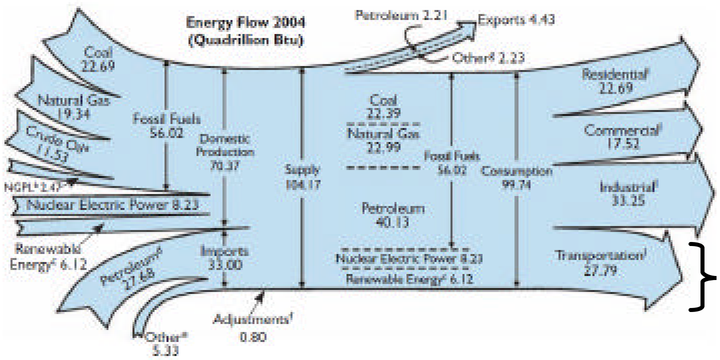
Energy



<u>Who Has the Oil?</u>

Graph courtesy of British Petroleum
Energy Security and Saving the Planet, Joseph W. Lstiburek, Ph.D, P.Eng., Fellow ASHRAE

Energy



Buildings consume 40%

Transportation consumes just under 30%

<u>U.S. Energy Flow</u>

Graph courtesy U.S. Energy Information Agency

Energy Security and Saving the Planet, Joseph W. Lstiburek, Ph.D, P.Eng., Fellow ASHRAE

Energy

What is the energy solution for transportation?

The answer: plug-in hybrid vehicles

Energy Security and Saving the Planet, Joseph W. Lstiburek, Ph.D, P.Eng., Fellow ASHRAE

Energy

What is the energy solution for buildings?

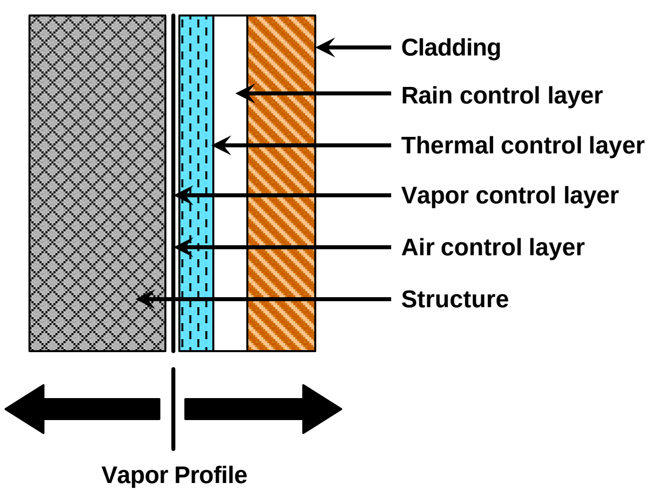
The answer:

Double and triple thermal resistance in typical building enclosures

and

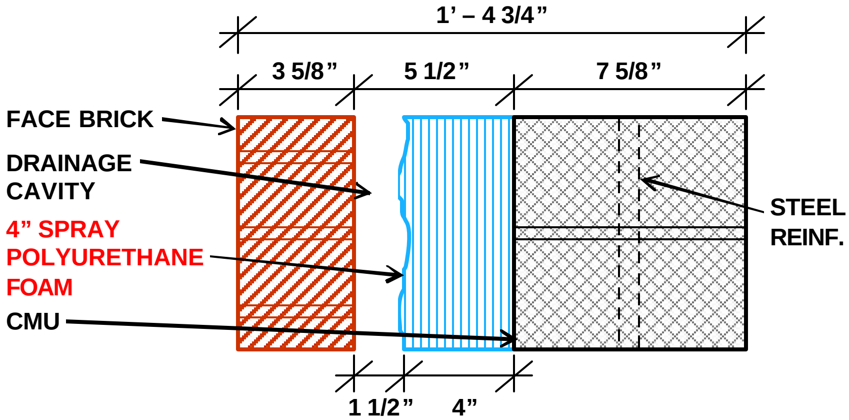
Reduce the amount of glass

The Perfect Wall



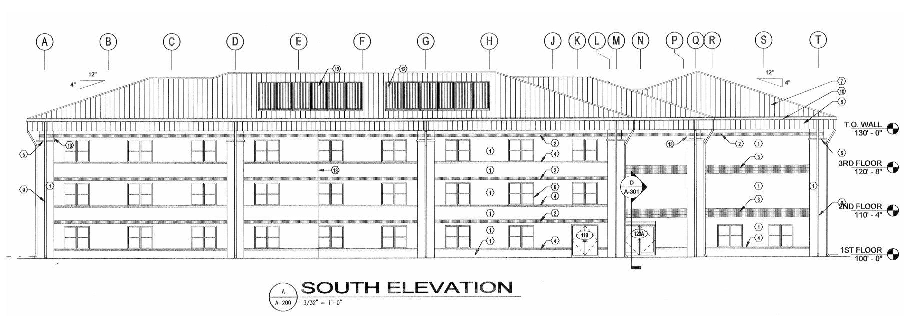
Proposed Masonry Wall

R-Value = 30.6



Example: Barracks Elevation

21% window openings (100 room dorm)



Saving Energy

1000 YEARS AGO, stone enclosure – R-2

500 YEARS AGO, thatched roofs improved enclosures – R-4

350 YEARS AGO, post and beam, waddle and daub cavity construction – R-6

250 YEARS AGO, log cabin timber construction – R-8

100 YEARS AGO, mass wall, 10% glazing ratio – R-8

IN 1972, non-thermally broken aluminum curtain walls – R-1.5

TODAY, thermally broken aluminum curtain walls – R-2

Saving Energy

- After 1000 years, we are still designing walls with R-2. It's the energy we are expending at 2.5 times that of what we are finding.
- Learn glass is most expensive and does not create an energy efficient building envelope
- When more than 30% glass is used in a building, it is not socially responsible.

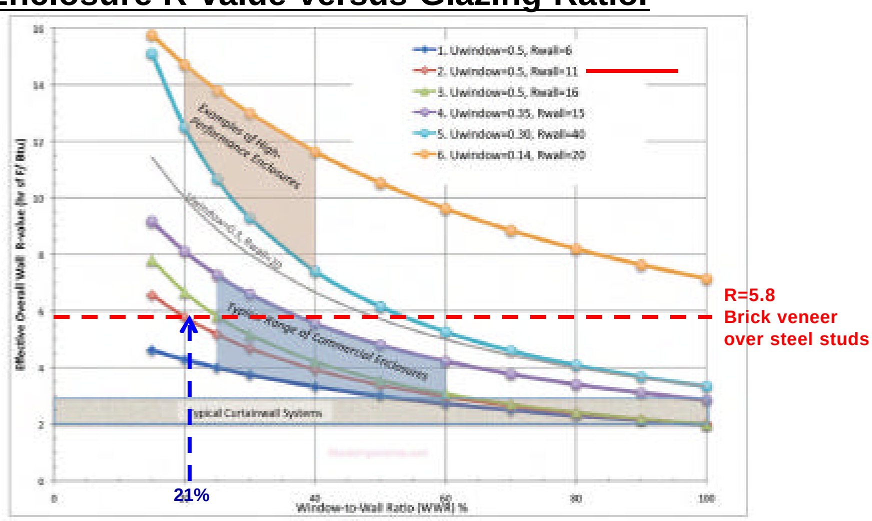
Saving Energy

Modern commercial vertical enclosures (glazing and wall) actually have a composite R-value that is rarely over 7, and more likely in the range of 3-to-5!

Prioritizing Green: It's The Energy Stupid, Joseph W. Lstiburek, Ph.D, P.Eng., Fellow ASHRAE

Saving Energy

Enclosure R-value versus Glazing Ratio.



Can Highly Glazed Building Facades Be Green?, John Straube, Building Science Insights, BSI-006, September, 2008.

Proposed Masonry Wall

21% glazing (R-3) & insulation (R-30.6)

$U_{overall}=(WWR*U_{window}+(1-WWR)*U_{wall})$

$U = (0.21*0.33)+(0.79*0.033)$

$U = 0.095$

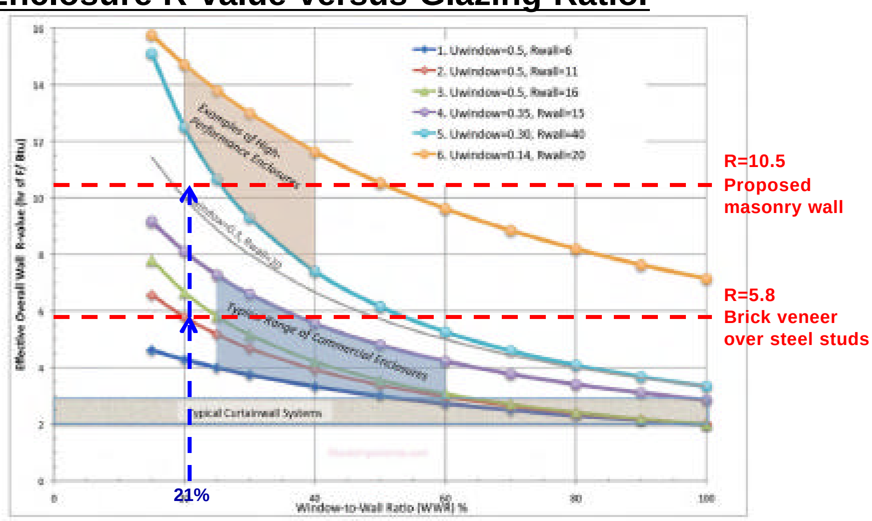
$U = 1/R$

$R = 10.5$ (composite)

Prioritizing Green: It's The Energy Stupid, Joseph W. Lstiburek, Ph.D, P.Eng., Fellow ASHRAE

Saving Energy

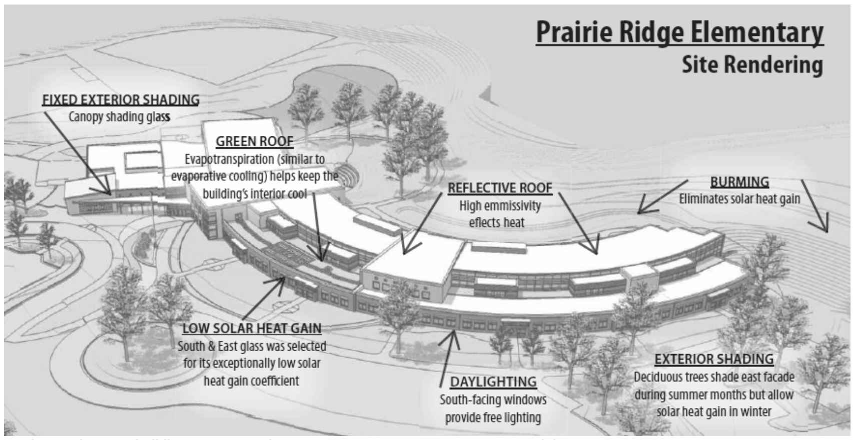
Enclosure R-value versus Glazing Ratio.



Can Highly Glazed Building Facades Be Green?, John Straube, Building Science Insights, BSI-006, September, 2008.

Saving Energy

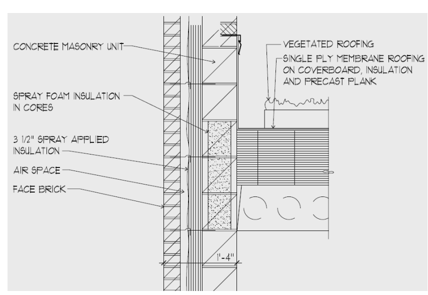
High Performance Low Energy Sustainable Building



Saving Energy

High Performance Low Energy Sustainable Building

- 16” multi-wythe masonry wall (R-26.3)
  - 3 5/8” face brick
  - 1 1/4” drainage cavity
  - 3 1/2” spray applied insulation
  - 7 5/8” block



Saving Energy

High Performance Low Energy Sustainable Building

- The team has designed buildings that are operating as low as $0.77/sf per year and only as high as $1.13/sf per year.
- According to the EPA's "Energy Star Target Finder," the average K-12 building consumes $1.39/sf per year.

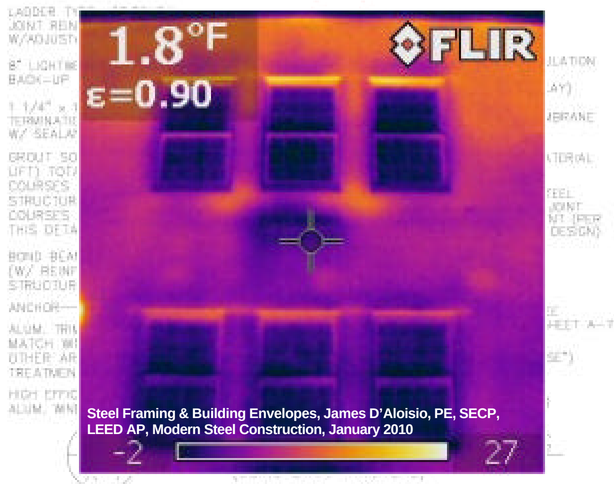
Saving Energy

High Performance Low Energy Sustainable Building

- Designing high performance low energy sustainable buildings, including higher insulated brick and block walls, has reduced energy consumption from 18.8% to 44.6%

Hi R-Wall Details

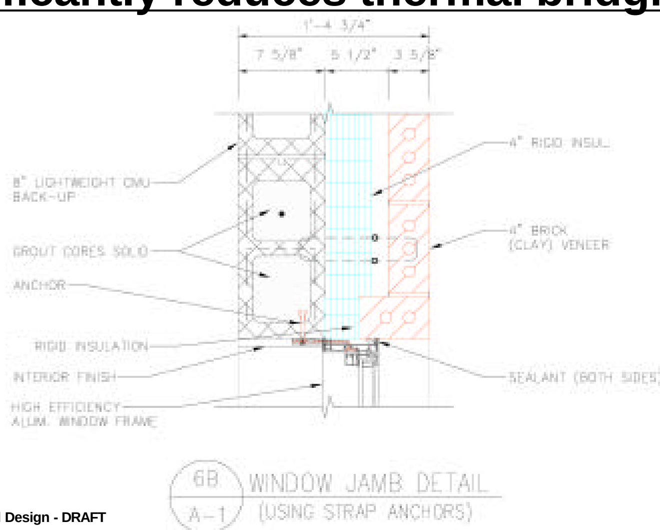
Significantly reduces thermal bridging



Steel Framing & Building Envelopes, James D'Aloisio, PE, SECP, LEED AP, Modern Steel Construction, January 2010

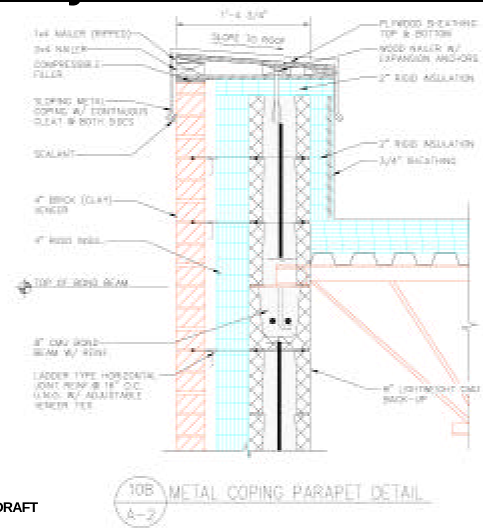
Hi R-Wall Details

Significantly reduces thermal bridging



Hi R-Wall Details

Significantly reduces thermal bridging



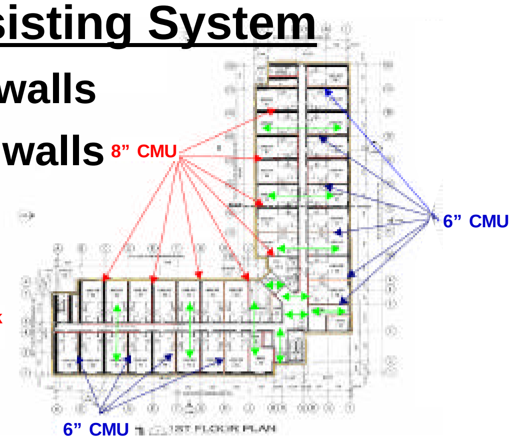
Structural Model

Lateral Force Resisting System

- All exterior and interior masonry walls

Gravity Force Resisting System

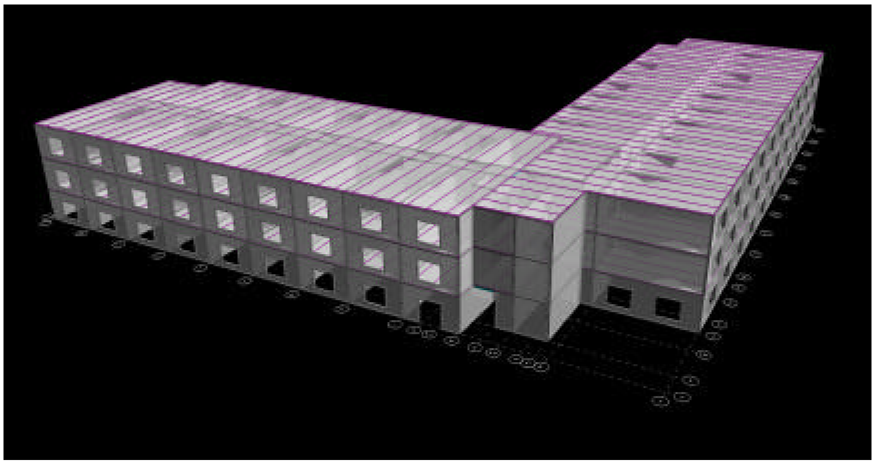
- Exterior masonry walls
- Corridor masonry walls



= 8" CMU Precast Plank Direction

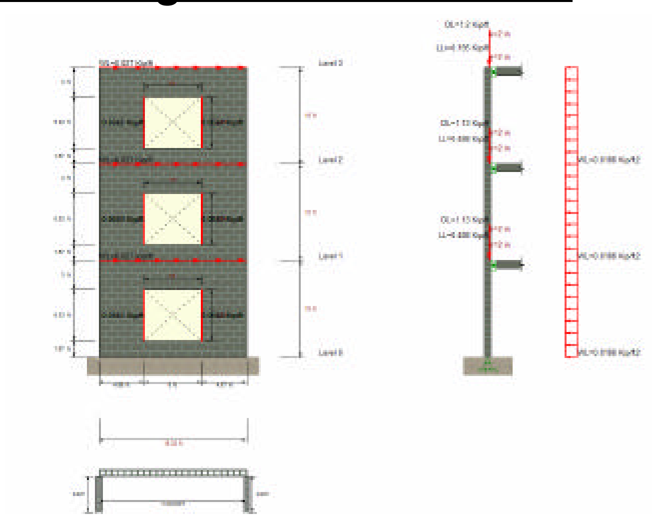
Structural Model

Full 3D Structural Model in RSS



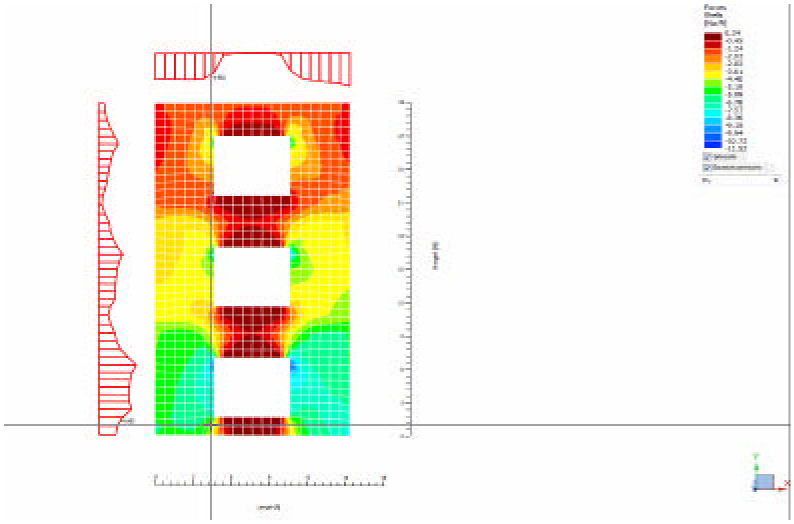
Structural Model

Load Bearing Shear Wall Loads



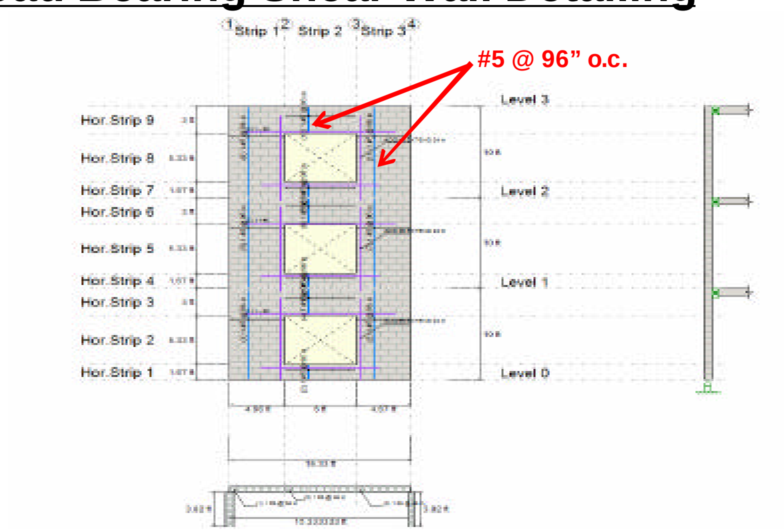
Structural Model

Load Bearing Shear Wall Vertical Force



Structural Model

Load Bearing Shear Wall Detailing

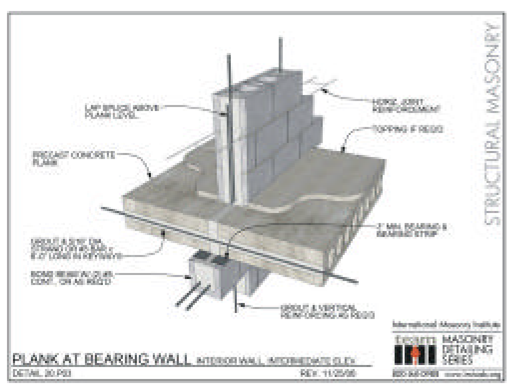


Construction Schedule

- Masonry products use abundant resources with long service lives
  - Stone, gravel, sand, clay, earth, gypsum, lime, perlite, quartz and silica
- 8” and 12” CMUs are readily available
  - No lead time required
  - No shop drawings required

Construction Schedule

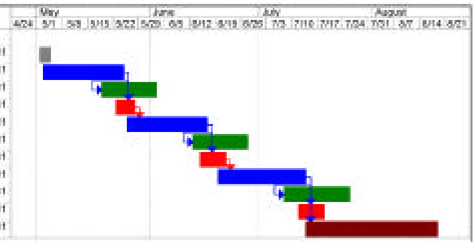
- Enhanced construction schedule
- Decreased building height
- Easier installation of continuous air barrier from wall to roof elements



http://www.imiweb.org/design_tools/masonry_details/details/02.120.0752.php

Construction Schedule

ID	Task Name	Duration	Start	Finish
1				
2	Foundations	3 days	Mon 5/2/11	Wed 5/4/11
3	1st Floor Bearing	16 days	Tue 5/3/11	Tue 5/24/11
4	1st Floor Non Bearing	11 days	Thu 5/19/11	Thu 6/2/11
5	2nd Floor Precast Plank	5 days	Mon 5/23/11	Fri 5/27/11
6	2nd Floor Bearing	16 days	Thu 5/26/11	Thu 6/16/11
7	2nd Floor Non Bearing	11 days	Mon 6/13/11	Mon 6/27/11
8	3rd Floor Precast Plank	5 days	Wed 6/15/11	Tue 6/21/11
9	3rd Floor Bearing	18 days	Mon 6/20/11	Wed 7/13/11
10	3rd Floor Non Bearing	12 days	Fri 7/8/11	Mon 7/25/11
11	Roof Precast Plank	5 days	Tue 7/12/11	Mon 7/18/11
12	Veneer	26 days	Thu 7/14/11	Thu 8/18/11



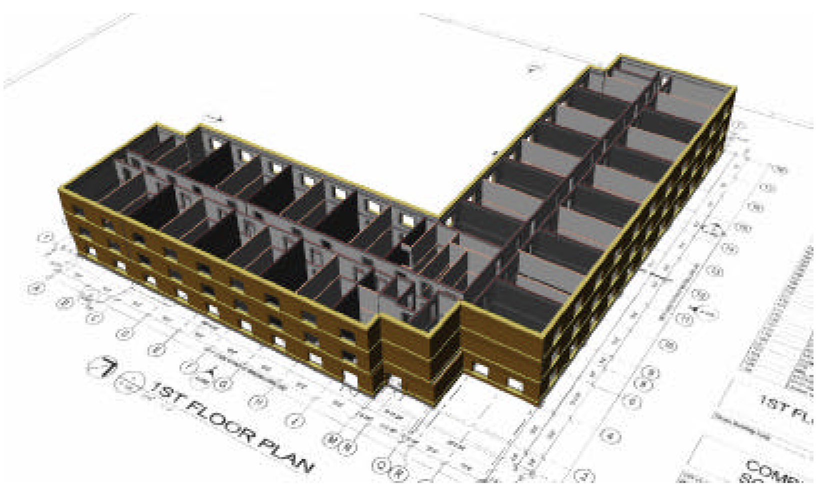
Average Crew Size
14 bricklayers
11 laborers

16 working weeks

- **Crew size could increase depending on finishing brick veneer and could save 10 working days**
- **Based on 54,766 sf**

Estimating Model

Tradesman 3D



Estimating Model

Initial Construction Cost

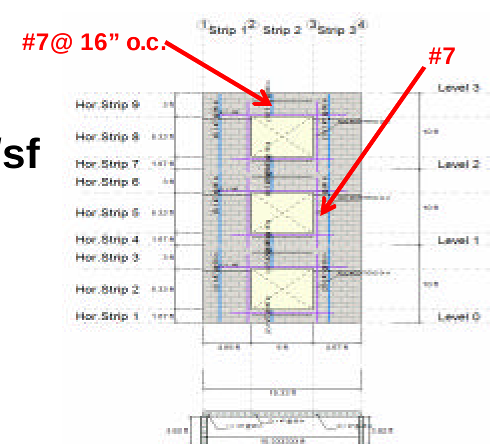
Total cost: $16.52/sf

- Based on SouthWest labor & materials
- Does not include premium finishes on interior walls
- Includes hollow core concrete floor planks

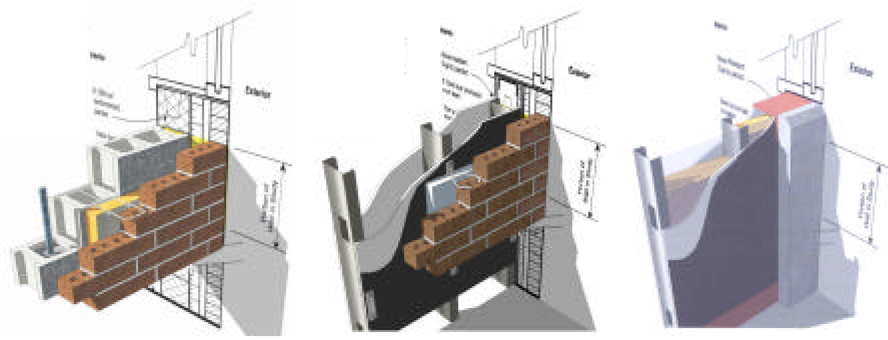
Estimating Model

Initial Construction Cost
Blast Resistance Windows (1 psi)

Total cost: $16.73/sf



Life Cycle Cost Analysis



An economic assessment of an item, system or facility and competing design alternatives considering the time value of money

Life Cycle Cost Analysis

70 years[4]	Total Initial Construction Cost, $M	Total Replacement/ Salvage[1], $G	Total Annual Costs[2], $G	Total Life Cycle Costs, $M	Total Life Cycle Costs[3], $/sf
Brick Veneer Over Block W/4" Spray Foam	1.08	26.44	133.75	1.24	24.87
Brick Veneer Over 6" Metal Stud W/Rigid Insulation	1.20	29.30	386.12	1.62	32.36
Insulated Precast Panels	2.23	52.22	186.04	2.47	49.37

[1]Clean, repoint, reseal, and paint
[2]Energy, fuel, maintenance, and repair
[3]Based on 50,000 sf exterior wall model
[4]Based on SouthWest labor & materials

Loadbearing Multi-Wythe Masonry

For All It's Worth

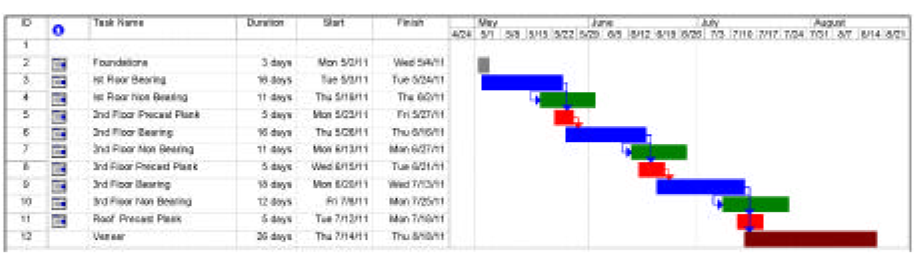
- Initial construction cost

LOW

Loadbearing Multi-Wythe Masonry

For All It's Worth

- Initial construction cost
- Construction schedule



ENHANCED

Loadbearing Multi-Wythe Masonry

For All It's Worth

- Initial construction cost
- Construction schedule
- Single source contractor

ACCOUNTABILITY

Loadbearing Multi-Wythe Masonry

For All It's Worth

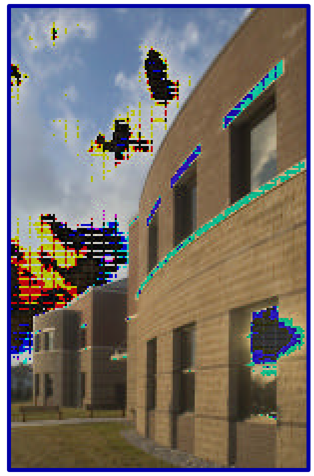
- Initial construction cost
- Construction schedule
- Single source contractor
- Life cycle cost

LOW

Loadbearing Multi-Wythe Masonry

For All It's Worth

- Initial construction cost
- Construction schedule
- Single source contractor
- Life cycle cost
- Maintenance cost



LOW

Loadbearing Multi-Wythe Masonry

For All It's Worth

- Initial construction cost
- Construction schedule
- Single source contractor
- Life cycle cost
- Maintenance cost
- Durability

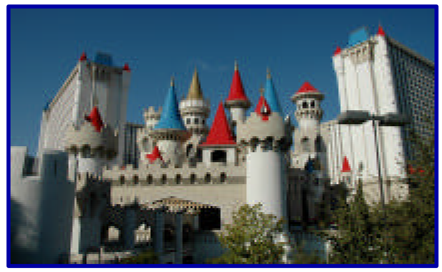
Fort Wayne Barracks, Detroit, MI
Built 1848

EXCELLENT

Loadbearing Multi-Wythe Masonry

For All It's Worth

- Initial construction cost
- Construction schedule
- Single source contractor
- Life cycle cost
- Maintenance cost
- Durability
- Structural system



Excalibur in Las Vegas, NV

28 stories tall (240ft)

Loadbearing Multi-Wythe Masonry

For All It's Worth

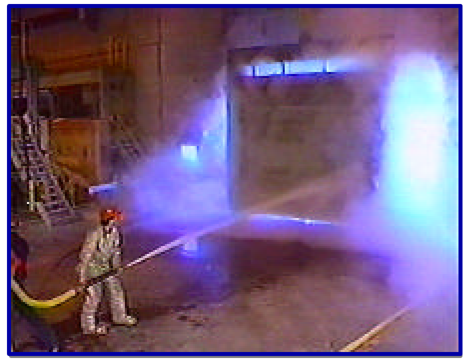
- Initial construction cost
- Construction schedule
- Single source contractor
- Life cycle cost
- Maintenance cost
- Durability
- Structural system
- Anchoring for stone

CONTINUOUS BACKING

Loadbearing Multi-Wythe Masonry

For All It's Worth

- Initial construction cost
- Construction schedule
- Single source contractor
- Life cycle cost
- Maintenance cost
- Durability
- Structural system
- Anchoring for stone
- Fire rating



EXCELLENT

Loadbearing Multi-Wythe Masonry

For All It's Worth

- Thermal resistance


the High R-WALL Model

Insulated Masonry Cavity Wall Reaches R-30+, 275% Higher Than Required by Michigan's Current Energy Code

Think Performance!!

LEARNING OBJECTIVES

New Standards Raise the Bar

EXCELLENT

Loadbearing Multi-Wythe Masonry

For All It's Worth

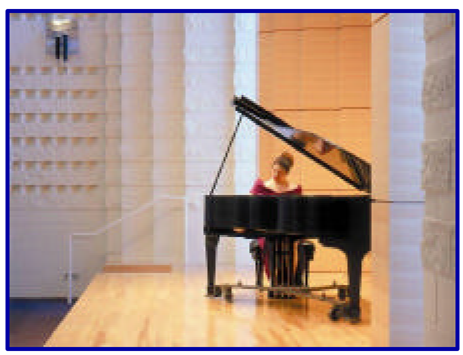
- Thermal resistance
- Thermal mass efficiency

HIGHER EFFECTIVE R-VALUE

Loadbearing Multi-Wythe Masonry

For All It's Worth

- Thermal resistance
- Thermal mass efficiency
- Sound resistance



GOOD

Loadbearing Multi-Wythe Masonry

For All It's Worth

- Thermal resistance
- Thermal mass efficiency
- Sound resistance
- Moisture resistance

EXCELLENT

Loadbearing Multi-Wythe Masonry

For All It's Worth

- Thermal resistance
- Thermal mass efficiency
- Sound resistance
- Moisture resistance
- Mold resistant

EXCELLENT

Loadbearing Multi-Wythe Masonry

For All It's Worth

- Thermal resistance
- Thermal mass efficiency
- Sound resistance
- Moisture resistance
- Mold resistant
- Structural redundancy

ALTERNATE LOAD PATH

Loadbearing Multi-Wythe Masonry

For All It's Worth

- Thermal resistance
- Thermal mass efficiency
- Sound resistance
- Moisture resistance
- Mold resistant
- Structural redundancy
- LEED points

UP TO 52 POINTS

Loadbearing Multi-Wythe Masonry

For All It's Worth

- Thermal resistance
- Thermal mass efficiency
- Sound resistance
- Moisture resistance
- Mold resistant
- Structural redundancy
- LEED points
- Sustainable

CONSIDER FUTURE GENERATIONS

Loadbearing Multi-Wythe Masonry

For All It's Worth

- Thermal resistance
- Thermal mass efficiency
- Sound resistance
- Moisture resistance
- Mold resistant
- Structural redundancy
- LEED points
- Sustainable
- Manufactured locally

SAME DOLLAR CIRCULATED 4 FOLD

Loadbearing Multi-Wythe Masonry

For All It's Worth

- Initial construction cost
- Construction schedule
- Single source contractor
- Life cycle cost
- Maintenance cost
- Durability
- Structural system
- Anchoring for stone
- Fire rating
- Thermal resistance
- Thermal mass efficiency
- Sound resistance
- Moisture resistance
- Mold resistant
- Structural redundancy
- LEED points
- Sustainable
- Manufactured locally

Energy

Insight
Energy Security (and saving the planet)

An edited version of this Insight first appeared in the ASHRAE Journal.

By Joseph W. Lstiburek, Ph.D., P.Eng., Fellow ASHRAE

Energy security is pretty easy to get a handle on—don't buy oil from the Middle East, Russia, Nigeria and Venezuela. We don't need it anyway. We have plenty of energy right here in good old North America. The problem is that it is not cheap energy and it is not clean energy. We can make it clean, and we will, but it will be even more expensive. And actually that is good because we won't waste it when it is expensive.

To be perfectly clear we don't have an energy crisis we have a cheap oil crisis. We are running out of light, sweet, Arabian crude (**Figure 1** and **Figure 2**). And guess who has the oil (**Figure 3**)? The sooner we run out of it the better. As soon as the price of oil gets high enough we will change over to another energy source.

Here's the way I see it. The first thing you have to understand is that energy security is first and foremost a car-truck-transportation problem that—as it gets solved—will change the rest of the economy—for the better I might add. In fact we have already solved the transportation problem although most folks don't appreciate it. The good news is that the Government didn't do it and couldn't do it. The bad news is that Government might yet still screw it up. I want the marketplace and innovation to sort it out. The only thing we need from government is a modicum of environmental protection so we don't pee in our collective planetary bed while this gets sorted out. I think we can count on that—the environmentalist's heads would otherwise explode.

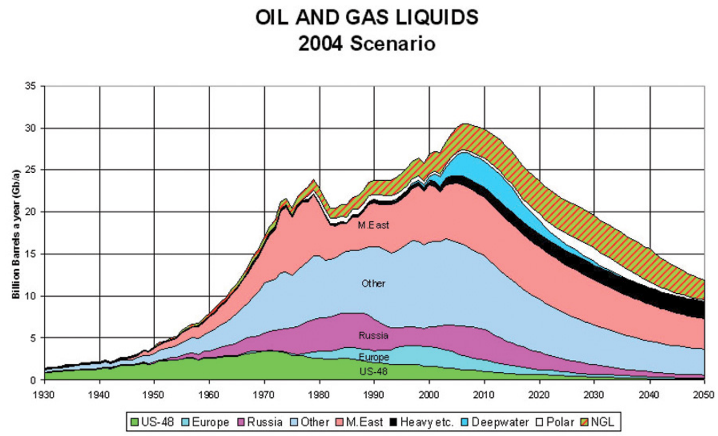


Figure 1: "King" Hubbert—When a modified Hubbert approach is applied to world oil production we see that either "peak oil" is here already or very close. M. King Hubbert was a geoscientist who worked for Shell Oil in Houston who predicted correctly that US oil production in the lower 48 states would peak in 1972. Dr. Hubbert predicted this in the 1950's. *Graph is from the Uppsala Hydrocarbon Depletion Study Group*.

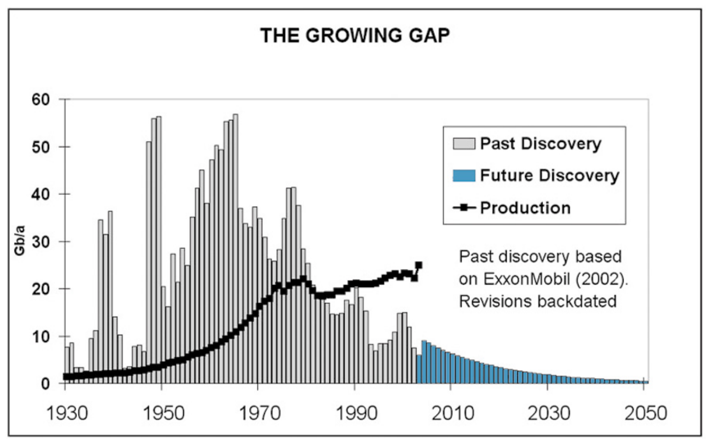


Figure 2: Where Have All the Dinosaurs Gone… Long Time Passing?—Oil comes from dead dinosaurs (according to the Fred Flintstone school of geology) and there aren't no more dinosaurs around to die….we aren't growing more dinosaurs. Let me translate. There is only a fixed amount of oil to find and that amount is a function of our Planets geologic history. When you are using twice as much as you are finding you will run out. I see a pattern developing here between current Government energy policy and current Government economic policy…Only a Government can spend twice as much as it collects. *Graph is courtesy of Chevron Oil*.

So what is this solution to energy security? The plug-in hybrid vehicle. That's it? Yes, that's it. Not fusion? No. Not solar? No. Not the flux capacitor? No.

A hybrid vehicle is nothing more than an electric vehicle with gasoline as the energy source for the electricity. When we add a big enough battery we can plug it in and

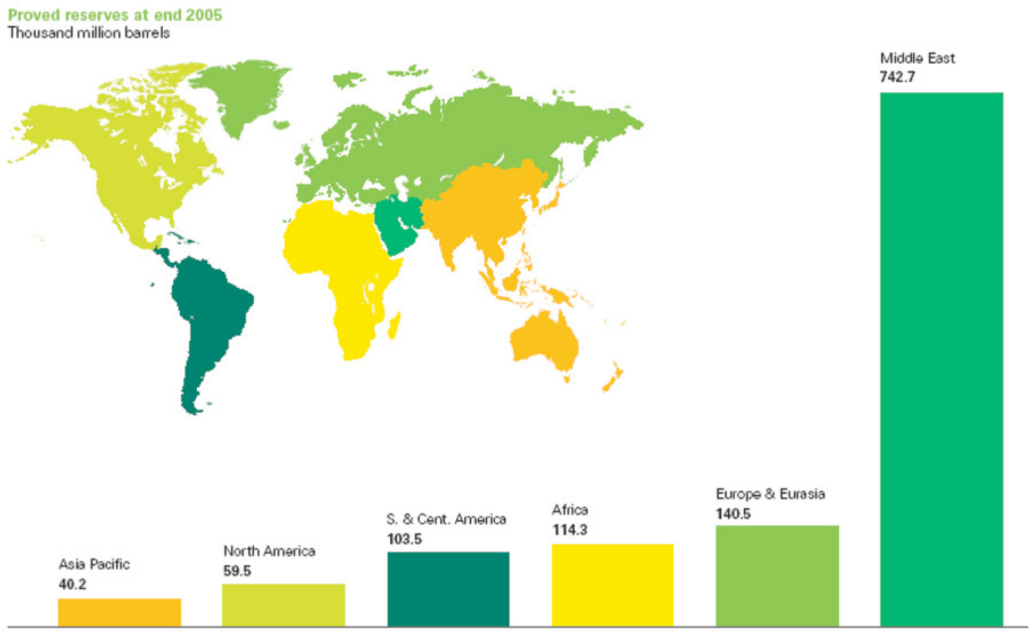


Figure 3: Who Has The Oil? Nice, stable governments. *Graph is courtesy of British Petroleum*.

horsepower in kilowatts? Do you have any idea what torque you can get with series-shunt electric drive? We don't have the tire technology to take the stress. Electric dragsters will leave the nitro burners in the dust.

So what is this transition of the transportation sector from petroleum to electricity and ethanol going to do to the rest of the economy? Well, electricity is going to get expensive—very expensive. And so is natural gas, because we make electricity from natural gas. Oh, we make electricity from coal too, but coal is dirty, and we are going to have to make it clean and that will make it expensive. So we will have expensive electricity made from natural gas and from clean coal. What about Nuclear? It will be cheaper to make the electricity out of clean coal than with Nukes. The big problem with Nuke is what to do with the waste. We were going to stick it in Nevada, but too many people live there now and the Congressional representation is now strong enough to kill that idea. So where to put it? What's a big state with no people and weak Congressional representation? I pick Montana.

run the vehicle using juice we get from the grid rather than juice we get from the gasoline. As we transition current hybrid vehicles from nickel hydride to lithium ion battery technology we are going to be able to plug-in the vehicle and get 50 to 75 miles between charges. This is a big deal because this is the distance of the average commute. And we don't have to worry about running out of battery power because we still have the gasoline there to take over when we run the battery down.

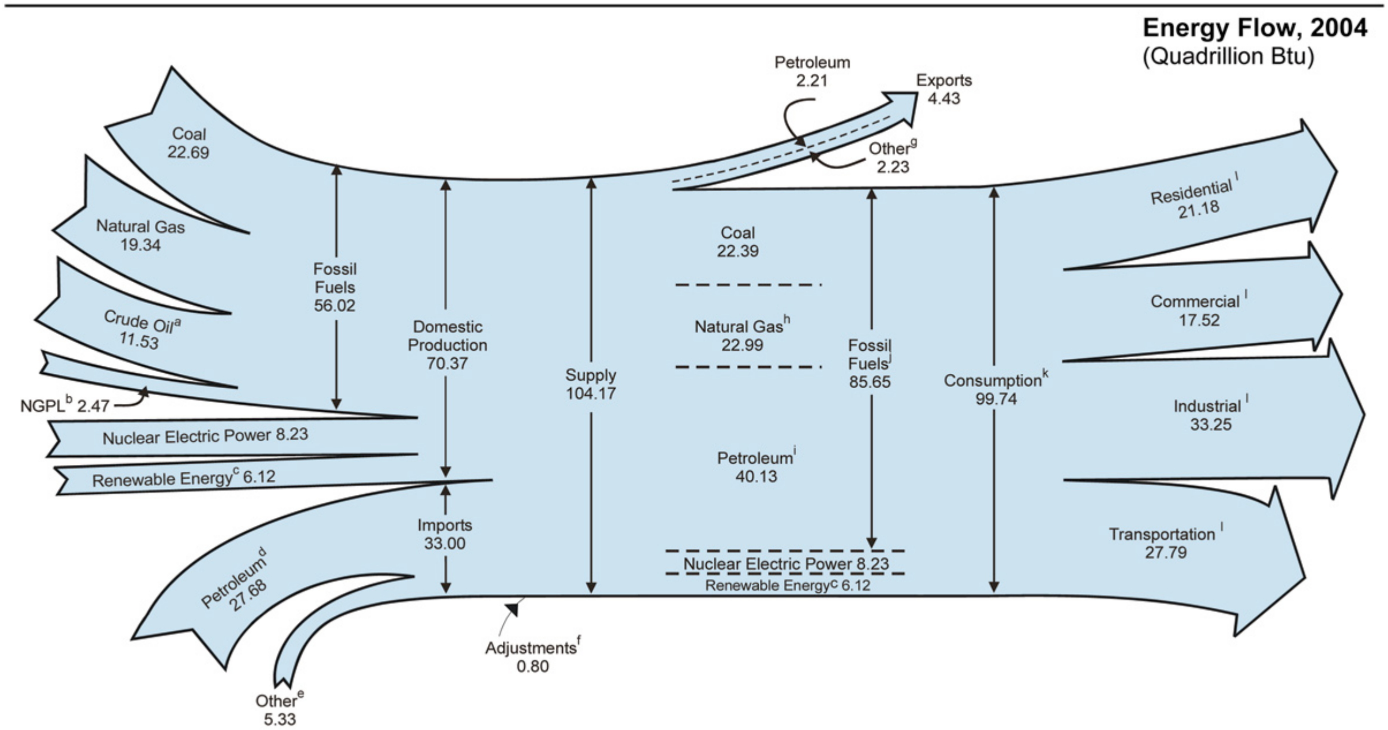
It gets even better when we dilute the gasoline with ethanol—and boy can we dilute it—up to 85 percent (E85 ethanol is 85 percent ethanol, 15 percent gasoline)—and presto—end of transportation energy problem, hello energy independence. The vehicles will have all electric drive[1] —gasoline/ethanol will be burned only to run a generator to charge the battery packs.

Will the vehicles get smaller? What are you on crack? This is America—the land of the 60 oz. Slurpee and the 40 oz. bladder. We are a nation of big assed Americans with big assed cars and trucks. We are going to go for high performance and size. How do you say 500 brake

With the plug-in hybrid I bet the cost of electricity will go to 35 cents/kilowatt and the cost of natural gas will double. At 35 cents/kilowatt that translates to 75 cent/gallon gasoline. Peanuts, nothing, zip, zilch. Electric plug-in hybrid vehicles win. The American Dream lives on—we do love our cars. Now, with winners, there are often losers.

Who loses? Pay attention here, now comes the fun part. Buildings consume 40 percent of all energy in the US economy (**Figure 4**)—more energy than the transportation sector (which pushes 30 percent). We cool our buildings with electricity and heat our buildings with natural gas. Folks, we are going to triple the cost of air conditioning and we are going to double the cost of heating. The transportation sector is going to compete

[1] The General Motors "Volt" is an impressive piece of work. The internal combustion engine runs only a generator to keep the battery pack charged. It is all electric drive. I had my doubts about GM–I still do–but they could actually pull this off. I can hardly wait for 2010 when it rolls out. This vehicle could change everything. Detroit could get its Mojo back – and help the Republic as well.



[a] Includes lease condensate.
[b] Natural gas plant liquids.
[c] Conventional hydroelectric power, wood, waste, ethanol blended into motor gasoline, geothermal, solar, and wind.
[d] Crude oil and petroleum products. Includes imports into the Strategic Petroleum Reserve.
[e] Natural gas, coal, coal coke, and electricity.
[f] Stock changes, losses, gains, miscellaneous blending components, and unaccounted-for supply.
[g] Coal, natural gas, coal coke, and electricity.
[h] Includes supplemental gaseous fuels.
[i] Petroleum products, including natural gas plant liquids.
[j] Includes 0.14 quadrillion Btu of coal coke net imports.
[k] Includes, in quadrillion Btu, 0.30 ethanol blended into motor gasoline, which is accounted for in both fossil fuels and renewable energy but counted only once in total consumption; and 0.04 electricity net imports.
[l] Primary consumption, electricity retail sales, and electrical system energy losses, which are allocated to the end-use sectors in proportion to each sector's share of total electricity retail sales. See Note, "Electrical Systems Energy Losses," at end of Section 2.
Notes: • Data are preliminary. • Totals may not equal sum of components due to independent rounding.
Sources: Tables 1.1, 1.2, 1.3, 1.4, 2.1a, and 10.1.

Energy Information Administration / Annual Energy Review 2004

Figure 4: Energy Flow In the US Economy—Neat graph – energy "input" into the economy on one side and where it goes – the "output" – on the other side. Note that the building sector currently uses the most energy – more than transportation and more than industry. The transportation sector will compete with the building sector for the same energy. Guess who will win? *Graph is from the US Energy Information Agency.*

with the building sector for the same energy and the transportation sector is going to win.

A rational person would say, OK, just make the buildings smaller, with smaller windows, and smaller appliances. I remind you this is America. Twiggy is an European icon. Anna Nicole is an American icon. Next question. We are not going to get smaller buildings but we are going to get ultra efficient buildings. We are going to double and triple the amount of thermal resistance in the typical building enclosure. We are going to insulate, and we are going to insulate big time.

Now this is both good and bad. Good for energy security, bad for building durability. Insulation reduces energy flow and here is a good time to remind everyone that there is no such thing as a free thermodynamic lunch. As the energy exchange across building enclosures reduces, drying potentials reduce and this means we are in for a world of hurt in the coming years in terms of corrosion, decay, mold and other moisture induced deterioration as we change our building technology to take into account the new energy cost realities. It gets ever worse, or better, depending on who profits from the problems, when you consider that over 80 percent of the buildings that will be around in 2035 are already here and they will have to be insulated as well (**Photograph 1** and **Figure 5**). Who knows how to do that? I can tell you who does not: the info babes and male models on cable TV doing renovation shows.

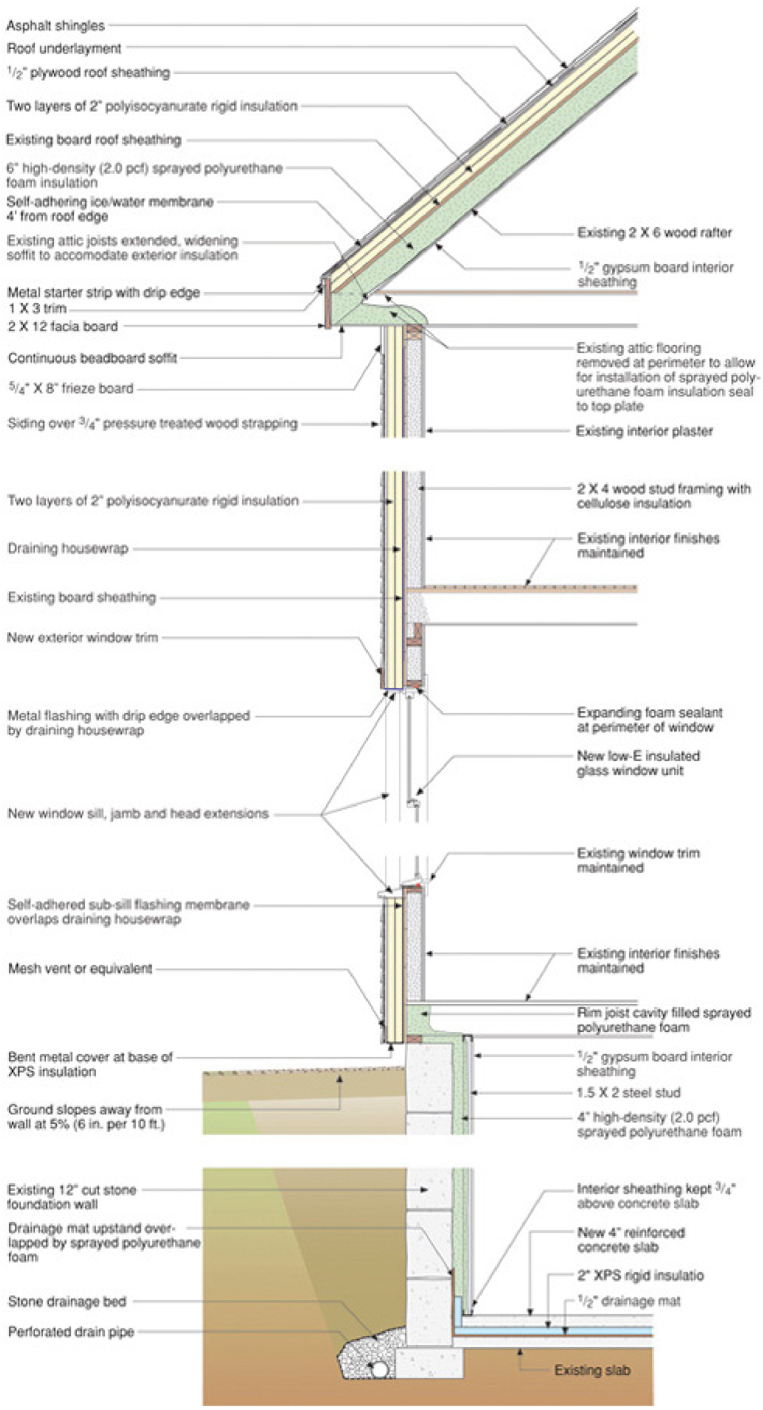


Figure 5: Super Insulated Retrofit—R-60 roof, R-40 walls, R-20 basement wall insulation, R-10 basement slab insulation. Reduces total energy consumption to 65 percent of that of a similar building constructed to the 2003 Model Energy Code.

Building science and building diagnostics and building technology and building rehabilitation are going to boom because things are going to bust. Can it get even better? Yes. They can't out source the jobs offshore to Bangalore, India. This has to be fixed by Americans right here in America. The future is not in plastics, my boy, the future is in construction. Actually, the future is in fixing construction.

Lets now go back a step and look at the ethanol part of this a little bit more closely. Where are we going to get the ethanol? Look around Grasshopper. The politicians are meddling. Corn is not the right play for the ethanol source, but that is where the subsidies are going. It is never smart to trade food for fuel. The price of corn is going way up. That means beef prices go up too—the Big Mac price index is in for a ride. Yes, food prices are going to go up because the politicians are meddling. Cellulosic ethanol is the answer, but we will get corn ethanol in the short term until this silliness gets sorted out.

Now, this is not the key point for us in the construction industry, entertaining as it may be. This ethanol thing is going to affect us in a big way once the marketplace figures out that cellulosic ethanol is the right play. One of the dominant building materials we use is cellulose fiber. It is likely to be a winner in the future as well. However, it does not make sense for us to get this cellulose fiber by cutting down 1,000-year-old trees in Washington State. We should be growing and harvesting our fibers in Iowa, and Nebraska and Mississippi and Alabama on plantations.

And we are beginning to do so. The days of 2x10's and dimensional lumber are over. The rise of engineered wood, OSB, hardboard, particleboard, fiberboard and laminated paper composites has arrived. All of these products are cellulose fiber based. All will be in competition for the same cellulose fibers that the transportation sector also covets. Cars will be competing with buildings for the same energy and raw materials. We know who will win. The car always wins. That means that the fibers the building sector will get will be second rate and expensive. And none of the engineered wood products are as durable as the real thing—wood. We will be adding stuff to the fibers to make the stuff work. I predict the stuff won't stay in the stuff and we will have environmental issues right along with the durability issues. Damage Functions and the Arrhenius[2] Equation here we come.

The steel industry and the concrete industry and the glass industry are going to take their lumps in all of this. Steel and glass and concrete architecture may win design awards, but you can't build energy-efficient structures out of steel and glass and concrete—unless you reduce the amount of glass and insulate the rest on the outside.

We are going to have fun boys and girls. Think about what lies ahead? Less robust materials in highly insulated building enclosures with low drying potentials. Stuff is going to stink, rot, break and otherwise annoy. This process has already begun, with part load humidity problems and mold. There are going to be a lot of mistakes in the next decade as we get all of these things sorted out. But I wouldn't trade this for anything else in the world. Because our country needs us to clean up the mess from the energy security ethanol hangover we are going to have.

Photograph 1: 1912 Sears Craftsman House Retrofit— Super insulated retrofit done to an existing century old building in Concord, MA. Section shown in **Figure 5**. This is what the future for existing buildings looks like.

[2] Svante Arrhenius. Dead, European, Nobel Prize Winner, no longer fashionable to study. Dr. Arrhenius showed that every 10 degree Kelvin rise in temperature "doubles the badness" for materials. Same for relative humidity and ultra-violet radiation. The Arrhenius Equation addresses the effect of the temperature, relative humidity and UV damage functions on building materials. He also "invented" the "Greenhouse Effect." It wasn't Al Gore – Mr. Gore was too busy inventing the internet…

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the Perfect Wall

Ultra efficient, to ensure energy will last for our grandchildren

by Joseph Lstiburek, PhD, PEng, FASHRAE

1000 years ago, stone enclosures - R-2 average performance.

500 years ago, thatched roofs improved enclosures - R-4 average performance.

350 years ago, post and beam, waddle and daub cavity construction - R-6 average performance.

250 years ago, log cabin timber construction - R-8 average performance.

100 years ago, mass wall, 10 percent glazing ratio - R-8 average performance.

In 1972, non-thermally broken aluminum curtain walls - R-1.5 average performance.

Today, thermally broken aluminum curtain walls - R-2 average performance.

Learn from this. Glass is the most expensive and does not work for creating an energy efficient building envelope. After 1000 years, we are still designing walls with R-2. It's the energy we are expending at **2.5 times** that of what we are finding.

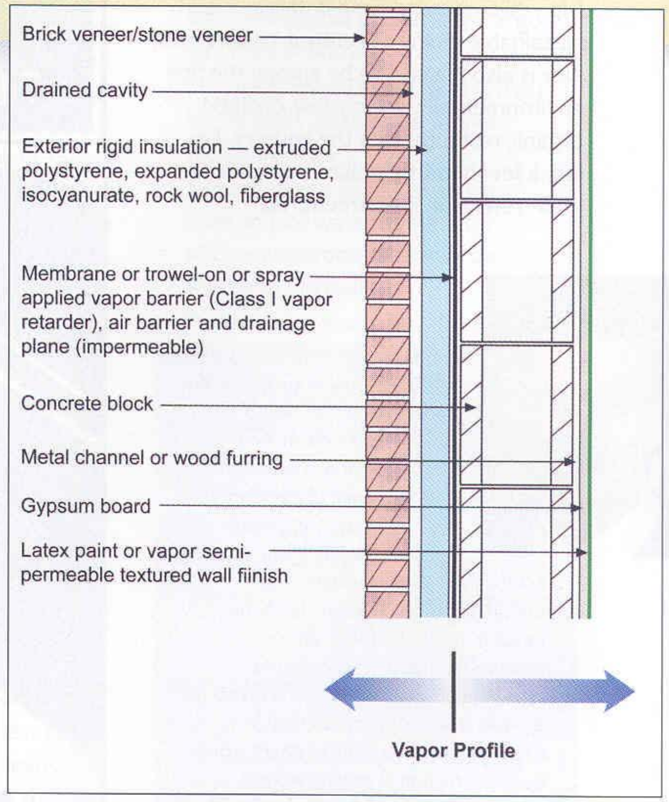

Figure 1: "The Institutional Wall" – The best wall that we know how to construct – it's the well insulated masonry cavity wall. Works everywhere in all climate zones.

Don't do stupid things. Life is tough enough.

Energy enters the US economy at a slower rate than what we consume. More energy goes into heating and cooling buildings than any other single use (40%) followed by the transportation sector (30%). We cool our buildings with electricity and heat our buildings with natural gas. We are going to triple the cost of air conditioning. We are going to double the cost of heating. The transportation sector will compete with the building sector for the same energy. The transportation sector will win.

A rational person would suggest making buildings smaller with smaller windows and smaller appliances. I remind you that this is America. We like to build big. We are not going to have smaller buildings, but we are going to have ultraefficient buildings. We will double and triple the amount of thermal resistance in the typical building enclosure. We will insulate. And insulate big time.

Energy security = changing design practices

This is good and bad. Good for energy security, bad for building durability. Insulation reduces energy flow. There is no such thing as a free thermodynamic lunch. Reducing the energy exchange across building enclosures reduces drying potentials. As we change our building technology to account for the new energy cost realities, we are in for a world of hurt in terms of corrosion, decay, mold and other moisture-induced deterioration. It gets worse, or better (depending on who profits from the problems), when you consider that more than 80% of the buildings that will be around in 2035 already exist and will need to be insulated. Who knows how to do that? I can tell you who does not: the models on TV doing renovation shows.

Building science, building diagnostics, building technology and building rehabilitation are going to boom because things are going to bust. Can it get even better? Yes. Jobs can't be outsourced offshore. This has to be fixed by Americans here in America. The future is in construction. Actually, the future is in fixing construction.

One of the dominant building materials we use is cellulose fiber. However, it does not make sense for us to get this cellulose fiber by cutting down 1000-year-old trees. We should grow and harvest fibers. We are beginning to do so. The days of 2 x 10s and dimensional lumber are over. The age of engineered wood – oriented strand board (OSB), hardboard, particle-board, fiberboard and laminated paper composites – has arrived. All these products are cellulose fiber based. All will be in competition for the same cellulose fibers that the transportation sector covets.

The fibers the building sector gets will be second rate and expensive. And, engineered wood products are not as durable as actual wood. We will be adding stuff to the fibers to make that product work. I predict this will be stuff that won't stay for the sake of durability. Damage functions and the Arrhenius[1] equation, here we come.

The steel, concrete and glass industries will take their lumps. Steel, glass and concrete architecture may win design awards, but you can't build energy-efficient structures out of them, unless you reduce the amount of glass and insulate the rest on the outside. LEED gives points for daylighting in certifying buildings. But, when more than 30% glass is used in a building, it is not socially responsible.

We are going to have fun. Think about what lies ahead: less robust materials in highly insulated building enclosures with low drying potentials. Stuff will stink, rot, break and annoy. This process already began with part load humidity problems and mold.

If you do the wrong thing right, it's still wrong, right?

The Perfect Wall will last a long time. People will take care of it. They like pretty things. People do not take care of ugly things. Ugly is not sustainable. Ugly is a machine that has to be fed.

Introducing the Insulated Masonry Cavity Wall – The Perfect Wall

The perfect wall is an environmental separator –it has to keep the outside out and the inside in. To do this, the wall assembly has to control rain, air, vapor and heat. In the old days, we had one

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[1]*Dr. Svante Arrhenius. Dead, European, Nobel Prize Winner, no longer fashionable to study. Arrhenius showed that every 10° Kelvin rise in temperature "doubles the badness" for materials. Same for relative humidity and ultra-violet radiation. The Arrhenius Equation addresses the effect of the temperature, relative humidity and UV damage functions on building materials. He also "invented" the "Greenhouse Effect."*

material to do this: rocks. We would pile a bunch of rocks up and have the rocks do it all. But over time rocks lost their appeal. They were heavy and fell down a lot. Heavy means expensive. And falling down is annoying. So construction evolved. Today walls need four principal control layers – especially if we don't build out of rocks. They are presented in order of importance:

- a rain control layer
- an air control layer
- a vapor control layer
- a thermal control layer

A point to this importance: If you can't keep the rain out, don't waste your time on the air. If you can't keep the air out, don't waste your time on the vapor.

The best place for the control layers is to locate them on the outside of the structure to protect the structure (Figure 2). When we built out of rocks, the rocks didn't need much protection.

When we build out of steel and wood, we need to protect the steel and wood. And since most of the bad stuff comes from outside, the best place to control the bad stuff is on the outside of the structure before it gets into the structure. Also, after generations of building out of rocks, folks somehow got the idea that they wanted to be comfortable – and they figured out that rocks were not the best insulation. Rocks are not that bad compared to windows. Memo to architects: You can't build an energy efficient green building out of glass, but you can get design awards. We all know which is more important.

Back to rocks: They are heavy. You need a lot of them to make the wall have any decent thermal resistance so we invented thermal insulation.

But where to put the insulation? If we put the insulation on the inside of the structure, the insulation does not protect the structure from heat and cold.

Remember, we really do want to protect that darn structure – especially for the sake of making the structural engineer's life happier. Expansion, contraction, corrosion, decay, ultraviolet radiation and almost all bad things are functions of temperature; so all the control layers go on the outside. Keep the structure

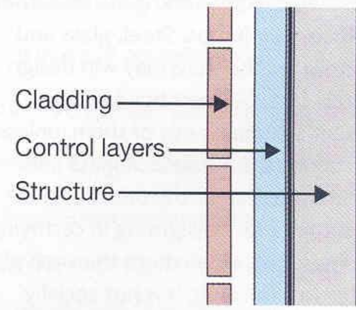

Figure 2: "The Perfect Wall"
In concept, the perfect wall has the rainwater control layer, the air control layer, the vapor control layer and the thermal control layer on the exterior of the structure. The cladding's function is principally to act as an ultraviolet screen. Oh, and architects might consider the aesthetics of the cladding to be important.

Keep the structure from going through temperature extremes. Protect it from water in its various forms and ultraviolet radiation and life is good.

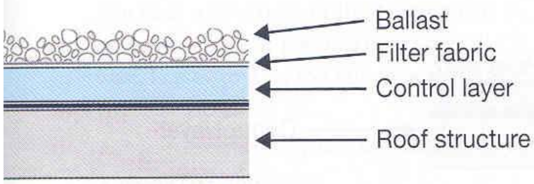

Figure 3: "The Perfect Roof"
The perfect roof is sometimes referred to as an "inverted roof" since the rainwater control layer is under the insulation and ballast (i.e. roof cladding). Personally, I don't view it as inverted. Those other folks got it wrong by locating the membrane exposed on the top of the insulation – it is they who are inverted.

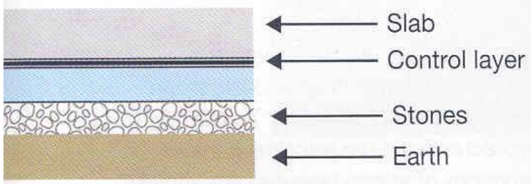

Figure 4: "The Perfect Slab"
The perfect slab has a stone layer that separates it from the earth that acts as a capillary break and a ground water control layer. This stone layer should be drained and vented to the atmosphere – just as you would drain and vent a wall cladding.

from going through temperature extremes. Protect it from water in its various forms and ultraviolet radiation and life is good.

What about this air control thing? Well, air can carry a lot of water and water is bad for the structure. So we have to keep air out of the structure as well because of the air-water thing – or if we let it get into the structure, we have to make sure it does not get cold enough to drop its water. Now, just one other thing tends to be important if you intend on living or working or keeping things safe in the building. We might want to control the interior environment.

We especially ought to be concerned about what is in the interior air because when we are in the interior we tend to breathe it. Well, it turns out that we can't control air until we enclose air. So we need an honest-to-goodness airtight enclosure to provide conditioning such as filtration and air change and temperature and humidity control. And once again, the best place to control this air thing is on the outside of the structure – but under the insulation layer so the air does not change temperature. **Presto: the perfect wall!** A water control layer, air control layer and vapor control layer directly on the structure and a thermal control layer over the top of the other control layers. (See Figure 2.)

This was figured out long before I was born – I think the Canadians figured it out first[2], but the Norwegians have some claims to this, plus the Russians. I am going to go with the Canadians on this one because I am biased and proud of it. For a more detailed discussion of the

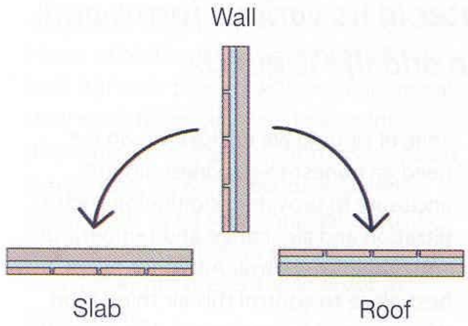

Figure 5: A Wall is a Roof is a Slab – The physics of walls, roofs and slabs are conceptually the same.

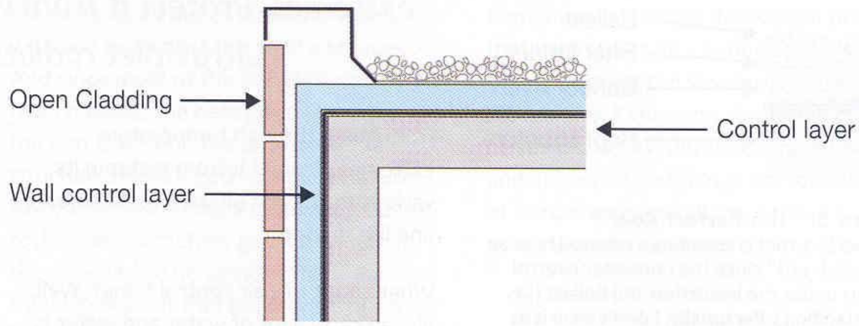

Figure 6: "The Roof-Wall Connection" Notice that the control layer for rain on the roof is connected to the control layer for rain on the wall, the control layer for air on the roof is connected to the control layer for air on the wall… and so it goes.

physics of all of this go to the old masters: Hutcheon and Handegord[3] and the new kids on the block, Burnett and Straube[4].

They're all connected: Roof, Slab, Walls

In a beautiful bit of elegance and symmetry, if you lie the perfect wall down you get the perfect roof (Figure 3). And then when you flip it the other way you get the perfect slab (Figure 4). The physics of walls, roofs and slabs are pretty much the same – no surprise (Figure 5). This insight was shone into a whole generation of practioners by Max Baker[5] when I was first getting started.

Notice in the perfect roof assembly, the critical control layer or membrane for rainwater control and air control and vapor control is located under the thermal insulation layer and the stone ballast (i.e. "roof cladding") so that it is protected from the principal damage functions of water, heat and ultraviolet radiation. Arrhenius would be proud. Why we put the most critical control layers on roofs on the very, very top where they can be trashed by these damage functions never fails to amaze me. Yes, I know, they are easier to replace when they are located there. Standard answer for our disposable, unlimited resource available society.

Most problems in building enclosures occur where roofs meet walls. The classic roof-wall intersection is presented in Figure 6 (with both credit and apology to Max Baker). Notice that the control layer for rain on the roof is connected to the control layer for rain on the wall, the control layer for air on the roof is connected to the control layer for air on the wall ... and so it goes. Beautiful. And when it is not so, ugly.

Time to put some meat on the bones of Figure 2. How should this perfect "conceptual" wall actually be built?

References

[2]Hutcheon, NB, CBD – *"50 Principles Applied to a Masonry Wall," Canadian Building Digest, National Research Council Canada, Ottawa, Ontario, Canada, February 1964*

[3]Hutcheon, NB, and Handegord, GO; *"Building Science for a Cold Climate," National Research Council of Canada, 1983*

[4]*JF Straube and Burnett, EFP; "Building Science for Building Enclosures," Building Science Press, Westford, MA, 2005 (buildingsciencepress.com)*

[5]*Baker, M; "Roofs," Multi-Science Publications Ltd, Montreal, 1980*

The best of the best of the best can be found in Figure 1. This is a very special wall. I refer to it as the 500-year wall for these reasons:

- it represents 500 years of evolution
- it will last 500 years

It is the type of wall that typically had been saved for special buildings. Buildings that are passed down from one generation to the next. Museums, art galleries, courthouses, libraries. I call this wall the "institutional wall." It is sweet in that it can be constructed in any climate zone. The only thing that may be changed is the level of thermal insulation. My advice here is very simple: Whatever you think the right amount of thermal insulation should be, double it. If you love your kids, don't argue with me.

My advice here is very simple: Whatever you think the right amount of thermal insulation should be, double it!

Joseph Lstiburek, BASc, M Eng, PhD, P Eng, FASHRAE, is a principal of Building Science Corporation in Waterloo, Ontario. He is one of the world's foremost authorities on energy efficient construction techniques. He is an expert in the areas of rain penetration, air barriers, vapor barriers, air quality, durability and construction technology. He specializes in rain damage and mold and microbial contamination of buildings. Lstiburek is past chairman of ASTM E241–*Increasing the Durability of Building Assemblies from Moisture Induced Damage*, contributor and reviewer of Chapters 21 and 22 of ASHRAE Fundamentals, voting member of ASHRAE Standard 62 – *Ventilation for Acceptable Indoor Air Quality*, ASHRAE Technical Committee 4.3 – *Ventilation Requirements and Infiltration*, ASHRAE Technical Committee 4.4 – *Building Materials and Building Envelope Performance*, author of numerous books and technical papers on building construction, building science, indoor air quality and durability

Lstiburek earned a Bachelor of Applied Science in Mechanical Engineering, Master of Engineering in Civil Engineering and a Doctorate in Building Science at the University of Toronto. He has been a licensed Professional Engineer in the Province of Ontario since 1982. **joe@buildingscience.com**

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the High R-WALL Model

Insulated Masonry Cavity Wall Reaches R-30+, 275% Higher Than Required by Michigan's Current Energy Code*

Think Performance!! *by Dan Zechmeister, PE, and Elizabeth Young*

CONTINUING EDUCATION

LEARNING OBJECTIVES

Upon reading the article you will:

1. Be able to calculate R-value for a masonry cavity wall with various insulation types.
2. Discover that the insulated masonry cavity wall has built in flexibility expandable to meet almost any design requirements.
3. Explore options for going well above and beyond today's minimum energy code requirements for commercial buildings.

R U losing heat? An energy crisis is upon us. Architects, mechanical engineers and owners are looking for ways to make buildings more energy efficient. Whether people are looking for ways to reduce the impacts of climate change or for savings on their energy bills, these days the masonry industry is being asked for more and more advice on building tighter, more efficient wall envelopes.

It is time to **THINK BIG!** Masonry is capable of so much. When masonry is chosen, designers and owners should take advantage of Masonry for ALL Its Worth. The insulated masonry cavity wall is extremely thermally efficient, durable and long lasting. Masonry has excellent acoustical properties, fire safe properties and is beautiful. It is a proven performer over millennia. But we can and we should still take advantage of more of masonry's attributes.

As ASHRAE Fellow Joseph Lstiburek, PhD, PEng, explains in his ASHRAE Journal, July 2008 article "Energy Security (and Saving the Planet)," there is "no such thing as a free thermodynamic lunch." Lstiburek explains, increased demand for hybrid vehicles will result in a struggle over electricity and the natural resources that produce it. Currently, buildings consume more than 40% of the energy in the US, with the transportation industry closing in on 30%. A civilization so married to its cars, we will soon see the transportation industry with the lion's share. Once that happens, Lstiburek predicts "we are going to triple the cost of air conditioning and double the cost of heating" our buildings.

Ahead of the Energy Game

Starting now, those of you designing and building loadbearing masonry buildings can help prevent unnecessary demand for energy by reducing the amount it takes to comfortably heat and cool a building. Strive to build masonry walls with an R-30+ model, 275% higher than required by Michigan's current energy code (ASHRAE 90.1-1999 *Energy Standard for Buildings Except Low-Rise Residential Buildings*, which requires R-7.6 continuous insulation for mass walls in Zone 5 (Detroit, Grand Rapids and Chicago) and 200% higher than is even required under ASHRAE 90.1-2007, the most current release and the reference used in prerequisite 2 (minimum energy performance) for the Optimal Energy Performance credits in Energy and Atmosphere category of LEED 2009. Think innovation credit here for greatly exceeding the requirement.

> *Build masonry walls with an R-30+ model, 275% higher than required by Michigan's energy code*

Increasing the thermal performance of the wall envelope will result in a more energy efficient building and lower energy costs over its lifetime, but increased performance of the envelope also allows for design and installation of a smaller, more efficient and less expensive HVAC system.

New Standards Raise the Bar

Since its launch in 2000, nearly 2000 buildings have become certified under the LEED for New Construction (NC) program. That is an impressive number, but LEED remains mostly a voluntary program. Michigan has 131 buildings certified, but another 451 that have been registered. Eighty-nine buildings within the city limits of Chicago alone have been certified and another 506 registered. The commitment is growing exponentially.

The American Institute of Architects (AIA) has set a goal for new and renovated buildings to be operating at zero carbon emissions by the year 2030. They are garnering support from the Obama adminstration, US Conference of Mayors, National Association of Governors and National Association of Counties, who have all agreed to write or revise energy policies in their jurisdictions to include provisions

**ASHRAE 90.1-1999 Energy Standard for Buildings Except Low-Rise Residential Buildings/2001 International Energy Conservation Code (IECC) or Equivalent. Illinois requires ASHRAE 90.1-2007/2009 IECC or Equivalent. Indiana's requirements are less stringent than Michigan's.*

relating to the built environment. Requirements and regulations for energy performance are not far away.

Cured concrete masonry units (CMU), unsealed and not painted, actually absorb CO_2 from the atmosphere. Over several years, 0.6 lbs of CO_2 per CMU (containing 3 lbs cement) is reabsorbed. Absorption is higher for CMU than for poured or wet cured concrete products because of its greater porosity. (AIA Environmental Resources Guide 1996-98.)

Portland Cement Association (PCA) has developed a sample ordinance to address high performance buildings. The PCA model includes guidelines for building structures that are more durable – resistant to fire, wind storms, flood, seismic events, hail impact and other potential disasters. Adoption of this ordinance will increase the appeal of masonry to designers, owners and building officials. Masonry is an obvious choice to meet these goals.

The International Code Council (ICC) has come on board, too. Its Sustainable Building Technology Committee (SBTC) is developing an International Green Construction Code that will set a baseline of green requirements that build upon the ICC Family of Codes, provide a regulatory framework mindful of green building rating systems, provide criteria to drive green building into everyday practice and address items such as energy efficiency and the building's impact on environment.

In fact, after devastating fires of the early 1990s, many jurisdictions throughout California set standards for building in high-hazard fire-risk zones. Most of the structures built in areas of high risk have at least some special features common to the International Urban-Wildland Interface Code (IUWIC), such as non-combustible wall surfaces, often masonry. This summer alone saw fires engulf 120,000 acres across Southern California.

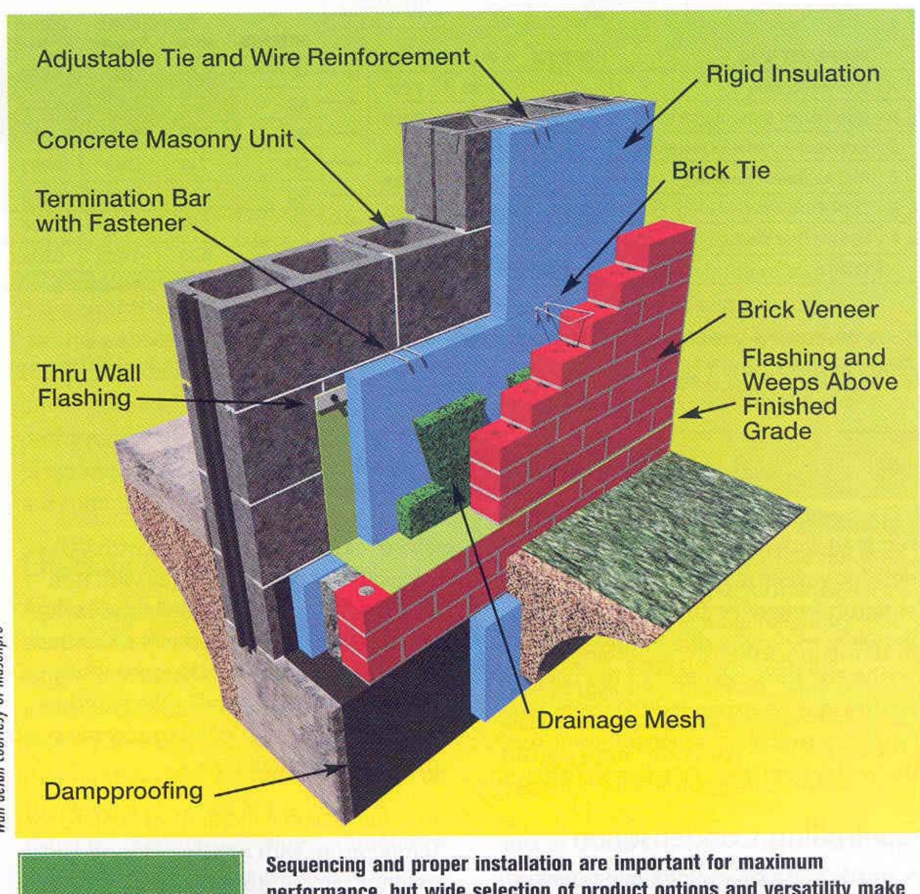
The bottom line is that things are changing. There is no status quo anymore. What was good yesterday must be improved today. The insulated masonry cavity wall is no exception. The masonry option is the best choice for low- to high-rise buildings. It is an adaptable option that can be designed to meet almost any configuration when it comes to sustainability, which encompasses energy efficiency, durability, low maintenance, fire safety, acoustics, etc.

Expanded Cavity Wall – a Diamond in the Rough

Because of the way an insulated masonry cavity wall is constructed, it can be expanded. Typically, CMU is laid, vertically and horizontally reinforced, flashed, dampproofed and/or waterproofed and/or air/vapor barrier applied if required, closed cell rigid or foam insulation installed in the cavity with remaining air space left for drainage, then the masonry veneer is anchored to the CMU. Read more about the four control layers: rain control layer, air control layer, vapor control layer and thermal control layer as explained by Lstiburek in his article "The Perfect Wall," on page 18 of this issue. Within the overall nominal wall thickness, the size, amount and type of products may vary. The backup wythe consisting of CMU may be 8", 10", 12", 14", even 16" in thickness. Cores of the CMU may be partially or fully grouted per structural requirements. Insulation may be closed cell rigid board (extruded polystyrene or foil faced polyisocyanurate) or sprayed on polyurethane foam. The exterior wythe of masonry veneer may be CMU, clay brick or stone. Masonry's versatility makes it attractive; it can be configured to meet almost any design requirements. (See Figure 1 below.)

To Your Advantage

Use the proposed high R multi-wythe masonry mass wall model to optimize energy performance. See Brick and Block Cavity Wall charts (Tables 3-5) to determine desired R-Value and options to attain it. Adopt maximum efficiency as your new standard. Take advantage of the fact that today's typical designs already incorporate masonry veneer with adjustable ties at a closer spacing than

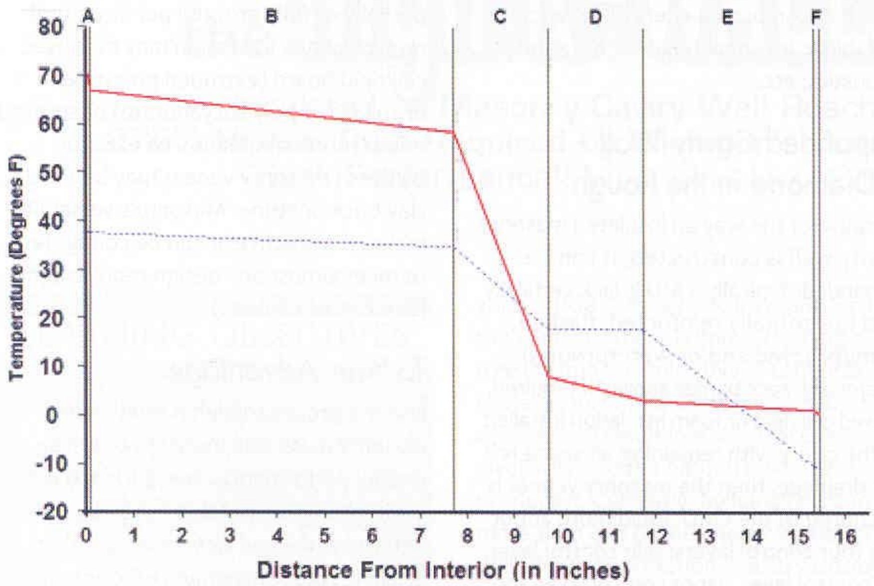


Wall detail courtesy of Masonpro

Figure 1 Cavity Wall

Sequencing and proper installation are important for maximum performance, but wide selection of product options and versatility make the insulated masonry cavity wall an attractive option.

DEWPOINT ANALYSIS



Legend	
———	Actual Temperature
- - - - -	Dewpoint Temperature

Dewpoint Theory predicts condensation in a system at any point where the actual and dewpoint temperature lines cross

Conditions		
Temperature	7.0	0.0
Humidity	3.0	5.0

	COMPONENT NAME	THICKNESS	R-VALUE	REP
A	Interior Air Film	0.100	0.68	0.001
B	Lightweight Block Agg 8 in	8.000	1.70	0.400
C	Extruded Polystrene Insulation	2.000	10.00	1.800
D	Wall Air Space NonRefl	2.000	0.97	0.016
E	Brick Face 4 in	3.625	0.4	1.178
F	Out Air Film Winter	0.100	0.17	0.001
	Total	15.450	13.92	3.396

INTERFACE	TEMPERATURE Actual	TEMPERATURE Dewpoint	ACCUM (oz/day-sf)
-A	70.00	37.28	0.000
AB	67.20	37.27	0.000
BC	58.03	34.59	0.000
CD	7.74	17.60	*0.003
DE	2.87	17.39	*0.003
EF	0.85	-10.93	0.000
FG	0.00	-10.98	0.000

* indicates area of condensation potential

Notice: This calculation is based on the theory of Water Vapor Migration presented in the ASHRAE 1993 Fundamentals Handbook. Actual performance may vary depending upon air infiltration, workmanship and building materials. Since the information is provided without charge, The Dow Chemical Company assumes no obligation or liability for its use.

Table 1 (winter) 8" block with rigid insulation

required with masonry backup. With a detailed wall-tie analysis performed by the structural engineer, the cavity (distance between the cavity side of the exterior wythe and the cavity side of the backup wythe) may be expanded to increase the insulation to achieve a higher R-value for the wall system. (See Side Bar on page 36.)

Controlling Condensation

A steady state dewpoint analysis was conducted using wintertime conditions of 70° interior temperature with 30% humidity and 0° exterior temperature with 55% humidity for an 8" CMU wall with R-10 continuous rigid insulation in the cavity and no vapor barrier. Results show the dewpoint occurring within the vicinity of the drainage cavity and in the exterior wythe, which is designed to accommodate moisture. (See Table 1.)

In summertime conditions of 70° interior temperature with 40% humidity and 90° exterior temperature with 90% humidity, no dewpoint is present in the wall. (Not shown.)

Determining Cavity Wall R-Values

R-value is a measure of thermal resistance. The higher a wall's R-value, the more resistant to steady state thermal loss or the better the insulative qualities of the wall. Values are measured under laboratory conditions in accordance with ASTM C1363. A material is evaluated for the flow of heat through it while one side of the material is held to a steady temperature. The amount of supplemental energy required to keep the other side of the material at a different constant temperature determines the R-value.

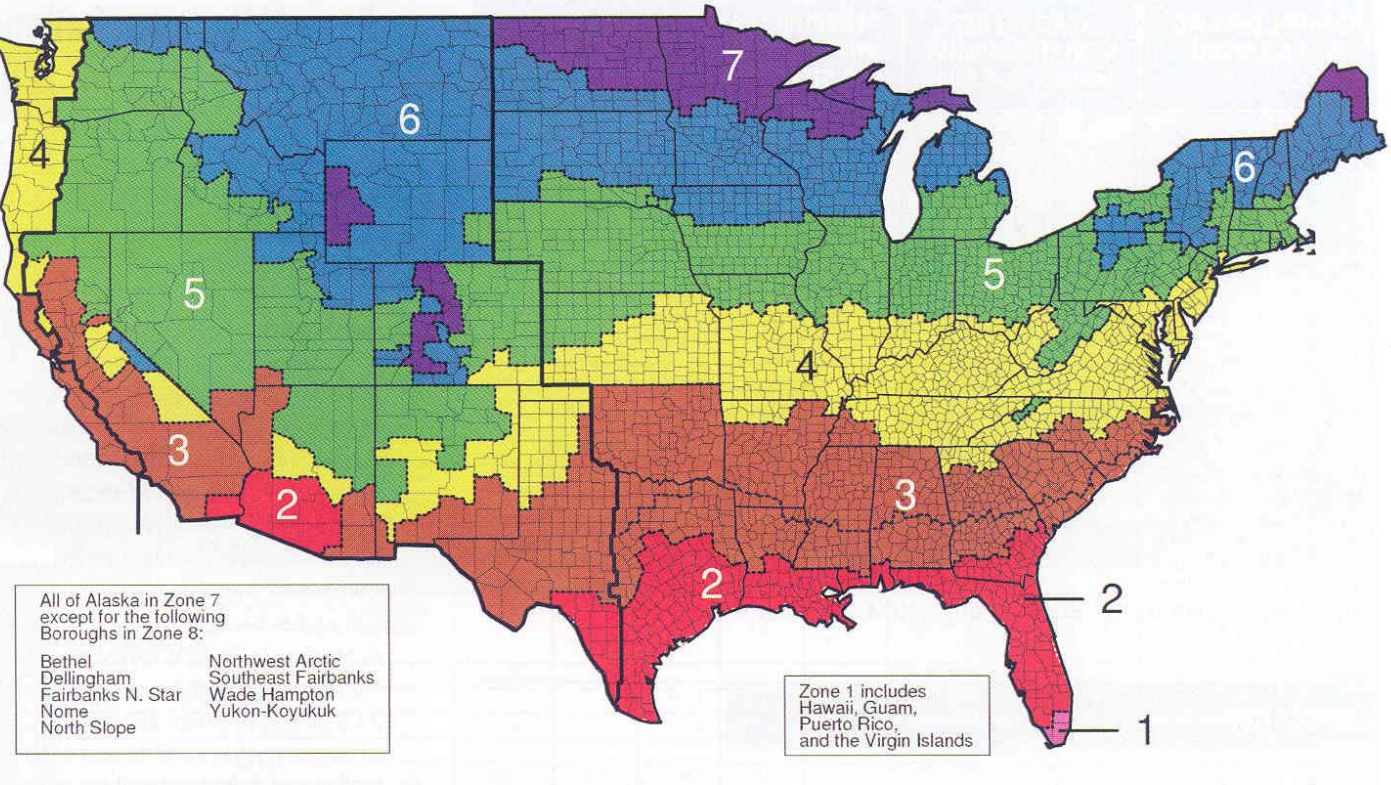
Multi-wythe masonry wall R-values are easily determined from existing industry tools and tables. NCMA TEK 6-1B, R-Values of Multi-Wythe Concrete Masonry Walls, presents R-values of various backup wythes, cavity insulations and veneers, which are subsequently added together to determine the overall R-value of the wall, as shown in Tables 3-5. NCMA TEK 6-2B, R-Values and U-Factors of Single Wythe Concrete Masonry Walls and BIA Technical Note 4 also provide information on determining R-values for various masonry applications.

Meeting Minimum Requirements

ASHRAE Standard 90.1 allows for prescriptive demonstration of compliance. Using the prescriptive method means complying with R-values or U-factors for walls above grade as stated by industry approved documentation, charts or tables. ASHRAE 90.1 provides two prescriptive compliance options: an overall wall U-factor or an insulation R-value. The wall needs to comply with one or the other, not both.

ASHRAE 90.1-99 is referenced by 2001 IECC (International Energy Conservation Code) Prescriptive R-value minimum requirements for the upper Midwest includes Zones 5, 6 and 7, are 7.6, 9.5, 11.4 continuous insulation respectively. (See Figure 2.) (90.1-2007 raises minimum requirements for Zone 5, which includes the lower half of MI and most of IL to 11.4 continuous insulation.) R-value requirements take into account thermal mass by allowing masonry walls to have

CLIMATE ZONES



Courtesy of ASHRAE

Figure 2 – Climate Zones Recognized by ASHRAE 90.1

a lower required R-value than non-mass walls (metal building, steel framed and wood framed). For a steel frame building in Zone 5, that R-7.6 value requirement for a masonry wall goes up to R-13 plus R-3.8 continuous insulation. The load-bearing CMU wall serves as the more thermally efficient choice.

A second acceptable method of demonstrating compliance includes system performance, which is a trade-off option. This option does allow lower R-values in one portion of a building envelope to be made up in another. For example, a roof that exceeds minimum prescriptive requirements can be used to offset a wall R-value lower than the prescriptive minimum. This kind of option is easily done through a software product such as COMcheck-EZ (energycodes.gov).

The third and final option is whole building analysis. This is highly advanced energy cost budgeting or energy modeling, which takes into account all aspects of building energy use, hour by hour, over the course of a year. This is the most challenging, but also perhaps the most accurate demonstration of a building's expected energy efficiency and performance. Department of Energy programs such as Energy Plus and DOE 2 are common for this analysis.

Effective R-Value

An R-value is a calculated number arrived at scientifically, again, under steady state laboratory conditions. In the dynamic conditions of a building's use, the actual performance of a wall system, for example, may not equal the performance based on the R-value obtained in the lab. This dynamic, real-world R-value is sometimes known as the Effective R-value. A high mass wall, such as an insulated masonry cavity wall, may effectively perform more energy efficiently than the individual steady state sum of its parts. Basically, the thermal performance of a masonry wall is made up of a steady state component (R-value) and a transient component (thermal mass). Current codes[1] recognize thermal mass by allowing masonry walls to comply using lower R-values than non-mass walls must meet.

That said, however, it can be difficult to put an official effective R-value number on a wall system, as performance varies based on climate in a building's specific geographic location, its solar orientation, type of masonry materials, type and location of insulation, internal heat gain, such as from lights, electrical equipment, people, hours of occupancy and more.

Just as a wall system of metal stud, batt insulation and gypsum board will likely have a lower effective R-value due to thermal bridging and potential

INSULATION & STEEL STUDS

NOMINAL FRAMING DEPTH & SPACING	"LABELED" BATT INSULATION R-VALUE (between steel studs)	"EFFECTIVE" R-VALUE W/BATT INSULATION & STEEL STUDS[2]	WALL THERMAL EFFICIENCY
4″ @ 16″ on center	R-11	5.5	50%
	R-13	6.0	46%
	R-15	6.4	43%
4″ @ 24″ on center	R-11	6.6	60%
	R-13	7.2	55%
	R-15	7.8	52%
6″ @ 16″ on center	R-19	7.1	37%
	R-21	7.4	35%
6″ @ 24″ on center	R-19	8.6	45%
	R-21	9.0	43%

Data Source: ASHRAE/EIS Standard 90.1–2004, Appendix A.

Table 2 – Effective R-value with batt insulation and steel studs

condensation at the studs than the steady state sum of its parts, see Table 2, a system of insulated masonry cavity wall will likely have a thermal performance better than the expectation. Energy monitoring over time is the only way to identify a wall system's effective performance. Even so, that can only be beneficial to the system, not individual wall components, making it difficult to speculate on a building envelope's potential effective R-value. A well-designed building should yield exceptional results, optimizing energy performance for the life of the building. Energy modeling does, however, have potential to be an interactive teaching tool, ensuring that the owner's resources go to the places where the most effect can be made.

"The amount of supplemental energy required to keep the other side of the material at a different constant temperature determines the R-value."

For example, taking advantage of daylighting and a building's orientation in conjunction with a tight thermal envelope can eliminate high upfront and operational costs of a large HVAC system in favor of a more cost effective and smaller system that can perform effectively in an already optimized space. Architects and mechanical engineers should work together to holistically evaluate the effective performance of the systems instead of designing a system to only meet the needs of a prescriptively arrived at individual R-value.

RU losing heat? No, **UR** saving energy with the expanded multi-wythe closed cell insulated masonry cavity wall system for the entire life of the building!

Wall Tie Analysis May Allow Cavity Width to Exceed Code Limitations

Anchor Requirements (up to 60')

Building Code Requirements for Masonry Structures (ACI 530-05/ASCE 5-05/TMS 402-05) allow for the cavity between the CMU backup and the masonry veneer to be 4½" maximum with a 1" minimum air space reserved for drainage. (Two inches or 51mm is considered the minimum space required for keeping the cavity free of mortar dropping and increasing resistance to water penetration according to NCMA [TEK 19-2A] and Canadian Standards Association CSAS304.1, as referenced in the Commentary section of ACI 530-05/ASCE 5-05/TMS 402-05.) According to Code Section 2.1.5.3 Noncomposite Action, subsection 2.1.5.3.1 (e); specified distances between wythes shall not exceed 4.5" unless a detailed wall-tie analysis is performed. Scott Walkowicz, PE, principal at Walkowicz Consulting Engineers, provided analysis using the International Building Code generated components and cladding loads for a building less than or equal to 60' tall for Exposure Category C conditions. The analysis assumes ties at 16" oc each way and uses Method 1 from ASCE 7-05 to calculate a maximum positive pressure of 23.7 psf.

Currently, Chapter 6: Veneer of the ACI 530 Code requires an adjustable two-piece anchor be provided for at least each 2.67 sf of wall area for the exterior masonry veneer wythe. Also, Chapter 2: Allowable Stress Design of Masonry of the ACI 530 Code requires that when using adjustable ties for noncomposite action, one tie shall be provided for each 1.77 sf of exterior masonry wythe. Currently, the industry is recommending controlling potential shrinkage in concrete masonry backup by placing horizontal joint reinforcement

BRICK & BLOCK CAVITY WALL INSULATION OPTIONS

Table 3: Extruded Polystyrene

BRICK & BLOCK CAVITY WALL										
total cavity space thickness (inches) including insulation and drainage cavity with adjustable ties spaced every 1.77 sf		3.5[1]	4[1]	4.5[1]	4.5[1]	5[2,7,8]	5.5[2,7,8]	6[2,8]	6.5[2,8]	7[2,8]
	thickness									
outside air surface (winter)[3]		0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17
4" face brick[3]	3.625	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40
air space (winter)[3,6]										
1"	1.0	0.97	0.97	0.97						
2"	2.0				0.97	0.97	0.97	0.97	0.97	0.97
insulation in cavity space										
2.5" extruded polysyterene, R-5.0/inch[5]	2.5	12.50			12.50					
3.0" extruded polysyterene, R-5.0/inch[5]	3.0		15.00			15.00				
3.5" extruded polysyterene, R-5.0/inch[5]	3.5			17.50			17.50			
4.0" extruded polysyterene, R-5.0/inch[5]	4							20.00		
4.5" extruded polysyterene, R-5.0/inch[5]	4.5								22.50	
5.0" extruded polysyterene, R-5.0/inch[5]	5									25.00
8" medium weight CMU[4] (115 pcf, @48"o.c.)	7.625	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14
inside air surface (winter)[3]		0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68
total wall thickness, inches		14.75	15.25	15.75	15.75	16.25	16.75	17.25	17.75	18.25
calculated R-value		15.86	18.36	20.86	15.86	18.36	20.86	23.36	25.86	28.36

Table 4: Spray Polyurethane Foam

BRICK & BLOCK CAVITY WALL										
total cavity space thickness (inches) including insulation and air space with adjustable ties spaced every 1.77 sf		3.5[1]	4[1]	4.5[1]	4.5[1]	5.0[2,7,8]	5.5[2,7,8]	6[2,8]	6.5[2,8]	7[2,8]
	thickness									
outside air surface (winter)[3]		0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17
4" face brick[3]	3.625	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40
air space (winter)[3,6]										
1"	1.0	0.97	0.97	0.97						
2"	2.0				0.97	0.97	0.97	0.97	0.97	0.97
insulation in cavity space										
2.5" spray polyurethane foam, R-6.8/inch[5]	2.5	17.00			17.00					
3.0" spray polyurethane foam, R-6.8/inch[5]	3		20.40			20.40				
3.5" spray polyurethane foam, R-6.8/inch[5]	3.5			23.80			23.80			
4.0" spray polyurethane foam, R-6.8/inch[5]	4							27.20		
4.5" spray polyurethane foam, R-6.8/inch[5]	4.5								30.60	
5.0" spray polyurethane foam, R-6.8/inch[5]	5									34.00
8" medium weight CMU[4] (115 pcf, @48"o.c.)	7.625	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14
inside air surface (winter)[3]		0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68
total wall thickness, inches		14.75	15.25	15.75	15.75	16.25	16.75	17.25	17.75	18.25
calculated R-value		20.36	23.76	27.16	20.36	23.76	27.16	30.56	33.96	37.36

Table 5: Polyisocyanurate

BRICK & BLOCK CAVITY WALL							
total cavity space thickness (inches) including insulation and drainage cavity with adjustable ties spaced every 1.77 sf		3.5[1]	4[1]	4.5[1]	4.5[1]	5[2,7,8]	5.5[2,7,8]
	thickness						
outside air surface (winter)[3]		0.17	0.17	0.17	0.17	0.17	0.17
4" face brick[3]	3.625	0.40	0.40	0.40	0.40	0.40	0.40
reflective air space (winter)[3,6,9]							
1"	1	2.80	2.80	2.80			
2"	2				2.80	2.80	2.80
insulation in cavity space							
2.5" polyisocyanurate foil faced[5]	2.5	17.80			17.80		
3.0" polyisocyanurate foil faced[5]	3		21.20			21.20	
3.5" polyisocyanurate foil faced[5]	3.5			24.60			24.60
8" medium weight CMU[4] (115 pcf, @48"o.c.)	7.625	1.14	1.14	1.14	1.14	1.14	1.14
inside air surface (winter)[3]		0.68	0.68	0.68	0.68	0.68	0.68
total wall thickness, inches		14.75	15.25	15.75	15.75	16.25	16.75
calculated R-value		22.99	26.39	29.79	22.99	26.39	29.79

1 Cavities up to 4½" do not need additional submitted structural engineer calculations as per Code

2 For requirements of expanding the cavity, see Wall Tie Analysis, p.36

3 BIA Tech Note 4 Heat Transmission (Reissued 1997)

4 NCMA 6-2B (2009) TEK R-Values & U Factors

5 R-value may vary by manufacturer

6 MSJC requires 1" air space minimum; Code Commentary recommends 2" for better resistance to water penetration

7 100 lb load per tie, see Wall Tie Analysis, p.36

8 Code load: 42 lbs per tie, see Wall Tie Analysis, p.36

9 Values include a reflective air space

every 16" vertically. Welded to this joint reinforcement is the adjustable tie assembly every 16" horizontally. Hence, the result is that most multi-wythe masonry walls are designed today with the exterior wythe as a veneer (non-structural) in lieu of the exterior wythe (structural), with tie spacings not at 2.67 sf (CH.6) as required by the Code for veneers, but at a much closer spacing of 1.77 sf (CH.2) (16" x 16"). By utilizing the rational design method allowed in Chapter 6: Veneer (Section 6.2.1), alternative design of anchor veneer is permitted under Section 1.3 Approval of Special Systems of Design or Construction. One of the conditions that must be satisfied is Section 6.2.1 (a): Loads shall be distributed through the veneer to the anchors and the backing using principles of mechanics.

Wall Tie Analysis

Basic design parameters that Walkowicz considered were tensile and compressive capacity of the tie given the longer length when the cavity is opened to greater than 4½" to accommodate more insulation. Testing has found that there is no difference in performance of the ties in tension, even with the longer lengths. Current tensile tests are typically limited by pullout of the vertical pintle leg from the eyelet. Capacity diminishes as the vertical offset between horizontal tie and eyelet increases. Test data would indicate a safety factor of at least 2.5:1 for a 100 lb load at ½" offset. Compressive capacity has several sub-issues and is not well documented with test data.

- First, local buckling can be ignored for round, solid ties because there is no un-stiffened element to fail.
- Global buckling or slenderness must be considered, since a compression element's capacity decreases with effective length. Equations are available through the AISC steel manual in the Specification Section for Compression Elements.
- The third issue to consider is the combined stress due to compression and bending that will be induced by bends or offsets in the pintle legs. Flexural limits will typically control tie design and must be designed, detailed and constructed properly to ensure performance comparable to intent.

Assuming 3⁄16" diameter round ties, 70 ksi (or 70,000 psi) steel, two legs per tie and a square tie configuration (legs perpendicular to the wall surface), calculations allow for up to ½" offset between the centerline of the tie and the centerline of the eyelet. For Code loads, the load per tie ends up being 42 lbs rather than 100 lbs, which is sometimes specified as a requirement of the contract documents.

1. The Code load tie pintle and eyelet legs can each span up to 9.5" based on combined axial and flexural stress.
2. The 100 lb tie pintle and eyelet legs can each span up to 3.5" based on combined axial and flexural stress.

Testing has found that there is no difference in performance of the ties in tension, even with the longer length.

Based on analytical methods, deflections should be very small for these loads and lengths. Mechanical play will be more of an issue. Note that the span distances are from the veneer inside face to the centerline of the vertical tie leg or the face of the backup to the center of the eyelet. Both eyelet extension and pintle leg elements would resist applied load and both would have sufficient capacity if their lengths are less than those provided. Final tie assembly length should probably be iterated based on the thickness of insulation that the eyelet will protrude beyond. Proper design and installation of expansion and/or control joints should be employed to limit forced displacement in the anchor assembly due to differential movement.

Insulation (R-value table) with explanation

Based on the tie analysis, open the cavity (4½" to 7") in a multi-wythe wall model to accommodate more insulation. Refer to Table 3, for a brick and block wall with extruded polystyrene insulation placed in the cavity. Calculated R-value ranges from 15.86 to 28.36 for overall wall thicknesses of 14¾" to 18¼". Table 4 shows a brick and block wall with closed cell spray polyurethane foam. Calculated R-value ranges from 20.36 to 37.36 for overall wall thicknesses of 14¾" to 18¼". Finally, refer to Table 5, for a brick and block wall with polyisocyanurate insulation placed in the cavity. Calculated R-value ranges from 22.99 to 29.79 for overall wall thicknesses of 14¾" to 16¾". Currently Polyiso is not manufactured thicker than 3½".

Brass Tacks

With the expanded cavity for additional rigid insulation, wall thickness may increase by as much as 2½" to a total wall thickness up to 18¼". To increase wall thickness, the footing will also need to be increased. By Code, footings need to be at least the same width as the wall, but most are 2" larger. The cost of widening the footings by another inch or two is a one-time cost. This expense is minimal compared to potential energy savings year after year. Increasing the overall wall thickness can be easily accommodated; 1) in the exterior wythe by laying out the masonry units with equally spaced head joints, and 2) in the backup wythe by cutting the masonry units where necessary. Easily customized upon order, eyelet extension needs to be custom ordered based on amount of insulation.

Availability of increased thicknesses of insulation varies by type and manufacturer. Rigid board can be special ordered up to a certain thickness. Beyond manufacturing limits, two pieces of board can be adhered together with a one component foam sealant to meet desired thickness at installation.

Challenge your status quo and think toward the future. Use the masonry option to create the most energy efficient wall system!

Daniel Zechmeister, PE, Honorary Affiliate member AIA Detroit, has been the executive director of the MIM since 1990. He is active in ASTM, MSJC, SEAMI, the MIOSHA Masonry Wall Bracing Advisory Committee and board member of the Building Enclosure Council. Zechmeister also has been a lecturer of Structural Theory and Construction Materials at Lawrence Technological University and Structural Masonry Design at both Lawrence Tech and Central Michigan University. Prior to joining the MIM, he worked with the Detroit City Engineering Department Inspection Bureau as an associate civil engineer. Zechmeister has also worked as a structural engineer for Albert Kahn Associates and Campbell Associates and as a civil engineer at HF Campbell Co and as a student engineer at the Detroit Metro Water Department. Zechmeister graduated from Wayne State University with a Bachelor of Science in Civil Engineering.
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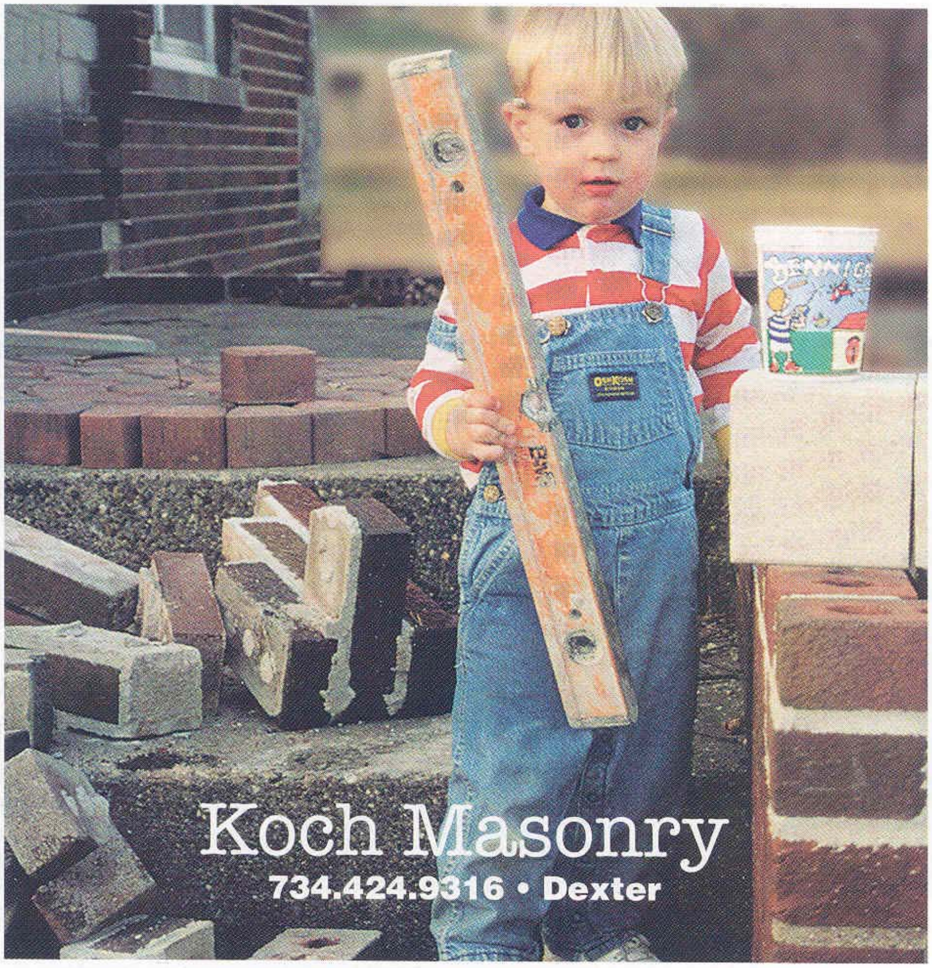
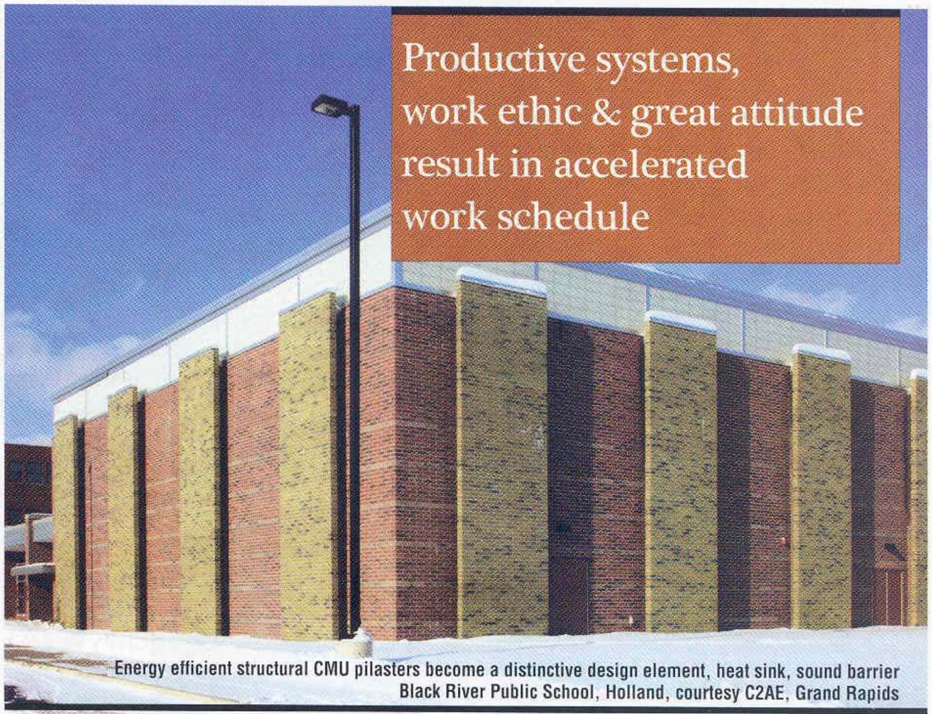




Insight
Prioritizing Green: It's The Energy Stupid*

An edited version of this Insight first appeared in the ASHRAE Journal.

By Joseph W. Lstiburek, Ph.D., P.Eng., Fellow ASHRAE

* *Credit to architect Edward Mazria; I think he said this first, if he didn't say it first he sure says it well.*

Many "green" buildings don't save energy (**see "*MIS-LEED-ING*" sidebar**). Why? They have too much glass, they are over-ventilated, they are leaky to air, they are fraught with thermal bridges and they rely on gimmicks and fads rather than physics.

Basically, the current green and sustainability craze can be summed up as architects and engineers behaving badly. The good news is that most of this nonsense can be easily remedied when adults finally get involved. The bad news is that the failures are beginning to bubble to the surface and we are in danger of ruining the "green brand."[1]

Before you can have a "green" building you need a building first. Presumably this building needs to be able to stand up, not be blown away in a hurricane, not fall down in an earthquake, not burn, not leak rainwater, not be moldy, not rot, not corrode and otherwise be able to meet applicable building codes such as having a basic provision for ventilation like that specified by Standard 62.1.

So what's with all these "green" programs providing "points" for "durability" and "indoor air quality"? I mean it's pretty pathetic if we have to reward architects and engineers when they provide details and specifications that should be basic to fundamental practice. If you design and install a controlled ventilation system that meets Standard 62 you get points. You get more points if you keep the rain out and design the building to dry if it gets wet. And you get still more points if the occupants are actually comfortable. Aren't these code requirements? Shouldn't these be "the standard of care"?

Have we architects and engineers sunk so low that we now get points if we meet basic building requirements that all buildings should meet in order to be called buildings?

Green programs waste a lot of time and money on stuff that is obvious and more time and money on stuff that is irrelevant or unimportant.

How about focusing on stuff that is important? It's become "all about the points" and the important stuff gets ignored. Chasing "green points" doesn't get you good buildings that are truly green. You can get a Leadership in Energy and Environmental Design (LEED) rating and not save any energy compared to traditional buildings. How can that possibly be green?

How To Be Green So, lets start with a basic requirement that we need a building that meets code and the standard of care. That would be a building that is structurally sound, is fire-safe, has a controlled ventilation system, does not leak rainwater and is comfortable. No points for this. This is what the minimum requirement for a building should be.

Now what's next? That's pretty easy. It's energy. What are the two greatest challenges facing the Republic since the pesky British at Bunker Hill and Robert E. Lee leading the Confederate Army? Global warming and energy security. The key to both Global Warming and Energy Security is energy conservation. Architect Edward Mazria likes to say "architects control the global thermostat." I think he is right.

Show me a building that meets code and the standard of care and saves energy and I will show you a green building. A "real" green building, not a social statement that saps money, time and resources from the real problems facing the planet.

You want to save serious energy and serious money? Easy, use less glass. Windows and curtain walls are the most expensive component in a building and

[1] "Michael Zatz, manager of the commercial building program for Energy Star, an EPA program to promote energy-efficient products and practices . . . says Energy Star has a user-support line that gets calls from green-building owners and managers who are disappointed in their building's energy performance." (4)

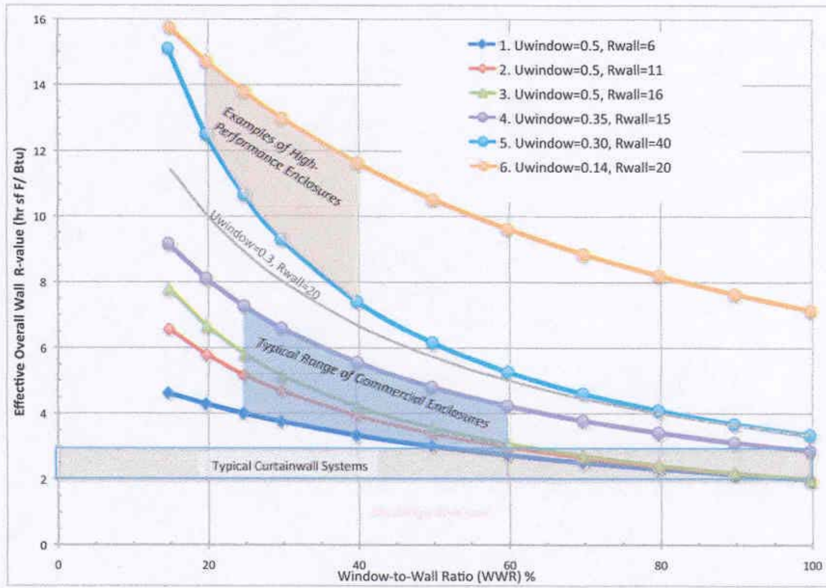
provide the worst energy performance. The more you use the more energy and money you burn. Limit the glazing area to approximately 30 percent—and use really good glass and frames (**Figure 1**).

Figure 1: Enclosure R-value versus Glazing Ratio. Bottom line is use less glass and use good glass and frames. Chart is courtesy of John Straube (6). Bad glass ruins good walls. Rock beats scissors, paper beats rock...

The impact of thermal bridging through commercial wall assemblies, and heat flow through window systems can be calculated with relatively good accuracy by calculating an area-weighted average of the R-values of the windows and opaque wall sections. The equation takes the form:

$$U_{overall} = (WWR * U_{window} + (1-WWR) * U_{wall}), \text{ where } U = {}^{1}/_{R}.$$

The results of a number of scenarios are plotted in the chart at right.



Typical curtainwall systems have an R-value of only 2 or 3, with "high performance" systems (not shown) using highly insulated spandrel panels and best-in-class double glazing may achieve R-4. Only a few systems, such as the Kawneer 7550 series, can achieve R-values of 6 or more.

Curve 1 above is for standard U=0.50 thermally-broken aluminum punched windows with air-filled double-glazed insulated glazing units in a R-12 batt-filled steel-stud brick veneer wall system (R-6). The overall effective R-value of this wall is around 3-to-4 over the normal range of window-to-wall (WWR) ratios of 25 to 50%.

Curve 2 shows that Increasing the R-value of the wall to R-11 by adding an inch of foam on the exterior, results in an increase of only R-0.5 to R-1.5 for the overall R-value for the same range of WWR.

Curve 3 shows how significant an impact window performance can make if a good wall is provided. An externally insulated R-16 wall, when mated with poor windows produces a vertical enclosure with an R-value of only R-3 to R-6 for the normal range of window area.

Curve 4 assumes a good quality window frame with top quality glazing (low-e, argon-filled): the result for the overall vertical enclosure is still only R-4 to R-7.

These first four curves cover the performance of a wide range of commercial enclosures with a wide range of cladding types. The conclusion is that modern commercial vertical enclosures actually have an R-value that is rarely over 7, and more likely in the range of 3-to-5!

Curves 5 and **6** provide an idea of the significant improvements that are possible. Using best-in-class thermally broken aluminum frames and high-performance glazing (U=0.30), **Curve 5** shows that even with an R-40 wall, the overall R-value will be in the 7-to-12 range for WWR of less than 40% (the highest ratio recommended for high-performance buildings). Even though this is a low-level, it is still about significantly more than the alternative. The grey curve below **Curve 5** shows the slight benefit gained by increasing wall R-value from 20-to-40, particularly at high glazing ratios.

Curve 6 employs low-e, argon-filled triple-glazed units in an insulated fiberglass frame, to deliver a U-value of only 0.14. Even with a wall insulated to "just" R20, such a combination can deliver an overall R-value of 12-14, two to three times more than typical commercial vertical enclosures.

In all cases, it can be seen that high glazing ratios generate enclosure walls that are expensive to purchase with very high heat loss and heat gain. This high ratio should be avoided in both individual spaces, such as meeting rooms, as for the whole building on average.

MIS-LEED-ING The reason we have lots of Greek symbols associated with statistics is that the ancient Greeks had figured out a lot of statistics and other sciences, including means and medians. Statistics really took off in 1600s England. Four hundred years ago an English statistician would have immediately recognized that it is really stupid to compare the median of one set of things to the average of another set of things. Of course if you were interested in trying to hide stuff you could try that approach and hope that no one noticed. Well, a bunch of folks noticed and put the US Green Building Council (USGBC) on notice.[i]

Let's start with a basic discussion of statistics and then progress to a more complex discussion of politics.

Let's say you have a collection of things—a "distribution". The medieval English found that there are many useful values within a distribution. Some of these would be the "minimum," the "first quartile" (i.e. 25th percentile), the "second quartile" (i.e. 50th percentile), the "third quartile" (i.e. 75th percentile), and the maximum. It is important to note that none of these values relate directly to the total of all of the numbers, or to the sample size. Now pay attention here, the second quartile has a special name; we call it "the median."

The medieval English and others also went on and defined a bunch of different "means." One of the best known is the "arithmetic mean." Most of us call this the "average." It is the value that when multiplied by the number of "things" (i.e. the sample size) gives you the total sum of the value of all of the "things." Civilians, and most of us, relate to "averages"—the "average" of something resonates with people. Let me put it more bluntly, people are really interested in "averages" as in "the average energy consumption of a bunch of buildings is this." Our children and grandchildren, for example, are much more interested in our means, and won't give a damn about our medians.

The median and the mean both have the property that they will be somewhere between the minimum and maximum values of a distribution. Beyond that they have nothing to do with each other. Let me repeat the "they have nothing to do with each other" part. It will be important later on.

For hundreds of years it has been known that some distributions are better characterized by medians rather than means. Fair enough. However, given that the two statistics have nothing to do with one another, when comparing one distribution to another it is not possible to make meaningful comparisons using the median of one and the mean of another. In a comparison of distributions you either have to use the mean or use the median as the

Then don't over-ventilate. This idea of getting green points by increasing the rates above those specified by ASHRAE Standard 62 is just madness. Whatever happened to source control? If you don't build stupid materials into the building, don't do stupid things in the building and don't connect the interior to exterior via the parking garage, 62 works very well.

Next, build an enclosure without big holes. Build tight, ventilate right. Tight is 2.0 $l/s/m^2$@75Pa (1). Right is ASHRAE Standard 62. How complicated can that be? Except we don't do it.

Moving on, don't insulate steel stud cavities; insulate them on the outside. Most of the time all that you will need is R-10 of *continuous* exterior insulation (that's between 1.5 and 2 inches of rigid insulation).

And don't use supply or return plenums—use something called "ducts" to avoid air quality problems and to ensure air goes where you want it.

How Not To Be Green Once we get an enclosure, we can then condition it. Note to architects: before you can control air you must first enclose air. The enclosure comes first and is more important than all the systems within it. Mechanical engineers—all call themselves green—all claim to do green design but when push comes to shove few of them want to do the additional work necessary to design a mechanical system matched to a high performance enclosure—they want their money for nothing and their chicks for free. Of course not too many clients actually want to pay the engineer for the design—and if the money is spent it is often wasted because the enclosure is bad. You can't make a building green by having the mechanical engineer try to compensate for stupid building enclosure design.

What's "green" about under floor supply plenums? How do they save any energy? They sure as heck don't contribute to indoor air quality – they make it worse. Do you want the breath air delivered in a ductless void under the floor than cannot be cleaned? You ever been in one? They are under everything—duh—so stuff collects in them. They have to be cleaned, but you can't clean them because you can't easily get at them and you can't easily clean them even if you get at them because they are filled with services and so they are filthy. And they are expensive. The building has to be taller. That burns up resources and money. But it's green. Says who? More money, more

Mis-LEED-ing (continued from page 3)

basis of comparison. If you have a problem with this take it up with the ancient Greeks and the medieval English and good luck to you in trying to change several hundred years of fundamental statistics.

Now to the politics; the USGBC wanted to see how well Leadership in Energy and Environmental Design (LEED) buildings were doing energy wise compared to regular buildings. This could be important given the claims about how wonderful LEED buildings were supposed to be according to the USGBC.[i] The New Buildings Institute (NBI) did the looking for the USGBC. Information on regular buildings came from Commercial Building Energy Consumption Survey (CBECS).

The findings were presented in a March 4, 2008 report "Energy Performance of LEED for New Construction Buildings." The trouble started with the following quote from the report: "For all 121 LEED buildings, the median measured Energy Use Intensity (EUI) was 69 kBtu/sf, 24 % below (better than) the CBECS national average for all commercial building stock. Comparisons by building activity type showed similar relationships. For offices, the single most common type, LEED EUIs averaged 33% below CBECS."

A civilian reading this would conclude, hot damn, LEED rocks. A long dead Greek or medieval Englishman would not conclude that, but who cares as the Greek and medieval Englishman are both dead and can't cause any trouble. But more troubling to the USGBC, a few very much alive folks who know a little bit about statistics and buildings said wait a minute, you can't say that because what you said makes no sense. A few even had the audacity to suggest that maybe someone was trying to pull a fast one.

So what do the NBI-LEED and CBECS statistics really show? Well the first thing we have to do is decide what we want to compare to. Most folks think we should compare the NBI-LEED buildings to recently constructed CBECS buildings, not all CBECS buildings. Why? The comparison buildings should be buildings constructed at the same time the NBI-LEED buildings were constructed. Apples to apples, right? The CBECS comparison distribution should be the CBECS 2000-2003 data. It wasn't and that's where lots of folks started to scratch their heads and wonder what was going on. The next thing we have to do is make sure stupid stuff is not included in the CBECS 2000-2003 data—such as warehouses and unoccupied buildings which skew the results (they make the CBECS buildings look more energy efficient then that actually are—memo to the USGBC, this helps your argument).Okay, that pares the CBECS distribution down to n=334 (5 vacant buildings and 56 non-refrigerated warehouses are no longer included). We have to do the same to the NBI-LEED data set. We should drop data centers as none are included in the CBECS data (this helps the efficiency of the data set as these are the highest energy use buildings). That pares the NBI-LEED distribution down to n=115.

Now we are ready to look at the data.

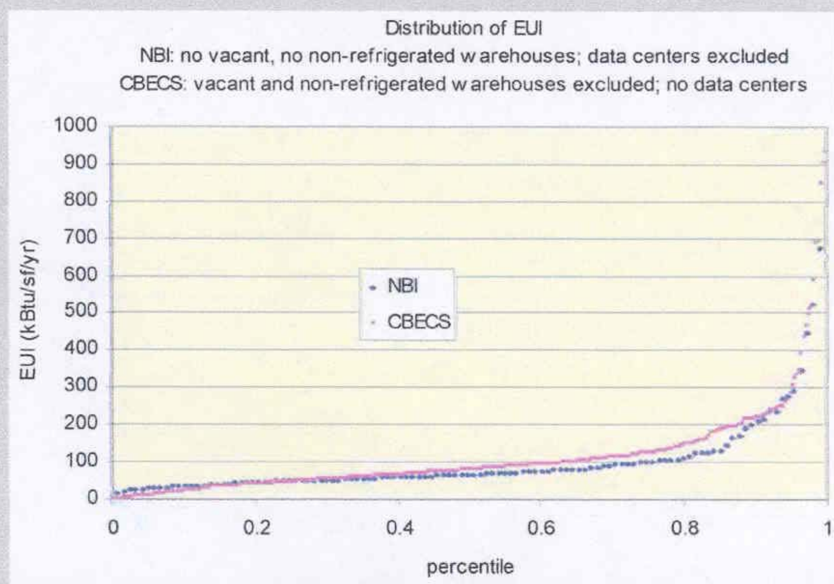
Check out the attached plot (Graph 1).[ii] The NBI-LEED data that does not include the high use data centers buildings is plotted against the CBECS 2000-2003 data that does not include the vacant buildings and non-refrigerated warehouses. The two distributions look pretty much the same don't they? They are not statistically different, by t-test, by mean-to-mean and quartile-to-quartile results.

NBI-LEED mean (n=115) is 96, compared to the CBECS mean (n=334) of 111

NBI-LEED median (n=115) is 67, compared to the CBECS median (n=334) of 81

NBI-LEED median is 72 % of the NBI-LEED mean

CBECS median is 73 % of the CBECS mean



Graph 1

Mis-LEED-ing (continued from page 4)

NBI compared the LEED median to the CBECS mean. Big, giant mistake, one that will haunt the report authors for a long time. If you compared means alone (i.e. averages) you could say LEED buildings performed about 15 percent better than typical buildings constructed at the same time. But that is misleading considering the scatter of the data. Let me repeat, LEED buildings are not statistically different than typical buildings, even though their mean is around 15 percent better (kind of like how a political candidate can be 3 points ahead but have it be a statistical dead heat). Aren't statistics great? Anyway, the number is certainly not 24-to-33 percent better. And even if NBI's claims for LEED were true, 30 percent energy savings for what is supposed to be the vanguard green program in the US is not very inspiring. Come on folks, we have to do better.

Someone had to play with the numbers to make the storyline work and that is just plain misleading. And, surprise, surprise the guy who blew the whistle is getting trashed.

So what does this mean? Let us translate—the LEED buildings did not conclusively save any energy compared to typical buildings built at the same time.[iv] This is not good.

LEED needs to be fixed. Manipulating a bunch of statistics to hide behind does not save any real energy. Let's fix the problem and save some energy

Where to start? Easy. Ask a few simple questions. How big is my building? Where is it? What is going on inside of it? How much energy did it use compared to a similar sized building in a similar location with a similar occupancy built to standard practice? If you can't show any energy savings for gods sake shut up and take your points and stick them where the sun doesn't shine. Okay, that is a little bit harsh. So what do we need to do to make the energy savings real? We have to start making the right design decisions at the front end, but we also have to be keeping track of how well we are doing on the back end so that we can continue to improve. Right now we are doing neither.

i Henry Gifford of New York City looked at the reported results and started asking questions. Hard questions. And the predictable response? A not so quiet campaign to discredit the messenger rather than address the questions raised. Questioning the orthodoxy of the Green movement is not a particularly smart career move. Not too many principled men and women around anymore. Well done, Henry.

ii Google "LEED" and you get: "Build green with LEED, www.usgbc.org. Sustainable building saves energy & money. Learn how with USGBC." Apparently LEED buildings do neither. They are certainly not cheaper.

iii The plot was created from data provided to Bill Rose by Cathy Turner of NBI with the permission of the USGBC. The USGBC says publicly they have nothing to hide. Great start to resolving the problem. A lot of us are pretty peeved (not Bill Rose, he doesn't get peeved) at the attitude from the USGBC so we developed our own attitude. This release of data goes a long way to ratcheting down the tension. After our side vents a little bit we both should get on with the business of getting better buildings. The statistical analysis was done by Paul Francisco.

iv Think about what is happening behind all of the numbers. The building codes use ASHRAE Standard 90.1 to establish a "floor" or minimum for energy performance. Very few buildings, if any, are built to go beyond the building code minimums so the CBECS plot is really a plot of ASHRAE 90.1. LEED uses ASHRAE Standard 90.1 to establish a target. Guess what? The target appears to have been met. The "target" resembles the "floor." There should be no surprise that the two data sets are pretty much the same. So how to fix this? Many folks, including the ones who helped me with this column feel that the problem is only partially LEED—they feel the real problem is ASHRAE Standard 90.1. I am not completely there yet. But the folks at Standard 90.1 are getting pretty hard to defend when they go out and say that airtight building enclosures do not save energy and airtightness standards have no place in 90.1. Fixing LEED might best happen while also fixing ASHRAE 90.1.

energy, more resources and more problems. What's green about that?

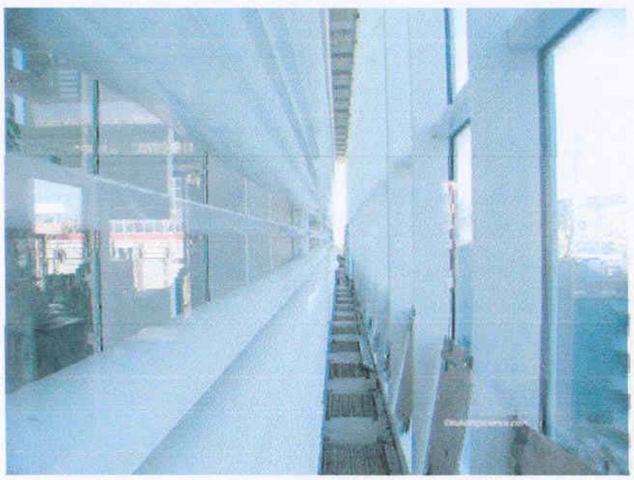
You want to have some fun? Go ask the folks at the General Services Administration (GSA) about how they feel about under floor supply plenums. While you're at it also ask them about computational fluid dynamics (CFD) and passive ventilation and San Francisco's Federal Building. They won't be able to say much because the ongoing employee litigation has them under a gag order. Go to Google and the Internet and enjoy. Or how about Seattle's new LEED city hall, which turned out to be a dog? Then we have Sir Norman Foster's London City Hall—supposed to be the greatest greenie public building ever. It just got rated an "E" on the efficiency scale that runs from A to F based on just released utility consumption. Apparently, the lunacy is not limited to this side of the Atlantic.

Double façades? Green? What's with that? I thought we killed that dumb idea after all the nonsense associated with "double envelope" houses in the 1970's.[2] It seems that really dumb ideas keep coming back every other generation—typically after the generation of adults that dealt with the dumb idea the

2 What a weird decade—not only did we have double envelope houses but we also had leisure suits and the "Bionic Woman." With double façades in vogue and the Bionic Woman* back on network TV can leisure suits be far behind?

* With the double facades, we can rebuild them, we have the technology, we can make them warmer, cooler, more comfortable, cheaper . . .

Photograph 1: Hooker Chemical Company—The folks that brought us the Love Canal also brought us the first double façade building in the United States in the 1970's.



Photograph 2: Mind the Gap—More Hooker Chemical Company building double façade. Not a heck of lot more needs to be said here. The population of a small village could live in this space.

first time around retires (**Photograph 1** and **Photograph 2**).

Here is the general premise behind the double façade. The outer façade creates a buffer space between it and the inner façade tempering the environment the inner façade sees. So we have to build two walls—not one—an outer wall and an inner wall with a bunch of space in between. Seems to me that if you built the inner wall correctly you don't need the outer wall—and vice versa. We call that a "duh" where I'm from. And then you get to use the space between them because there is no space between them—it is all inside—we call that rentable floor area where I'm from. Double facades are a low energy way to provide an all glass enclosure, but they always use more energy than a decent façade with less than 100 percent glass. Why ever go there?

Oh, I forgot about all the passive ventilation "magic" that happens between the two facades and the operable windows you can have between the inner façade and the "magic" space. All brought to you with the precision and predictability of computational fluid dynamics (CFD) and the stack effect. Emswiler (2) and Hutcheon (3) are rolling over in their graves and Shaw and Tamura (4) are none too pleased. I call on the ghosts of building science past to rise up and put a pox on all your houses.

I have got news for all you façadists—you can have operable windows in a single façade and you can get a lot more control and predictability with things called fans, ductwork and controls. Oh, by the way, you can get it at a lot less cost, using a lot less materials (i.e. "resource efficiency") and using a lot less energy. But, but, fans use energy—it's not natural to use fans. The other way, the "magic" way uses "natural" forces that are good because nature is good and man is inherently evil. Didn't we have this argument over two hundred plus years ago with a dead French guy called Rousseau? If we taught architects more physics and less philosophy they wouldn't fall for this garbage—and while I'm at it shame on you engineers for using bad physics to deceive gullible architects.

Green roofs? Grass and dirt are not energy efficient. Work with me here. Which saves more energy—2 inches of dirt or 2 inches of insulation? Which saves more energy—grass or a white colored membrane? Which is more expensive and does not save energy—grass and dirt or insulation and a white colored membrane? Which needs to be watered to keep the grass from dying and blowing away? But they are beautiful and look cool. And that apparently is more important than cost and energy savings. Okay, I can live with the beautiful and looking cool argument if that is in fact the argument—but don't clutter it with half-truths such as heat island effects and water run-off. There are other ways to deal with each.

I know I will not win the argument on green roofs, so my advice is to at least build the green roofs correctly.

In the "green world" folks sometimes get so preoccupied with "green materials" that they forget that at the end of the day the assembly still has to work (**Figure 2** and **Figure 3**).

And enough with the awards before a building is built and the performance is verified.[3] Award plaques should come with removable screws.[4] Show me the utility bills. Compare the building to a building of similar size and similar occupancy in a similar climate. And if you don't show any savings—shut up. You can't be "green" if you don't save any energy. Don't talk to me about biological diversity, recycled materials, and natural ventilation until after you have saved the energy. Spare me the social engineering and the smaller is better and how we all have to share the planet and how we are all equal until you have saved the energy. Don't talk to me about carbon off-sets until you have saved the energy. You need some carbon savings before you can trade any (the Kyoto protocol requires that the carbon credits be verified, i.e. a piece of paper saying we intended for there to be carbon reductions doesn't do it). Save one and you can trade one. Don't build an award winning energy pig and say you are green because you plantéd some trees in Zaire and brought clean water to a village. Those are all good things but they mean nothing to me because you still have a poor building.

[3] Larry Spielvogel was right about this—he got trashed when he had the audacity to question the claims of energy savings based on computer simulations—a.k.a. "Nintendo Engineering;" as one Fellow to another —you done good big guy.

[4] This idea is from the irrepressible Henry Gifford, New York City, NY. Yo, you talking to me?

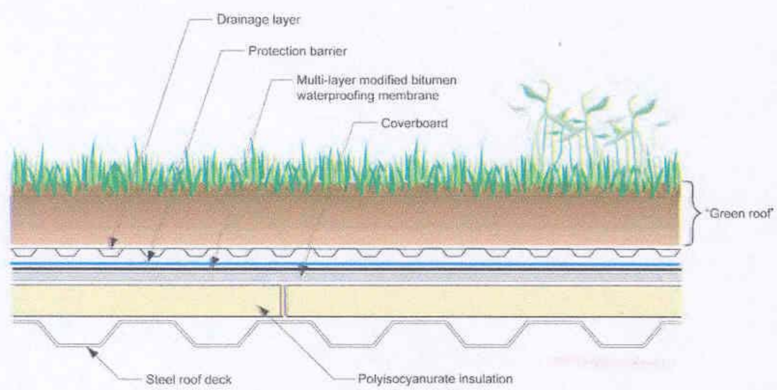


Figure 2: Bad Green Roof—The insulation is under the membrane. This is bad. The insulation can collapse and loose support for the membrane. The membrane can tear and leak. The reason for this bad design choice is often a preoccupation with the "greenness" of the blowing agent of the rigid insulation. Successful green roofs have historically used extruded polystyrene (XPS). XPS can get wet and still perform. The blowing agent of XPS is arguably not the "greenest of the green." Unproven "green" blowing agents used with polyisocyanurate insulation seem attractive at first blush, but insulation assemblies need to be protected from water and hence the location under the membrane and the structural loading of the overbuild assembly needs to be taken into account.

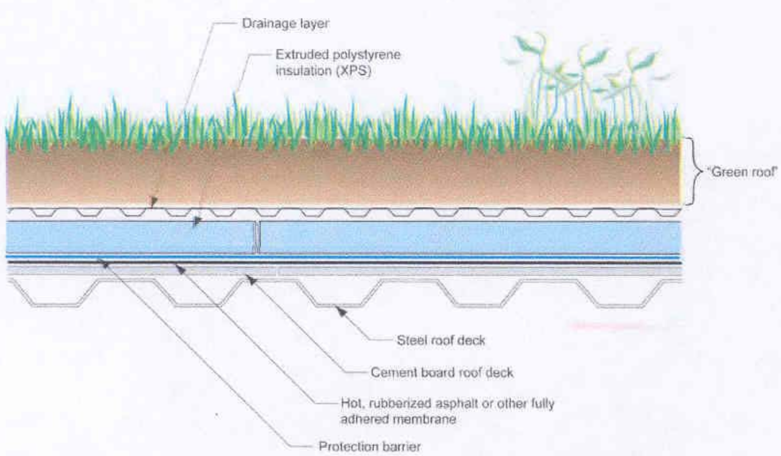


Figure 3: Good Green Roof—The insulation is over the top of the membrane. This is good. This configuration has a multi-decade track record.

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Royal Building Scientist: Charles questions 'green' buildings

Oct 12, 2008

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http://www.dimateark.org/shared/reader/welcome.aspx?lnkid=108119&keybold=carbon%20consumption

The Prince of Wales has criticised the "green building industry" for relying on eco-gadgets like wind turbines and solar panels to justify inefficient buildings.

The Prince called on developers to use traditional methods and materials alongside the best in "eco-technology" to solve the problem of creating environmentally friendly properties instead of opting for "slick, highly marketed techno-fixes".

His comments received a mixed welcome from Paul King, chief executive of the UK Green Building Council, who said they would provoke a healthy debate but risked undermining the efforts of the UK's emerging green building industry.

In the foreword to a green supplement in the magazine House & Garden, the Prince wrote: "Why, I must ask, does being 'green' mean building with glass and steel and concrete and then adding wind turbines, solar panels, water heaters, sedum roofs, glass atria - all the paraphernalia of a new 'green building industry' - to offset buildings that are inefficient in the first place?

"That many of these add-ons are mere gestures, at best, is now clear, as their impacts on home energy consumption can now be measured and usually offer scant justification for the radical nature of the design."

Experts believe small-scale energy generation can help in the push for more renewable energy with businesses, communities, schools and homes playing their part by installing items like solar panels for heating, biomass boilers and combined heat and power supplies.

In December last year, the Government outlined a multi-million pound Government scheme to fund schools to install renewable energy sources such as wood-burning boilers, wind turbines and solar panels to cut carbon emissions.

Charles added: "We must act now, by using traditional methods and materials to work with nature rather than against her, while incorporating the best of contemporary eco-technology in an integrated and sympathetic manner."

Speaking about the Prince's comments, Mr King said: "In a way he is right - there are examples of high-profile buildings being passed off as 'green', when the most important thing is to reduce environmental impacts through good design in the first place.

"However, he risks undermining the efforts of UK's emerging 'green building industry', the vast majority of whom are designing an increasingly large number of fantastic buildings - not just environmentally sound, but excellent architecture in their own right."

Typical Reaction from the Architects

Attack the messenger rather than fix the problem. Criticism of any kind is bad because "green" is good; don't criticize green because that would prevent people from adoption green. The most interesting thing is that Prince Charles actually "gets It" but his rather astute observations are downplayed! —JWL

Article reprinted with permission from Vol 4 No 3 The Masonry Edge/StoryPole – Optimize Energy Performance

do you know what your building energy cost is?

Do you know how to reduce it?

by Perry Hausman, PE, LEED AP

CONTINUING EDUCATION

LEARNING OBJECTIVES

Upon reading the article you will:

1. Identify no cost and low life-cycle cost strategies of gaining optimal energy performance from a building's design.
2. Describe how an insulated masonry cavity wall's thermal mass affects a building's energy load.
3. Observe how load components can be relative to one another.

As a firm committed to design integrity, quality and environmental responsibility, TowerPinkster continually explores innovative new strategies to create sustainable, cost-effective designs. Most recently, the firm has been utilizing a design approach that consistently and successfully achieves energy efficiency for a variety of clients from education and healthcare to municipalities. The team has designed buildings that are operating as low as $0.77 /sf/year and only as high as $1.13 /sf/year. While increasing square-footage, some replacement building designs have achieved lower operational costs than the original building. According to the EPA's "Energy Star Target Finder," the average K-12 building consumes $1.39 /sf/year.

Through an integrated and inclusive approach to projects, client's energy-use challenges are addressed early in the design process. One of the contributing factors to energy-efficiency is the use of insulated masonry cavity walls and Tower-Pinkster has adopted the use of this high performance envelope design to achieve significant savings.

First Things First

TowerPinkster first takes one step back to explore ways current energy loads can be reduced. Before spending money on a high-performance, energy-conserving HVAC system or renewable energy, it makes sense to reduce the overall energy consumption of the building using passive energy-conservation measures (ECMs).

A holistic design approach has resulted in significant cost savings for clients by responding to the owner's low-energy design criteria from the early stages of conceptual design. Through inclusive design charrettes with a multi-disciplinary design team, owners and key stakeholders are involved in discussions that include proper siting of the building; the selection of envelope construction and materials based on life-cycle cost (not first-cost); and responsible use and placement of glazing, coupled with daylight harvesting. This article will further explore this project approach to designing a high-performance, low-energy, sustainable building.

Siting

Our efforts begin even before the building is located on the site. In fact, determining the best location and orientation of the building requires input from many different disciplines. An architect's vision is a good

Kalamazoo Public School's new Prairie Ridge Elementary School is a real-life example of the energy savings that can be achieved through passive energy design. An energy model was used to determine the energy savings related to each of the energy conservation measures (ECMs) considered on the project. Only the best performers were selected. Prairie Ridge employs many of the strategies described in this article including daylighting, burming and the orientation of a portion of the building along an east-west axis. Otherstrategies include a reflective roof membrane, which reduces the effort that the cooling system must exert to maintain a comfortable environment and a green roof that provides an evaporative cooling effect on the roof while also serving as an outdoor learning environment for students. As a result, Prairie Ridge saves more than 28% on energy bills! That's 11% more in energy savings than the HVAC system's contribution alone, which is expected to last 25 to 30 years. The structure is insulated masonry cavity wall that exceeds Michigan's energy code requirements by 59%. Prairie Ridge's design is currently under review by the Green Building Certification Institute and is anticipating a LEED Gold certification.

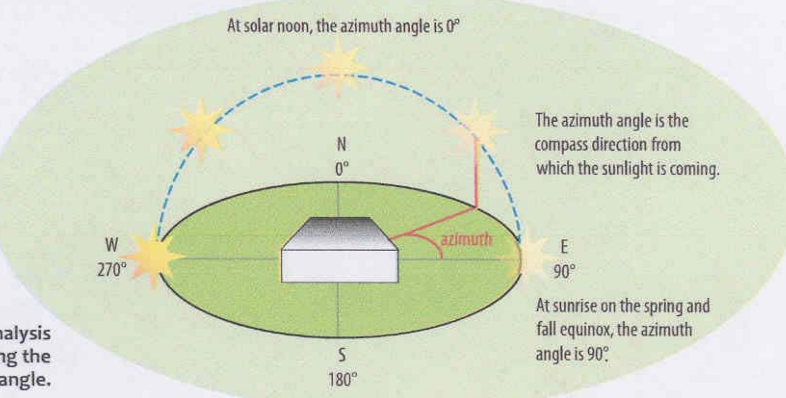
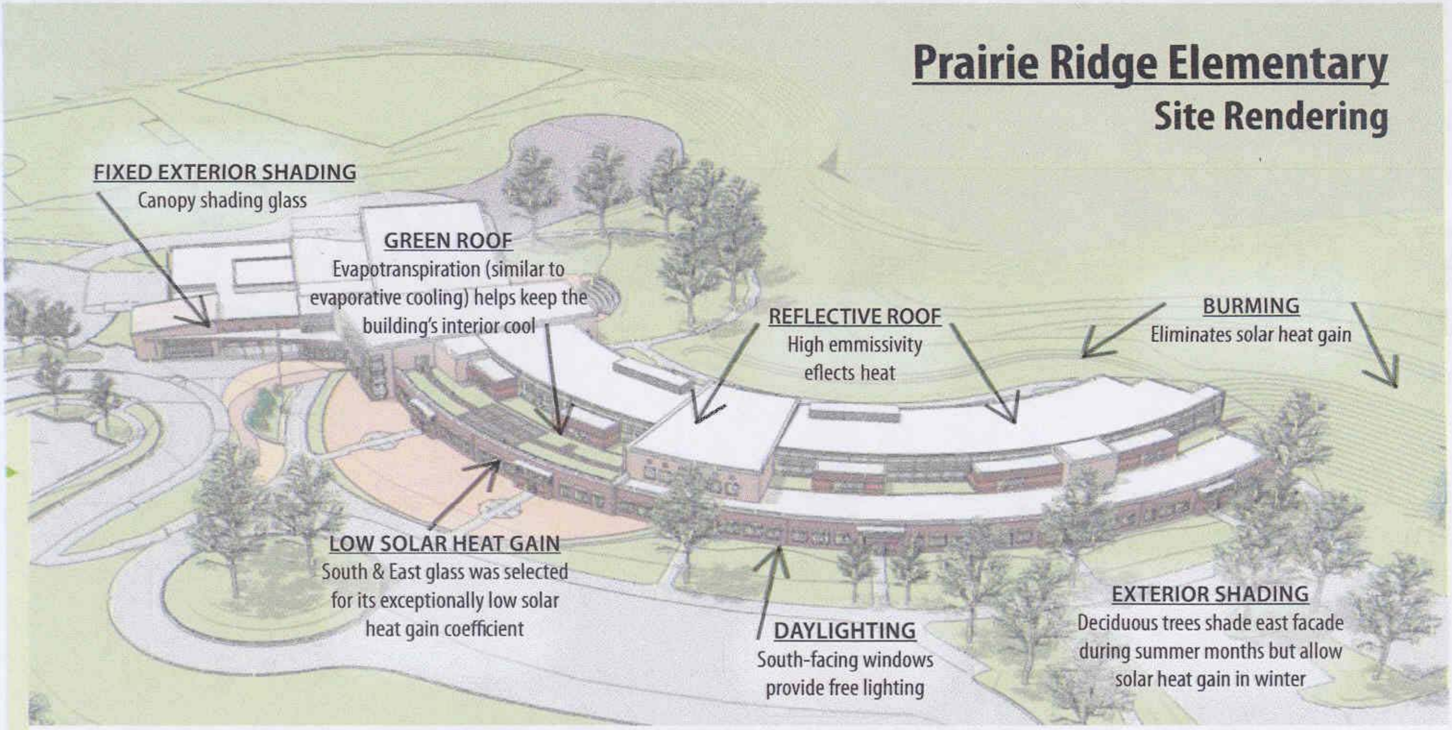


Figure 1: Site analysis includes determining the sun's azimuth angle.



Taking advantage of all passive energy conservation measures, beginning with the way a building is oriented on the site, increases the potential for a low-energy, high-performance, cost-effective building.

starting place. Civil, structural, landscape architecture and mechanical disciplines can all provide valuable information that will influence the building's final placement and orientation.

It's important to realize that the sun's vertical angle and azimuth are relative to the latitude, longitude, time of day and time of year at the specific building site (Figure 1).

An analysis is required for each project, but some generalities follow. When considering the placement of new facilities located in the Midwest, positioning the west or east facades into the earth – "burming" – eliminates 100% of unwanted solar heat gain associated with these orientations and reduces thermal transmission in cold climates. There is a trade-off however, when burming the entire facade, daylighting becomes difficult or impossible. Again, a detailed analysis is required of specific building features to determine the best burming technique. Designing the building to take advantage of exterior shading of west and east faces and high summer solar angles on south faces can also greatly reduce solar gain. Shading can be achieved with well-placed coniferous or deciduous trees, other nearby buildings, or with a building design that shades a portion of itself. Integrated design of multiple-story construction can also reduce the total exposure of the building. Less exposure equals less wall area for thermal transmission. An energy model can provide valuable feedback on the energy consumption of the building resulting from its location orientation and surrounding features.

Daylighting

There is no more impactful energy conservation design measure than daylighting. In essence, it provides a double benefit: It reduces the need for electrical energy and minimizes waste heat from electric lights. Minimizing waste heat allows the HVAC system to be sized smaller and consume less energy. Moreover, sunlight provides more light and less heat than electric lights, thereby further reducing cooling loads. Since electric lighting accounts for up to 15% of the total energy consumption of a building, small reductions can have a large effect on the total energy used. (Refer to Prairie Ridge example above.)

Daylighting begins with a close look at the orientation of the building in relation to the sun's path across the sky and is most cost-effective with a building oriented on an east-west axis. North and south-facing glass is maximized, making best use of natural daylighting. Properly siting a building can also reduce solar heat gain by taking advantage of the sun's angle and path in the sky. The placement of glazing with respect to the local solar angles and the thermal performance of the building envelope are additional considerations. Roof monitors and clerestories with vertical glazing provide the best source of daylight because they both have the ability to flood the space with uniform light levels while reducing glare. Typically, south-facing glazing provides the best source of daylighting with north-facing glazing as the next best option.

Use of properly designed exterior shading devices such as overhangs and fins can also limit unwanted solar gain while allowing daylight to penetrate the perimeter 10' to 15'. South-facing exterior and interior light shelves can bounce daylight up to 20' into perimeter spaces. Light shelves on the north have little benefit.

In the Midwest, solar gain is not always unwanted. Solar gain can be used for passive heating in the winter. By allowing the low solar angle and obtuse azimuth to penetrate the building, large thermal masses absorb the sun's heat and slowly radiate that heat back into the space, benefiting the building's heating system. (See highlighted text on opposite page.)

Envelope

Once the building has been sited, careful selection of building envelope materials helps contribute to the overall energy efficiency of the building. Obviously building size, height, structure and aesthetics come into play, but Tower Pinkster has found that a fresh look at some construction methods and materials has lead to successful holistic building design.

- A cavity wall's superior resistance to rain penetration, superior thermal properties, excellent resistance to sound transmission and high resistance to fire are all properties that help a building last 50 years or more.
- The investment in insulation is one that continues to pay dividends but without maintenance costs. It just continues to work, saving energy for the life of the building.
- Spray foam insulation in the cavity wall is ideal because:
  - The dewpoint temperature occurs in the cavity, not in the brick or block.
  - The spray foam insulation is not water permeable. Condensation can only occur in the drainage/air space where it is easily drained and directed out of the cavity through weep holes.
  - The impermeability of the spray foam mitigates any chance of mold inside the insulation.

Making it Real

To help the entire design team maximize energy-efficiency, TowerPinkster's mechanical engineers develop an energy model of the building and its energy-consuming devices. (See example at right.) Energy modeling software allows a quick and easy parametric analysis of various ECMs and provides a clear picture of the largest energy consumers, or wasters, in the proposed design. Armed with this knowledge, life-cycle cost analyses become simple and the project team understands where the biggest "bang for the buck" can be achieved.

Prairie Ridge's superior masonry envelope allowed us to eliminate the very common perimeter radiant heat that is often placed at the least beneath glazing, but often along the entire length of exterior walls, increasing the attractiveness of the superior envelope, creating increased work and storage space and saving the owner first cost on the mechanical systems.

Architects and engineers are continually striving to design the most efficient and responsible buildings they can. With proper siting of the building, daylighting and appropriate building envelope design, TowerPinkster will continue to provide responsible solutions to meet our clients' needs. Our clients have been thrilled with the energy they save, year after year, with the effective use of passive energy-conservation design including cavity wall construction. And in the end, it's not just about energy – in fact, it's about the end-user. Our goal is to make our buildings comfortable places to learn, work and play. And that's called Making It Real.

*American Society of Heating Refrigeration and Air conditioning (ASHRAE) Standard 90.1-2004 Table A3.1A

COOLING COIL LOAD INFORMATION

Load Component	Sensible Btu/h	Latent Btu/h	Total Btu/h	Percent of Total
Solar Gain	70,772		70,772	7.1%
Glass Transmission	27,707		27,707	2.8%
Wall Transmission	11,796		11,796	1.2%
Roof Transmission	0		0	0.0%
Floor Transmission	0		0	0.0%
Adj Floor Transmission	0		0.00	0.0%
Partition Transmission	0		0	0.0%
Net Ceiling Load	0		0	0.0%
Lighting	97,229		97,229	9.7%
People	29,563	25,822	55,384	5.5%
Misc. Equipment Loads	223,925	0	223,925	22.3%
Cooling Infiltration	45,553	53,602	99,155	9.9%
Sub-Total ==>	506,543	79,424	585,967	58.4%
Ventilation Load	121,588	141,537	263,125	26.2%
Exhaust Heat	-1,942	0	-1,942	-0.2%
Supply Fan Load	117,537		117,537	11.7%
Return Fan Load	21,411		21,411	2.1%
Net Duct Heat Pickup	0		0	0.0%
Wall Load to Plenum	0		0	0.0%
Roof Load to Plenum	15,278		15,278	1.5%
Adj Floor to Plenum	0		0	0.0%
Lighting Load to Plenum	0		0	0.0%
Misc. Equip. Load to Plenum	0	0	0	0.0%
Glass Transmission to Plenum	0		0	0.0%
Glass Solar to Plenum	0		0	0.0%
Over/Under Sizing	1,598		1,598	0.2%
Reheat at Design	0	0	0	0.0%
Underfloor Sup Heat Pickup	0		0	0.0%
Supply Air Leakage	0	0	0	0.0%
Total Cooling Loads	782,014	220,961	1,002,975	100.0 %

Energy modeling outputs, such as this one, allow a quick and easy parametric analysis of various energy conservation measures and provides a clear picture of the largest energy consumers in the proposed design.

Perry Hausman, PE, LEED AP, is a mechancial engineer with TowerPinkster, and is an expert in low-energy mechanical systems. His designs have achieved a savings of more than 30% on energy dollar-cost when compared to the Michigan Energy Code. He has expertly applied the LEED rating system to many projects for both new construction and renovation.

Hausman also has extensive experience designing computer simulated energy models. By simulating the building envelope, mechanical and electrical systems, these energy models create a holistic analysis of the building, pinpoint key areas for potential improvement and help clients achieve the greatest energy efficiency for their dollar.

Hausman is a frequent lecturer on the topic of sustainable design, having given presentations to the Kalamazoo Rotary Club, the Otsego Rotary Club, the Kalamazoo Regional Chamber of Commerce, the Climate Change Coalition and Western Michigan University.

Hausman received his Bachelor of Science degree in Construction Engineering and Management from Western Michigan University. He is a registered, professional engineer in the State of Michigan.

phausman@towerpinkster.com 616.456.9944

Responsible use of glazing quantity includes selecting a window-to-wall ratio that optimizes the ability to harvest natural daylight while reducing the energy consumption of the HVAC system. It's a delicate balance that only a skilled energy modeler can pinpoint. Responsible glazing placement reduces the quantity needed on the building faces that receive the largest solar gain, which are usually the west and south faces. Typically, a building properly sited is best placed on an east-west axis and has a narrow floor plate, therefore reducing south facing walls. The intent of an elongated east-west axis building is to minimize internal building areas that daylight cannot reach.

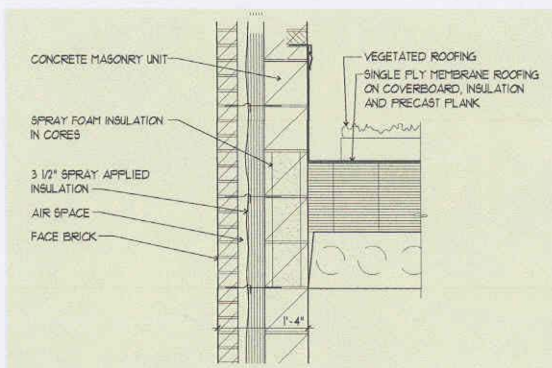
For example, careful window selection offers another opportunity for passive energy conservation design. Clear glass is more effective for daylighting applications, allowing for smaller glazed openings as compared to tinted or low-e glass, which can be reserved for locations not employing daylighting. All windows should be thermally broken and, at a minimum, double-pane and preferably argon-filled. The use of an energy model's parametric analysis capabilities will accurately determine the optimum characteristics of the glazing on each face of a building.

Exterior shading devices should be designed to complement the daylighting strategy while reducing solar heat gain. A daylighting study is typically required to determine the optimal dimensions and position of exterior shading devices. Avoid relying on interior shading devices to passively reduce internal heat gain. Internal shades are useful in reducing unwanted glare and can control the light after it has entered the building; however, once the solar radiation has entered the building, it is converted to heat and must be actively handled by the HVAC system. (See rendering on previous page.)

Buildings are operating as low as \$0.77 /sf/year and only as high as \$1.13 /sf/year. The average K-12 building consumes \$1.39 /sf/year.

In the Midwest, the building shell is responsible for 10% to 30% of the heating load; therefore, passive energy conservation also requires designers to take a close look at the wall and roof construction. It is generally accepted that for buildings designed to last more than 50 years, masonry wall construction offers the lowest life-cycle cost analysis (LCA) of any conventional wall construction. Features that contribute to its low LCA include its low-maintenance cost, superior thermal performance and thermal mass. Let's investigate the anatomy of a face brick and block loadbearing cavity wall system.

A standard 16" wall thickness allows for easy construction and includes up to a 4¾" air space between the brick and block. Assuming the wall is constructed with 7⅝" block and 3⅝" face brick, this allows for 3½" of insulation plus a 1¼" air gap.



TowerPinkster has continued to alter its high performance insulated cavity wall design to achieve maximum efficiency. As a result, many of their projects feature R-values in the high 20s.

According to ASHRAE*: 3.5" of R-7 insulation achieves a realistic assembly U-value of 0.038 which is equivalent to R-26.3. This is 69% better than the code required U-value for a mass wall located in the Midwest.

A masonry wall with insulation in the cavity provides significant thermal mass on the interior of the building which contributes to the "flywheel effect" and allows the building to "coast" through the typical peak cooling hours that occur in mid afternoon. This thermal mass can delay the thermal gain typically by six hours or more. Properly designed, the thermal mass can be responsible for delaying the building's peak cooling load until the early evening when lower off-peak energy rates apply, thereby reducing the owner's energy bill, although not necessarily the energy consumption. It is noted that a 1¼" air gap may be problematic if, during erection of the face brick, the mortar squeezes out of the joint and into the air gap, restricting airflow and creating a potential water trap. Some applications may be better served with reduced insulation and a larger air gap.

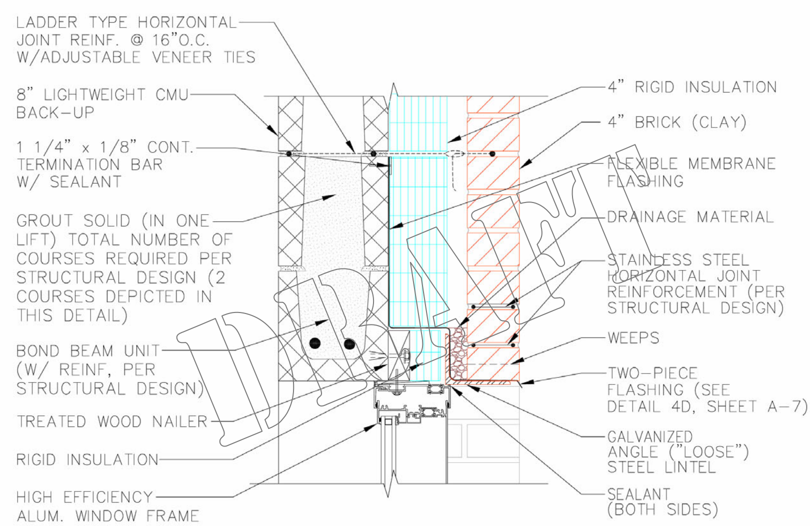
In recent years, TowerPinkster has changed wall system design on several projects. The new high performance insulated masonry cavity wall was first introduced at Otsego High School with 2" of spray foam insulation. This technique was also applied at Kalamazoo College's Hicks Student Center, Kalamazoo Public School's Prairie Ridge Elementary and the new Linden Grove Middle School and most recently at the Kalamazoo Regional Education Service Agency's new Special Education Building where 3.5" of spray foam insulation was applied. By steadily increasing the quantity of insulation at each of these schools, the buildings have become more energy efficient.

Choosing the right insulation can also provide multiple benefits. Spray foam insulation is an example of a sustainable product that performs on many fronts. Its thermal insulation provides reduction in heat transfer, its vapor barriers offer humidity and moisture control and it functions as an air barrier offering reduced infiltration, all of which lead to superior energy performance.

TowerPinkster's experience demonstrates that insulated masonry cavity wall construction is ideal for buildings designed for energy efficiency and longevity. This is particularly true because the insulation is not interrupted by framing members. Because insulation is continuous, the rated insulation value is a true representation of the installed performance. (See rendering on previous page.)

According to TowerPinkster's architects and engineers:

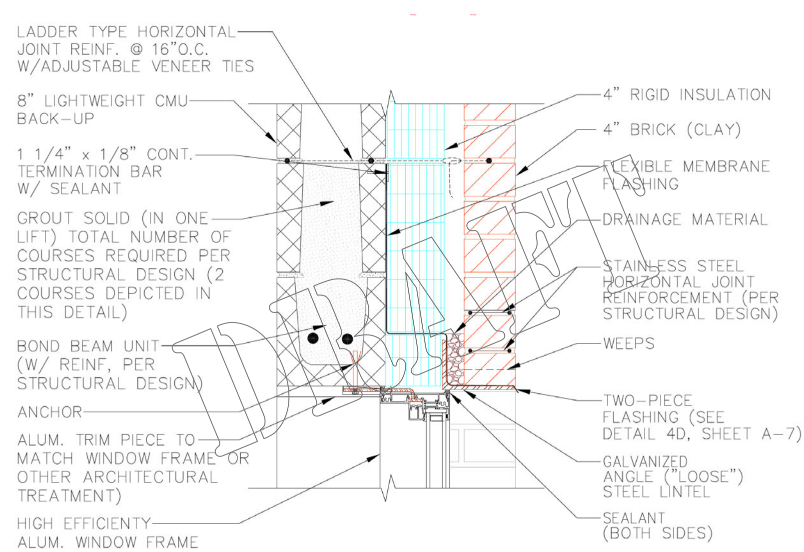
Details



5A / A-1 MASONRY LINTEL @ WINDOW OPENING

(USING RECEPTORS)

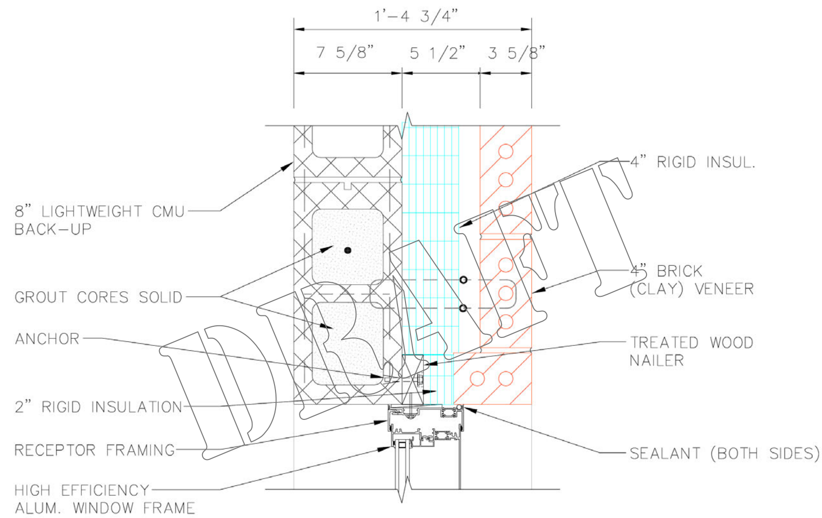
MIM Generic Wall Design



5A.1 / A-1 MASONRY LINTEL @ WINDOW OPENING

(USING STRAP ANCHORS)

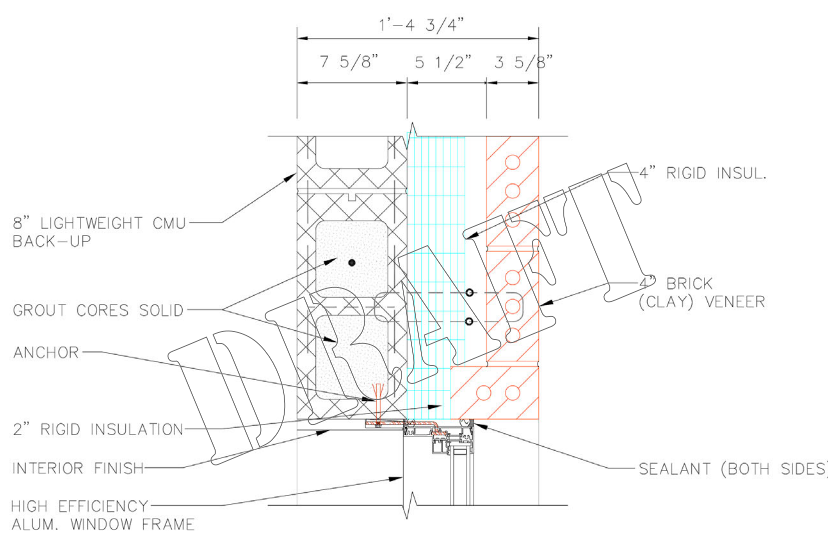
MIM Generic Wall Design



6B
A-1

WINDOW JAMB DETAIL (USING RECEPTORS)

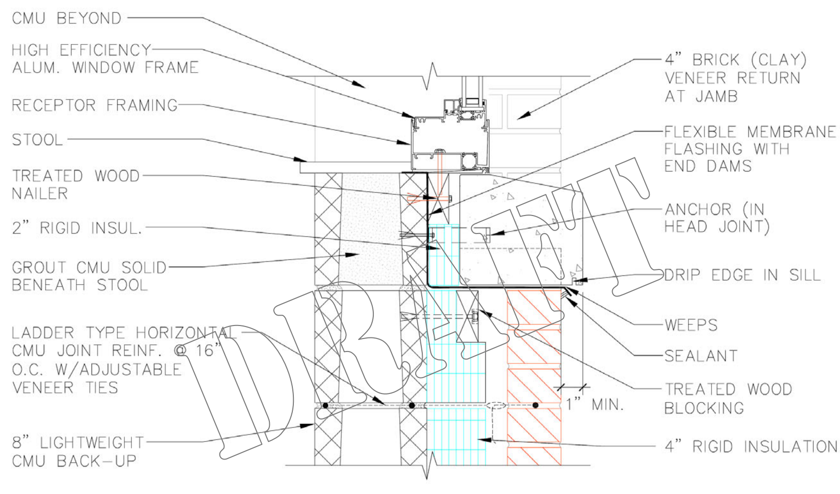
MIM Generic Wall Design



6B
A-1

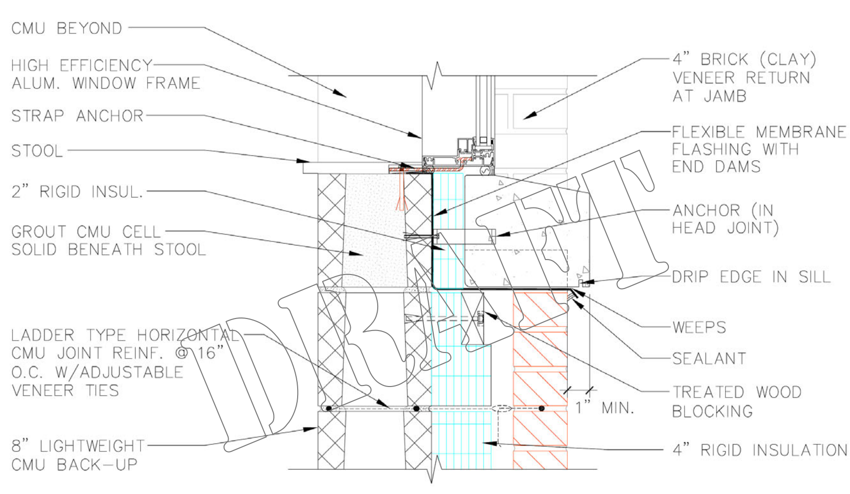
WINDOW JAMB DETAIL (USING STRAP ANCHORS)

MIM Generic Wall Design



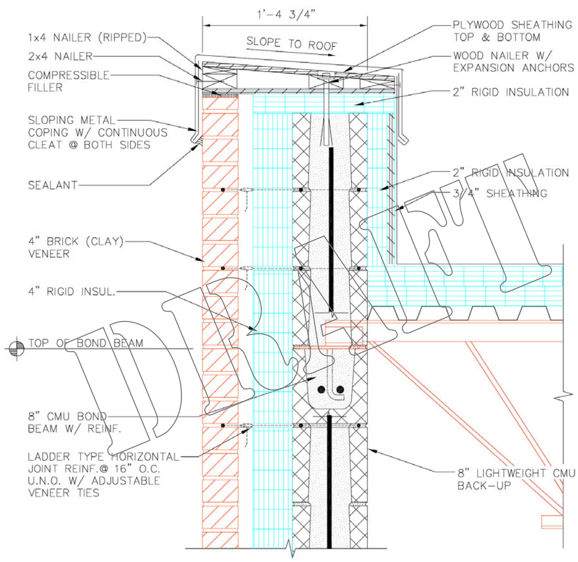
7B
A-1
NATURAL STONE OR PRECAST CONCRETE SILL DETAIL
(USING WINDOW RECEPTORS)

MIM Generic Wall Design



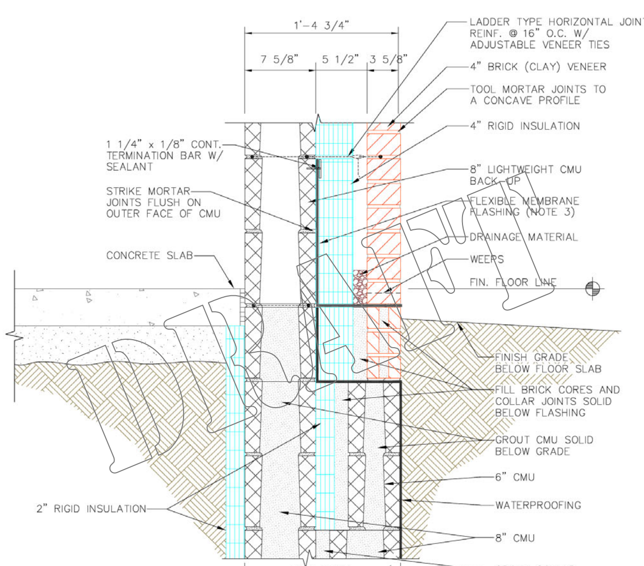
7B.1
A-1
NATURAL STONE OR PRECAST CONCRETE SILL DETAIL
(USING STRAP ANCHORS)

MIM Generic Wall Design



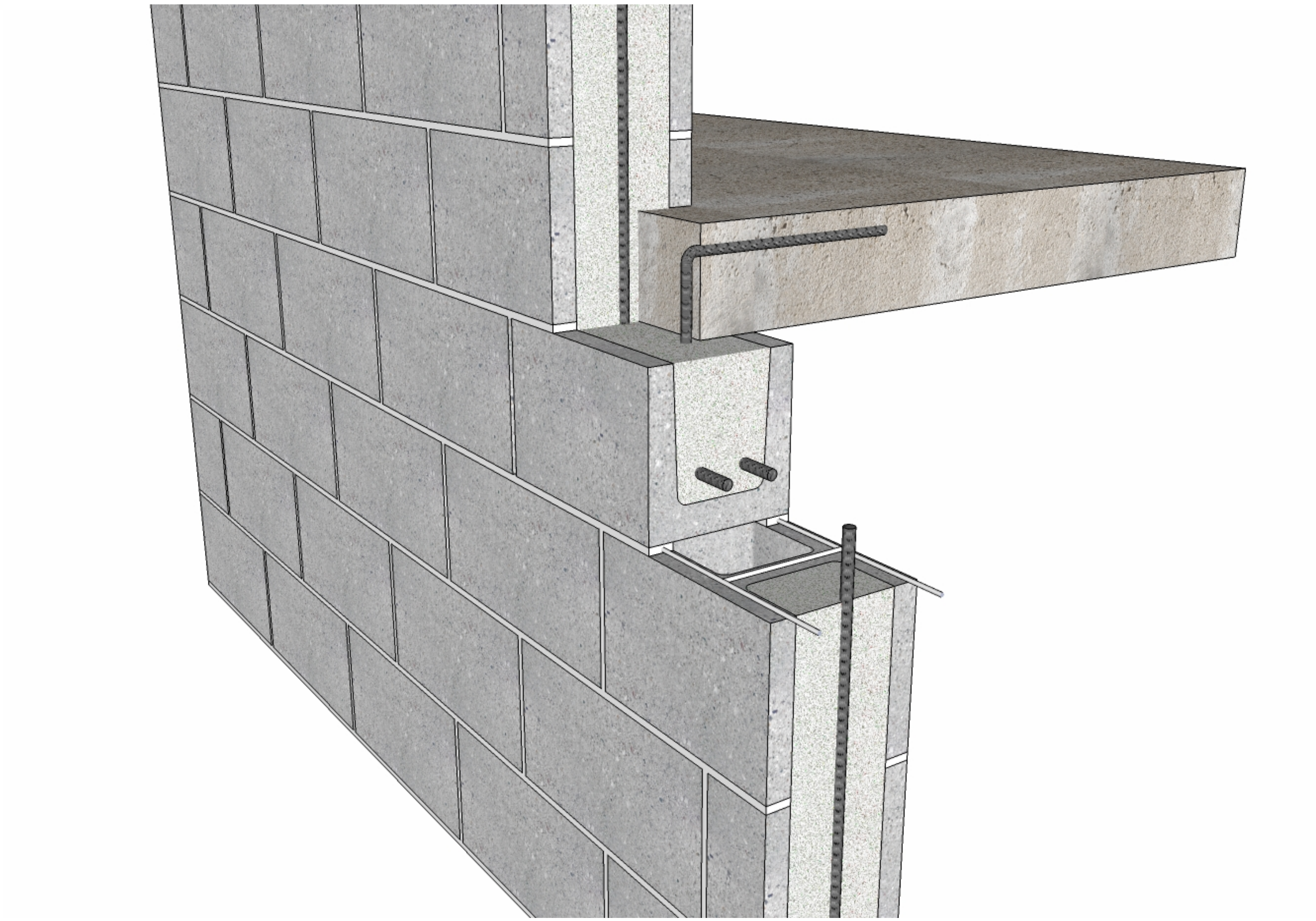
10B
A-2
METAL COPING PARAPET DETAIL

MIM Generic Wall Design



2A
A-2
BASE DETAIL W/ VENEER BELOW GRADE

MIM Generic Wall Design



FLOOR CONNECTION DETAIL

DETAIL 02.010.0701 REV. 08/31/07

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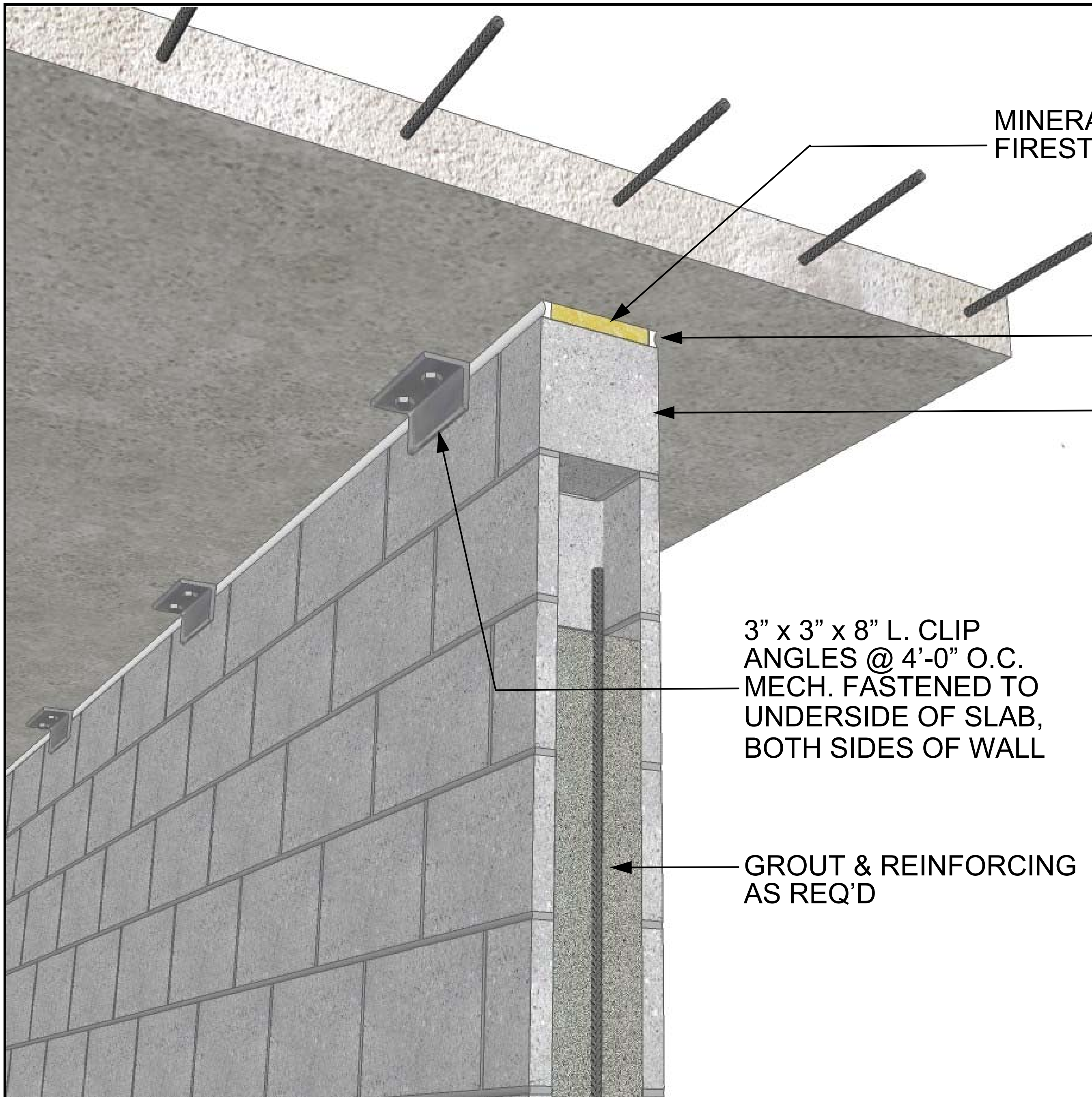

CONCRETE MASONRY FIREWALL T/ WALL AT SLAB ABOVE

DETAIL 02.010.0702

REV. 08/31/07

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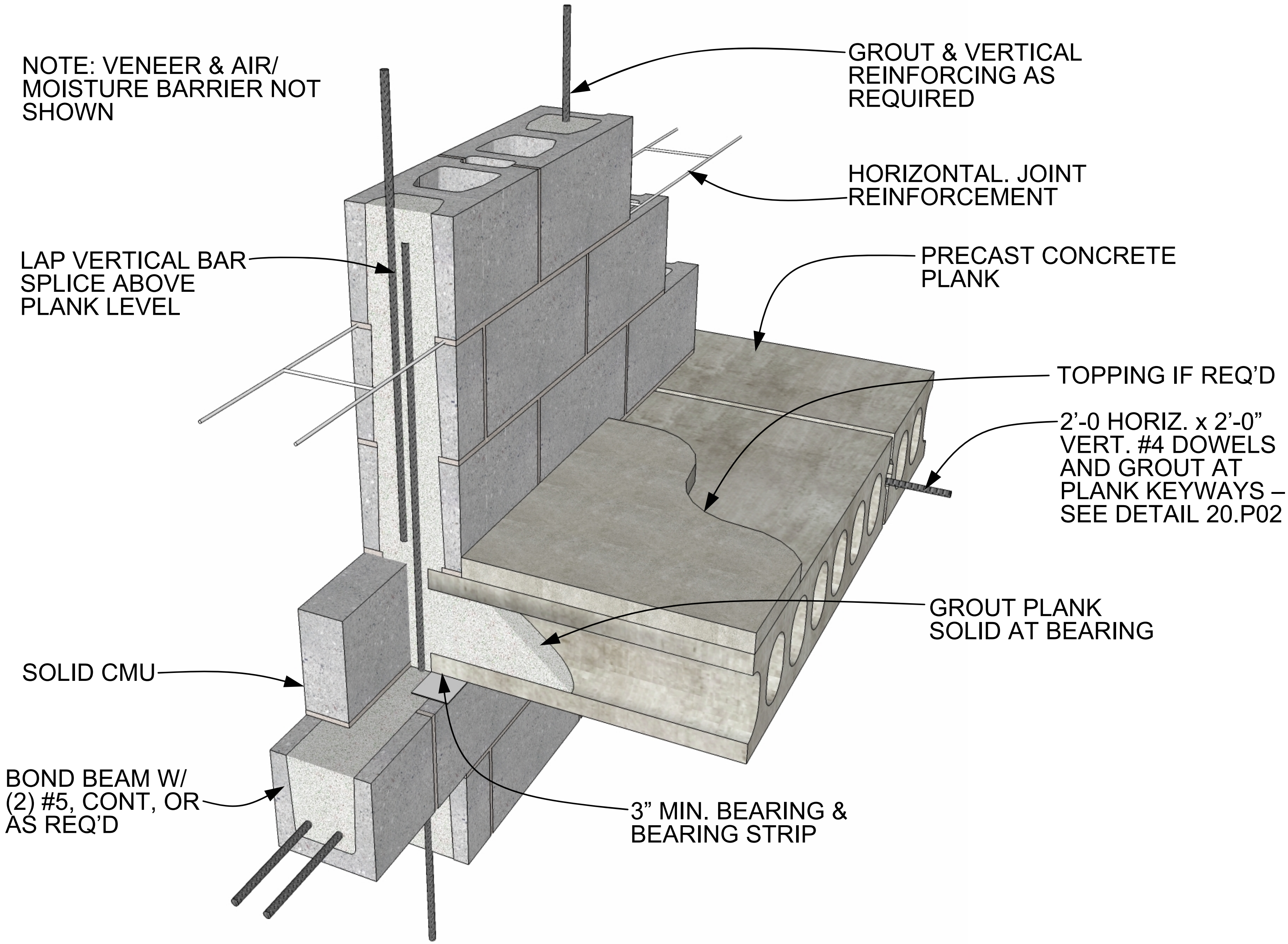

PLANK AT BEARING WALL
INTERMEDIATE ELEVATION

DETAIL 02.120.0751

REV. 11/25/08

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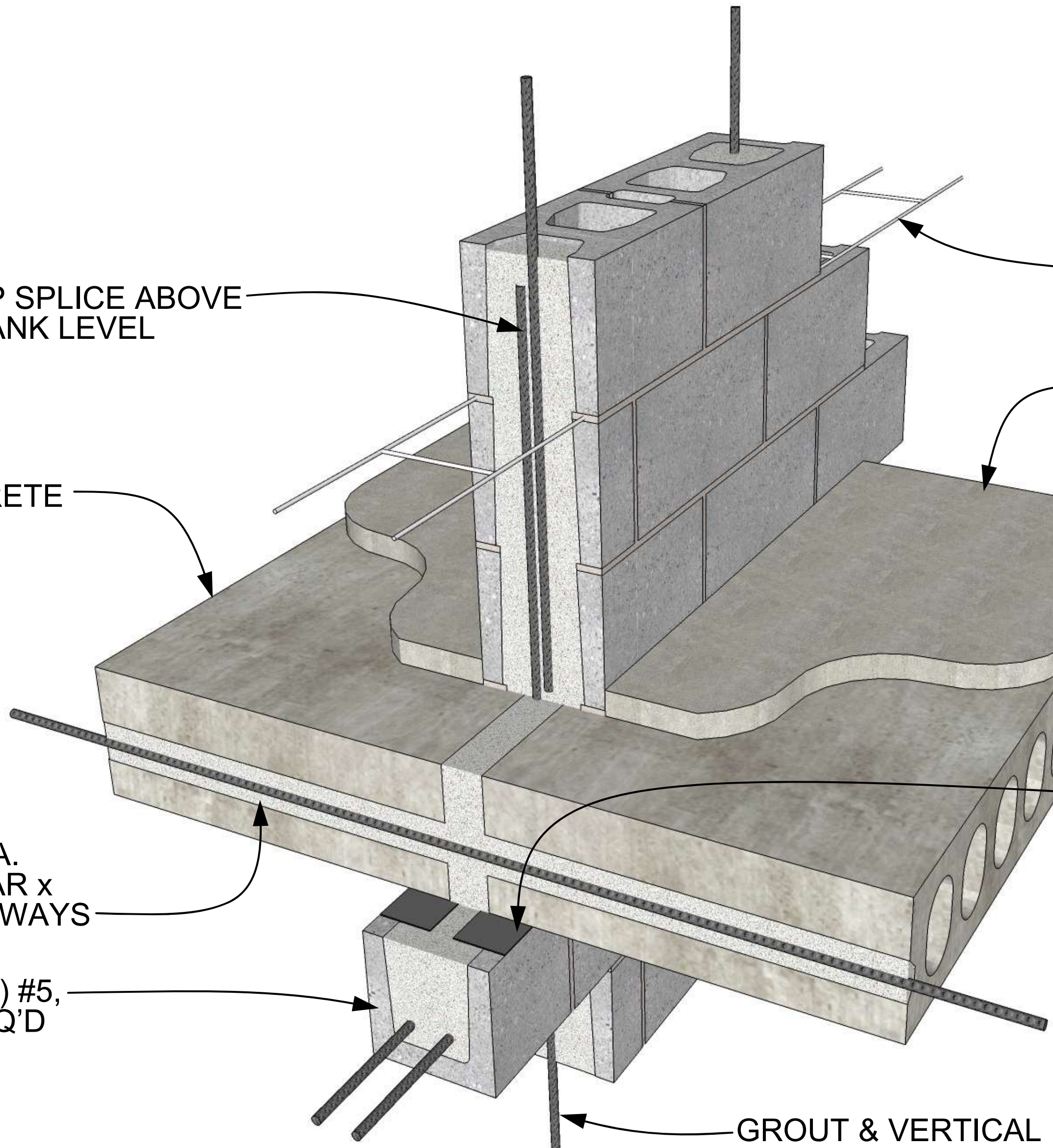

PLANK AT BEARING WALL

INTERIOR WALL, INTERMEDIATE ELEV.

DETAIL 02.120.0752

REV. 11/25/08

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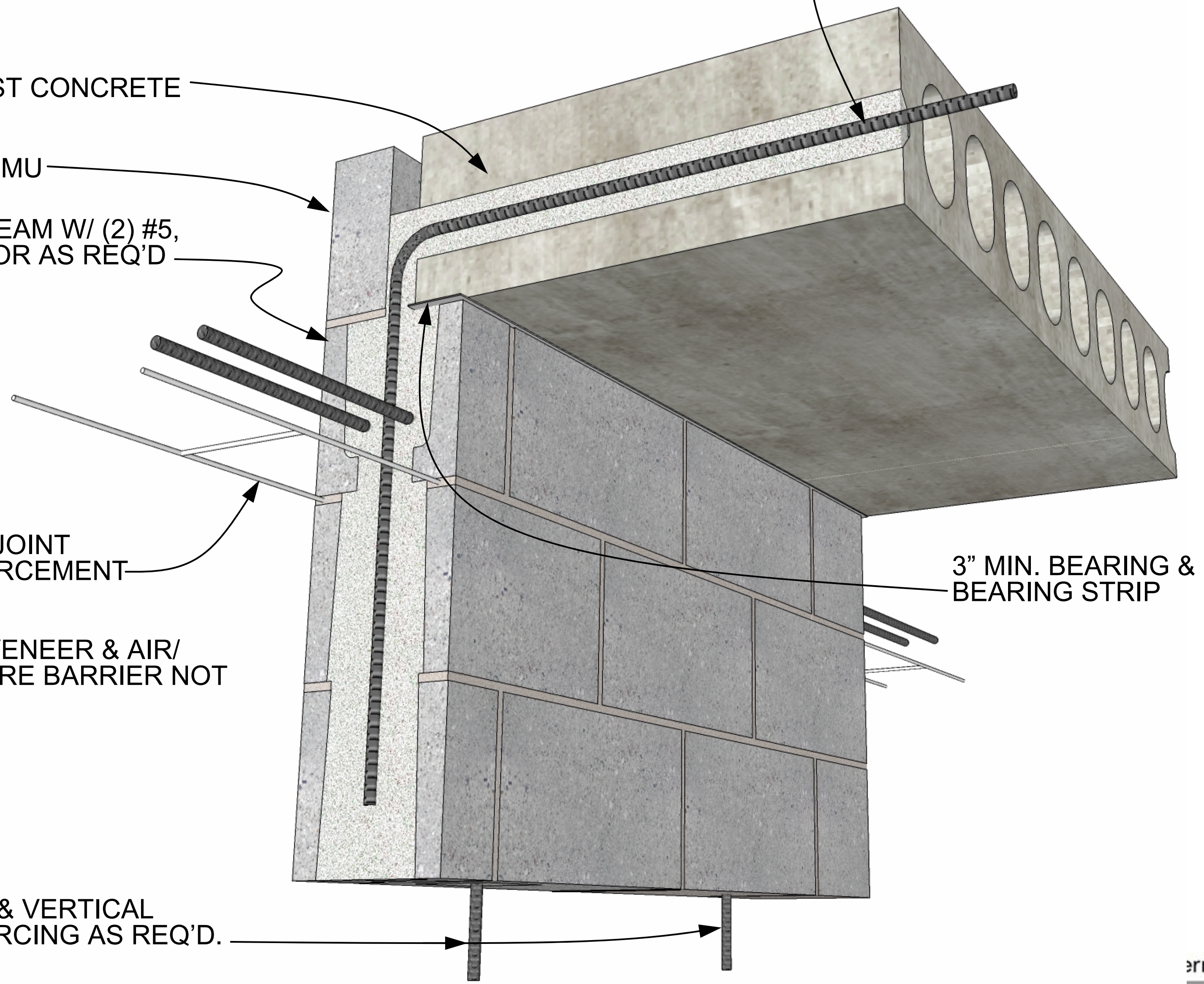

PLANK AT BEARING WALL TOP OF WALL

DETAIL 02.120.0851

REV. 11/25/08

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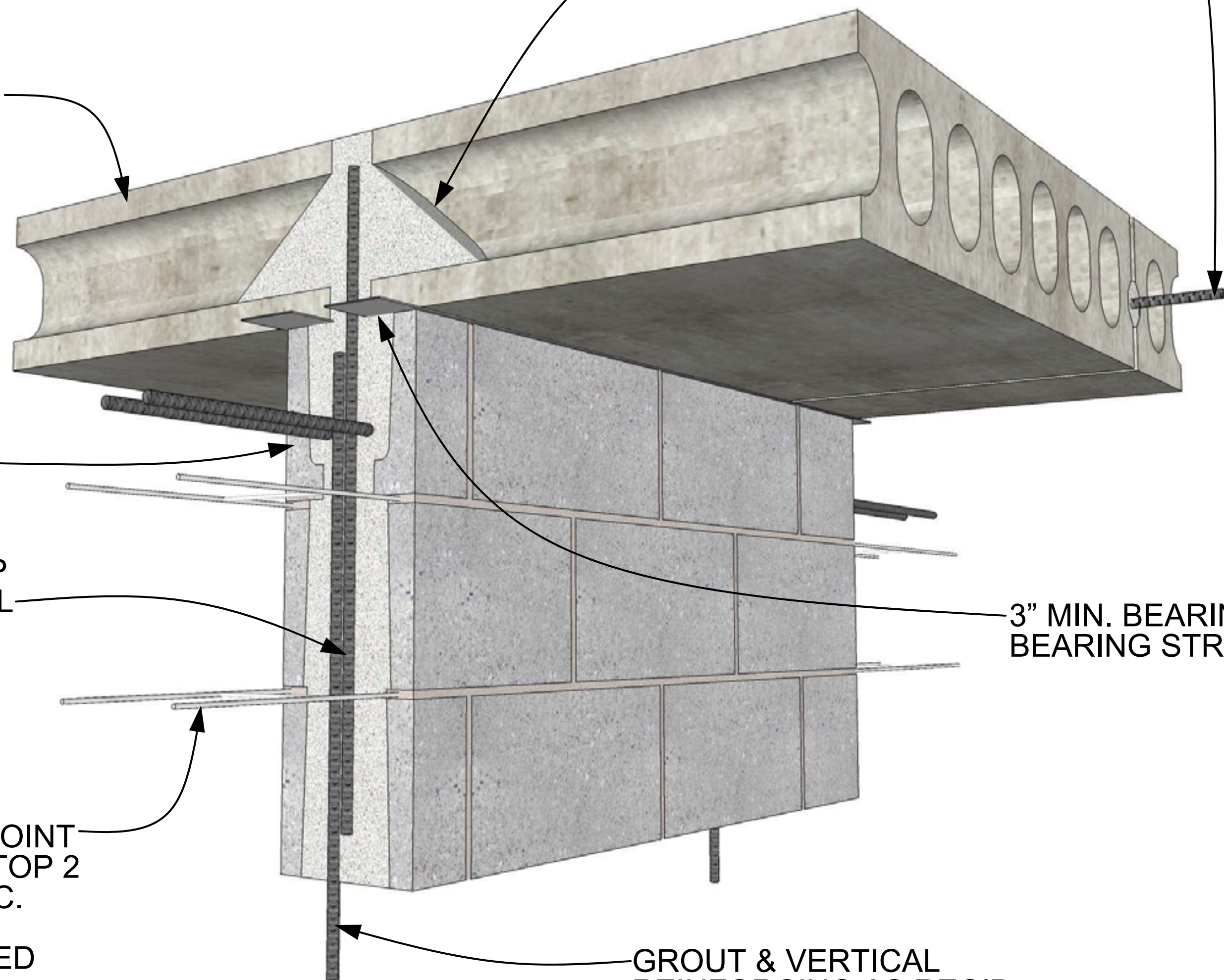

PLANK AT BEARING WALL INTERIOR, TOP OF WALL

DETAIL 02.120.0852

REV. 11/25/08

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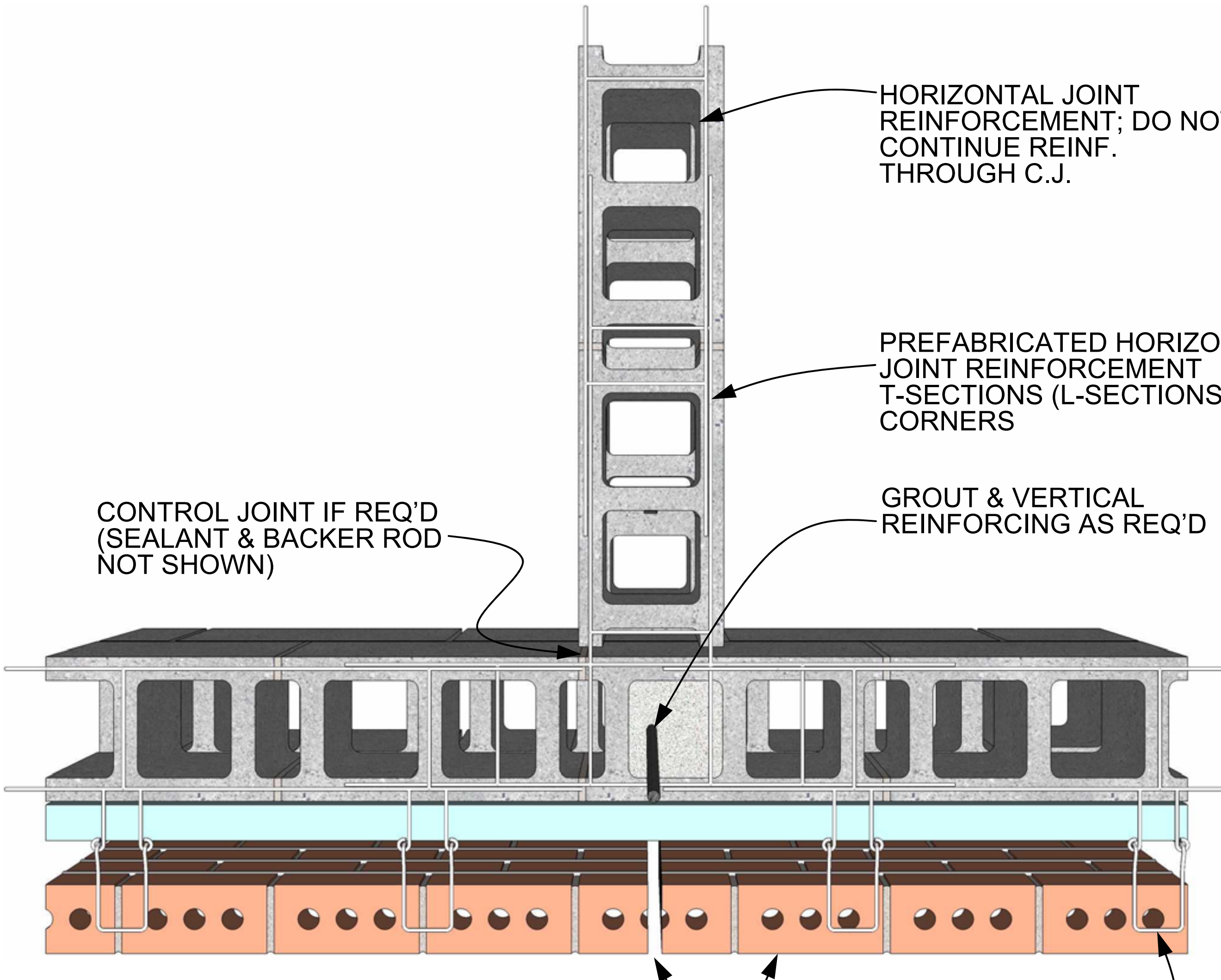

WALL INTERSECTION DETAIL

DETAIL 02.120.1501 REV. 08/21/09

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Structural

RAM Elements

Bentley
Sustaining Infrastructure

The Structural Engineer's Toolkit System is now even better

Announcing Hybrid Masonry Design

In 2008, Bentley's RAM software developers worked hand-in-hand with IMI, NCMA, and David Biggs of Ryan-Biggs Associates, P.C. of New York to enhance the RAM Advanse program (since renamed to **RAM Elements**) with the ability to design hybrid masonry structures. The hybrid masonry concept has existed for many years, but Mr. Biggs has pioneered the design procedure for utilizing structural masonry infill within a structural steel frame, allowing for faster and more economical designs including irregular configurations, wall openings and more all done with a whole building approach, not just structural components.

DETAIL FOR THIS...

OR THIS?

IF YOU'VE EVER FOUND YOURSELF:

--designing steel buildings that contain CMU walls as partitions only

--trying to develop construction details for interaction between CMU walls and structural steel framing

--handling requests for information (RFIs) from the field with questions about detailing masonry and steel interaction

--handling complaints from architects about interferences between steel frames and CMU walls, fireproofing, etc.

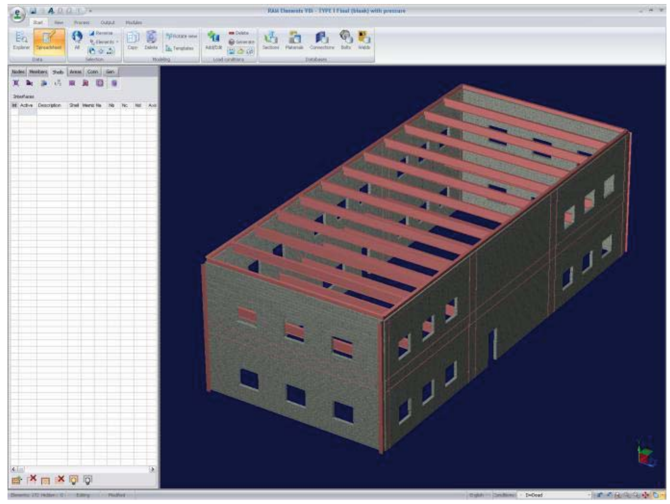
...THEN HYBRID MASONRY MAY BE FOR YOU. AND RAM ELEMENTS IS THE TOOL TO MAKE YOUR DESIGN WORK EASIER

team IMI
UNION MASONRY CRAFTWORKERS CONTRACTORS & CONSULTANTS

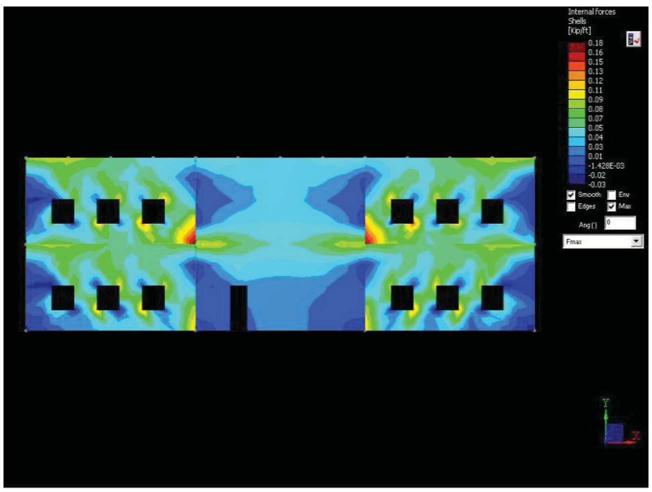
NATIONAL CONCRETE MASONRY ASSOCIATION
Sustainable Concrete Products for Structures and Hardscapes

RYAN-BIGGS

RAM Elements – The Structural Engineer's Toolkit System

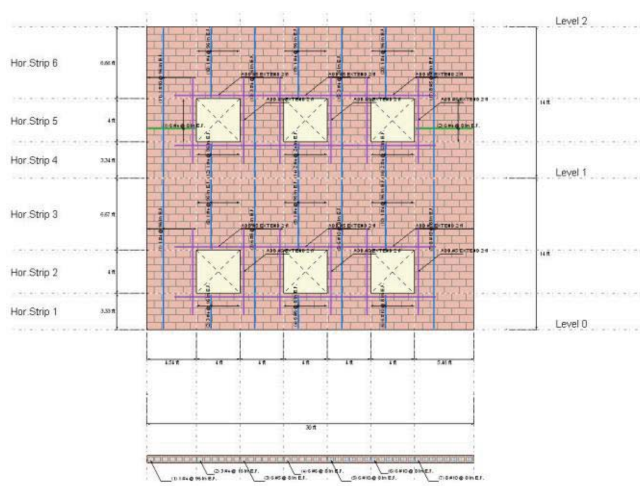


RAM Elements allows you to model an entire building, including wall openings, etc., and specify Type I, IIA, IIB, IIIA, or IIIB hybrid walls (as well as traditional loadbearing masonry walls) as required for your structure's design.



RAM Elements will automatically configure the releases for the finite element modeling of your hybrid masonry walls. Output options include design code checks, traditional color-coded FEA output, and…

…full reinforcing bar layouts that can be exported for use in your drawings or for reviewing with architects and contractors.



To learn more about the capabilities of RAM Elements for both general structural analysis/design and as an everyday component toolkit for retaining walls, continuous beams, footings, trusses, and more, please visit http://www.bentley.com/en-US/Products/RAM+Elements/

Microsoft

Current Date: 6/30/2010 3:51 PM
Units system: English
File name: C:\Users\Scott Walkowicz\Documents\001 Masonry Coalition 2009\Projects\Masonry v Wood\100 Room Dorm Conversion\3-Story Load Bearing Wall with Shear 20100630.msw\

Design Results

Masonry wall

GENERAL INFORMATION:

Global status : OK

Design code	:	ACI 530-05

Geometry:

Total height	:	30.00 [ft]
Wall Thickness	:	7.63 [in]
Total length	:	15.33 [ft]
Base support type	:	Continuous
Wall bottom restraint	:	Pinned
Column bottom restraint	:	Fixed
Rigidity elements	:	Flanges

Materials:

Material	:	CMU 2.5-60
Mortar type	:	Port/Mort - M/S
Mortar bed type	:	Face shell bed
Grouting type	:	Partial grouting
Masonry compression strength (F`m)	:	2.5 [Kip/in2]
Steel tension strength (fy)	:	60 [Kip/in2]
Steel allowable tension strength (Fs)	:	24 [Kip/in2]
Steel elasticity modulus (Es)	:	29000 [Kip/in2]
Masonry elasticity modulus (Em)	:	2250 [Kip/in2]
Masonry unit weight	:	0.14 [Kip/ft3]
Effective masonry unit weight	:	0.0742176 [Kip/ft3]

Number of stories: **3**

Story	Story height [ft]
1	10.00
2	10.00
3	10.00

Openings:

Reference	X Coordinate [ft]	Y Coordinate [ft]	Width [ft]	Height [ft]
Lower left	4.66	1.67	6.00	5.33
Lower left	4.66	11.67	6.00	5.33
Lower left	4.67	21.67	6.00	5.33

Flanges:

Distance [ft]	Thickness [in]	Width [ft]	Position X	Position Z
0.00	7.63	3.82	Centered	Front
15.33	7.63	3.82	Centered	Front

Load conditions:

ID	Comb.	Category	Description
DL	No	DL	Dead Load
LL	No	LL	Live Load
LLr	No	LLR	Live Load Roof
SnL	No	SNOW	Snow Load
WL	No	WIND	Wind Load
SM1	Yes		DL
DM1	Yes		DL
D1	Yes		DL
D2	Yes		DL+LL
D3	Yes		DL+LLr
D4	Yes		DL+SnL
D5	Yes		DL+0.75LL
D6	Yes		DL+0.75SnL
D7	Yes		DL+0.75LLr
D8	Yes		DL+0.75LL+0.75LLr
D9	Yes		DL+0.75LL+0.75SnL
D10	Yes		DL+WL
D11	Yes		DL+0.75WL+0.75LL
D12	Yes		DL+0.75WL+0.75SnL
D13	Yes		DL+0.75WL+0.75LLr
D14	Yes		DL+0.75WL+0.75LL+0.75LLr
D15	Yes		DL+0.75WL+0.75LL+0.75SnL
D16	Yes		0.6DL+WL
S1	Yes		DL
S2	Yes		DL+LL
S3	Yes		DL+LLr
S4	Yes		DL+SnL
S5	Yes		DL+0.75LL
S6	Yes		DL+0.75SnL
S7	Yes		DL+0.75LLr
S8	Yes		DL+0.75LL+0.75LLr
S9	Yes		DL+0.75LL+0.75SnL
S10	Yes		DL+WL
S11	Yes		DL+0.75WL+0.75LL
S12	Yes		DL+0.75WL+0.75SnL
S13	Yes		DL+0.75WL+0.75LLr
S14	Yes		DL+0.75WL+0.75LL+0.75LLr
S15	Yes		DL+0.75WL+0.75LL+0.75SnL
S16	Yes		0.6DL+WL

Distributed loads:

Consider self weight : DL

Story	Condition	Direction	Magnitude [Kip/ft]	Eccentricity [ft]
1	DL	Vertical	1.13	0.17
2	DL	Vertical	1.13	0.17
3	DL	Vertical	1.20	0.17
1	LL	Vertical	0.65	0.17
2	LL	Vertical	0.65	0.17

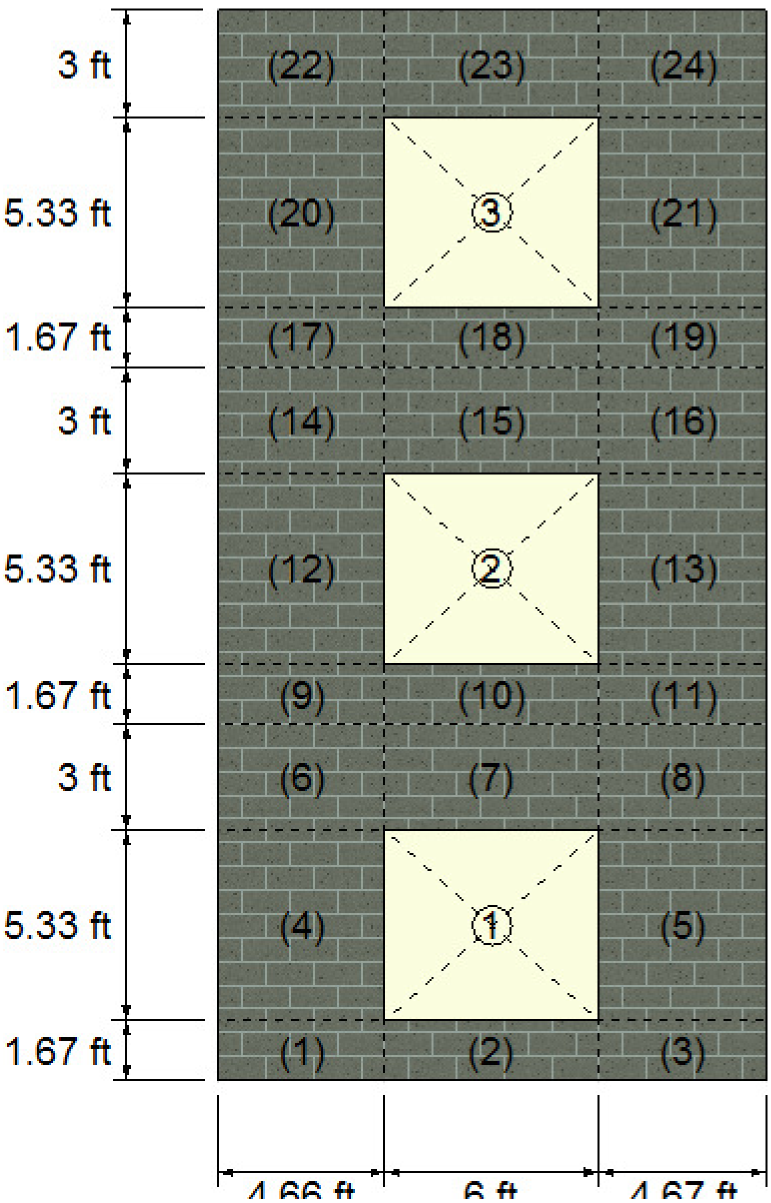
3	LLr	Vertical	0.26	0.17
3	SnL	Vertical	0.65	0.17
1	WL	Horizontal	0.04	0.00
2	WL	Horizontal	0.04	0.00
3	WL	Horizontal	0.04	0.00

Out-of-plane loads:

Story	Condition	Magnitude [Kip/ft2]
1	WL	0.03
2	WL	0.03
3	WL	0.03

BEARING WALL DESIGN:

Status : OK



Geometry:

Segment	X Coordinate [ft]	Y Coordinate [ft]	Width [ft]	Height [ft]
1	0.00	0.00	4.66	1.67
2	4.66	0.00	6.00	1.67
3	10.66	0.00	4.67	1.67
4	0.00	1.67	4.66	5.33
5	10.66	1.67	4.67	5.33
6	0.00	7.00	4.66	3.00
7	4.66	7.00	6.00	3.00
8	10.66	7.00	4.67	3.00
9	0.00	10.00	4.66	1.67
10	4.66	10.00	6.00	1.67
11	10.66	10.00	4.67	1.67
12	0.00	11.67	4.66	5.33
13	10.66	11.67	4.67	5.33
14	0.00	17.00	4.66	3.00
15	4.66	17.00	6.00	3.00
16	10.66	17.00	4.67	3.00
17	0.00	20.00	4.66	1.67
18	4.66	20.00	6.00	1.67
19	10.66	20.00	4.67	1.67
20	0.00	21.67	4.66	5.33
21	10.66	21.67	4.67	5.33
22	0.00	27.00	4.66	3.00
23	4.66	27.00	6.00	3.00
24	10.66	27.00	4.67	3.00

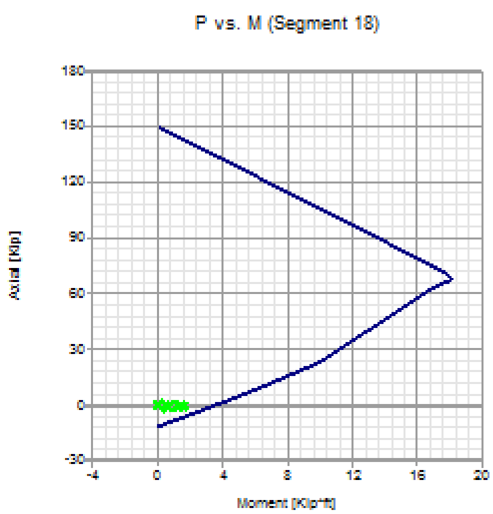
Vertical reinforcement:

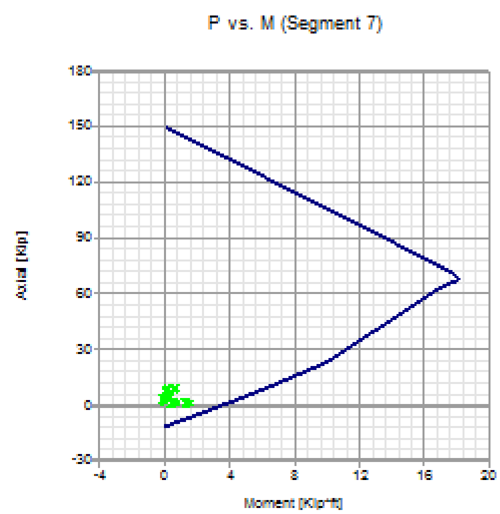
Segment	Bars	Spacing [in]	Ld [in]
1	1-#5	96.00	40.62
2	1-#5	96.00	40.62
3	1-#5	96.00	40.62
4	1-#5	96.00	40.62
5	1-#5	96.00	40.62
6	1-#5	96.00	40.62
7	1-#5	96.00	40.62
8	1-#5	96.00	40.62
9	1-#5	96.00	40.62
10	1-#5	96.00	40.62
11	1-#5	96.00	40.62
12	1-#5	96.00	40.62
13	1-#5	96.00	40.62
14	1-#5	96.00	40.62
15	1-#5	96.00	40.62
16	1-#5	96.00	40.62
17	1-#5	96.00	40.62
18	1-#5	96.00	40.62
19	1-#5	96.00	40.62
20	1-#5	96.00	40.62
21	1-#5	96.00	40.62
22	1-#5	96.00	40.62
23	1-#5	96.00	40.62
24	1-#5	96.00	40.62

Results: Combined axial flexure

Segment	Condition	P [Kip]	M [Kip*ft]	Ma [Kip*ft]	Ratio
1	D16(Top)	14.26	-0.23	6.77	0.03
2	D16(Max)	2.40	-0.10	4.30	0.02
3	D16(Top)	16.01	-0.24	7.24	0.03
4	D16(Max)	14.48	-0.32	6.83	0.05
5	D16(Max)	16.31	-0.36	7.31	0.05
6	D16(Top)	8.07	1.04	5.11	0.20
7	D10(Top)	1.23	1.64	3.95	0.41
8	D16(Top)	9.75	1.05	5.57	0.19
9	D16(Bottom)	8.07	1.04	5.11	0.20
10	D10(Bottom)	1.23	1.64	3.95	0.41
11	D16(Bottom)	9.75	1.05	5.57	0.19
12	D11(Bottom)	16.32	0.56	7.31	0.08
13	D11(Bottom)	18.28	0.57	7.81	0.07
14	D16(Top)	7.10	0.59	4.84	0.12
15	D16(Top)	3.74	0.81	4.69	0.17
16	D16(Top)	8.02	0.58	5.10	0.11
17	D16(Bottom)	4.15	1.14	4.00	0.28
18	D10(Bottom)	-0.27	1.70	3.51	0.48
19	D16(Bottom)	4.97	1.14	4.24	0.27
20	D16(Top)	5.20	-0.64	4.30	0.15
21	D16(Top)	5.65	-0.65	4.43	0.15
22	D4(Top)	8.32	-1.42	5.18	0.27
23	D4(Top)	11.21	-1.85	6.80	0.27
24	D4(Top)	8.44	-1.42	5.21	0.27

Interaction diagrams, P vs. M:





Results: Axial compression

Segment	Condition	P [Kip]	Pa [Kip]	Ratio
1	D9(Top)	30.46	81.67	0.37
2	D15(Bottom)	5.08	105.08	0.05
3	D15(Top)	33.07	81.79	0.40
4	D9(Max)	31.49	81.67	0.39
5	D15(Max)	33.74	81.79	0.41
6	D9(Bottom)	30.29	81.67	0.37
7	D2(Max)	9.39	105.08	0.09
8	D15(Bottom)	33.06	81.79	0.40
9	D9(Top)	18.65	81.67	0.23
10	D4(Max)	1.71	105.08	0.02
11	D15(Top)	20.54	81.79	0.25
12	D9(Top)	19.65	81.67	0.24
13	D15(Max)	21.84	81.79	0.27
14	D9(Bottom)	19.65	81.67	0.24
15	D2(Top)	8.71	105.08	0.08
16	D15(Bottom)	21.42	81.79	0.26
17	D4(Top)	11.03	81.67	0.14
18	D4(Top)	0.33	105.08	0.00
19	D4(Top)	11.72	81.79	0.14
20	D4(Top)	12.68	81.67	0.16
21	D4(Top)	12.99	81.79	0.16
22	D4(Bottom)	12.68	81.67	0.16
23	D4(Top)	11.21	105.08	0.11
24	D4(Bottom)	12.99	81.79	0.16

Results: Axial tension

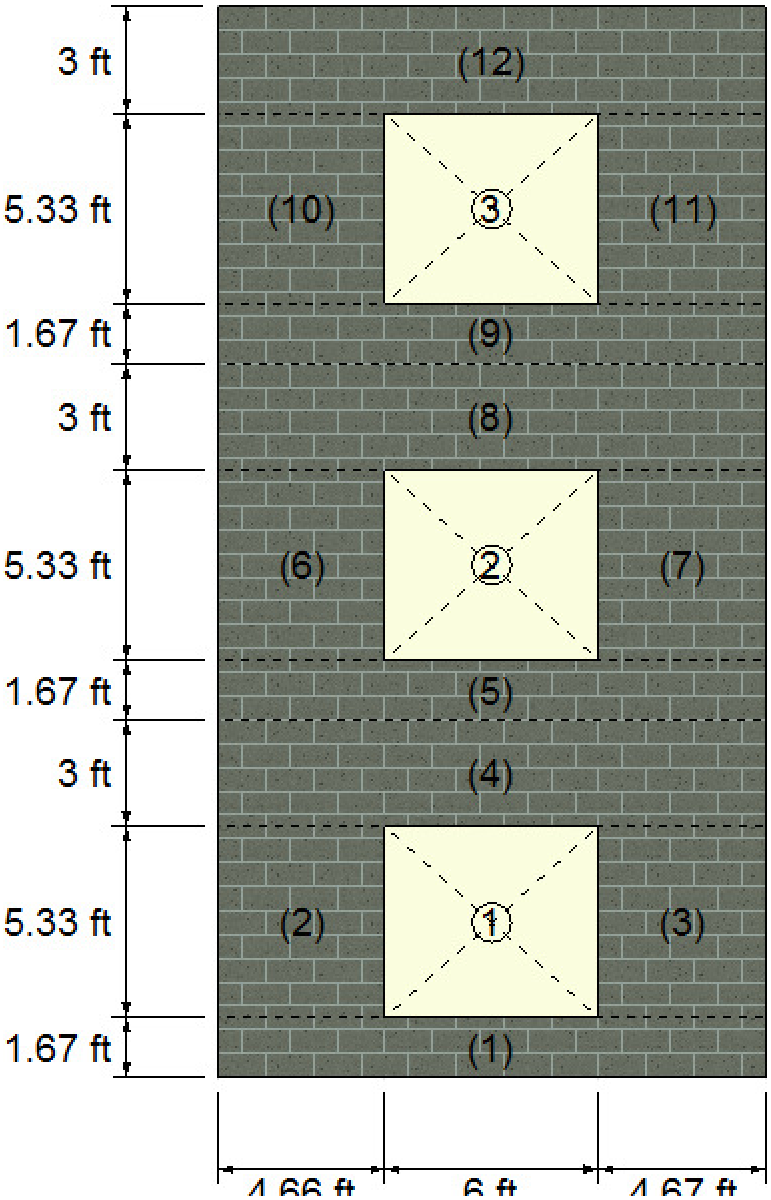
Segment	Condition	ft [Kip/in2]	Fs [Kip/in2]	Ratio
1	DM1(Top)	0.00	24.00	0.00
2	DM1(Top)	0.00	24.00	0.00
3	DM1(Top)	0.00	24.00	0.00
4	DM1(Top)	0.00	24.00	0.00
5	DM1(Top)	0.00	24.00	0.00
6	DM1(Top)	0.00	24.00	0.00
7	DM1(Top)	0.00	24.00	0.00
8	DM1(Top)	0.00	24.00	0.00
9	DM1(Top)	0.00	24.00	0.00
10	DM1(Top)	0.00	24.00	0.00
11	DM1(Top)	0.00	24.00	0.00
12	DM1(Top)	0.00	24.00	0.00
13	DM1(Top)	0.00	24.00	0.00
14	DM1(Top)	0.00	24.00	0.00
15	DM1(Top)	0.00	24.00	0.00
16	DM1(Top)	0.00	24.00	0.00
17	DM1(Top)	0.00	24.00	0.00
18	D2(Bottom)	2.76	24.00	0.11
19	DM1(Top)	0.00	24.00	0.00
20	DM1(Top)	0.00	24.00	0.00
21	DM1(Top)	0.00	24.00	0.00
22	DM1(Top)	0.00	24.00	0.00
23	DM1(Top)	0.00	24.00	0.00
24	DM1(Top)	0.00	24.00	0.00

Results:Shear

Segment	Condition	fv [Kip/in2]	Fv [Kip/in2]	Ratio
1	D10(Max)	0.001	0.050	0.02
2	D10(Max)	0.001	0.050	0.01
3	D10(Max)	0.001	0.050	0.02
4	D2(Top)	0.001	0.050	0.02
5	D2(Top)	0.001	0.050	0.02
6	D15(Top)	0.004	0.050	0.08
7	D10(Top)	0.003	0.050	0.06
8	D15(Top)	0.004	0.050	0.09
9	D15(Max)	0.004	0.050	0.09
10	D10(Max)	0.003	0.050	0.06
11	D15(Max)	0.004	0.050	0.09
12	D15(Bottom)	0.003	0.050	0.05
13	D15(Bottom)	0.003	0.050	0.06
14	D16(Top)	0.002	0.050	0.05
15	D16(Top)	0.002	0.050	0.03
16	D2(Top)	0.002	0.050	0.04
17	D15(Max)	0.005	0.050	0.10
18	D10(Max)	0.003	0.050	0.07
19	D15(Max)	0.005	0.050	0.10
20	D15(Bottom)	0.003	0.050	0.06
21	D15(Bottom)	0.003	0.050	0.07
22	D4(Top)	0.004	0.050	0.08
23	D15(Max)	0.002	0.050	0.05
24	D4(Top)	0.004	0.050	0.08

SHEAR WALL DESIGN:

Status : OK



Geometry:

Segment	X Coordinate [ft]	Y Coordinate [ft]	Width [ft]	Height [ft]
1	0.00	0.00	15.33	1.67
2	0.00	1.67	4.66	5.33
3	10.66	1.67	4.67	5.33
4	0.00	7.00	15.33	3.00
5	0.00	10.00	15.33	1.67
6	0.00	11.67	4.66	5.33
7	10.66	11.67	4.67	5.33
8	0.00	17.00	15.33	3.00
9	0.00	20.00	15.33	1.67
10	0.00	21.67	4.66	5.33
11	10.66	21.67	4.67	5.33
12	0.00	27.00	15.33	3.00

Reinforcement:

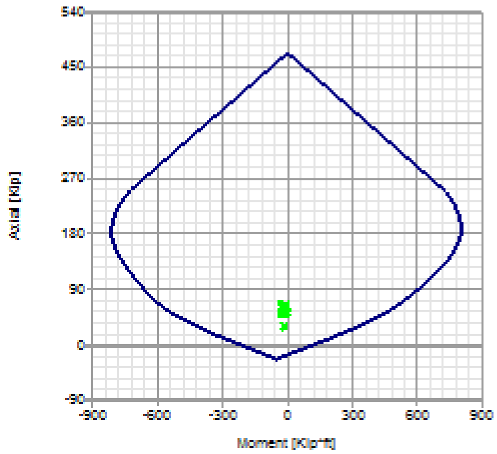
	Vertical reinforcement			Horizontal reinforcement		
Segment	**Bars**	**Spacing** [in]	**Ld** [in]	**Bars**	**Spacing** [in]	**Ld** [in]
1	1-#5	96.00	0.00	--	0.00	0.00
	1-#5	96.00	0.00	--	0.00	0.00
	1-#5	96.00	0.00	--	0.00	0.00
2	1-#5	96.00	0.00	--	0.00	0.00
3	1-#5	96.00	0.00	--	0.00	0.00
4	1-#5	96.00	0.00	--	0.00	0.00
	1-#5	96.00	0.00	--	0.00	0.00
	1-#5	96.00	0.00	--	0.00	0.00
5	1-#5	96.00	0.00	--	0.00	0.00
	1-#5	96.00	0.00	--	0.00	0.00
	1-#5	96.00	0.00	--	0.00	0.00
6	1-#5	96.00	0.00	--	0.00	0.00
7	1-#5	96.00	0.00	--	0.00	0.00
8	1-#5	96.00	0.00	--	0.00	0.00
	1-#5	96.00	0.00	--	0.00	0.00
	1-#5	96.00	0.00	--	0.00	0.00
9	1-#5	96.00	0.00	--	0.00	0.00
	1-#5	96.00	0.00	--	0.00	0.00
	1-#5	96.00	0.00	--	0.00	0.00
10	1-#5	96.00	0.00	--	0.00	0.00
11	1-#5	96.00	0.00	--	0.00	0.00
12	1-#5	96.00	0.00	--	0.00	0.00
	1-#5	96.00	0.00	--	0.00	0.00
	1-#5	96.00	0.00	--	0.00	0.00

Results: Combined axial flexure

Segment	Condition	P [Kip]	M [Kip*ft]	Ma [Kip*ft]	Ratio
1	D15(Max)	64.89	-18.42	585.53	0.03
2	D2(Bottom)	29.84	-5.87	88.13	0.07
3	D2(Bottom)	31.72	5.31	64.10	0.08
4	D16(Top)	30.66	-13.62	415.19	0.03
5	D15(Top)	38.52	-14.24	461.03	0.03
6	D2(Bottom)	18.32	-4.32	68.27	0.06
7	D11(Bottom)	19.10	4.28	40.72	0.11
8	D10(Top)	32.62	-10.47	426.71	0.02
9	D15(Top)	18.44	-7.21	343.26	0.02
10	D4(Bottom)	12.69	-9.88	57.55	0.17
11	D4(Bottom)	13.00	10.02	28.41	0.35
12	D10(Top)	19.27	-2.71	348.11	0.01

Interaction diagrams, P vs. M:

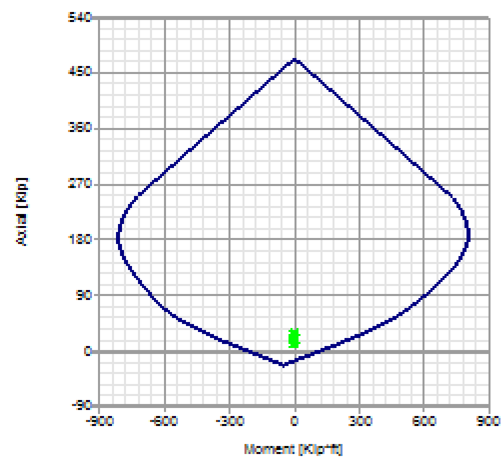
P vs. M (Segment 1)



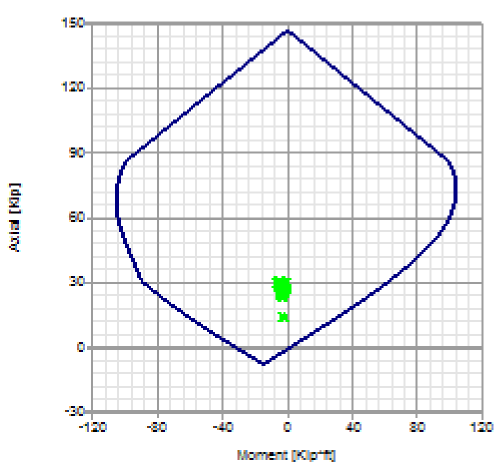
P vs. M (Segment 10)

P vs. M (Segment 11)

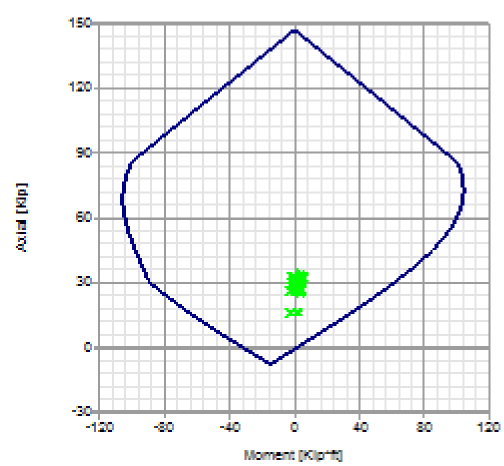
P vs. M (Segment 12)



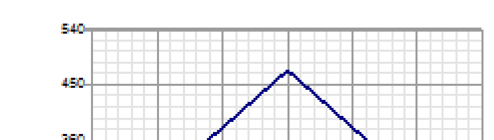
P vs. M (Segment 2)



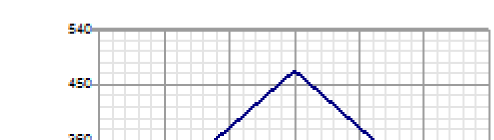
P vs. M (Segment 3)



P vs. M (Segment 4)



P vs. M (Segment 5)



Results: Axial compression

Segment	Condition	P [Kip]	Pa [Kip]	Ratio
1	D15(Bottom)	65.40	325.09	0.20
2	D9(Max)	31.29	100.55	0.31
3	D15(Max)	34.06	100.66	0.34
4	D15(Top)	65.00	325.09	0.20
5	D9(Bottom)	39.51	325.09	0.12
6	D9(Max)	19.96	100.55	0.20
7	D15(Max)	21.84	100.66	0.22
8	D9(Bottom)	42.44	325.09	0.13
9	D4(Bottom)	22.82	325.09	0.07
10	D4(Max)	12.96	100.55	0.13
11	D4(Max)	13.37	100.66	0.13
12	D4(Bottom)	27.96	325.09	0.09

Results: Axial tension

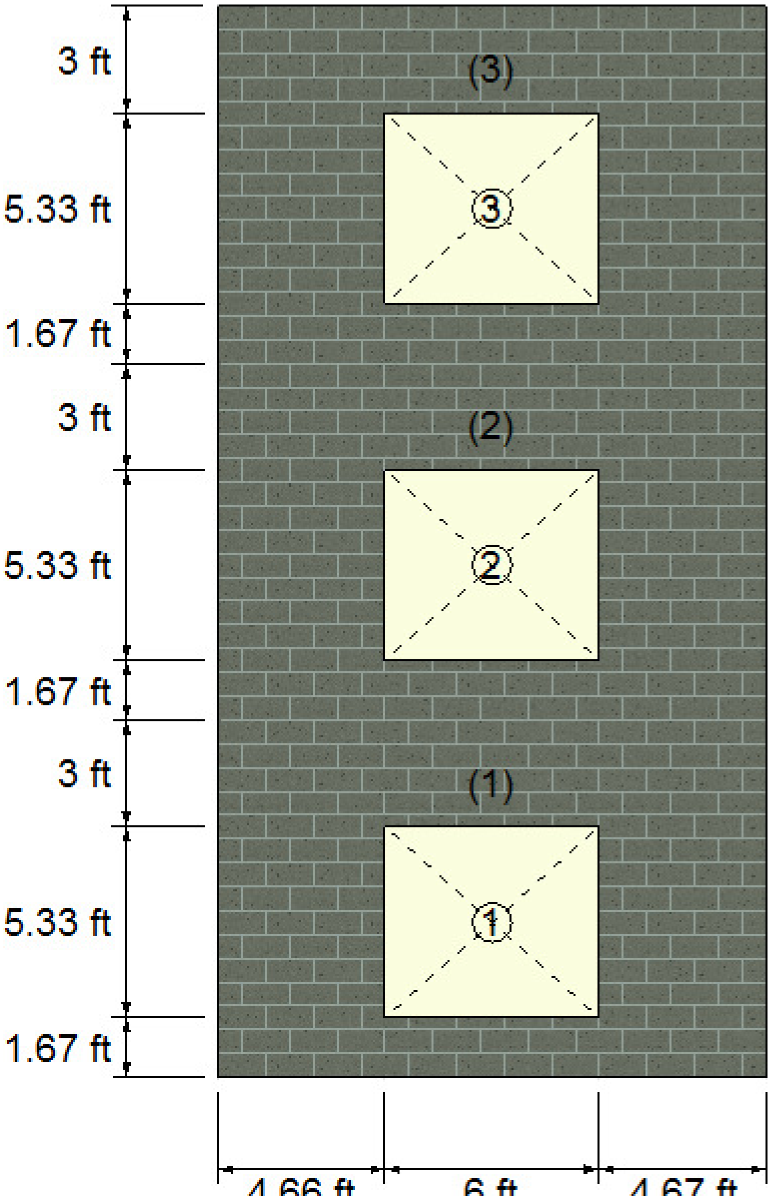
Segment	Condition	ft [Kip/in2]	Fs [Kip/in2]	Ratio
1	DM1(Top)	0.00	24.00	0.00
2	DM1(Top)	0.00	24.00	0.00
3	DM1(Top)	0.00	24.00	0.00
4	DM1(Top)	0.00	24.00	0.00
5	DM1(Top)	0.00	24.00	0.00
6	DM1(Top)	0.00	24.00	0.00
7	DM1(Top)	0.00	24.00	0.00
8	DM1(Top)	0.00	24.00	0.00
9	DM1(Top)	0.00	24.00	0.00
10	DM1(Top)	0.00	24.00	0.00
11	DM1(Top)	0.00	24.00	0.00
12	DM1(Top)	0.00	24.00	0.00

Results: Shear

Segment	Condition	fv [Kip/in2]	Fv [Kip/in2]	Ratio
1	D15(Max)	0.003	0.042	0.06
2	D2(Bottom)	0.012	0.046	0.26
3	D15(Bottom)	0.015	0.057	0.26
4	D15(Top)	0.002	0.035	0.06
5	D10(Top)	0.002	0.046	0.04
6	D2(Bottom)	0.017	0.060	0.29
7	D15(Bottom)	0.018	0.061	0.30
8	D15(Top)	0.001	0.037	0.04
9	D15(Max)	0.001	0.035	0.02
10	D4(Bottom)	0.025	0.052	0.47
11	D4(Bottom)	0.025	0.052	0.48
12	D10(Max)	0.001	0.063	0.02

LINTEL DESIGN:

Status : OK



Geometry:

Lintel	X Coordinate [ft]	Y Coordinate [ft]	Length [ft]	Depth [in]
1	4.66	1.67	6.00	23.63
2	4.66	11.67	6.00	23.63
3	4.67	21.67	6.00	23.63

Reinforcement:

	Top long. reinforcement		Bottom long. reinforcement		Transverse reinforcement		
Lintel	Bars	Extent [in]	Bars	Extent [in]	Bars	Spacing [in]	Ld [in]
1	--	0.00	1-#5	40.62	#5	24.00	40.62
2	--	0.00	1-#5	40.62	#5	24.00	40.62
3	--	0.00	1-#5	40.62	#5	24.00	40.62

Results: Bending

Lintel	Condition	M [Kip*ft]	Ma [Kip*ft]	Ratio
1	D2	7.25	12.65	0.57
2	D2	6.63	12.65	0.52
3	D4	8.83	12.65	0.70

Results: Shear

Lintel	Condition	fv [Kip/in2]	Fv [Kip/in2]	Ratio
1	D15	0.031	0.150	0.21
2	D15	0.027	0.150	0.18
3	D4	0.032	0.150	0.22

Results: Deflection

Lintel	Condition	δ [in]	δa [in]	Ratio
1	S2	0.02	0.12	0.13
2	S2	0.01	0.12	0.12
3	S4	0.02	0.12	0.16

Notes:

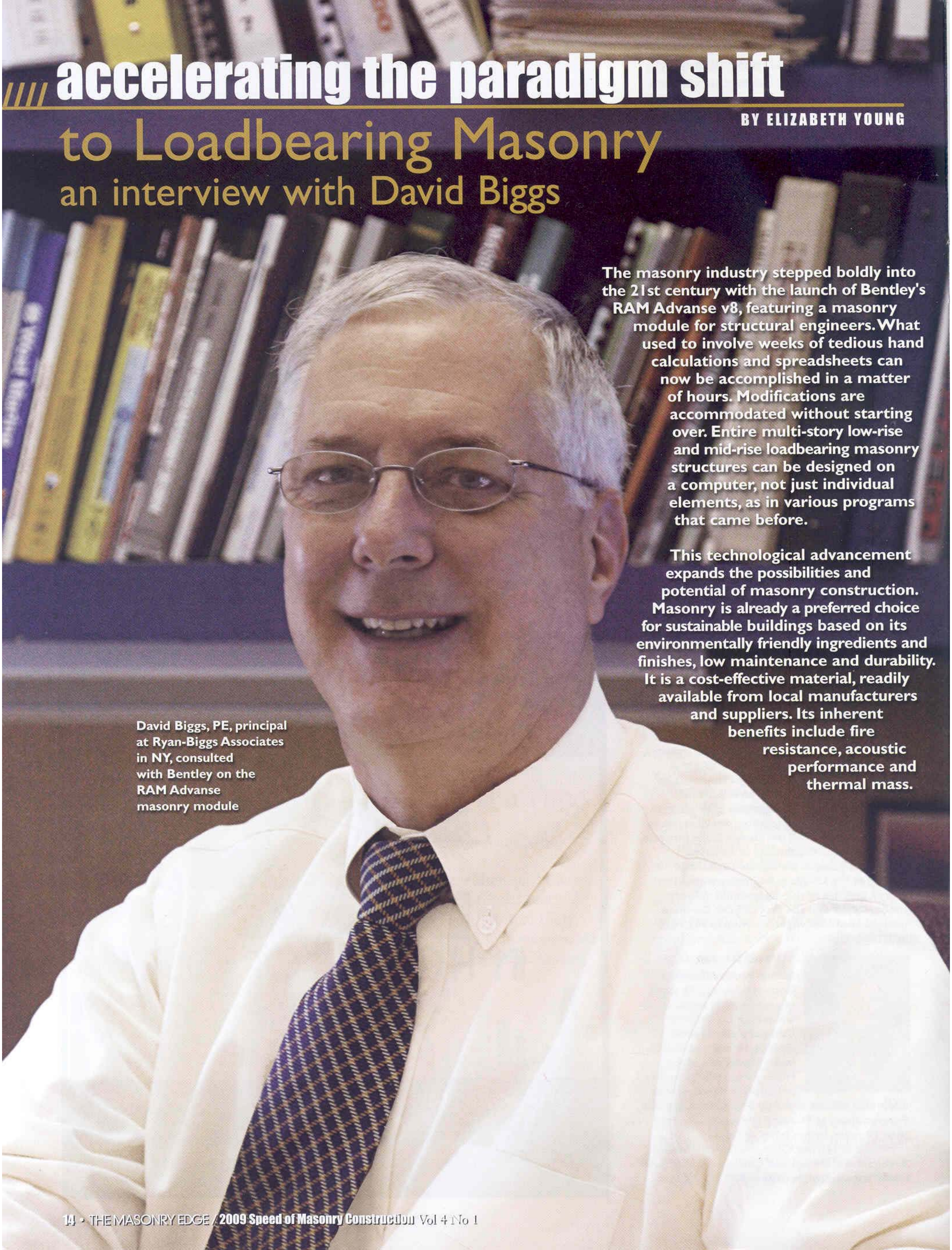
* P = Axial load
* Pa = Allowable compressive force due to axial load.
* M = Moment at the section under consideration.
* Ma = Maximum moment in member due to the applied loading
* fa = Calculated compressive stress due to axial load only
* fb = Calculated compressive stress due to axial flexure only
* ft = Calculated axial tension
* Fa = Allowable compressive stress due to axial load only
* Fb = Allowable compressive stress due to axial flexure only
* fv = Calculated shear stress
* Fs = Allowable tensile or compressive stress
* Fv = Allowable shear stress
* ld = Embedment length
* As = Effective cross sectional area of reinforcement
* δ = Calculated deflection
* δa= Allowable deflection

accelerating the paradigm shift

to Loadbearing Masonry

an interview with David Biggs

BY ELIZABETH YOUNG



The masonry industry stepped boldly into the 21st century with the launch of Bentley's RAM Advanse v8, featuring a masonry module for structural engineers. What used to involve weeks of tedious hand calculations and spreadsheets can now be accomplished in a matter of hours. Modifications are accommodated without starting over. Entire multi-story low-rise and mid-rise loadbearing masonry structures can be designed on a computer, not just individual elements, as in various programs that came before.

This technological advancement expands the possibilities and potential of masonry construction. Masonry is already a preferred choice for sustainable buildings based on its environmentally friendly ingredients and finishes, low maintenance and durability. It is a cost-effective material, readily available from local manufacturers and suppliers. Its inherent benefits include fire resistance, acoustic performance and thermal mass.

David Biggs, PE, principal at Ryan-Biggs Associates in NY, consulted with Bentley on the RAM Advanse masonry module

Masonry has an uncanny ability to instill a sense of permanence and security in a place, a community. It can bring about a feeling of warmth, the familiar, of home. Long popular with architects for these reasons, as well as its beauty and varied palette, masonry will certainly gain popularity with engineers as a result of the time-saving convenience this software affords.

David Biggs, PE, principal at Ryan-Biggs Associates in Troy, NY, worked with Bentley on its latest version of the RAM Advanse masonry module. His expertise in structural engineering includes evaluating existing structures, historic restoration, forensic evaluations of failures and designing masonry structures. He is noted for developing products for the masonry industry and innovative code and guideline development for prestressed masonry. Biggs has been recognized as an Honorary Member of The Masonry Society (2007) and a Distinguished Member of the American Society of Civil Engineers (2005). Most notably, Biggs volunteered his services with the FEMA-ASCE Building Performance Assessment Team that evaluated the building performance and reported to Congress on the World Trade Center (WTC) attacks of September 2001.

I had the opportunity of conversing with him relevant to the development of this masonry software.

How did your involvement with the Bentley RAM Advanse masonry module come about?

I contacted several software companies with engineering programs and asked if masonry was being considered and would hybrid masonry interest them. I was basically told "we have our existing programs and limited resources to work on something new." Mike Markovitz at Bentley was willing to listen and work with us on tweaking the masonry program it had launched months earlier. We didn't have to start from scratch.

Bentley had the RAM Structural System and RAM Advanse programs already available. It was the first to integrate masonry into whole building design. Since Bentley had added a masonry module in RAM Advanse, I was interested in designing a hybrid system of structural steel and reinforced masonry using the masonry module. Technically, it could be done, just not easily. Bentley worked with me and showed me how to do it, but it took about 45 minutes to do one wall.

Through conversations with people in the industry, like Dan Zechmeister, executive director of the Masonry Institute of Michigan, I was encouraged to keep working on the idea of making hybrid masonry engineering less complicated and less time-consuming.

Over the past two years, Bentley has added hybrid masonry and improved its masonry module. Now the program is more user friendly. It is faster for the hybrid systems and the all-masonry buildings. It allows us to design masonry on a competitive level with systems such as structural steel and concrete that have had full building design programs for decades.

There were members from several organizations instrumental in bringing this project about. What was the process like?

It started just from talking with people like Zechmeister. The International Masonry Institute (IMI) contacted me once it heard about the hybrid masonry concept. IMI has been a leader in advancing the masonry industry and wanted to be involved.

Basically, I went to the masonry industry to get financial backing to help Bentley make its product better. IMI was interested. I then approached the National Concrete Masonry Association (NCMA) because masonry structural systems ultimately benefit them. I went to the steel people and, while they didn't provide financial support, they are giving moral support. In fact, the American Institute of Steel Construction (AISC) has written a letter in support of a research grant we have applied for with the National Science Foundation to do hybrid research.

I am pleased we have two industries cooperating in the development of this hybrid concept and supporting the software programming. The masonry people know their product is the most cost effective with myriad inherent benefits but they were lagging a generation behind in collaborating to develop software design. During these rough economic times, masonry should see tremendous market share growth because it offers such value. Engineers were clamoring for a software tool to allow them to be more competitive in designing masonry and see this as an opportunity to introduce masonry as more than just a veneer or a backup wall.

The steel people see this as another tool to make their buildings economical. It will help them be more competitive in the low- to mid-rise building market.

As a matter of fact, we have been invited to present the hybrid system at the North American Steel Conference, being held in conjunction with the Structural Engineering Institute Structures Congress in Orlando in 2010. Imagine that, giving a seminar that includes masonry at a steel conference!

Why was the timing right for this now?

It was just a matter of time. Bentley already had steel and concrete system software so it was moving on to the other major materials. The light-gauge metal framing industry is trying to get into the package, too. They are also gradually adding more wood framing to their programs. It was time to do masonry. Now that Bentley has added the masonry module, its competition will likely add these.

You introduced the concept of the hybrid structural system. How did the idea of "load sharing" of steel and masonry come about?

Many engineers have been using it; it just didn't have a name. What I did was to give it a name.

My thoughts on this grew out of the WTC work. I was looking at buildings in that area to see how they stood up to the fires, debris and other impacts of the event. Many of them were built around the turn of the century — steel frames encased in brick and stone. We call them transitional buildings. Decades earlier these would have been all loadbearing masonry but, around the turn of the 20th century until the

1940s, this type of building was the norm. I was struck by how well this kind of rugged building stood up and thought about why we didn't still build them like this.

In the 1940s, there was an interest in lighter exterior walls. Problems had resulted from building masonry tight to steel because of moisture, corrosion and cracking. We've solved a lot of those problems. Now we build masonry cavity walls which protect the steel from moisture and corrosion. We build in joints for movement, which minimize cracking.

There have been a lot of masonry advancements, but it took people asking "What did you learn?" and "What can we do differently?" that forced me to think about it. It was a natural progression back to this type of structure. Masonry buildings with inherent arching action did not collapse. They allowed safe egress, even when damaged. We have learned much from history. Masonry is strong, durable, sustainable. It performs so well in so many areas and it's cost efficient. Masonry walls also have the strongest R-Value in the built environment for energy efficiency. And they are beautiful. A century ago, masonry walls were empirically designed. Today, we have taller, thinner engineered wall systems. The software will allow them to be easily designed quickly and efficiently.

Can you describe the three hybrid systems in RAM Advanse?

Hybrid Type 1:

A non-loadbearing masonry shear wall within a bay of a steel frame. If the building begins to sway, the load is transferred to the masonry shear wall. It isn't built tight to the steel columns; it is essentially a stand-alone wall functioning as a backup to the veneer.

Hybrid Type 2:

A loadbearing masonry shear wall which can carry more of the load if the building begins to sway. It's similar to Type 1, but the masonry shear wall is built tight to the underside of the steel and carries a specific portion of the load all the time.

Hybrid Type 3:
Masonry locks to the columns, similar to the transitional building. The Type 3 system is the one we have applied for the National Science Foundation grant to study. There isn't much research on how this type of building reacts in high seismic zones. Research partners include University of Illinois at Urbana-Champaign and University of Hawaii.

What were your ultimate goals in developing this software? How will this affect engineering masonry from now on?

The best scenario I could envision, and this is what I told IMI and NCMA when I approached them for support, is that other software companies can see the benefit of this masonry module and will add it to their programs. That is happening. We're helping to grow the industry.

Masonry has been behind steel and concrete in this engineering technology for 20 years. It is great that IMI and NCMA were willing to spur it ahead. Having software to analyze masonry will convert more engineers to a masonry option. This is a generation geared to computers. Previously, engineering masonry was calculated by hand. This software makes designing masonry about as quick as other structural systems.

You are traveling the country conducting seminars and training classes. What has the reception been ? Are engineers eager to try something new?

There is a group who are just curious and another group who can see direct application to the work they are doing.

In seminars, we explain the hybrid systems. The Bentley people demonstrate the software. Then we discuss the all-masonry option and the Bentley people demonstrate that, so the engineers see the software in use. Some of the seminars have a training session added during which engineers go through a hands-on use of the software. The Bentley trainers are very knowledgeable.

Many engineers have experience with steel-frame buildings. Those familiar with Bentley Structural System for steel don't need much hand-holding with the masonry module. They have already gone through the learning curve of engineering software. Remember, hybrid is not a system that applies to all building types. The real bread-and-butter type of building for this application is the three- to six- or seven-story in low to moderate seismic.

We may even begin to see 12 to15 stories, but this is not going to compete with high-rise steel buildings. More work is required to apply it to high seismic areas.

Are engineers sharing projects with you that they are working on?

IMI is tracking projects under design or construction. We're seeing it in low to moderate earthquake areas and in low- to mid-rise buildings. Projects are fitting the mold we expected.

You are one of the foremost experts on masonry in the country. What drew you to masonry?

Survival. I was groomed to be a concrete expert and started that way. However, I moved back to New York just as the area was converting from mostly concrete structures to structural steel. While everyone had to be accomplished in steel, masonry was also a component to almost all the projects we were doing. I feel blessed to be in an area with historical masonry buildings. My first forensic project in grad school was masonry and I liked it.

Having software to analyze masonry will convert more engineers to a masonry option

So, I chose to concentrate on masonry. I found that there was not a lot of engineering information on masonry, so I went searching and took a course from Jim Amrhein (former executive director of the Masonry Institute of America) in the late 1970s. That got me jump started. He was wonderful, a real legend in the industry. We went on to co-author the IMI publication "Masonry Tallwall Design Guide."

What other masonry products have you been involved in developing?

I helped Dur-O-Wal with a prestressed anchoring system. I helped figure out a prefabricated 10" thick masonry wall system for a mason contractor who does design-build for hotels. They are 38' long, story-high exterior and interior walls of full-bed brick with an insulated cavity, post-tensioned and reinforced. I've worked on flashing systems and mortarless masonry systems with post-tensioning. People come to me with an idea and say "How do we do this?" If I can, I help them figure it out. There are many creative people in this country that only need a little engineering help.

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Initial Construction Cost

100 Room Dormitory Prevailing Wage

Quantity/Bid Price Report

Classification AIR — Air Deduction

Flr	Description	Quantity	Unit	Marked Up Mat. Cost	Marked Up Lay-Cost	Amount	Wall Height	Length	Qty	Opn Odd Adj	Shape
T	**AIR** Air Dedcution @ Odd Coure			**$0.000** / SqFt		SqFt	Show as SqFt				
1	Ext Bearing	387	SqFt	$0.00	$0.00	386.522	10' 8"	598' 8"	1	Opn Odd Adj	Rect
1	Ext Non-Bearing	59	SqFt	$0.00	$0.00	58.667	10' 8"	94' 8"	1	Opn Odd Adj	Rect
1	Ext Stairs	56	SqFt	$0.00	$0.00	55.500	10' 8"	90' 0"	1	Odd Adj	Rect
1	Precast Plank (2nd Flr)	0	SqFt	$0.00	$0.00	0.007	0' 1"	0' 1"	1	Adj	Rect
2	Precast Plank (3rd Flr)	0	SqFt	$0.00	$0.00	0.007	0' 1"	0' 1"	1	Adj	Rect
3	Precast Plank (Roof)	0	SqFt	$0.00	$0.00	0.007	0' 1"	0' 1"	1	Adj	Rect
	Material [AIR] Totals	501	SqFt	$0.00	$0.00	500.710					

Classification ANC — WALL ANCHORS

Flr	Description	Quantity	Unit	Marked Up Mat. Cost	Marked Up Lay-Cost	Amount	Wall Height	Length	Qty	Opn Odd Adj	Shape
	DECKANGLE 4"x4"x12" Mill Galv 12ga			$4.000 / Each		Each	Show as Each				
1	Int Flr1 6" Partitions 1hr	138	Each	$585.12	$1,023.98	138.000	9' 4"	548' 0"	1		Rect
2	Int Flr2 6" Partitions 1hr	130	Each	$551.20	$964.62	130.000	9' 4"	518' 8"	1	Opn	Rect
3	Int Flr3 6" Partitions 1hr	130	Each	$551.20	$964.62	130.000	9' 4"	519' 4"	1	Opn	Rect
	Material [DECKANGLE] Totals	398	Each	$1,687.52	$2,953.23	398.000					
	STNANC S.S. stone anchor			**$0.000** / Each		Each	Show as Each				
3	Ext Bearing	290	Each	$0.00	$0.00	289.938	11' 4"	581' 4"	1	Opn Odd Adj	Rect
3	Ext Non-Bearing	48	Each	$0.00	$0.00	47.667	11' 4"	95' 4"	1	Opn Odd Adj	Rect
3	Ext Stairs	44	Each	$0.00	$0.00	44.146	11' 4"	92' 8"	1	Odd Adj	Rect
	Material [STNANC] Totals	382	Each	$0.00	$0.00	381.750					
	Class Totals WALL ANCHORS	780	Each	$1,687.52	$2,953.23	779.750					

Classification AVB — Air-Vapor Barrier Material

Flr	Description	Quantity	Unit	Marked Up Mat. Cost	Marked Up Lay-Cost	Amount	Wall Height	Length	Qty	Opn Odd Adj	Shape
	B.O.WALL Termination Air Barrier			$0.200 / SqFt		SqFt	Show as SqFt				
1	Ext Bearing	594	SqFt	$125.93	$0.00	594.000	10' 8"	598' 8"	1	Opn Odd Adj	Rect
1	Ext Non-Bearing	95	SqFt	$20.14	$0.00	95.000	10' 8"	94' 8"	1	Opn Odd Adj	Rect
1	Ext Stairs	90	SqFt	$19.08	$0.00	90.000	10' 8"	90' 0"	1	Odd Adj	Rect
2	Ext Bearing	582	SqFt	$123.38	$0.00	582.000	10' 0"	581' 4"	1	Opn Odd Adj	Rect
2	Ext Non-Bearing	96	SqFt	$20.35	$0.00	96.000	10' 0"	95' 4"	1	Opn Odd Adj	Rect
2	Ext Stairs	93	SqFt	$19.72	$0.00	93.000	10' 0"	92' 8"	1	Odd Adj	Rect
3	Ext Bearing	582	SqFt	$123.38	$0.00	582.000	11' 4"	581' 4"	1	Opn Odd Adj	Rect
3	Ext Non-Bearing	96	SqFt	$20.35	$0.00	96.000	11' 4"	95' 4"	1	Opn Odd Adj	Rect
3	Ext Stairs	93	SqFt	$19.72	$0.00	93.000	11' 4"	92' 8"	1	Odd Adj	Rect
	Material [B.O.WALL] Totals	2,321	SqFt	$492.05	$0.00	2,321.000					
	CJ/CORNER Termination Air Barrier			$0.200 / SqFt		SqFt	Show as SqFt				
1	Ext Bearing	149	SqFt	$31.66	$0.00	149.324	10' 8"	598' 8"	1	Opn Odd Adj	Rect
1	Ext Non-Bearing	64	SqFt	$13.57	$0.00	63.996	10' 8"	94' 8"	1	Opn Odd Adj	Rect
1	Ext Stairs	96	SqFt	$20.35	$0.00	95.994	10' 8"	90' 0"	1	Odd Adj	Rect
2	Ext Bearing	100	SqFt	$21.20	$0.00	100.000	10' 0"	581' 4"	1	Opn Odd Adj	Rect
2	Ext Non-Bearing	60	SqFt	$12.72	$0.00	60.000	10' 0"	95' 4"	1	Opn Odd Adj	Rect
2	Ext Stairs	90	SqFt	$19.08	$0.00	90.000	10' 0"	92' 8"	1	Odd Adj	Rect
3	Ext Bearing	100	SqFt	$21.20	$0.00	100.000	11' 4"	581' 4"	1	Opn Odd Adj	Rect

AVB Continued

		Quantity		Marked Up Mat. Cost	Marked Up Lay-Cost	Amount	Wall Height	Length	Qty	Opn Odd Adj	Shape
3	Ext Non-Bearing	60	SqFt	$12.72	$0.00	60.000	11' 4"	95' 4"	1	Opn Odd Adj	Rect
3	Ext Stairs	90	SqFt	$19.08	$0.00	90.000	11' 4"	92' 8"	1	Odd Adj	Rect
Material [CJ/CORNER] Totals		809	SqFt	$171.57	$0.00	809.314					
PLANKEND	Termination Air Barrier			$0.200 / SqFt		SqFt	Show as SqFt				
1	Ext Bearing	594	SqFt	$125.93	$0.00	594.000	10' 8"	598' 8"	1	Opn Odd Adj	Rect
2	Ext Bearing	582	SqFt	$123.38	$0.00	582.000	10' 0"	581' 4"	1	Opn Odd Adj	Rect
3	Ext Bearing	582	SqFt	$123.38	$0.00	582.000	11' 4"	581' 4"	1	Opn Odd Adj	Rect
Material [PLANKEND] Totals		1,758	SqFt	$372.70	$0.00	1,758.000					
T.O.WALL	Termination Air Barrier			$0.200 / SqFt		SqFt	Show as SqFt				
3	Ext Bearing	582	SqFt	$123.38	$0.00	582.000	11' 4"	581' 4"	1	Opn Odd Adj	Rect
WIN/DOOR	Termination Air Barrier			$0.200 / SqFt		SqFt	Show as SqFt				
1	Ext Bearing	843	SqFt	$178.72	$0.00	843.000	10' 8"	598' 8"	1	Opn Odd Adj	Rect
1	Ext Non-Bearing	86	SqFt	$18.23	$0.00	86.000	10' 8"	94' 8"	1	Opn Odd Adj	Rect
2	Ext Bearing	805	SqFt	$170.66	$0.00	805.000	10' 0"	581' 4"	1	Opn Odd Adj	Rect
2	Ext Non-Bearing	34	SqFt	$7.21	$0.00	34.000	10' 0"	95' 4"	1	Opn Odd Adj	Rect
3	Ext Bearing	805	SqFt	$170.66	$0.00	805.000	11' 4"	581' 4"	1	Opn Odd Adj	Rect
3	Ext Non-Bearing	34	SqFt	$7.21	$0.00	34.000	11' 4"	95' 4"	1	Opn Odd Adj	Rect
Material [WIN/DOOR] Totals		2,607	SqFt	$552.68	$0.00	2,607.000					
Class Totals	Air-Vapor Barrier Material	8,077	SqFt	$1,712.39	$0.00	8,077.314					

Classification **BRI** — **BRICKS**

		Quantity		Marked Up Mat. Cost	Marked Up Lay-Cost	Amount	Wall Height	Length	Qty	Opn Odd Adj	Shape
JAMBRET	Modular			$0.600 / Piece		SqFt	3.00% waste	6.752 Pieces per SqFt			
1	Ext Bearing	1,836	Pieces	$1,167.64	$2,311.78	264.000	10' 8"	598' 8"	1	Opn Odd Adj	Rect
1	Ext Non-Bearing	235	Pieces	$149.40	$295.78	33.778	10' 8"	94' 8"	1	Opn Odd Adj	Rect
2	Ext Bearing	1,731	Pieces	$1,100.81	$2,179.46	248.889	10' 0"	581' 4"	1	Opn Odd Adj	Rect
2	Ext Non-Bearing	99	Pieces	$62.90	$124.54	14.222	10' 0"	95' 4"	1	Opn Odd Adj	Rect
3	Ext Bearing	1,731	Pieces	$1,100.81	$2,179.46	248.889	11' 4"	581' 4"	1	Opn Odd Adj	Rect
3	Ext Non-Bearing	99	Pieces	$62.90	$124.54	14.222	11' 4"	95' 4"	1	Opn Odd Adj	Rect
Material [JAMBRET] Totals		5,730	Pieces	$3,644.47	$7,215.56	824.000					
MOD HALF	Modular Half			$0.300 / Piece		SqFt	3.00% waste	13.688 Pieces per SqFt			
1	Ext Bearing	2,256	Pieces	$717.47	$1,603.77	160.026	10' 8"	598' 8"	1	Opn Odd Adj	Rect
1	Ext Non-Bearing	343	Pieces	$109.23	$244.16	24.362	10' 8"	94' 8"	1	Opn Odd Adj	Rect
1	Ext Stairs	286	Pieces	$90.93	$203.25	20.281	10' 8"	90' 0"	1	Odd Adj	Rect
2	Ext Bearing	2,035	Pieces	$647.00	$1,446.27	144.309	10' 0"	581' 4"	1	Opn Odd Adj	Rect
2	Ext Non-Bearing	261	Pieces	$83.01	$185.55	18.515	10' 0"	95' 4"	1	Opn Odd Adj	Rect
2	Ext Stairs	264	Pieces	$83.88	$187.50	18.709	10' 0"	92' 8"	1	Odd Adj	Rect
3	Ext Bearing	2,209	Pieces	$702.35	$1,569.99	156.654	11' 4"	581' 4"	1	Opn Odd Adj	Rect
3	Ext Non-Bearing	335	Pieces	$106.68	$238.46	23.793	11' 4"	95' 4"	1	Opn Odd Adj	Rect
3	Ext Stairs	357	Pieces	$113.44	$253.58	25.303	11' 4"	92' 8"	1	Odd Adj	Rect
Material [MOD HALF] Totals		8,346	Pieces	$2,653.98	$5,932.52	591.951					
MOD+20	Modular +20			$0.600 / Piece		SqFt	3.00% waste	6.752 Pieces per SqFt			
1	Ext Bearing	30,529	Pieces	$19,416.27	$20,699.34	4,389.945	10' 8"	598' 8"	1	Opn Odd Adj	Rect
1	Ext Non-Bearing	4,496	Pieces	$2,859.52	$3,048.48	646.527	10' 8"	94' 8"	1	Opn Odd Adj	Rect

100 Room Dormitory Prevailing Wage

Quantity/Bid Price Report

BRI Continued

		Quantity		Marked Up Mat. Cost	Marked Up Lay-Cost	Amount	Wall Height	Length	Qty	Opn Odd Adj	Shape
2	Ext Bearing	27,235	Pieces	$17,321.27	$18,465.90	3,916.274	10' 0"	581' 4"	1	Opn Odd Adj	Rect
2	Ext Non-Bearing	4,676	Pieces	$2,974.09	$3,170.62	672.430	10' 0"	95' 4"	1	Opn Odd Adj	Rect
2	Ext Stairs	4,704	Pieces	$2,991.78	$3,189.48	676.430	10' 0"	92' 8"	1	Odd Adj	Rect
3	Ext Bearing	32,536	Pieces	$20,692.94	$22,060.37	4,678.596	11' 4"	581' 4"	1	Opn Odd Adj	Rect
3	Ext Non-Bearing	6,407	Pieces	$4,075.14	$4,344.43	921.373	11' 4"	95' 4"	1	Opn Odd Adj	Rect
3	Ext Stairs	6,358	Pieces	$4,043.77	$4,310.99	914.281	11' 4"	92' 8"	1	Odd Adj	Rect
Material [MOD+20] Totals		116,941	Pieces	$74,374.78	$79,289.62	16,815.856					
MOD-20	Modular -20			$0.600 / Piece		SqFt	3.00% waste	6.752	Pieces per SqFt		
1	Ext Stairs	4,965	Pieces	$3,157.81	$3,978.58	713.970	10' 8"	90' 0"	1	Odd Adj	Rect
SOLDIER	Modular			$0.600 / Piece		SqFt	3.00% waste	6.767	Pieces per SqFt		
1	Ext Bearing	2,782	Pieces	$1,769.26	$3,502.90	399.123	10' 8"	598' 8"	1	Opn Odd Adj	Rect
1	Ext Non-Bearing	1,320	Pieces	$839.29	$1,661.68	189.333	10' 8"	94' 8"	1	Opn Odd Adj	Rect
1	Ext Stairs	1,241	Pieces	$789.05	$1,562.22	178.000	10' 8"	90' 0"	1	Odd Adj	Rect
2	Ext Bearing	2,700	Pieces	$1,717.00	$3,399.43	387.333	10' 0"	581' 4"	1	Opn Odd Adj	Rect
2	Ext Non-Bearing	1,329	Pieces	$845.20	$1,673.39	190.667	10' 0"	95' 4"	1	Opn Odd Adj	Rect
2	Ext Stairs	1,278	Pieces	$812.69	$1,609.02	183.333	10' 0"	92' 8"	1	Odd Adj	Rect
3	Ext Bearing	2,700	Pieces	$1,717.00	$3,399.43	387.333	11' 4"	581' 4"	1	Opn Odd Adj	Rect
3	Ext Non-Bearing	443	Pieces	$281.73	$557.80	63.556	11' 4"	95' 4"	1	Opn Odd Adj	Rect
3	Ext Stairs	426	Pieces	$270.90	$536.34	61.111	11' 4"	92' 8"	1	Odd Adj	Rect
Material [SOLDIER] Totals		14,217	Pieces	$9,042.13	$17,902.20	2,039.789					
Class Totals BRICKS		150,200	Pieces	$92,873.16	$114,318.47	20,985.566					

Classification CK Caulk

		Quantity		Marked Up Mat. Cost	Marked Up Lay-Cost	Amount	Wall Height	Length	Qty	Opn Odd Adj	Shape
EXT CJ/EJ	Exteior EJ/CJ			$2.000 / LinFt		LinFt	2.00% waste	Show as LinFt			
1	Ext Bearing	250	LinFt	$530.51	$0.00	245.333	10' 8"	598' 8"	1	Opn Odd Adj	Rect
1	Ext Non-Bearing	33	LinFt	$69.20	$0.00	32.000	10' 8"	94' 8"	1	Opn Odd Adj	Rect
1	Ext Stairs	33	LinFt	$69.20	$0.00	32.000	10' 8"	90' 0"	1	Odd Adj	Rect
2	Ext Bearing	235	LinFt	$497.35	$0.00	230.000	10' 0"	581' 4"	1	Opn Odd Adj	Rect
2	Ext Non-Bearing	31	LinFt	$64.87	$0.00	30.000	10' 0"	95' 4"	1	Opn Odd Adj	Rect
2	Ext Stairs	31	LinFt	$64.87	$0.00	30.000	10' 0"	92' 8"	1	Odd Adj	Rect
3	Ext Bearing	266	LinFt	$563.67	$0.00	260.667	11' 4"	581' 4"	1	Opn Odd Adj	Rect
3	Ext Non-Bearing	35	LinFt	$73.52	$0.00	34.000	11' 4"	95' 4"	1	Opn Odd Adj	Rect
3	Ext Stairs	35	LinFt	$73.52	$0.00	34.000	11' 4"	92' 8"	1	Odd Adj	Rect
Material [EXT CJ/EJ] Totals		947	LinFt	$2,006.71	$0.00	928.000					
EXT STONE	Caulk Stone Joints			$2.000 / LinFt		LinFt	2.00% waste	Show as LinFt			
3	Ext Bearing	591	LinFt	$1,253.92	$0.00	579.875	11' 4"	581' 4"	1	Opn Odd Adj	Rect
3	Ext Non-Bearing	97	LinFt	$206.15	$0.00	95.333	11' 4"	95' 4"	1	Opn Odd Adj	Rect
3	Ext Stairs	90	LinFt	$190.92	$0.00	88.292	11' 4"	92' 8"	1	Odd Adj	Rect
Material [EXT STONE] Totals		779	LinFt	$1,650.99	$0.00	763.500					
INT CJ/EJ	Inteior EJ/CJ			$2.000 / LinFt		LinFt	2.00% waste	Show as LinFt			
1	Ext Bearing	250	LinFt	$530.51	$0.00	245.333	10' 8"	598' 8"	1	Opn Odd Adj	Rect
1	Ext Non-Bearing	33	LinFt	$69.20	$0.00	32.000	10' 8"	94' 8"	1	Opn Odd Adj	Rect
1	Ext Stairs	33	LinFt	$69.20	$0.00	32.000	10' 8"	90' 0"	1	Odd Adj	Rect
1	Int Flr1 6" Partitions 1hr	724	LinFt	$1,533.86	$0.00	709.333	9' 4"	548' 0"	1		Rect
1	Int Flr1 Corridor	609	LinFt	$1,291.67	$0.00	597.333	9' 4"	646' 0"	1	Opn Odd Adj	Rect

CK Continued

		Quantity		Marked Up Mat. Cost	Marked Up Lay-Cost	Amount	Wall Height	Length	Qty	Opn Odd Adj	Shape
1	Int Flr1 Shear Walls	653	LinFt	$1,383.94	$0.00	640.000	10' 0"	420' 8"	1	Odd	Rect
2	Ext Bearing	235	LinFt	$497.35	$0.00	230.000	10' 0"	581' 4"	1	Opn Odd Adj	Rect
2	Ext Non-Bearing	31	LinFt	$64.87	$0.00	30.000	10' 0"	95' 4"	1	Opn Odd Adj	Rect
2	Ext Stairs	31	LinFt	$64.87	$0.00	30.000	10' 0"	92' 8"	1	Odd Adj	Rect
2	Int Flr2 6" Partitions 1hr	762	LinFt	$1,614.59	$0.00	746.667	9' 4"	518' 8"	1	Opn	Rect
2	Int Flr2 Corridor	590	LinFt	$1,251.31	$0.00	578.667	9' 4"	632' 8"	1	Opn Odd Adj	Rect
2	Int Flr2 Shear Walls	694	LinFt	$1,470.43	$0.00	680.000	10' 0"	453' 4"	1	Odd	Rect
3	Ext Bearing	266	LinFt	$563.67	$0.00	260.667	11' 4"	581' 4"	1	Opn Odd Adj	Rect
3	Ext Non-Bearing	35	LinFt	$73.52	$0.00	34.000	11' 4"	95' 4"	1	Opn Odd Adj	Rect
3	Ext Stairs	35	LinFt	$73.52	$0.00	34.000	11' 4"	92' 8"	1	Odd Adj	Rect
3	Int Flr3 6" Partitions 1hr	762	LinFt	$1,614.59	$0.00	746.667	9' 4"	519' 4"	1	Opn	Rect
3	Int Flr3 Corridor	590	LinFt	$1,251.31	$0.00	578.667	9' 4"	632' 8"	1	Opn Odd Adj	Rect
3	Int Flr3 Shear Walls	694	LinFt	$1,470.43	$0.00	680.000	10' 0"	453' 4"	1	Odd	Rect
Material [INT CJ/EJ] Totals		7,023	LinFt	$14,888.84	$0.00	6,885.333					
Class Totals	Caulk	8,748	LinFt	$18,546.54	$0.00	8,576.833					

Classification CMU C.M.U.

		Quantity		Marked Up Mat. Cost	Marked Up Lay-Cost	Amount	Wall Height	Length	Qty	Opn Odd Adj	Shape
...08 FDN	8x8x16 HW Foundation			$0.770 / Piece		SqFt	1.00% waste	1.125	Pieces per SqFt		
FDN	Ext FDN	590	Pieces	$481.77	$1,409.35	519.481	0' 8"	782' 8"	1		Rect
FDN	Int FDN	786	Pieces	$641.42	$1,876.38	691.625	0' 8"	1043' 4"	1		Rect
Material [...08 FDN] Totals		1,376	Pieces	$1,123.19	$3,285.73	1,211.106					
..04PLANK	4x8x16 MW			$0.670 / Piece		SqFt	1.00% waste	1.125	Pieces per SqFt		
1	Ext Bearing	454	Pieces	$322.12	$1,604.40	399.177	10' 8"	598' 8"	1	Opn Odd Adj	Rect
1	Int Flr1 Stairs/Elev.	93	Pieces	$66.35	$330.47	82.222	10' 0"	126' 0"	1	Opn Odd	Rect
2	Ext Bearing	439	Pieces	$311.71	$1,552.55	386.278	10' 0"	581' 4"	1	Opn Odd Adj	Rect
2	Int Flr2 Stairs/Elev.	93	Pieces	$66.35	$330.47	82.222	10' 0"	126' 0"	1	Opn Odd	Rect
3	Ext Bearing	439	Pieces	$311.71	$1,552.55	386.278	11' 4"	581' 4"	1	Opn Odd Adj	Rect
3	Int Flr3 Stairs/Elev.	93	Pieces	$66.35	$330.47	82.222	10' 0"	126' 0"	1	Opn Odd	Rect
Material [..04PLANK] Totals		1,612	Pieces	$1,144.60	$5,700.92	1,418.399					
..06+20	6x8x16 MW			$0.750 / Piece		SqFt	1.00% waste	1.125	Pieces per SqFt		
1	Int Flr1 6" Partitions 1hr	5,548	Pieces	$4,410.81	$15,585.03	4,882.889	9' 4"	548' 0"	1		Rect
2	Int Flr2 6" Partitions 1hr	5,179	Pieces	$4,116.93	$14,546.65	4,557.556	9' 4"	518' 8"	1	Opn	Rect
3	Int Flr3 6" Partitions 1hr	5,186	Pieces	$4,122.55	$14,566.51	4,563.778	9' 4"	519' 4"	1	Opn	Rect
Material [..06+20] Totals		15,912	Pieces	$12,650.28	$44,698.18	14,004.222					
..06BBLIN	6x8x16 BB Lintel MW			$1.090 / Piece		SqFt	1.00% waste	1.125	Pieces per SqFt		
2	Int Flr2 6" Partitions 1hr	4	Pieces	$4.08	$9.93	3.111	9' 4"	518' 8"	1	Opn	Rect
3	Int Flr3 6" Partitions 1hr	4	Pieces	$4.08	$9.93	3.111	9' 4"	519' 4"	1	Opn	Rect
Material [..06BBLIN] Totals		7	Pieces	$8.17	$19.86	6.222					
..06H	6x8x8 Half MW			$0.750 / Piece		SqFt	1.00% waste	2.250	Pieces per SqFt		
1	Int Flr1 6" Partitions 1hr	537	Pieces	$427.17	$1,509.35	236.444	9' 4"	548' 0"	1		Rect
2	Int Flr2 6" Partitions 1hr	576	Pieces	$457.68	$1,617.16	253.333	9' 4"	518' 8"	1	Opn	Rect
3	Int Flr3 6" Partitions 1hr	576	Pieces	$457.68	$1,617.16	253.333	9' 4"	519' 4"	1	Opn	Rect
Material [..06H] Totals		1,689	Pieces	$1,342.53	$4,743.67	743.111					

100 Room Dormitory Prevailing Wage

Quantity/Bid Price Report

CMU Continued

#	Description	Quantity		Marked Up Mat. Cost	Marked Up Lay-Cost	Amount	Wall Height	Length	Qty	Opn Odd Adj	Shape
..08 BU	8x8x16 MW			$0.870 / Piece		SqFt	1.00% waste	1.125	Pieces per SqFt		
1	Ext Bearing	3,563	Pieces	$3,285.95	$8,300.19	3,135.898	10' 8"	598' 8"	1	Opn Odd Adj	Rect
1	Ext Non-Bearing	756	Pieces	$697.64	$1,762.20	665.778	10' 8"	94' 8"	1	Opn Odd Adj	Rect
1	Ext Stairs	830	Pieces	$765.28	$1,933.07	730.333	10' 8"	90' 0"	1	Odd Adj	Rect
2	Ext Bearing	3,471	Pieces	$3,200.89	$8,085.33	3,054.722	10' 0"	581' 4"	1	Opn Odd Adj	Rect
2	Ext Non-Bearing	897	Pieces	$827.10	$2,089.23	789.333	10' 0"	95' 4"	1	Opn Odd Adj	Rect
2	Ext Stairs	858	Pieces	$791.36	$1,998.94	755.222	10' 0"	92' 8"	1	Odd Adj	Rect
3	Ext Bearing	3,893	Pieces	$3,590.05	$9,068.33	3,426.111	11' 4"	581' 4"	1	Opn Odd Adj	Rect
3	Ext Non-Bearing	968	Pieces	$892.30	$2,253.92	851.556	11' 4"	95' 4"	1	Opn Odd Adj	Rect
3	Ext Stairs	922	Pieces	$849.98	$2,147.02	811.167	11' 4"	92' 8"	1	Odd Adj	Rect
Material [..08 BU] Totals		16,158	Pieces	$14,900.55	$37,638.23	14,220.121					
..08+20..	8x8x16 MW			$0.870 / Piece		SqFt	1.00% waste	1.125	Pieces per SqFt		
1	Int Flr1 Shear Walls	4,235	Pieces	$3,905.45	$11,896.06	3,727.111	10' 0"	420' 8"	1	Odd	Rect
2	Int Flr2 Shear Walls	4,567	Pieces	$4,211.89	$12,829.48	4,019.556	10' 0"	453' 4"	1	Odd	Rect
3	Int Flr3 Shear Walls	4,567	Pieces	$4,211.89	$12,829.48	4,019.556	10' 0"	453' 4"	1	Odd	Rect
Material [..08+20..] Totals		13,369	Pieces	$12,329.23	$37,555.01	11,766.222					
..08+30	8x8x16 MW			$0.870 / Piece		SqFt	1.00% waste	1.125	Pieces per SqFt		
1	Int Flr1 Corridor	4,273	Pieces	$3,940.34	$11,029.18	3,760.409	9' 4"	646' 0"	1	Opn Odd Adj	Rect
2	Int Flr2 Corridor	4,171	Pieces	$3,846.77	$10,767.27	3,671.111	9' 4"	632' 8"	1	Opn Odd Adj	Rect
3	Int Flr3 Corridor	4,171	Pieces	$3,846.77	$10,767.27	3,671.111	9' 4"	632' 8"	1	Opn Odd Adj	Rect
Material [..08+30] Totals		12,615	Pieces	$11,633.89	$32,563.72	11,102.631					
..08-20	8x8x16 MW			$0.870 / Piece		SqFt	1.00% waste	1.125	Pieces per SqFt		
1	Int Flr1 Stairs/Elev.	940	Pieces	$866.69	$2,804.94	827.111	10' 0"	126' 0"	1	Opn Odd	Rect
2	Int Flr2 Stairs/Elev.	940	Pieces	$866.69	$2,804.94	827.111	10' 0"	126' 0"	1	Opn Odd	Rect
3	Int Flr3 Stairs/Elev.	940	Pieces	$866.69	$2,804.94	827.111	10' 0"	126' 0"	1	Opn Odd	Rect
Material [..08-20] Totals		2,819	Pieces	$2,600.06	$8,414.82	2,481.333					
..08BB	8x8x16 BB MW			$1.090 / Piece		SqFt	1.00% waste	1.125	Pieces per SqFt		
1	Ext Bearing	454	Pieces	$524.06	$1,274.12	399.189	10' 8"	598' 8"	1	Opn Odd Adj	Rect
1	Ext Non-Bearing	72	Pieces	$82.85	$201.44	63.111	10' 8"	94' 8"	1	Opn Odd Adj	Rect
1	Ext Stairs	63	Pieces	$72.86	$177.14	55.500	10' 8"	90' 0"	1	Odd Adj	Rect
1	Int Flr1 Corridor	488	Pieces	$564.33	$1,372.01	429.861	9' 4"	646' 0"	1	Opn Odd Adj	Rect
1	Int Flr1 Shear Walls	319	Pieces	$368.17	$895.11	280.444	10' 0"	420' 8"	1	Odd	Rect
1	Int Flr1 Stairs/Elev.	91	Pieces	$105.61	$256.76	80.444	10' 0"	126' 0"	1	Opn Odd	Rect
2	Ext Bearing	439	Pieces	$506.82	$1,232.20	386.056	10' 0"	581' 4"	1	Opn Odd Adj	Rect
2	Ext Non-Bearing	72	Pieces	$83.44	$202.85	63.556	10' 0"	95' 4"	1	Opn Odd Adj	Rect
2	Ext Stairs	65	Pieces	$75.20	$182.82	57.278	10' 0"	92' 8"	1	Odd Adj	Rect
2	Int Flr2 Corridor	479	Pieces	$553.72	$1,346.22	421.778	9' 4"	632' 8"	1	Opn Odd Adj	Rect
2	Int Flr2 Shear Walls	343	Pieces	$396.76	$964.62	302.222	10' 0"	453' 4"	1	Odd	Rect
2	Int Flr2 Stairs/Elev.	91	Pieces	$105.61	$256.76	80.444	10' 0"	126' 0"	1	Opn Odd	Rect
3	Ext Bearing	877	Pieces	$1,013.65	$2,464.40	772.111	11' 4"	581' 4"	1	Opn Odd Adj	Rect
3	Ext Non-Bearing	144	Pieces	$166.87	$405.71	127.111	11' 4"	95' 4"	1	Opn Odd Adj	Rect
3	Ext Stairs	130	Pieces	$150.39	$365.63	114.556	11' 4"	92' 8"	1	Odd Adj	Rect
3	Int Flr3 Corridor	479	Pieces	$553.72	$1,346.22	421.778	9' 4"	632' 8"	1	Opn Odd Adj	Rect
3	Int Flr3 Shear Walls	343	Pieces	$396.76	$964.62	302.222	10' 0"	453' 4"	1	Odd	Rect
3	Int Flr3 Stairs/Elev.	91	Pieces	$105.61	$256.76	80.444	10' 0"	126' 0"	1	Opn Odd	Rect
Material [..08BB] Totals		5,043	Pieces	$5,826.45	$14,165.39	4,438.105					

CMU Continued

		Quantity		Marked Up Mat. Cost	Marked Up Lay-Cost	Amount	Wall Height	Length	Qty	Opn Odd Adj	Shape
..08BBLIN	8x8x16 BB Lintel MW			$1.090 / Piece		SqFt	1.00% waste	1.125	Pieces per SqFt		
1	Ext Bearing	201	Pieces	$231.93	$563.88	176.667	10' 8"	598' 8"	1	Opn Odd Adj	Rect
1	Ext Non-Bearing	18	Pieces	$21.01	$51.07	16.000	10' 8"	94' 8"	1	Opn Odd Adj	Rect
1	Int Flr1 Corridor	147	Pieces	$170.08	$413.51	129.556	9' 4"	646' 0"	1	Opn Odd Adj	Rect
1	Int Flr1 Stairs/Elev.	14	Pieces	$16.34	$39.72	12.444	10' 0"	126' 0"	1	Opn Odd	Rect
2	Ext Bearing	194	Pieces	$224.64	$546.15	171.111	10' 0"	581' 4"	1	Opn Odd Adj	Rect
2	Ext Non-Bearing	7	Pieces	$7.59	$18.44	5.778	10' 0"	95' 4"	1	Opn Odd Adj	Rect
2	Int Flr2 Corridor	148	Pieces	$171.54	$417.06	130.667	9' 4"	632' 8"	1	Opn Odd Adj	Rect
2	Int Flr2 Stairs/Elev.	14	Pieces	$16.34	$39.72	12.444	10' 0"	126' 0"	1	Opn Odd	Rect
3	Ext Bearing	194	Pieces	$224.64	$546.15	171.111	11' 4"	581' 4"	1	Opn Odd Adj	Rect
3	Ext Non-Bearing	7	Pieces	$7.59	$18.44	5.778	11' 4"	95' 4"	1	Opn Odd Adj	Rect
3	Int Flr3 Corridor	148	Pieces	$171.54	$417.06	130.667	9' 4"	632' 8"	1	Opn Odd Adj	Rect
3	Int Flr3 Stairs/Elev.	14	Pieces	$16.34	$39.72	12.444	10' 0"	126' 0"	1	Opn Odd	Rect
Material [..08BBLIN] Totals		1,107	Pieces	$1,279.57	$3,110.91	974.667					
..08BN	8x8x16 BN MW			$1.090 / Piece		SqFt	1.00% waste	1.125	Pieces per SqFt		
1	Ext Bearing	297	Pieces	$343.08	$834.11	261.333	10' 8"	598' 8"	1	Opn Odd Adj	Rect
1	Ext Non-Bearing	36	Pieces	$42.01	$102.14	32.000	10' 8"	94' 8"	1	Opn Odd Adj	Rect
1	Int Flr1 Corridor	442	Pieces	$511.13	$1,242.66	389.333	9' 4"	646' 0"	1	Opn Odd Adj	Rect
1	Int Flr1 Stairs/Elev.	55	Pieces	$63.02	$153.20	48.000	10' 0"	126' 0"	1	Opn Odd	Rect
2	Ext Bearing	283	Pieces	$326.75	$794.39	248.889	10' 0"	581' 4"	1	Opn Odd Adj	Rect
2	Ext Non-Bearing	16	Pieces	$18.67	$45.39	14.222	10' 0"	95' 4"	1	Opn Odd Adj	Rect
2	Int Flr2 Corridor	431	Pieces	$498.29	$1,211.45	379.556	9' 4"	632' 8"	1	Opn Odd Adj	Rect
2	Int Flr2 Stairs/Elev.	55	Pieces	$63.02	$153.20	48.000	10' 0"	126' 0"	1	Opn Odd	Rect
3	Ext Bearing	283	Pieces	$326.75	$794.39	248.889	11' 4"	581' 4"	1	Opn Odd Adj	Rect
3	Ext Non-Bearing	16	Pieces	$18.67	$45.39	14.222	11' 4"	95' 4"	1	Opn Odd Adj	Rect
3	Int Flr3 Corridor	431	Pieces	$498.29	$1,211.45	379.556	9' 4"	632' 8"	1	Opn Odd Adj	Rect
3	Int Flr3 Stairs/Elev.	55	Pieces	$63.02	$153.20	48.000	10' 0"	126' 0"	1	Opn Odd	Rect
Material [..08BN] Totals		2,400	Pieces	$2,772.68	$6,741.01	2,112.000					
..08BN16"	8x8x16 BN 16" Long BN MW			$2.200 / Piece		SqFt	1.00% waste	1.125	Pieces per SqFt		
1	Ext Bearing	150	Pieces	$349.77	$421.31	132.000	10' 8"	598' 8"	1	Opn Odd Adj	Rect
1	Ext Non-Bearing	9	Pieces	$21.20	$25.53	8.000	10' 8"	94' 8"	1	Opn Odd Adj	Rect
2	Ext Bearing	159	Pieces	$370.96	$446.85	140.000	10' 0"	581' 4"	1	Opn Odd Adj	Rect
2	Ext Non-Bearing	5	Pieces	$10.60	$12.77	4.000	10' 0"	95' 4"	1	Opn Odd Adj	Rect
3	Ext Bearing	159	Pieces	$370.96	$446.85	140.000	11' 4"	581' 4"	1	Opn Odd Adj	Rect
3	Ext Non-Bearing	5	Pieces	$10.60	$12.77	4.000	11' 4"	95' 4"	1	Opn Odd Adj	Rect
Material [..08BN16"] Totals		486	Pieces	$1,134.09	$1,366.08	428.000					
..08BNH	8x8x8 BNH MW			$1.090 / Piece		SqFt	1.00% waste	2.250	Pieces per SqFt		
1	Ext Bearing	297	Pieces	$343.08	$834.11	130.667	10' 8"	598' 8"	1	Opn Odd Adj	Rect
1	Ext Non-Bearing	36	Pieces	$42.01	$102.14	16.000	10' 8"	94' 8"	1	Opn Odd Adj	Rect
1	Int Flr1 Corridor	438	Pieces	$506.46	$1,231.31	192.889	9' 4"	646' 0"	1	Opn Odd Adj	Rect
1	Int Flr1 Stairs/Elev.	53	Pieces	$60.68	$147.53	23.111	10' 0"	126' 0"	1	Opn Odd	Rect
2	Ext Bearing	283	Pieces	$326.75	$794.39	124.444	10' 0"	581' 4"	1	Opn Odd Adj	Rect
2	Ext Non-Bearing	16	Pieces	$18.67	$45.39	7.111	10' 0"	95' 4"	1	Opn Odd Adj	Rect
2	Int Flr2 Corridor	430	Pieces	$497.12	$1,208.61	189.333	9' 4"	632' 8"	1	Opn Odd Adj	Rect
2	Int Flr2 Stairs/Elev.	53	Pieces	$60.68	$147.53	23.111	10' 0"	126' 0"	1	Opn Odd	Rect
3	Ext Bearing	283	Pieces	$326.75	$794.39	124.444	11' 4"	581' 4"	1	Opn Odd Adj	Rect
3	Ext Non-Bearing	16	Pieces	$18.67	$45.39	7.111	11' 4"	95' 4"	1	Opn Odd Adj	Rect

CMU Continued

		Quantity		Marked Up Mat. Cost	Marked Up Lay-Cost	Amount	Wall Height	Length	Qty	Opn Odd Adj	Shape
3	Int Flr3 Corridor	430	Pieces	$497.12	$1,208.61	189.333	9' 4"	632' 8"	1	Opn Odd Adj	Rect
3	Int Flr3 Stairs/Elev.	53	Pieces	$60.68	$147.53	23.111	10' 0"	126' 0"	1	Opn Odd	Rect
Material [..08BNH] Totals		2,388	Pieces	$2,758.68	$6,706.96	1,050.667					
..08H	8x8x8 Half MW			$0.870 / Piece		SqFt	1.00% waste	2.250 Pieces per SqFt			
1	Ext Bearing	387	Pieces	$356.73	$1,086.62	170.222	10' 8"	598' 8"	1	Opn Odd Adj	Rect
1	Ext Non-Bearing	85	Pieces	$78.24	$238.32	37.333	10' 8"	94' 8"	1	Opn Odd Adj	Rect
1	Ext Stairs	106	Pieces	$97.80	$297.90	46.667	10' 8"	90' 0"	1	Odd Adj	Rect
1	Int Flr1 Corridor	420	Pieces	$387.47	$1,180.24	184.889	9' 4"	646' 0"	1	Opn Odd Adj	Rect
1	Int Flr1 Shear Walls	452	Pieces	$417.28	$1,271.03	199.111	10' 0"	420' 8"	1	Odd	Rect
1	Int Flr1 Stairs/Elev.	105	Pieces	$96.87	$295.06	46.222	10' 0"	126' 0"	1	Opn Odd	Rect
2	Ext Bearing	363	Pieces	$334.38	$1,018.53	159.556	10' 0"	581' 4"	1	Opn Odd Adj	Rect
2	Ext Non-Bearing	85	Pieces	$78.24	$238.32	37.333	10' 0"	95' 4"	1	Opn Odd Adj	Rect
2	Ext Stairs	106	Pieces	$97.80	$297.90	46.667	10' 0"	92' 8"	1	Odd Adj	Rect
2	Int Flr2 Corridor	407	Pieces	$375.36	$1,143.36	179.111	9' 4"	632' 8"	1	Opn Odd Adj	Rect
2	Int Flr2 Shear Walls	481	Pieces	$443.36	$1,350.47	211.556	10' 0"	453' 4"	1	Odd	Rect
2	Int Flr2 Stairs/Elev.	105	Pieces	$96.87	$295.06	46.222	10' 0"	126' 0"	1	Opn Odd	Rect
3	Ext Bearing	396	Pieces	$365.12	$1,112.15	174.222	11' 4"	581' 4"	1	Opn Odd Adj	Rect
3	Ext Non-Bearing	88	Pieces	$81.03	$246.83	38.667	11' 4"	95' 4"	1	Opn Odd Adj	Rect
3	Ext Stairs	109	Pieces	$100.59	$306.41	48.000	11' 4"	92' 8"	1	Odd Adj	Rect
3	Int Flr3 Corridor	407	Pieces	$375.36	$1,143.36	179.111	9' 4"	632' 8"	1	Opn Odd Adj	Rect
3	Int Flr3 Shear Walls	481	Pieces	$443.36	$1,350.47	211.556	10' 0"	453' 4"	1	Odd	Rect
3	Int Flr3 Stairs/Elev.	105	Pieces	$96.87	$295.06	46.222	10' 0"	126' 0"	1	Opn Odd	Rect
Material [..08H] Totals		4,687	Pieces	$4,322.73	$13,167.09	2,062.667					
Class Totals C.M.U.		81,669	Pieces	$75,826.69	$219,877.58	68,019.473					

Classification **CON** — **Control Joints**

		Quantity		Marked Up Mat. Cost	Marked Up Lay-Cost	Amount	Wall Height	Length	Qty	Opn Odd Adj	Shape
CJ	Control Joint Material			$1.300 / LinFt		LinFt		Show as LinFt			
1	Ext Bearing	245	LinFt	$338.07	$59.16	245.333	10' 8"	598' 8"	1	Opn Odd Adj	Rect
1	Ext Non-Bearing	32	LinFt	$44.10	$7.72	32.000	10' 8"	94' 8"	1	Opn Odd Adj	Rect
1	Ext Stairs	32	LinFt	$44.10	$7.72	32.000	10' 8"	90' 0"	1	Odd Adj	Rect
2	Ext Bearing	230	LinFt	$316.94	$55.47	230.000	10' 0"	581' 4"	1	Opn Odd Adj	Rect
2	Ext Non-Bearing	30	LinFt	$41.34	$7.23	30.000	10' 0"	95' 4"	1	Opn Odd Adj	Rect
2	Ext Stairs	30	LinFt	$41.34	$7.23	30.000	10' 0"	92' 8"	1	Odd Adj	Rect
3	Ext Bearing	261	LinFt	$359.20	$62.86	260.667	11' 4"	581' 4"	1	Opn Odd Adj	Rect
3	Ext Non-Bearing	34	LinFt	$46.85	$8.20	34.000	11' 4"	95' 4"	1	Opn Odd Adj	Rect
3	Ext Stairs	34	LinFt	$46.85	$8.20	34.000	11' 4"	92' 8"	1	Odd Adj	Rect
Material [CJ] Totals		928	LinFt	$1,278.78	$223.79	928.000					

Classification **CSZ** — **Cast Stone**

		Quantity		Marked Up Mat. Cost	Marked Up Lay-Cost	Amount	Wall Height	Length	Qty	Opn Odd Adj	Shape
BAND	Cont Band			**$0.000** / Piece		CbcFt		1.108 Pieces per CbcFt			
1	Ext Bearing	95	Pieces	$0.00	$0.00	86.142	10' 8"	598' 8"	1	Opn Odd Adj	Rect
1	Ext Non-Bearing	19	Pieces	$0.00	$0.00	17.153	10' 8"	94' 8"	1	Opn Odd Adj	Rect
1	Ext Stairs	22	Pieces	$0.00	$0.00	20.228	10' 8"	90' 0"	1	Odd Adj	Rect
2	Ext Bearing	93	Pieces	$0.00	$0.00	83.780	10' 0"	581' 4"	1	Opn Odd Adj	Rect
2	Ext Non-Bearing	22	Pieces	$0.00	$0.00	20.162	10' 0"	95' 4"	1	Opn Odd Adj	Rect
2	Ext Stairs	23	Pieces	$0.00	$0.00	20.830	10' 0"	92' 8"	1	Odd Adj	Rect

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Quantity/Bid Price Report

CSZ Continued

		Quantity		Marked Up Mat. Cost	Marked Up Lay-Cost	Amount	Wall Height	Length	Qty	Opn Odd Adj	Shape
3	Ext Bearing	93	Pieces	$0.00	$0.00	83.780	11' 4"	581' 4"	1	Opn Odd Adj	Rect
3	Ext Non-Bearing	22	Pieces	$0.00	$0.00	20.162	11' 4"	95' 4"	1	Opn Odd Adj	Rect
3	Ext Stairs	23	Pieces	$0.00	$0.00	20.830	11' 4"	92' 8"	1	Odd Adj	Rect
Material [BAND] Totals		413	Pieces	$0.00	$0.00	373.065					
COPING	19x5x48			**$0.000** / Piece		CbcFt		2.639 CbcFt per Piece			
3	Ext Bearing	145	Pieces	$0.00	$0.00	382.556	11' 4"	581' 4"	1	Opn Odd Adj	Rect
3	Ext Non-Bearing	24	Pieces	$0.00	$0.00	62.894	11' 4"	95' 4"	1	Opn Odd Adj	Rect
3	Ext Stairs	22	Pieces	$0.00	$0.00	58.248	11' 4"	92' 8"	1	Odd Adj	Rect
Material [COPING] Totals		191	Pieces	$0.00	$0.00	503.698					
WINSILL	Window Sill			**$0.000** / Piece		CbcFt		1.111 CbcFt per Piece			
1	Ext Bearing	105	Pieces	$0.00	$0.00	116.111	10' 8"	598' 8"	1	Opn Odd Adj	Rect
1	Ext Non-Bearing	6	Pieces	$0.00	$0.00	7.037	10' 8"	94' 8"	1	Opn Odd Adj	Rect
2	Ext Bearing	111	Pieces	$0.00	$0.00	123.148	10' 0"	581' 4"	1	Opn Odd Adj	Rect
2	Ext Non-Bearing	3	Pieces	$0.00	$0.00	3.704	10' 0"	95' 4"	1	Opn Odd Adj	Rect
3	Ext Bearing	111	Pieces	$0.00	$0.00	123.148	11' 4"	581' 4"	1	Opn Odd Adj	Rect
3	Ext Non-Bearing	3	Pieces	$0.00	$0.00	3.704	11' 4"	95' 4"	1	Opn Odd Adj	Rect
Material [WINSILL] Totals		339	Pieces	$0.00	$0.00	376.852					
Class Totals	Cast Stone	943	Pieces	$0.00	$0.00	1,253.615					

Classification FIR — Fire Safeing

		Quantity		Marked Up Mat. Cost	Marked Up Lay-Cost	Amount	Wall Height	Length	Qty	Opn Odd Adj	Shape
FIRECLK	Fire Caulk Precast/Wall			$0.650 / LinFt		LinFt	2.00% waste	Show as LinFt			
1	Int Flr1 Corridor	1,315	LinFt	$906.29	$1,388.17	1,289.582	9' 4"	646' 0"	1	Opn Odd Adj	Rect
1	Int Flr1 Shear Walls	858	LinFt	$591.27	$905.66	841.333	10' 0"	420' 8"	1	Odd	Rect
1	Int Flr1 Stairs/Elev.	123	LinFt	$84.80	$129.89	120.667	10' 0"	126' 0"	1	Opn Odd	Rect
2	Int Flr2 Corridor	1,291	LinFt	$889.25	$1,362.07	1,265.333	9' 4"	632' 8"	1	Opn Odd Adj	Rect
2	Int Flr2 Shear Walls	925	LinFt	$637.19	$975.98	906.667	10' 0"	453' 4"	1	Odd	Rect
2	Int Flr2 Stairs/Elev.	123	LinFt	$84.80	$129.89	120.667	10' 0"	126' 0"	1	Opn Odd	Rect
3	Int Flr3 Corridor	1,291	LinFt	$889.25	$1,362.07	1,265.333	9' 4"	632' 8"	1	Opn Odd Adj	Rect
3	Int Flr3 Shear Walls	925	LinFt	$637.19	$975.98	906.667	10' 0"	453' 4"	1	Odd	Rect
3	Int Flr3 Stairs/Elev.	123	LinFt	$84.80	$129.89	120.667	10' 0"	126' 0"	1	Opn Odd	Rect
Material [FIRECLK] Totals		6,974	LinFt	$4,804.85	$7,359.62	6,836.915					
TOW	TopOfWallSpray/Fiber1.5"			$1.300 / LinFt		LinFt	2.00% waste	Show as LinFt			
1	Int Flr1 6" Partitions 1hr	559	LinFt	$770.95	$885.65	548.500	9' 4"	548' 0"	1		Rect
2	Int Flr2 6" Partitions 1hr	529	LinFt	$728.31	$836.67	518.167	9' 4"	518' 8"	1	Opn	Rect
3	Int Flr3 6" Partitions 1hr	529	LinFt	$729.25	$837.75	518.833	9' 4"	519' 4"	1	Opn	Rect
Material [TOW] Totals		1,617	LinFt	$2,228.52	$2,560.08	1,585.500					
Class Totals	Fire Safeing	8,591	LinFt	$7,033.36	$9,919.69	8,422.415					

Classification FLA — Flashing

		Quantity		Marked Up Mat. Cost	Marked Up Lay-Cost	Amount	Wall Height	Length	Qty	Opn Odd Adj	Shape
T **BASE**	S.S.Counter Flash			**$0.000** / LinFt		LinFt		Show as LinFt			
1	Ext Bearing	580	LinFt	$0.00	$0.00	579.667	10' 8"	598' 8"	1	Opn Odd Adj	Rect
1	Ext Non-Bearing	88	LinFt	$0.00	$0.00	88.000	10' 8"	94' 8"	1	Opn Odd Adj	Rect
1	Ext Stairs	90	LinFt	$0.00	$0.00	90.000	10' 8"	90' 0"	1	Odd Adj	Rect

FLA Continued

		Quantity		Marked Up Mat. Cost	Marked Up Lay-Cost	Amount	Wall Height	Length	Qty	Opn Odd Adj	Shape
2	Ext Bearing	581	LinFt	$0.00	$0.00	581.333	10' 0"	581' 4"	1	Opn Odd Adj	Rect
2	Ext Non-Bearing	95	LinFt	$0.00	$0.00	95.333	10' 0"	95' 4"	1	Opn Odd Adj	Rect
2	Ext Stairs	93	LinFt	$0.00	$0.00	92.667	10' 0"	92' 8"	1	Odd Adj	Rect
3	Ext Bearing	581	LinFt	$0.00	$0.00	581.333	11' 4"	581' 4"	1	Opn Odd Adj	Rect
3	Ext Non-Bearing	95	LinFt	$0.00	$0.00	95.333	11' 4"	95' 4"	1	Opn Odd Adj	Rect
3	Ext Stairs	93	LinFt	$0.00	$0.00	92.667	11' 4"	92' 8"	1	Odd Adj	Rect
Material [BASE] Totals		2,296	LinFt	$0.00	$0.00	2,296.333					
BASEDRIP	SS with Drip 16"			**$0.000** / LinFt		LinFt		Show as LinFt			
1	Ext Bearing	580	LinFt	$0.00	$0.00	579.667	10' 8"	598' 8"	1	Opn Odd Adj	Rect
1	Ext Non-Bearing	88	LinFt	$0.00	$0.00	88.000	10' 8"	94' 8"	1	Opn Odd Adj	Rect
1	Ext Stairs	90	LinFt	$0.00	$0.00	90.000	10' 8"	90' 0"	1	Odd Adj	Rect
2	Ext Bearing	581	LinFt	$0.00	$0.00	581.333	10' 0"	581' 4"	1	Opn Odd Adj	Rect
2	Ext Non-Bearing	95	LinFt	$0.00	$0.00	95.333	10' 0"	95' 4"	1	Opn Odd Adj	Rect
2	Ext Stairs	93	LinFt	$0.00	$0.00	92.667	10' 0"	92' 8"	1	Odd Adj	Rect
3	Ext Bearing	581	LinFt	$0.00	$0.00	581.333	11' 4"	581' 4"	1	Opn Odd Adj	Rect
3	Ext Non-Bearing	95	LinFt	$0.00	$0.00	95.333	11' 4"	95' 4"	1	Opn Odd Adj	Rect
3	Ext Stairs	93	LinFt	$0.00	$0.00	92.667	11' 4"	92' 8"	1	Odd Adj	Rect
Material [BASEDRIP] Totals		2,296	LinFt	$0.00	$0.00	2,296.333					
T **PRESSURE**	Pressure Bar S.S.			**$0.000** / LinFt		LinFt		Show as LinFt			
1	Ext Bearing	1,102	LinFt	$0.00	$0.00	1,101.780	10' 8"	598' 8"	1	Opn Odd Adj	Rect
1	Ext Non-Bearing	136	LinFt	$0.00	$0.00	136.320	10' 8"	94' 8"	1	Opn Odd Adj	Rect
1	Ext Stairs	90	LinFt	$0.00	$0.00	90.000	10' 8"	90' 0"	1	Odd Adj	Rect
2	Ext Bearing	1,095	LinFt	$0.00	$0.00	1,095.100	10' 0"	581' 4"	1	Opn Odd Adj	Rect
2	Ext Non-Bearing	115	LinFt	$0.00	$0.00	114.640	10' 0"	95' 4"	1	Opn Odd Adj	Rect
2	Ext Stairs	93	LinFt	$0.00	$0.00	93.000	10' 0"	92' 8"	1	Odd Adj	Rect
3	Ext Bearing	1,095	LinFt	$0.00	$0.00	1,095.100	11' 4"	581' 4"	1	Opn Odd Adj	Rect
3	Ext Non-Bearing	115	LinFt	$0.00	$0.00	114.640	11' 4"	95' 4"	1	Opn Odd Adj	Rect
3	Ext Stairs	93	LinFt	$0.00	$0.00	93.000	11' 4"	92' 8"	1	Odd Adj	Rect
Material [PRESSURE] Totals		3,934	LinFt	$0.00	$0.00	3,933.580					
SS18"	S. S. Flashing 16 oz/18"			**$0.000** / LinFt		LinFt		Show as LinFt			
3	Ext Bearing	580	LinFt	$0.00	$0.00	579.875	11' 4"	581' 4"	1	Opn Odd Adj	Rect
3	Ext Non-Bearing	95	LinFt	$0.00	$0.00	95.333	11' 4"	95' 4"	1	Opn Odd Adj	Rect
3	Ext Stairs	88	LinFt	$0.00	$0.00	88.292	11' 4"	92' 8"	1	Odd Adj	Rect
Material [SS18"] Totals		764	LinFt	$0.00	$0.00	763.500					
WHEADDRIP	SS with Drip 16"			**$0.000** / LinFt		LinFt		Show as LinFt			
1	Ext Bearing	265	LinFt	$0.00	$0.00	265.000	10' 8"	598' 8"	1	Opn Odd Adj	Rect
1	Ext Non-Bearing	24	LinFt	$0.00	$0.00	24.000	10' 8"	94' 8"	1	Opn Odd Adj	Rect
2	Ext Bearing	257	LinFt	$0.00	$0.00	256.667	10' 0"	581' 4"	1	Opn Odd Adj	Rect
2	Ext Non-Bearing	9	LinFt	$0.00	$0.00	8.667	10' 0"	95' 4"	1	Opn Odd Adj	Rect
3	Ext Bearing	257	LinFt	$0.00	$0.00	256.667	11' 4"	581' 4"	1	Opn Odd Adj	Rect
3	Ext Non-Bearing	9	LinFt	$0.00	$0.00	8.667	11' 4"	95' 4"	1	Opn Odd Adj	Rect
Material [WHEADDRIP] Totals		820	LinFt	$0.00	$0.00	819.667					
T **WINHEAD**	S.S.Counter Flash			**$0.000** / LinFt		LinFt		Show as LinFt			
1	Ext Bearing	265	LinFt	$0.00	$0.00	265.000	10' 8"	598' 8"	1	Opn Odd Adj	Rect
1	Ext Non-Bearing	24	LinFt	$0.00	$0.00	24.000	10' 8"	94' 8"	1	Opn Odd Adj	Rect
2	Ext Bearing	257	LinFt	$0.00	$0.00	256.667	10' 0"	581' 4"	1	Opn Odd Adj	Rect

FLA Continued

Flr	Description	Quantity	Unit	Marked Up Mat. Cost	Marked Up Lay-Cost	Amount	Wall Height	Length	Qty	Opn Odd Adj	Shape
2	Ext Non-Bearing	9	LinFt	$0.00	$0.00	8.667	10' 0"	95' 4"	1	Opn Odd Adj	Rect
3	Ext Bearing	257	LinFt	$0.00	$0.00	256.667	11' 4"	581' 4"	1	Opn Odd Adj	Rect
3	Ext Non-Bearing	9	LinFt	$0.00	$0.00	8.667	11' 4"	95' 4"	1	Opn Odd Adj	Rect
Material [WINHEAD] Totals		820	LinFt	$0.00	$0.00	819.667					
Class Totals Flashing		10,929	LinFt	$0.00	$0.00	10,929.080					

Classification **GRO** **Grout**

Flr	Description	Quantity	Unit	Marked Up Mat. Cost	Marked Up Lay-Cost	Amount	Wall Height	Length	Qty	Opn Odd Adj	Shape
G6CMU	grout 6" cmu in Cu.Ft.			$3.700 / CbcFt		CbcFt	3.00% waste	Show as CbcFt			
2	Int Flr2 6" Partitions 1hr	3	CbcFt	$11.41	$17.02	2.824	9' 4"	518' 8"	1	Opn	Rect
3	Int Flr3 6" Partitions 1hr	3	CbcFt	$11.41	$17.02	2.824	9' 4"	519' 4"	1	Opn	Rect
Material [G6CMU] Totals		6	CbcFt	$22.82	$34.05	5.648					
G8CMU	grout 8" cmu in Cu.Ft.			$3.700 / CbcFt		CbcFt	3.00% waste	Show as CbcFt			
1	Ext Bearing	583	CbcFt	$2,285.93	$779.79	565.873	10' 8"	598' 8"	1	Opn Odd Adj	Rect
1	Ext Non-Bearing	82	CbcFt	$320.31	$109.26	79.291	10' 8"	94' 8"	1	Opn Odd Adj	Rect
1	Ext Stairs	77	CbcFt	$300.61	$102.55	74.416	10' 8"	90' 0"	1	Odd Adj	Rect
1	Int Flr1 Corridor	471	CbcFt	$1,847.00	$630.06	457.216	9' 4"	646' 0"	1	Opn Odd Adj	Rect
1	Int Flr1 Shear Walls	383	CbcFt	$1,500.55	$511.88	371.455	10' 0"	420' 8"	1	Odd	Rect
1	Int Flr1 Stairs/Elev.	94	CbcFt	$368.75	$125.79	91.283	10' 0"	126' 0"	1	Opn Odd	Rect
2	Ext Bearing	574	CbcFt	$2,249.47	$767.35	556.847	10' 0"	581' 4"	1	Opn Odd Adj	Rect
2	Ext Non-Bearing	77	CbcFt	$301.80	$102.95	74.708	10' 0"	95' 4"	1	Opn Odd Adj	Rect
2	Ext Stairs	67	CbcFt	$262.17	$89.43	64.899	10' 0"	92' 8"	1	Odd Adj	Rect
2	Int Flr2 Corridor	460	CbcFt	$1,805.75	$615.99	447.006	9' 4"	632' 8"	1	Opn Odd Adj	Rect
2	Int Flr2 Shear Walls	392	CbcFt	$1,538.77	$524.91	380.915	10' 0"	453' 4"	1	Odd	Rect
2	Int Flr2 Stairs/Elev.	94	CbcFt	$368.75	$125.79	91.283	10' 0"	126' 0"	1	Opn Odd	Rect
3	Ext Bearing	768	CbcFt	$3,012.15	$1,027.52	745.645	11' 4"	581' 4"	1	Opn Odd Adj	Rect
3	Ext Non-Bearing	108	CbcFt	$425.32	$145.09	105.287	11' 4"	95' 4"	1	Opn Odd Adj	Rect
3	Ext Stairs	96	CbcFt	$374.77	$127.84	92.772	11' 4"	92' 8"	1	Odd Adj	Rect
3	Int Flr3 Corridor	460	CbcFt	$1,805.75	$615.99	447.006	9' 4"	632' 8"	1	Opn Odd Adj	Rect
3	Int Flr3 Shear Walls	392	CbcFt	$1,538.77	$524.91	380.915	10' 0"	453' 4"	1	Odd	Rect
3	Int Flr3 Stairs/Elev.	94	CbcFt	$368.75	$125.79	91.283	10' 0"	126' 0"	1	Opn Odd	Rect
FDN	Ext FDN	149	CbcFt	$584.68	$199.45	144.735	0' 8"	782' 8"	1		Rect
FDN	Int FDN	198	CbcFt	$778.43	$265.54	192.697	0' 8"	1043' 4"	1		Rect
Material [G8CMU] Totals		5,619	CbcFt	$22,038.49	$7,517.89	5,455.530					
GCAVITY	grout cavity in Cu.Ft.			$3.700 / CbcFt		CbcFt	3.00% waste	Show as CbcFt			
1	Ext Bearing	28	CbcFt	$109.07	$325.56	27.000	10' 8"	598' 8"	1	Opn Odd Adj	Rect
1	Ext Non-Bearing	5	CbcFt	$20.20	$60.29	5.000	10' 8"	94' 8"	1	Opn Odd Adj	Rect
1	Ext Stairs	4	CbcFt	$16.16	$48.23	4.000	10' 8"	90' 0"	1	Odd Adj	Rect
2	Ext Bearing	28	CbcFt	$109.07	$325.56	27.000	10' 0"	581' 4"	1	Opn Odd Adj	Rect
2	Ext Non-Bearing	3	CbcFt	$12.12	$36.17	3.000	10' 0"	95' 4"	1	Opn Odd Adj	Rect
2	Ext Stairs	4	CbcFt	$16.16	$48.23	4.000	10' 0"	92' 8"	1	Odd Adj	Rect
3	Ext Bearing	28	CbcFt	$109.07	$325.56	27.000	11' 4"	581' 4"	1	Opn Odd Adj	Rect
3	Ext Non-Bearing	3	CbcFt	$12.12	$36.17	3.000	11' 4"	95' 4"	1	Opn Odd Adj	Rect
3	Ext Stairs	4	CbcFt	$16.16	$48.23	4.000	11' 4"	92' 8"	1	Odd Adj	Rect
Material [GCAVITY] Totals		107	CbcFt	$420.12	$1,254.01	104.000					
GHM	grout for hm frame			$3.700 / CbcFt		CbcFt	3.00% waste	Show as CbcFt			
1	Ext Bearing	3	CbcFt	$12.62	$33.49	3.125	10' 8"	598' 8"	1	Opn Odd Adj	Rect

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Quantity/Bid Price Report

GRO Continued

		Quantity		Marked Up Mat. Cost	Marked Up Lay-Cost	Amount	Wall Height	Length	Qty	Opn Odd Adj	Shape
1	Ext Non-Bearing	2	CbcFt	$8.42	$22.33	2.083	10' 8"	94' 8"	1	Opn Odd Adj	Rect
1	Int Flr1 Corridor	44	CbcFt	$172.53	$457.75	42.708	9' 4"	646' 0"	1	Opn Odd Adj	Rect
1	Int Flr1 Stairs/Elev.	4	CbcFt	$16.83	$44.66	4.167	10' 0"	126' 0"	1	Opn Odd	Rect
2	Int Flr2 6" Partitions 1hr	1	CbcFt	$4.21	$11.16	1.042	9' 4"	518' 8"	1	Opn	Rect
2	Int Flr2 Corridor	45	CbcFt	$176.74	$468.91	43.750	9' 4"	632' 8"	1	Opn Odd Adj	Rect
2	Int Flr2 Stairs/Elev.	4	CbcFt	$16.83	$44.66	4.167	10' 0"	126' 0"	1	Opn Odd	Rect
3	Int Flr3 6" Partitions 1hr	1	CbcFt	$4.21	$11.16	1.042	9' 4"	519' 4"	1	Opn	Rect
3	Int Flr3 Corridor	45	CbcFt	$176.74	$468.91	43.750	9' 4"	632' 8"	1	Opn Odd Adj	Rect
3	Int Flr3 Stairs/Elev.	4	CbcFt	$16.83	$44.66	4.167	10' 0"	126' 0"	1	Opn Odd	Rect
Material [GHM] Totals		155	CbcFt	$605.95	$1,607.70	150.000					
PLANK	8,000 S.F.=1 CY of Grout			$3.700 / CbcFt		CbcFt	3.00% waste	Show as CbcFt			
1	Precast Plank (2nd Flr)	83	CbcFt	$327.21	$1,309.05	81.000	0' 1"	0' 1"	1	Adj	Rect
2	Precast Plank (3rd Flr)	83	CbcFt	$327.21	$1,309.05	81.000	0' 1"	0' 1"	1	Adj	Rect
3	Precast Plank (Roof)	83	CbcFt	$327.21	$1,309.05	81.000	0' 1"	0' 1"	1	Adj	Rect
Material [PLANK] Totals		250	CbcFt	$981.64	$3,927.16	243.000					
Class Totals	Grout	6,137	CbcFt	$24,069.01	$14,340.82	5,958.178					

Classification **HML** — **set hollow metal frame**

		Quantity		Marked Up Mat. Cost	Marked Up Lay-Cost	Amount	Wall Height	Length	Qty	Opn Odd Adj	Shape
HMFRM	masonry both sides			**$0.000** / Each		Each		Show as Each			
1	Ext Bearing	3	Each	$0.00	$0.00	3.000	10' 8"	598' 8"	1	Opn Odd Adj	Rect
1	Ext Non-Bearing	2	Each	$0.00	$0.00	2.000	10' 8"	94' 8"	1	Opn Odd Adj	Rect
1	Int Flr1 Corridor	41	Each	$0.00	$0.00	41.000	9' 4"	646' 0"	1	Opn Odd Adj	Rect
1	Int Flr1 Stairs/Elev.	4	Each	$0.00	$0.00	4.000	10' 0"	126' 0"	1	Opn Odd	Rect
2	Int Flr2 6" Partitions 1hr	1	Each	$0.00	$0.00	1.000	9' 4"	518' 8"	1	Opn	Rect
2	Int Flr2 Corridor	42	Each	$0.00	$0.00	42.000	9' 4"	632' 8"	1	Opn Odd Adj	Rect
2	Int Flr2 Stairs/Elev.	4	Each	$0.00	$0.00	4.000	10' 0"	126' 0"	1	Opn Odd	Rect
3	Int Flr3 6" Partitions 1hr	1	Each	$0.00	$0.00	1.000	9' 4"	519' 4"	1	Opn	Rect
3	Int Flr3 Corridor	42	Each	$0.00	$0.00	42.000	9' 4"	632' 8"	1	Opn Odd Adj	Rect
3	Int Flr3 Stairs/Elev.	4	Each	$0.00	$0.00	4.000	10' 0"	126' 0"	1	Opn Odd	Rect
Material [HMFRM] Totals		144	Each	$0.00	$0.00	144.000					

Classification **INR** — **Rigid Insul.**

		Quantity		Marked Up Mat. Cost	Marked Up Lay-Cost	Amount	Wall Height	Length	Qty	Opn Odd Adj	Shape
SPRAYFOAM	4" Sprayfoam Insulation			$3.400 / SqFt		SqFt		Show as SqFt			
1	Ext Bearing	5,191	SqFt	$18,708.85	$0.00	5,191.135	10' 8"	598' 8"	1	Opn Odd Adj	Rect
1	Ext Non-Bearing	897	SqFt	$3,232.39	$0.00	896.889	10' 8"	94' 8"	1	Opn Odd Adj	Rect
1	Ext Stairs	920	SqFt	$3,315.68	$0.00	920.000	10' 8"	90' 0"	1	Odd Adj	Rect
2	Ext Bearing	4,681	SqFt	$16,869.72	$0.00	4,680.833	10' 0"	581' 4"	1	Opn Odd Adj	Rect
2	Ext Non-Bearing	921	SqFt	$3,320.49	$0.00	921.333	10' 0"	95' 4"	1	Opn Odd Adj	Rect
2	Ext Stairs	889	SqFt	$3,204.56	$0.00	889.167	10' 0"	92' 8"	1	Odd Adj	Rect
3	Ext Bearing	5,454	SqFt	$19,657.22	$0.00	5,454.278	11' 4"	581' 4"	1	Opn Odd Adj	Rect
3	Ext Non-Bearing	1,048	SqFt	$3,778.59	$0.00	1,048.444	11' 4"	95' 4"	1	Opn Odd Adj	Rect
3	Ext Stairs	1,008	SqFt	$3,631.83	$0.00	1,007.722	11' 4"	92' 8"	1	Odd Adj	Rect
Material [SPRAYFOAM] Totals		21,010	SqFt	$75,719.32	$0.00	21,009.801					

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Quantity/Bid Price Report

		Quantity		Marked Up Mat. Cost	Marked Up Lay-Cost	Amount	Wall Height		Length		Qty	Opn Odd Adj	Shape
Classification LUM		**PT Lumber**											
WINDOW	Window Surround			$1.500 / LinFt		LinFt			Show as LinFt				
1	Ext Bearing	822	LinFt	$1,306.98	$1,321.53	822.000	10'	8"	598'	8"	1	Opn Odd Adj	Rect
1	Ext Non-Bearing	82	LinFt	$130.38	$131.83	82.000	10'	8"	94'	8"	1	Opn Odd Adj	Rect
2	Ext Bearing	805	LinFt	$1,279.95	$1,294.20	805.000	10'	0"	581'	4"	1	Opn Odd Adj	Rect
2	Ext Non-Bearing	34	LinFt	$54.06	$54.66	34.000	10'	0"	95'	4"	1	Opn Odd Adj	Rect
3	Ext Bearing	805	LinFt	$1,279.95	$1,294.20	805.000	11'	4"	581'	4"	1	Opn Odd Adj	Rect
3	Ext Non-Bearing	34	LinFt	$54.06	$54.66	34.000	11'	4"	95'	4"	1	Opn Odd Adj	Rect
Material [WINDOW] Totals		2,582	LinFt	$4,105.38	$4,151.09	2,582.000							
Classification MNE		**Mortar Net**											
MN	Mortar Net 2" Thick			$1.390 / LinFt		LinFt			Show as LinFt				
1	Ext Bearing	845	LinFt	$1,244.53	$76.69	844.667	10'	8"	598'	8"	1	Opn Odd Adj	Rect
1	Ext Non-Bearing	112	LinFt	$165.02	$10.17	112.000	10'	8"	94'	8"	1	Opn Odd Adj	Rect
1	Ext Stairs	90	LinFt	$132.61	$8.17	90.000	10'	8"	90'	0"	1	Odd Adj	Rect
2	Ext Bearing	838	LinFt	$1,234.71	$76.08	838.000	10'	0"	581'	4"	1	Opn Odd Adj	Rect
2	Ext Non-Bearing	104	LinFt	$153.23	$9.44	104.000	10'	0"	95'	4"	1	Opn Odd Adj	Rect
2	Ext Stairs	93	LinFt	$136.54	$8.41	92.667	10'	0"	92'	8"	1	Odd Adj	Rect
3	Ext Bearing	838	LinFt	$1,234.71	$76.08	838.000	11'	4"	581'	4"	1	Opn Odd Adj	Rect
3	Ext Non-Bearing	104	LinFt	$153.23	$9.44	104.000	11'	4"	95'	4"	1	Opn Odd Adj	Rect
3	Ext Stairs	93	LinFt	$136.54	$8.41	92.667	11'	4"	92'	8"	1	Odd Adj	Rect
Material [MN] Totals		3,116	LinFt	$4,591.11	$282.90	3,116.000							
Classification MOR		**Mortar (CuFt)**											
Mortar[1]	[1] Type N Masonry CementTruckload			$3.00 / CbcFt		CbcFt			Show as CbcFt				
1	Ext Bearing	778	CbcFt	$2,477.55	$0.00	778.142	10'	8"	598'	8"	1	Opn Odd Adj	Rect
1	Ext Non-Bearing	133	CbcFt	$423.55	$0.00	133.026	10'	8"	94'	8"	1	Opn Odd Adj	Rect
1	Ext Stairs	135	CbcFt	$430.01	$0.00	135.056	10'	8"	90'	0"	1	Odd Adj	Rect
2	Ext Bearing	701	CbcFt	$2,232.27	$0.00	701.106	10'	0"	581'	4"	1	Opn Odd Adj	Rect
2	Ext Non-Bearing	132	CbcFt	$421.62	$0.00	132.423	10'	0"	95'	4"	1	Opn Odd Adj	Rect
2	Ext Stairs	130	CbcFt	$413.71	$0.00	129.937	10'	0"	92'	8"	1	Odd Adj	Rect
3	Ext Bearing	815	CbcFt	$2,594.96	$0.00	815.019	11'	4"	581'	4"	1	Opn Odd Adj	Rect
3	Ext Non-Bearing	152	CbcFt	$482.54	$0.00	151.556	11'	4"	95'	4"	1	Opn Odd Adj	Rect
3	Ext Stairs	149	CbcFt	$473.01	$0.00	148.560	11'	4"	92'	8"	1	Odd Adj	Rect
Mortar [2] Totals		3,125	CbcFt	$9,949.21	$0.00	3,124.824							
Mortar[2]	[2] Type S Masonry Cement Truckload			$3.10 / CbcFt		CbcFt			Show as CbcFt				
1	Ext Bearing	492	CbcFt	$1,615.99	$0.00	492.368	10'	8"	598'	8"	1	Opn Odd Adj	Rect
1	Ext Non-Bearing	86	CbcFt	$282.16	$0.00	85.971	10'	8"	94'	8"	1	Opn Odd Adj	Rect
1	Ext Stairs	85	CbcFt	$278.24	$0.00	84.777	10'	8"	90'	0"	1	Odd Adj	Rect
1	Int Flr1 6" Partitions 1hr	516	CbcFt	$1,695.03	$0.00	516.450	9'	4"	548'	0"	1		Rect
1	Int Flr1 Corridor	527	CbcFt	$1,729.50	$0.00	526.955	9'	4"	646'	0"	1	Opn Odd Adj	Rect
1	Int Flr1 Shear Walls	425	CbcFt	$1,394.37	$0.00	424.843	10'	0"	420'	8"	1	Odd	Rect
1	Int Flr1 Stairs/Elev.	115	CbcFt	$376.27	$0.00	114.643	10'	0"	126'	0"	1	Opn Odd	Rect
2	Ext Bearing	478	CbcFt	$1,568.20	$0.00	477.809	10'	0"	581'	4"	1	Opn Odd Adj	Rect
2	Ext Non-Bearing	93	CbcFt	$305.65	$0.00	93.129	10'	0"	95'	4"	1	Opn Odd Adj	Rect

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Quantity/Bid Price Report

MOR Continued

		Quantity		Marked Up Mat. Cost	Marked Up Lay-Cost	Amount	Wall Height		Length		Qty	Opn Odd Adj	Shape
2	Ext Stairs	87	CbcFt	$286.68	$0.00	87.348	10'	0"	92'	8"	1	Odd Adj	Rect
2	Int Flr2 6" Partitions 1hr	489	CbcFt	$1,603.74	$0.00	488.636	9'	4"	518'	8"	1	Opn	Rect
2	Int Flr2 Corridor	515	CbcFt	$1,690.03	$0.00	514.929	9'	4"	632'	8"	1	Opn Odd Adj	Rect
2	Int Flr2 Shear Walls	458	CbcFt	$1,501.69	$0.00	457.543	10'	0"	453'	4"	1	Odd	Rect
2	Int Flr2 Stairs/Elev.	115	CbcFt	$376.27	$0.00	114.643	10'	0"	126'	0"	1	Opn Odd	Rect
3	Ext Bearing	595	CbcFt	$1,953.15	$0.00	595.096	11'	4"	581'	4"	1	Opn Odd Adj	Rect
3	Ext Non-Bearing	112	CbcFt	$368.66	$0.00	112.324	11'	4"	95'	4"	1	Opn Odd Adj	Rect
3	Ext Stairs	105	CbcFt	$344.06	$0.00	104.830	11'	4"	92'	8"	1	Odd Adj	Rect
3	Int Flr3 6" Partitions 1hr	489	CbcFt	$1,605.71	$0.00	489.236	9'	4"	519'	4"	1	Opn	Rect
3	Int Flr3 Corridor	515	CbcFt	$1,690.03	$0.00	514.929	9'	4"	632'	8"	1	Opn Odd Adj	Rect
3	Int Flr3 Shear Walls	458	CbcFt	$1,501.69	$0.00	457.543	10'	0"	453'	4"	1	Odd	Rect
3	Int Flr3 Stairs/Elev.	115	CbcFt	$376.27	$0.00	114.643	10'	0"	126'	0"	1	Opn Odd	Rect
FDN	Ext FDN	50	CbcFt	$164.41	$0.00	50.093	0'	8"	782'	8"	1		Rect
FDN	Int FDN	67	CbcFt	$218.89	$0.00	66.692	0'	8"	1043'	4"	1		Rect
Mortar [2] Totals		6,985	CbcFt	$22,926.69	$0.00	6,985.428							
Class Totals Mortar (CuFt)				$32,875.90	$0.00	10,110.252							

Classification **PCF** **Precast Plank**

		Quantity		Marked Up Mat. Cost	Marked Up Lay-Cost	Amount	Wall Height		Length		Qty	Opn Odd Adj	Shape
1STFLRPLK	8" Precast Plank			$430.769 / Piece		SqFt			76.923 SqFt per Piece				
1	Precast Plank (2nd Flr)	233	Pieces	$106,414.67	$2,542.30	17,927.000	0'	1"	0'	1"	1	Adj	Rect
2STFLRPLK	8" Precast Plank			$560.000 / Piece		SqFt			83.333 SqFt per Piece				
2	Precast Plank (3rd Flr)	218	Pieces	$129,642.24	$2,382.48	18,200.000	0'	1"	0'	1"	1	Adj	Rect
3	Precast Plank (Roof)	218	Pieces	$129,642.24	$2,382.48	18,200.000	0'	1"	0'	1"	1	Adj	Rect
Material [2STFLRPLK] Totals		437	Pieces	$259,284.48	$4,764.96	36,400.000							
Class Totals Precast Plank		670	Pieces	$365,699.15	$7,307.26	54,327.000							

Classification **REB** **Rebar**

		Quantity		Marked Up Mat. Cost	Marked Up Lay-Cost	Amount	Wall Height		Length		Qty	Opn Odd Adj	Shape
#4	#4 w/shops Vert.			$0.244 / LinFt		LinFt			Show as LinFt				
1	Int Flr1 Shear Walls	1,728	LinFt	$446.93	$416.72	1,728.000	10'	0"	420'	8"	1	Odd	Rect
2	Int Flr2 Shear Walls	1,728	LinFt	$446.93	$416.72	1,728.000	10'	0"	453'	4"	1	Odd	Rect
3	Int Flr3 Shear Walls	1,728	LinFt	$446.93	$416.72	1,728.000	10'	0"	453'	4"	1	Odd	Rect
Material [#4] Totals		5,184	LinFt	$1,340.79	$1,250.15	5,184.000							
#4PLANK	Plank L Shape w/shops			$0.976 / Piece		LinFt			4.000 LinFt per Piece				
1	Int Flr1 Shear Walls	211	Pieces	$218.29	$407.07	844.000	10'	0"	420'	8"	1	Odd	Rect
2	Int Flr2 Shear Walls	227	Pieces	$234.85	$437.94	908.000	10'	0"	453'	4"	1	Odd	Rect
3	Int Flr3 Shear Walls	227	Pieces	$234.85	$437.94	908.000	10'	0"	453'	4"	1	Odd	Rect
Material [#4PLANK] Totals		665	Pieces	$687.98	$1,282.95	2,660.000							
#5	#5 w/shops Vert.			$0.381 / LinFt		LinFt			Show as LinFt				
1	Ext Bearing	3,320	LinFt	$1,340.82	$800.64	3,320.000	10'	8"	598'	8"	1	Opn Odd Adj	Rect
1	Ext Non-Bearing	411	LinFt	$165.85	$99.03	410.667	10'	8"	94'	8"	1	Opn Odd Adj	Rect
1	Ext Stairs	465	LinFt	$187.79	$112.14	465.000	10'	8"	90'	0"	1	Odd Adj	Rect
1	Int Flr1 Corridor	1,375	LinFt	$555.31	$331.59	1,375.000	9'	4"	646'	0"	1	Opn Odd Adj	Rect
1	Int Flr1 Stairs/Elev.	416	LinFt	$167.94	$100.28	415.833	10'	0"	126'	0"	1	Opn Odd	Rect
2	Ext Bearing	2,838	LinFt	$1,146.29	$684.48	2,838.333	10'	0"	581'	4"	1	Opn Odd Adj	Rect

REB Continued

		Quantity		Marked Up Mat. Cost	Marked Up Lay-Cost	Amount	Wall Height	Length	Qty	Opn Odd Adj	Shape
2	Ext Non-Bearing	321	LinFt	$129.77	$77.49	321.333	10' 0"	95' 4"	1	Opn Odd Adj	Rect
2	Ext Stairs	288	LinFt	$116.11	$69.33	287.500	10' 0"	92' 8"	1	Odd Adj	Rect
2	Int Flr2 6" Partitions 1hr	13	LinFt	$5.38	$3.22	13.333	9' 4"	518' 8"	1	Opn	Rect
2	Int Flr2 Corridor	1,317	LinFt	$532.02	$317.68	1,317.333	9' 4"	632' 8"	1	Opn Odd Adj	Rect
2	Int Flr2 Stairs/Elev.	416	LinFt	$167.94	$100.28	415.833	10' 0"	126' 0"	1	Opn Odd	Rect
3	Ext Bearing	3,490	LinFt	$1,409.47	$841.63	3,490.000	11' 4"	581' 4"	1	Opn Odd Adj	Rect
3	Ext Non-Bearing	353	LinFt	$142.70	$85.21	353.333	11' 4"	95' 4"	1	Opn Odd Adj	Rect
3	Ext Stairs	318	LinFt	$128.49	$76.73	318.167	11' 4"	92' 8"	1	Odd Adj	Rect
3	Int Flr3 6" Partitions 1hr	13	LinFt	$5.38	$3.22	13.333	9' 4"	519' 4"	1	Opn	Rect
3	Int Flr3 Corridor	1,317	LinFt	$532.02	$317.68	1,317.333	9' 4"	632' 8"	1	Opn Odd Adj	Rect
3	Int Flr3 Stairs/Elev.	416	LinFt	$167.94	$100.28	415.833	10' 0"	126' 0"	1	Opn Odd	Rect
Material [#5] Totals		17,088	LinFt	$6,901.23	$4,120.91	17,088.167					
#5BB REBA	#5 w/shops Bond Beam			$0.381 / LinFt		LinFt		Show as LinFt			
1	Ext Bearing	1,898	LinFt	$766.35	$457.61	1,897.566	10' 8"	598' 8"	1	Opn Odd Adj	Rect
1	Ext Non-Bearing	262	LinFt	$105.95	$63.26	262.333	10' 8"	94' 8"	1	Opn Odd Adj	Rect
1	Ext Stairs	192	LinFt	$77.34	$46.18	191.500	10' 8"	90' 0"	1	Odd Adj	Rect
1	Int Flr1 Corridor	1,858	LinFt	$750.47	$448.13	1,858.248	9' 4"	646' 0"	1	Opn Odd Adj	Rect
1	Int Flr1 Shear Walls	961	LinFt	$388.24	$231.83	961.333	10' 0"	420' 8"	1	Odd	Rect
1	Int Flr1 Stairs/Elev.	314	LinFt	$126.68	$75.64	313.667	10' 0"	126' 0"	1	Opn Odd	Rect
2	Ext Bearing	1,836	LinFt	$741.69	$442.88	1,836.500	10' 0"	581' 4"	1	Opn Odd Adj	Rect
2	Ext Non-Bearing	233	LinFt	$94.10	$56.19	233.000	10' 0"	95' 4"	1	Opn Odd Adj	Rect
2	Ext Stairs	197	LinFt	$79.49	$47.47	196.833	10' 0"	92' 8"	1	Odd Adj	Rect
2	Int Flr2 6" Partitions 1hr	5	LinFt	$1.88	$1.13	4.667	9' 4"	518' 8"	1	Opn	Rect
2	Int Flr2 Corridor	1,837	LinFt	$742.03	$443.08	1,837.333	9' 4"	632' 8"	1	Opn Odd Adj	Rect
2	Int Flr2 Shear Walls	1,032	LinFt	$416.65	$248.79	1,031.667	10' 0"	453' 4"	1	Odd	Rect
2	Int Flr2 Stairs/Elev.	314	LinFt	$126.68	$75.64	313.667	10' 0"	126' 0"	1	Opn Odd	Rect
3	Ext Bearing	3,160	LinFt	$1,276.06	$761.97	3,159.667	11' 4"	581' 4"	1	Opn Odd Adj	Rect
3	Ext Non-Bearing	449	LinFt	$181.20	$108.20	448.667	11' 4"	95' 4"	1	Opn Odd Adj	Rect
3	Ext Stairs	394	LinFt	$158.99	$94.93	393.667	11' 4"	92' 8"	1	Odd Adj	Rect
3	Int Flr3 6" Partitions 1hr	5	LinFt	$1.88	$1.13	4.667	9' 4"	519' 4"	1	Opn	Rect
3	Int Flr3 Corridor	1,837	LinFt	$742.03	$443.08	1,837.333	9' 4"	632' 8"	1	Opn Odd Adj	Rect
3	Int Flr3 Shear Walls	1,032	LinFt	$416.65	$248.79	1,031.667	10' 0"	453' 4"	1	Odd	Rect
3	Int Flr3 Stairs/Elev.	314	LinFt	$126.68	$75.64	313.667	10' 0"	126' 0"	1	Opn Odd	Rect
Material [#5BB REBA] Totals		18,128	LinFt	$7,321.03	$4,371.58	18,127.648					
#5PLKDOWE	Plank L Shape Plank dowel			$1.524 / Piece		LinFt		4.000 LinFt per Piece			
1	Ext Bearing	150	Pieces	$242.32	$289.39	600.000	10' 8"	598' 8"	1	Opn Odd Adj	Rect
1	Ext Non-Bearing	24	Pieces	$38.77	$46.30	96.000	10' 8"	94' 8"	1	Opn Odd Adj	Rect
1	Ext Stairs	23	Pieces	$37.16	$44.37	92.000	10' 8"	90' 0"	1	Odd Adj	Rect
1	Int Flr1 Corridor	323	Pieces	$521.79	$623.15	1,292.000	9' 4"	646' 0"	1	Opn Odd Adj	Rect
1	Int Flr1 Stairs/Elev.	63	Pieces	$101.77	$121.54	252.000	10' 0"	126' 0"	1	Opn Odd	Rect
2	Ext Bearing	146	Pieces	$235.85	$281.67	584.000	10' 0"	581' 4"	1	Opn Odd Adj	Rect
2	Ext Non-Bearing	24	Pieces	$38.77	$46.30	96.000	10' 0"	95' 4"	1	Opn Odd Adj	Rect
2	Ext Stairs	23	Pieces	$37.16	$44.37	92.000	10' 0"	92' 8"	1	Odd Adj	Rect
2	Int Flr2 Corridor	317	Pieces	$512.09	$611.57	1,268.000	9' 4"	632' 8"	1	Opn Odd Adj	Rect
2	Int Flr2 Stairs/Elev.	63	Pieces	$101.77	$121.54	252.000	10' 0"	126' 0"	1	Opn Odd	Rect
3	Ext Bearing	146	Pieces	$235.85	$281.67	584.000	11' 4"	581' 4"	1	Opn Odd Adj	Rect
3	Ext Non-Bearing	24	Pieces	$38.77	$46.30	96.000	11' 4"	95' 4"	1	Opn Odd Adj	Rect
3	Ext Stairs	23	Pieces	$37.16	$44.37	92.000	11' 4"	92' 8"	1	Odd Adj	Rect
3	Int Flr3 Corridor	317	Pieces	$512.09	$611.57	1,268.000	9' 4"	632' 8"	1	Opn Odd Adj	Rect
3	Int Flr3 Stairs/Elev.	63	Pieces	$101.77	$121.54	252.000	10' 0"	126' 0"	1	Opn Odd	Rect

REB Continued

		Quantity		Marked Up Mat. Cost	Marked Up Lay-Cost	Amount	Wall Height	Length	Qty	Opn Odd Adj	Shape
Material [#5PLKDOWE] Totals		1,729	Pieces	$2,793.10	$3,335.66	6,916.000					
Class Totals Rebar				$19,044.13	$14,361.25	49,975.814					

Classification **STE** **Steel Lintels**

		Quantity		Marked Up Mat. Cost	Marked Up Lay-Cost	Amount	Height	Length	Qty	Opn Odd Adj	Shape
LINTEL<6'	6x4x3/8 F&I Lintel (glvz)			**$0.000** / Piece		LinFt		6.000 LinFt per Piece			
1	Ext Non-Bearing	2	Pieces	$0.00	$17.65	9.333	10' 8"	94' 8"	1	Opn Odd Adj	Rect
LINTEL>6'	6x4x3/8 F&I Lintel (glvz)			**$0.000** / Piece		LinFt		8.000 LinFt per Piece			
1	Ext Bearing	33	Pieces	$0.00	$375.92	265.000	10' 8"	598' 8"	1	Opn Odd Adj	Rect
1	Ext Non-Bearing	2	Pieces	$0.00	$20.81	14.667	10' 8"	94' 8"	1	Opn Odd Adj	Rect
2	Ext Bearing	32	Pieces	$0.00	$364.10	256.667	10' 0"	581' 4"	1	Opn Odd Adj	Rect
2	Ext Non-Bearing	1	Piece	$0.00	$12.29	8.667	10' 0"	95' 4"	1	Opn Odd Adj	Rect
3	Ext Bearing	32	Pieces	$0.00	$364.10	256.667	11' 4"	581' 4"	1	Opn Odd Adj	Rect
3	Ext Non-Bearing	1	Piece	$0.00	$12.29	8.667	11' 4"	95' 4"	1	Opn Odd Adj	Rect
Material [LINTEL>6'] Totals		101	Pieces	$0.00	$1,149.51	810.333					
W12X9	W12x9 I Beam			**$0.000** / Piece		LinFt		8.000 LinFt per Piece			
1	Int Flr1 Corridor	2	Pieces	$0.00	$160.77	16.000	9' 4"	646' 0"	1	Opn Odd Adj	Rect
2	Ext Bearing	1	Piece	$0.00	$80.39	8.000	10' 0"	581' 4"	1	Opn Odd Adj	Rect
2	Int Flr2 Corridor	1	Piece	$0.00	$80.39	8.000	9' 4"	632' 8"	1	Opn Odd Adj	Rect
3	Int Flr3 Corridor	1	Piece	$0.00	$80.39	8.000	9' 4"	632' 8"	1	Opn Odd Adj	Rect
Material [W12X9] Totals		5	Pieces	$0.00	$401.93	40.000					
Class Totals Steel Lintels		108	Pieces	$0.00	$1,569.09	859.667					

Classification **WEE** **Plastic Weeps**

		Quantity		Marked Up Mat. Cost	Marked Up Lay-Cost	Amount	Height	Length	Qty	Opn Odd Adj	Shape
WEEPVENT	Plastic Weep vents			$0.640 / Each		Each		Show as Each			
1	Ext Bearing	798	Each	$541.19	$72.43	797.750	10' 8"	598' 8"	1	Opn Odd Adj	Rect
1	Ext Non-Bearing	94	Each	$63.77	$8.53	94.000	10' 8"	94' 8"	1	Opn Odd Adj	Rect
1	Ext Stairs	67	Each	$45.45	$6.08	67.000	10' 8"	90' 0"	1	Odd Adj	Rect
2	Ext Bearing	804	Each	$545.09	$72.95	803.500	10' 0"	581' 4"	1	Opn Odd Adj	Rect
2	Ext Non-Bearing	83	Each	$56.31	$7.54	83.000	10' 0"	95' 4"	1	Opn Odd Adj	Rect
2	Ext Stairs	69	Each	$46.81	$6.26	69.000	10' 0"	92' 8"	1	Odd Adj	Rect
3	Ext Bearing	1,093	Each	$741.79	$99.27	1,093.438	11' 4"	581' 4"	1	Opn Odd Adj	Rect
3	Ext Non-Bearing	155	Each	$104.81	$14.03	154.500	11' 4"	95' 4"	1	Opn Odd Adj	Rect
3	Ext Stairs	135	Each	$91.73	$12.28	135.219	11' 4"	92' 8"	1	Odd Adj	Rect
Material [WEEPVENT] Totals		3,297	Each	$2,236.96	$299.36	3,297.406					

Classification **WIR** **Wire**

		Quantity		Marked Up Mat. Cost	Marked Up Lay-Cost	Amount	Height	Length	Qty	Opn Odd Adj	Shape
HDL-841.5	9 Gage Hot Dipped 8-4-1.5			$0.198 / LinFt		LinFt		Show as LinFt			
1	Ext Bearing	3,956	LinFt	$830.27	$0.00	3,955.932	10' 8"	598' 8"	1	Opn Odd Adj	Rect
1	Ext Non-Bearing	667	LinFt	$140.02	$0.00	667.139	10' 8"	94' 8"	1	Opn Odd Adj	Rect
1	Ext Stairs	693	LinFt	$145.45	$0.00	693.000	10' 8"	90' 0"	1	Odd Adj	Rect
2	Ext Bearing	3,821	LinFt	$801.97	$0.00	3,821.084	10' 0"	581' 4"	1	Opn Odd Adj	Rect
2	Ext Non-Bearing	713	LinFt	$149.56	$0.00	712.584	10' 0"	95' 4"	1	Opn Odd Adj	Rect
2	Ext Stairs	719	LinFt	$150.83	$0.00	718.667	10' 0"	92' 8"	1	Odd Adj	Rect

WIR Continued

		Quantity		Marked Up Mat. Cost	Marked Up Lay-Cost	Amount	Wall Height		Length		Qty	Opn Odd Adj	Shape
3	Ext Bearing	4,461	LinFt	$936.18	$0.00	4,460.566	11'	4"	581'	4"	1	Opn Odd Adj	Rect
3	Ext Non-Bearing	818	LinFt	$171.62	$0.00	817.709	11'	4"	95'	4"	1	Opn Odd Adj	Rect
3	Ext Stairs	821	LinFt	$172.38	$0.00	821.333	11'	4"	92'	8"	1	Odd Adj	Rect
Material [HDL-841.5] Totals		16,668	LinFt	$3,498.28	$0.00	16,668.015							
MGL9GA06"	9 Gage Hot Dipped			$0.074 / LinFt		LinFt			Show as LinFt				
1	Int Flr1 6" Partitions 1hr	3,648	LinFt	$286.15	$0.00	3,648.000	9'	4"	548'	0"	1		Rect
2	Int Flr2 6" Partitions 1hr	3,438	LinFt	$269.69	$0.00	3,438.144	9'	4"	518'	8"	1	Opn	Rect
3	Int Flr3 6" Partitions 1hr	3,442	LinFt	$270.00	$0.00	3,442.146	9'	4"	519'	4"	1	Opn	Rect
Material [MGL9GA06"] Totals		10,528	LinFt	$825.84	$0.00	10,528.291							
MGL9GA08"	9 Gage Hot Dipped			$0.074 / LinFt		LinFt			Show as LinFt				
1	Int Flr1 Corridor	3,771	LinFt	$295.76	$0.00	3,770.513	9'	4"	646'	0"	1	Opn Odd Adj	Rect
1	Int Flr1 Shear Walls	3,267	LinFt	$256.24	$0.00	3,266.667	10'	0"	420'	8"	1	Odd	Rect
1	Int Flr1 Stairs/Elev.	904	LinFt	$70.94	$0.00	904.358	10'	0"	126'	0"	1	Opn Odd	Rect
2	Int Flr2 Corridor	3,683	LinFt	$288.89	$0.00	3,682.891	9'	4"	632'	8"	1	Opn Odd Adj	Rect
2	Int Flr2 Shear Walls	3,523	LinFt	$276.37	$0.00	3,523.333	10'	0"	453'	4"	1	Odd	Rect
2	Int Flr2 Stairs/Elev.	904	LinFt	$70.94	$0.00	904.358	10'	0"	126'	0"	1	Opn Odd	Rect
3	Int Flr3 Corridor	3,683	LinFt	$288.89	$0.00	3,682.891	9'	4"	632'	8"	1	Opn Odd Adj	Rect
3	Int Flr3 Shear Walls	3,523	LinFt	$276.37	$0.00	3,523.333	10'	0"	453'	4"	1	Odd	Rect
3	Int Flr3 Stairs/Elev.	904	LinFt	$70.94	$0.00	904.358	10'	0"	126'	0"	1	Opn Odd	Rect
Material [MGL9GA08"] Totals		24,163	LinFt	$1,895.32	$0.00	24,162.703							
Class Totals	Wire	51,359	LinFt	$6,219.44	$0.00	51,359.009							

100 Room Dormitory Prevailing Wage

Quantity/Bid Price Report

Crew Section

ID	Description	Production Masons	Prod-Mason Days	Crew Days	Cost Per Day Whole Crew	Cost Per Day Per Prod-Mason	Extended Labor Cost	Super	Layout	Saw	Tender/ Other
B	Lansing Jackson Brick crew	8.50	255.7	30.081	$3,086.79	$363.15	$92,854.32	0.12	0.03	0.06	0.86
C	Lansing Jackson Caulk crew	2.00	30.7	15.359	$416.70	$208.35	$6,399.90				
L	Lansing Jackson crew	8.00	523.3	65.410	$3,086.79	$385.85	$201,906.02	0.13	0.03	0.13	0.92
P	Lansing Jackson Plank Crew	4.00	25.7	6.437	$1,396.32	$349.08	$8,987.54	0.13			0.78
	Lay Crew Totals		835.4	117.286			$310,147.77				
1	Lansing pointing/patching crew	4.00	17.6	4.403	$833.40	$208.35	$3,669.17				
	All Crew Totals		853.0	121.689			$313,816.94				

(Ratio to Production Masons of: Super, Layout, Saw, Tender/Other)

Totals by Labor ID

ID	Estimated Hours	Base	Fringe	Burden	Total	Cost / Hour
BL Lansing 10	7,467.94	$164,294.57	$0.00	$30,197.34	$194,491.92	$26.04
BLF-Lansing 10	789.67	$19,741.83	$0.00	$3,628.55	$23,370.38	$29.60
LB-Lansing 10	4,686.55	$65,611.65	$0.00	$12,059.42	$77,671.07	$16.57
LBF-Lansing 10	917.35	$15,492.97	$0.00	$2,790.61	$18,283.58	$19.93
	13,861.50	$265,141.02	$0.00	$48,675.92	$313,816.94	$22.64

Totals by Equipment ID

ID	Description	Cost	Days	Cost / Day
Lift Caulking	Lift Caulking	$1,535.86	15.359	$100.00

Report Run
7/ 2/10 9:24 AM

100 Room Dormitory Prevailing Wage

Quantity/Bid Price Report

		Costs & Taxes	Overhead	Profit	OH + Profit	Totals	% of Bid
Material Costs		$691,998.93					
Misc. Taxable Costs		$0.00					
Taxable Sub-Total		$691,998.93					
Tax	6.000%	$41,519.94	0.00%	0.00%			
Material + Misc. Taxable Costs + Tax		$733,518.87	$0.00	$0.00	$0.00	$733,518.87	64.4%
Base		$265,141.02					
Fringe	0.000%	$0.00					
Burden	18.359%	$48,675.92	25.00%	0.00%			
Crew Labor Cost		$313,816.94	$78,454.23	$0.00	$78,454.23	$392,271.17	34.4%
Subbed Out			0.00%	0.00%			
Cleaning Cost		$11,723.45	$0.00	$0.00	$0.00	$11,723.45	1.0%
			0.00%	0.00%			
Equipment		$1,535.86	$0.00	$0.00	$0.00	$1,535.86	0.1%
Mobilization		$0.00					
Crane(Plank)		$0.00					
		$0.00					
		$0.00					
		$0.00					
		$0.00	0.00%	0.00%			
Misc. Sub-Total		$0.00	$0.00	$0.00	$0.00	$0.00	
		Percent of Cost	7.40%		7.40%	**Bid Price**	
Grand Totals		$1,060,595.11	$78,454.23	$0.00	$78,454.23	$1,139,049.35	

	Without Misc. or OH&P	With Misc. and OH&P	Total Square Feet
Average Cost Per Square Foot	$15.38	$16.52	68,959.35

Project Notes:
Air Barrier and Terminations Included
8" Precast Hollow Core Plank Furnished and Installed
Caulking of Masonry CJs/Ejs Included
FIre Caulking/Fire Safing of Masonry walls included
Loose Steel Galv. Lintels Furnished and Installed

Loadbearing Masonry's Bottom Line

COMPARISON OF CMU BACKUP AND METAL STUD BACKUP FOR CONDENSATION POTENTIAL AND INITIAL CONSTRUCTION COST REVEALS CMU TO BE THE BEST CHOICE

BY DAN ZECHMEISTER, PE

Given the current state of the economy, it is more important than ever to be frugal. Commercial, institutional and municipal building owners have heightened concerns about saving energy, maintenance dollars and following environmentally responsible practices, both initially and over the lives of their investments. With today's technology and energy supply and demand, the viable solution has become loadbearing masonry, both for initial construction cost savings, energy savings and to produce a higher quality system that benefits owners and occupants for life. All at a lower cost. Of all the masonry wall systems available to designers and builders today, the loadbearing insulated multi-wythe cavity wall system is the best bargain for the money. This article reveals the bottom line of the loadbearing multi-wythe cavity masonry wall system based on performance relative to condensation potential and initial construction cost compared to three metal stud wall systems:

1. masonry veneer and metal studs with batt insulation
2. masonry veneer and metal studs with batt and rigid insulation
3. masonry veneer and metal studs with rigid insulation.

The paradigm shift is to loadbearing masonry for all its worth: enclosure and finish, sustainability, lateral load resistance, low maintenance, durability, LEED points, sound transmission resistance, fire resistance, loadbearing resistance, low initial and life cycle costs, structural redundancy, water resistance, mold resistance, thermal resistance. Take advantage of all this added value!

CONTINUING EDUCATION AIA

Learning Objectives

After reading this article, you will have learned:

1. How four masonry wall systems compare for condensation potential
2. How four masonry wall systems compare for initial construction costs
3. There are many advantages and benefits to a loadbearing multi-wythe cavity masonry wall system in addition to condensation potential and initial construction cost

See page 98 for test and answer form.

Condensation potential

Energy conservation for the design of buildings is a prime concern, especially considering today's high cost of energy and the environmental shift toward saving our natural resources. In addition there are minimum building code requirements to meet. Thermal transmission through a masonry wall system will occur to varying degrees depending on the components making up the wall system. Some components, such as masonry materials, have low conductivity values while others, like metal studs, have high conductivity values. Metal studs act as a thermal bridge providing a path for thermal transmission (heat loss) from the controlled interior environment to the exterior environment. For example, a typical building may have an interior temperature of 70°F and an exterior temperature of 0°F in the winter. When there is a temperature differential along with humidity, there is potential for condensation occurring at the dewpoint.

If condensation is occurring in the metal stud space, corrosion is likely on the metal studs, on brick-tie connections to the studs and on the threads of the fastener screws. If batt insulation gets wet, its R-value decreases. If the wallboard gets wet, there is a potential for mold to have an impact on the building with its indoor air quality and the health of its occupants.

According to the National Concrete Masonry Association, "The amount of water vapor in the air is typically measured by relative humidity, which is the ratio of the amount of water vapor in the air at a given temperature (partial water vapor pressure) to the ultimate amount it can hold in vapor form at that temperature (the saturation water vapor pressure)… When warm moist air comes into contact with a cold surface, the air cools and can no longer hold all of its water vapor. The excess moisture condenses out of the air and deposits on the cold surface… Two barrier-type products are used to reduce moisture flow through a wall: airflow retarders and water vapor retarders. Airflow retarders are designed to reduce airflow and thereby the associated heat and moisture flows… Water vapor retarders are designed to restrict water vapor flow by diffusion."[1] Whether the backup to the masonry veneer is block or metal stud, the backup is the structural component of the wall assembly. It is critical for the backup to remain as dry as possible!

When metal stud was first introduced as a backup material for masonry veneer in the 1960s, it was common to see batt insulation placed between the metal studs. In the first two decades of use, it was not uncommon for proponents of the system to state that it offered a higher R-value. They promoted, for example, a thermal resistance of R-19, placing 5 1/2″ to 6 1/2″ of batt insulation between 6″ metal studs. A critical examination of the thermal transmission of this system reveals that the insulation envelope is interrupted with metal studs acting as thermal bridges. Table 1 illustrates the R-value correction factors implemented as a result. The table shows the effective framing/cavity R-value for R-19 insulation placed between 6″ metal studs placed 16″ oc is R-7.1. This subsequent correction of the effective R-value represents a significant 63% reduction in the energy envelope resistance. This reduction will certainly affect the building owners' fuel costs especially if the capacity of the mechanical heating and cooling equipment was calculated based on the wall system having at least an R-value of R-19. Just as critical as the simultaneous heat loss through the metal studs is the potential for condensation occurring at the dewpoint.

Just as critical as the simultaneous heat loss through the metal studs is the potential for condensation occurring at the dewpoint.

NOMINAL FRAMING DEPTH & SPACING	"LABELED" BATT INSULATION R-VALUE (between steel studs)	"EFFECTIVE" R-VALUE W/BATT INSULATION & STEEL STUDS[1]	WALL THERMAL EFFICIENCY
4″ @ 16″ on center	R-11	5.5	50%
	R-13	6.0	46%
	R-15	6.4	43%
4″ @ 24″ on center	R-11	6.6	60%
	R-13	7.2	55%
	R-15	7.8	52%
6″ @ 16″ on center	R-19	7.1	37%
	R-21	7.4	35%
6″ @ 24″ on center	R-19	8.6	45%
	R-21	9.0	43%

[1] Data Source: ASHRAE/EIS Standard 90.1–2004, Appendix A.

Table 1. Effective R-value with batt insulation and steel studs

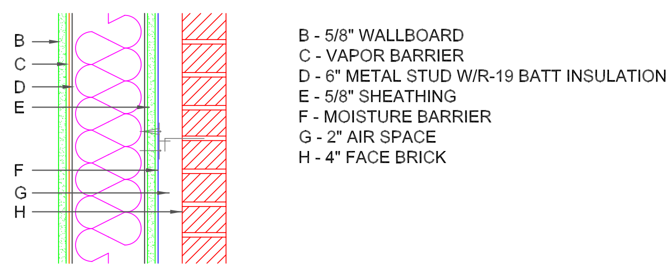


Figure 1. 6 inch metal studs with batt insulation (system 1)

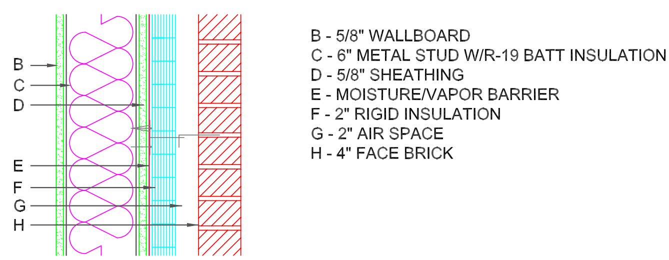


Figure 3. 6 inch metal studs with batt and rigid insulation (system 2)

BATT INSULATION PLACED BETWEEN METAL STUDS (SYSTEM 1)

Metal stud backup with batt insulation was first introduced more than 40 years ago and, though energy inefficient, it is still being used today. A dewpoint analysis[2] was performed for 6″ studs with R-19 batt insulation placed between the metal studs, (Figure 1). In addition, a vapor barrier was placed on the interior side of the batt insulation with a moisture barrier placed over the exterior sheathing. The criteria used for temperature and humidity for the Detroit area was:

	TEMPERATURE	HUMIDITY
WINTER – INTERIOR	70°F	30%
WINTER – EXTERIOR	0°F	55%
SUMMER – INTERIOR	70°F	40%
SUMMER – EXTERIOR	90°F	90%

In Figure 2 (page 40), the dewpoint is occurring in the summertime within the metal stud cavity space. Once again, not only has the effective R-value of the system been dramatically reduced, but simultaneously, the dewpoint is occurring within the metal stud cavity space. **Based on the summertime conditions presented: with batt insulation placed between the metal studs, and with an interior side vapor barrier, the wall system is not effective in controlling the dewpoint.**

BATT INSULATION PLACED BETWEEN METAL STUDS WITH CONTINUOUS RIGID INSULATION IN THE CAVITY (SYSTEM 2)

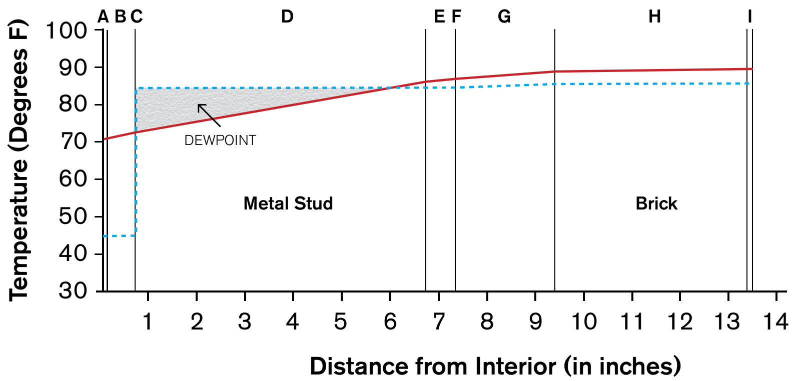
ASHRAE Standard 90.1 includes three options for demonstrating energy code compliance: 1) prescriptive, 2) system performance and 3) energy cost budget. ASHRAE prescribes that metal stud walls have a minimum R-13 plus R-3.8 continuous insulation. A dewpoint analysis[2] was performed for Figure 3 for the

continued on page 42

[1] National Concrete Masonry Association NCMA, TEK 6-17A (2000), "Condensation Control in Concrete Masonry Walls": pages 1-2.

[2] Brick Industry Association, "Technical Notes on Brick Construction, 28B Brick Veneer/Steel Stud Walls," Dec 2005: page 5.

DEWPOINT ANALYSIS



Actual Temperature
Dewpoint Temperature

Conditions:

	Interior	Exterior
Temperature	70.0	90.0
Humidity	40.0	90.0

Dewpoint theory predicts condensation in a system at any point where the actual and dewpoint temperature lines cross.

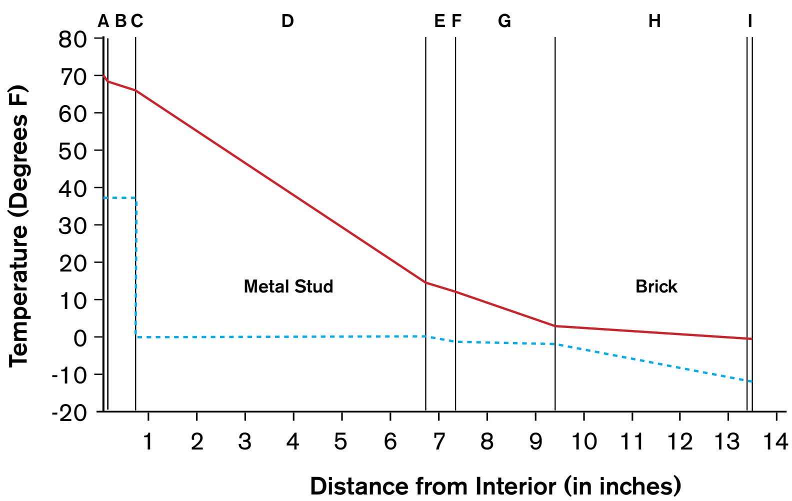
	COMPONENT NAME	THICKNESS	R-VALUE	REP
A	Interior Air Film	0.100	0.68	0.001
B	Drywall .625 in	0.625	0.56	0.023
C	Polyethylene 6 mil	0.006	0.01	17.000
D	Steel Stud	6.000	19.00	0.002
E	DENS-GLASS Gold .625 in	0.625	0.67	0.083
F	WEATHERMATE Plus Hswrp	0.010	0.01	0.150
G	Wall Air Space NonRefl	2.000	3.64	0.016
H	Brick Face 4 in	4.000	0.80	1.300
I	Out Air Film Summer	0.100	0.25	0.001
	Total	13.466	25.62	18.576

INTERFACE	TEMPERATURE Actual	Dewpoint	ACCUM (oz/day-sf)
-A	70.00	44.59	0.000
AB	70.53	44.60	0.000
BC	70.97	44.71	0.000
CD	70.98	84.62	*0.017
DE	85.81	84.62	0.000
EF	86.33	84.74	0.000
FG	86.34	84.94	0.000
GH	89.18	84.97	0.000
HI	89.80	86.70	0.000
IJ	90.00	86.70	0.000

* indicates area of condensation potential

Notice: This calculation is based on the theory of Water Vapor Migration presented in the ASHRAE 1993 Fundamentals Handbook. Actual performance may vary depending upon air infiltration, workmanship and building materials. Since the information is provided without charge, The Dow Chemical Company assumes no obligation or liability for its use.

Figure 2 (summer). 6 inch metal studs with batt insulation (system 1)



Actual Temperature
Dewpoint Temperature

Conditions:

	Interior	Exterior
Temperature	70.0	0.0
Humidity	30.0	55.0

Dewpoint theory predicts condensation in a system at any point where the actual and dewpoint temperature lines cross.

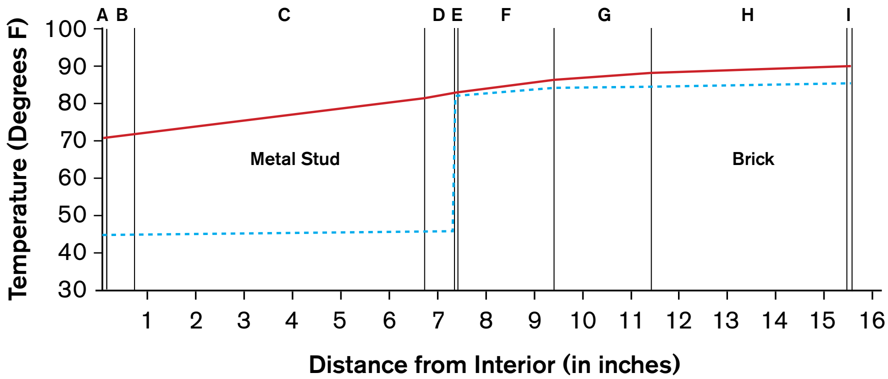
	COMPONENT NAME	THICKNESS	R-VALUE	REP
A	Interior Air Film	0.100	0.68	0.001
B	Drywall .625 in	0.625	0.56	0.023
C	Polyethylene 6 mil	0.006	0.01	17.000
D	Steel Stud	6.000	19.00	0.002
E	DENS-GLASS Gold .625 in	0.625	0.67	0.083
F	WEATHERMATE Plus Hswrp	0.010	0.01	0.150
G	Wall Air Space NonRefl	2.000	3.64	0.016
H	Brick Face 4 in	4.000	0.80	1.300
I	Out Air Film Winter	0.100	0.17	0.001
	Total	13.466	25.54	18.576

INTERFACE	TEMPERATURE Actual	Dewpoint	ACCUM (oz/day-sf)
-A	70.00	37.28	0.000
AB	68.14	37.28	0.000
BC	66.60	37.25	0.000
CD	66.57	-0.03	0.000
DE	14.50	-0.04	0.000
EF	12.66	-0.50	0.000
FG	12.64	-1.36	0.000
GH	2.66	-1.45	0.000
HI	0.47	-10.97	0.000
IJ	0.00	-10.98	0.000

* indicates area of condensation potential

Notice: This calculation is based on the theory of Water Vapor Migration presented in the ASHRAE 1993 Fundamentals Handbook. Actual performance may vary depending upon air infiltration, workmanship and building materials. Since the information is provided without charge, The Dow Chemical Company assumes no obligation or liability for its use.

Figure 2 (winter). 6 inch metal studs with batt insulation (system 1)



Conditions:

	Interior	Exterior
Temperature	70.0	90.0
Humidity	40.0	90.0

Dewpoint theory predicts condensation in a system at any point where the actual and dewpoint temperature lines cross.

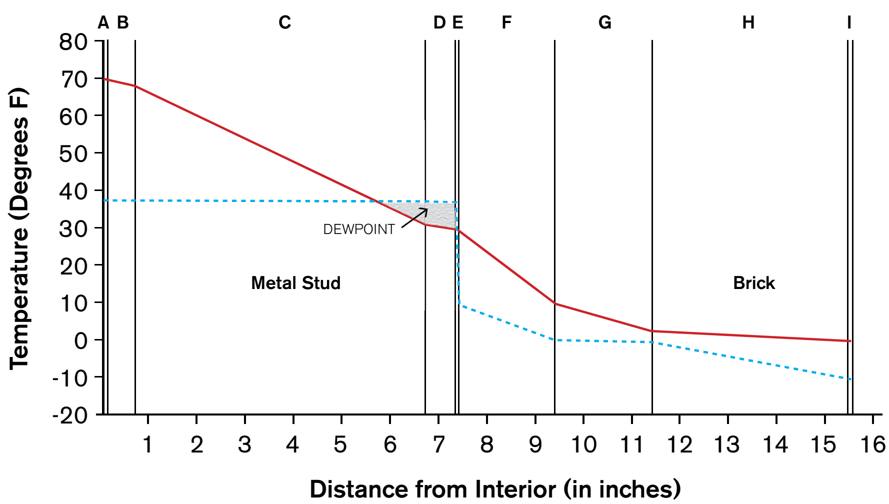
	COMPONENT NAME	THICKNESS	R-VALUE	REP
A	Interior Air Film	0.100	0.68	0.001
B	Drywall .625 in	0.625	0.56	0.023
C	Steel Stud	6.000	19.00	0.002
D	DENS-GLASS Gold .625 in	0.625	0.67	0.083
E	Procor Vapor Barrier	0.065	0.01	12.500
F	Cavitymate Insulation	2.000	10.00	1.800
G	Wall Air Space NonRefl	2.000	3.64	0.016
H	Brick Face 4 in	4.000	0.80	1.300
I	Out Air Film Summer	0.100	0.25	0.001
	Total	15.515	35.61	15.726

INTERFACE	TEMPERATURE Actual	TEMPERATURE Dewpoint	ACCUM (oz/day-sf)
-A	70.00	44.59	0.000
AB	70.38	44.60	0.000
BC	70.70	44.73	0.000
CD	81.37	44.74	0.000
DE	81.74	45.19	0.000
EF	81.75	81.55	0.000
FG	87.37	84.62	0.000
GH	89.41	84.64	0.000
HI	89.86	86.70	0.000
IJ	90.00	86.70	0.000

* indicates area of condensation potential

Notice: This calculation is based on the theory of Water Vapor Migration presented in the ASHRAE 1993 Fundamentals Handbook. Actual performance may vary depending upon air infiltration, workmanship and building materials. Since the information is provided without charge, The Dow Chemical Company assumes no obligation or liability for its use.

Figure 4 (summer). 6 inch metal studs with batt and rigid insulation (system 2)



Conditions:

	Interior	Exterior
Temperature	70.0	0.0
Humidity	30.0	55.0

Dewpoint theory predicts condensation in a system at any point where the actual and dewpoint temperature lines cross.

	COMPONENT NAME	THICKNESS	R-VALUE	REP
A	Interior Air Film	0.100	0.68	0.001
B	Drywall .625 in	0.625	0.56	0.023
C	Steel Stud	6.000	19.00	0.002
D	DENS-GLASS Gold .625 in	0.625	0.67	0.083
E	Procor Vapor Barrier	0.065	0.01	12.500
F	Cavitymate Insulation	2.000	10.00	1.800
G	Wall Air Space NonRefl	2.000	3.64	0.016
H	Brick Face 4 in	4.000	0.80	1.300
I	Out Air Film Winter	0.100	0.17	0.001
	Total	15.515	35.53	15.726

INTERFACE	TEMPERATURE Actual	TEMPERATURE Dewpoint	ACCUM (oz/day-sf)
-A	70.00	37.28	0.000
AB	68.66	37.28	0.000
BC	67.56	37.24	0.000
CD	30.12	37.24	*0.119
DE	28.80	37.12	*0.033
EF	28.78	9.27	0.000
FG	9.08	-0.01	0.000
GH	1.91	-0.11	0.000
HI	0.33	-10.97	0.000
IJ	0.00	-10.98	0.000

* indicates area of condensation potential

Notice: This calculation is based on the theory of Water Vapor Migration presented in the ASHRAE 1993 Fundamentals Handbook. Actual performance may vary depending upon air infiltration, workmanship and building materials. Since the information is provided without charge, The Dow Chemical Company assumes no obligation or liability for its use.

Figure 4 (winter). 6 inch metal studs with batt and rigid insulation (system 2)

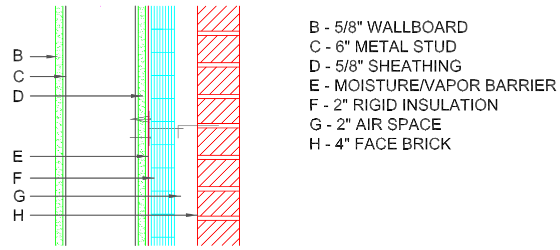


Figure 5. 6 inch metal studs with rigid insulation (system 3)

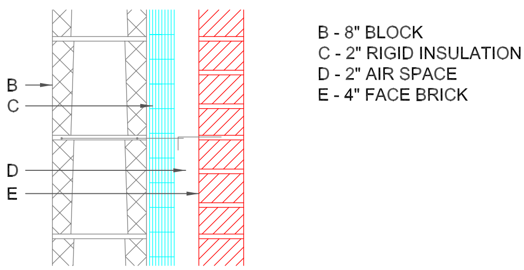


Figure 7. 8 inch block with rigid insulation

continued from page 39

following system consisting of 6˝ studs with R-19 batt insulation placed between the studs, R-10 continuous rigid insulation in the cavity and with a moisture/vapor barrier. The moisture/vapor barrier was placed on the interior side of the continuous rigid insulation. According to the Brick Industry Association, "Water-resistant barriers are membranes which prevent liquid water from passing through them. These are different from vapor retarders, intended to prevent water vapor diffusion, and air barriers, intended to prevent air flow through the wall system. Such a membrane should be located between the air space and the sheathing or between the rigid insulation and the sheathing…" [2] In Figure 4 (page 41), the dewpoint is occurring in the wintertime in the metal stud cavity space. **Based on the wintertime conditions presented; with batt insulation placed between the metal studs, with continuous rigid insulation in the cavity, and with a moisture/vapor barrier, the wall system is not effective in controlling the dewpoint.**

METAL STUDS WITH CONTINUOUS RIGID INSULATION IN THE CAVITY (SYSTEM 3)

A dewpoint analysis [2] was performed for Figure 5 for the following system consisting of 6˝ studs with R-10 continuous rigid insulation in the cavity and with a moisture/vapor barrier. The moisture/vapor barrier was placed on the interior side of the continuous rigid insulation. In Figure 6 (page 43), with a moisture/vapor barrier, the dewpoint is occurring in the summertime in the rigid insulation. **Based on summertime conditions presented; with continuous rigid insulation in the cavity and with a moisture/vapor barrier, the wall system is not effective in controlling the dewpoint.**

MULTI-WYTHE MASONRY CAVITY WALL

For a loadbearing multi-wythe masonry cavity wall with rigid insulation placed between the brick and block wythes, shown in Figure 7, a dewpoint analysis [2] was performed for 8˝ block with R-10 continuous rigid insulation in the cavity and no vapor barrier. In Figure 8 (page 44), with no vapor barrier, the dewpoint is occurring in the wintertime in the drainage cavity, which is designed to accommodate moisture. **Based on the wintertime conditions presented with continuous rigid insulation in the cavity, the loadbearing multi-wythe masonry wall system is effective in controlling the dewpoint.**

Irrespective of whether the backup to the masonry veneer is block or metal stud, it is the structural component of the wall assembly and it is crucial to keep it as dry as possible. If condensation is occurring in the metal stud space, corrosion is likely on the metal studs, on brick-tie connections to the studs and on the threads of the fastener screws. If batt insulation gets wet, its R-value decreases. If the wallboard gets wet, there is a potential for mold to have an impact on the building with its indoor air quality and the health of its occupants.

Initial construction cost comparison

ESTIMATE

A comparison of the initial construction cost per wall square foot of the masonry veneer and metal stud systems with the loadbearing multi-wythe cavity wall was performed. For an unbiased cost comparison, RS Means 2007 Concrete & Masonry Cost Data, 25th Annual Edition, and the RS Means 2007 Building Construction Cost Data, 65th Annual Edition, were used. To perform the cost analysis, the 2007 Means Cost Works was used incorporating the "Estimator" option based on a US National Average. The US National Average is the average of 30 major US cities including Detroit.

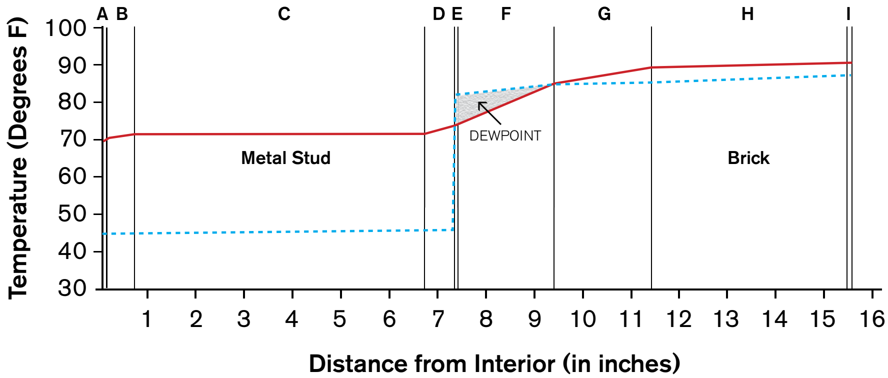
SYSTEM DESCRIPTIONS

For the initial construction cost comparison, masonry veneer and metal stud wall systems consist of the following components: brick veneer, brick veneer expansion joints, drainage cavity, flashing and weep holes, rigid insulation, moisture and vapor barrier(s), exterior sheathing, metal studs, batt insulation, adjustable brick ties, interior wall board, perimeter steel beam, perimeter steel column, concrete column pier, concrete spread footing and a concrete foundation wall (see Tables 2, 3 and 4).

Brick used meets ASTM C216 specification for face brick, grade SW for severe weathering. Brick expansion joints are placed every 20´ oc. Code [3] requires a minimum 1˝ drainage cavity, but 2˝ is suggested for a more effective drainage cavity. Flashing and weep holes are placed at the base of the wall and 2˝ of R-10 rigid insulation is used. Applied sheet membrane (moisture/vapor barrier) is placed over a water resistant exterior sheathing in Systems 2 and 3. A plastic sheet (vapor barrier) is placed on the interior side of the batt insulation along with a

continued on page 48

[3] Building Code Requirements for Masonry Structures (ACI 530-02/ASCE 5-02/TMS 402-02) and Specification for Masonry Structures (ACI 530.1-02/ASCE 6-02/TMS 602-02).



Actual Temperature
Dewpoint Temperature

Conditions:	Interior	Exterior
Temperature	70.0	90.0
Humidity	40.0	90.0

Dewpoint theory predicts condensation in a system at any point where the actual and dewpoint temperature lines cross.

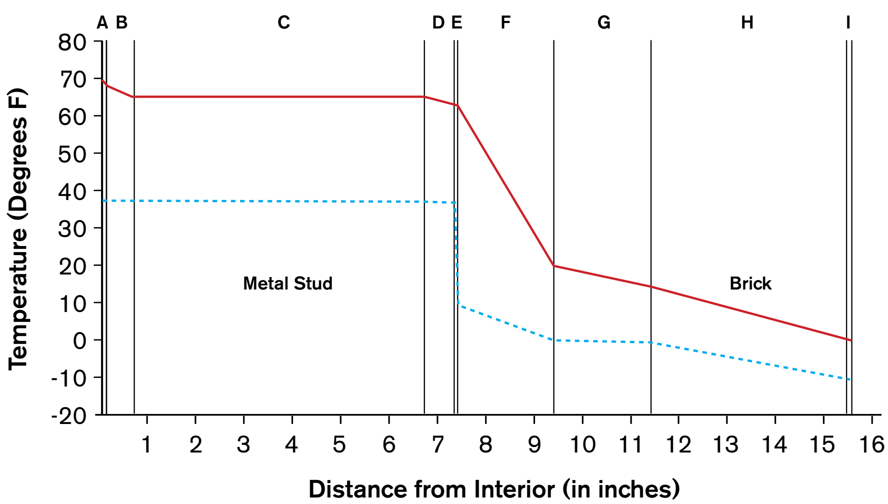
	COMPONENT NAME	THICKNESS	R-VALUE	REP
A	Interior Air Film	0.100	0.68	0.001
B	Drywall .625 in	0.625	0.56	0.023
C	Steel Stud	6.000	0.02	0.002
D	DENS-GLASS Gold .625 in	0.625	0.67	0.083
E	Procor Vapor Barrier	0.065	0.01	12.500
F	Cavitymate Insulation	2.000	10.00	1.800
G	Wall Air Space NonRefl	2.000	3.64	0.016
H	Brick Face 4 in	4.000	0.80	1.300
I	Out Air Film Summer	0.100	0.17	0.001
	Total	15.515	16.55	15.726

INTERFACE	TEMPERATURE Actual	TEMPERATURE Dewpoint	ACCUM (oz/day-sf)
-A	70.00	44.59	0.000
AB	70.82	44.60	0.000
BC	71.50	44.73	0.000
CD	71.52	44.74	0.000
DE	72.33	45.19	0.000
EF	72.34	81.55	*0.006
FG	84.43	84.62	*0.000
GH	88.83	84.64	0.000
HI	89.79	86.70	0.000
IJ	90.00	86.70	0.000

* indicates area of condensation potential

Notice: This calculation is based on the theory of Water Vapor Migration presented in the ASHRAE 1993 Fundamentals Handbook. Actual performance may vary depending upon air infiltration, workmanship and building materials. Since the information is provided without charge, The Dow Chemical Company assumes no obligation or liability for its use.

Figure 6 (summer). 6 inch metal studs with rigid insulation (system 3)



Actual Temperature
Dewpoint Temperature

Conditions:	Interior	Exterior
Temperature	70.0	0.0
Humidity	30.0	55.0

Dewpoint theory predicts condensation in a system at any point where the actual and dewpoint temperature lines cross.

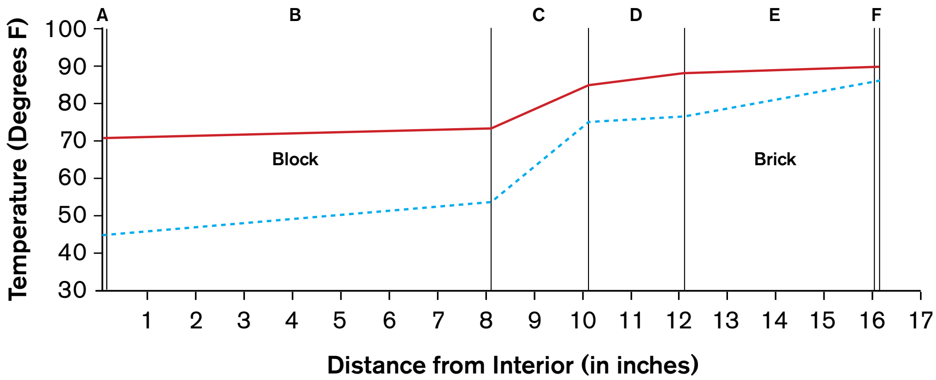
	COMPONENT NAME	THICKNESS	R-VALUE	REP
A	Interior Air Film	0.100	0.68	0.001
B	Drywall .625 in	0.625	0.56	0.023
C	Steel Stud	6.000	0.02	0.002
D	DENS-GLASS Gold .625 in	0.625	0.67	0.083
E	Procor Vapor Barrier	0.065	0.01	12.500
F	Cavitymate Insulation	2.000	10.00	1.800
G	Wall Air Space NonRefl	2.000	3.64	0.016
H	Brick Face 4 in	4.000	0.80	1.300
I	Out Air Film Winter	0.100	0.17	0.001
	Total	15.515	16.55	15.726

INTERFACE	TEMPERATURE Actual	TEMPERATURE Dewpoint	ACCUM (oz/day-sf)
-A	70.00	37.28	0.000
AB	67.12	37.28	0.000
BC	64.76	37.24	0.000
CD	64.67	37.24	0.000
DE	61.84	37.12	0.000
EF	61.79	9.27	0.000
FG	19.50	-0.01	0.000
GH	4.10	-0.11	0.000
HI	0.72	-10.97	0.000
IJ	0.00	-10.98	0.000

* indicates area of condensation potential

Notice: This calculation is based on the theory of Water Vapor Migration presented in the ASHRAE 1993 Fundamentals Handbook. Actual performance may vary depending upon air infiltration, workmanship and building materials. Since the information is provided without charge, The Dow Chemical Company assumes no obligation or liability for its use.

Figure 6 (winter). 6 inch metal studs with rigid insulation (system 3)



Actual Temperature
Dewpoint Temperature

Conditions:	Interior	Exterior
Temperature	70.0	90.0
Humidity	40.0	90.0

Dewpoint theory predicts condensation in a system at any point where the actual and dewpoint temperature lines cross.

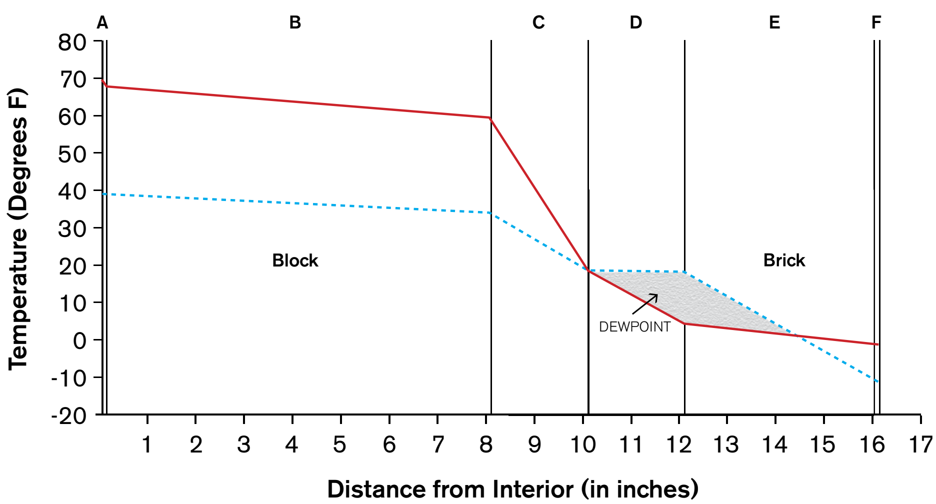
	COMPONENT NAME	THICKNESS	R-VALUE	REP
A	Interior Air Film	0.100	0.68	0.001
B	Block Cinder Agg 8 in	8.000	1.70	0.400
C	Cavitymate Insulation	2.000	10.00	1.800
D	Wall Air Space NonRefl	2.000	3.64	0.016
E	Brick Face 4 in	4.000	0.80	1.300
F	Out Air Film Summer	0.100	0.25	0.001
	Total	16.200	17.07	3.518

INTERFACE	TEMPERATURE Actual	TEMPERATURE Dewpoint	ACCUM (oz/day-sf)
-A	70.00	44.59	0.000
AB	70.80	44.62	0.000
BC	72.79	53.14	0.000
CD	84.50	76.22	0.000
DE	88.77	76.37	0.000
EF	89.71	86.70	0.000
FG	90.00	86.70	0.000

* indicates area of condensation potential

Notice: This calculation is based on the theory of Water Vapor Migration presented in the ASHRAE 1993 Fundamentals Handbook. Actual performance may vary depending upon air infiltration, workmanship and building materials. Since the information is provided without charge, The Dow Chemical Company assumes no obligation or liability for its use.

Figure 8 (summer). 8 inch block with rigid insulation



Actual Temperature
Dewpoint Temperature

Conditions:	Interior	Exterior
Temperature	70.0	0.0
Humidity	30.0	55.0

Dewpoint theory predicts condensation in a system at any point where the actual and dewpoint temperature lines cross.

	COMPONENT NAME	THICKNESS	R-VALUE	REP
A	Interior Air Film	0.100	0.68	0.001
B	Block Cinder Agg 8 in	8.000	1.70	0.400
C	Cavitymate Insulation	2.000	10.00	1.800
D	Wall Air Space NonRefl	2.000	3.64	0.016
E	Brick Face 4 in	4.000	0.80	1.300
F	Out Air Film Winter	0.100	0.17	0.001
	Total	16.200	16.99	3.518

INTERFACE	TEMPERATURE Actual	TEMPERATURE Dewpoint	ACCUM (oz/day-sf)
-A	70.00	37.28	0.000
AB	67.20	37.27	0.000
BC	60.19	34.59	0.000
CD	18.99	18.60	0.000
DE	4.00	18.40	*0.003
EF	0.70	-10.93	0.000
FG	0.00	-10.98	0.000

* indicates area of condensation potential

Notice: This calculation is based on the theory of Water Vapor Migration presented in the ASHRAE 1993 Fundamentals Handbook. Actual performance may vary depending upon air infiltration, workmanship and building materials. Since the information is provided without charge, The Dow Chemical Company assumes no obligation or liability for its use.

Figure 8 (winter). 8 inch block with rigid insulation

LINE NUMBER	DESCRIPTION	CREW	DAILY OUTPUT	LABOR HOURS	QUANTITY	UNIT	EXT. MATERIAL	EXT. LABOR	EXT. EQUIPMENT	EXT. TOTAL	EXT. TOTAL INCL O&P
042113132020	Red brick, veneer, running bond, T.L. lots, 6.75/S.F., 4″ x 2-2/3″ x 8″, includes 3% brick and 25% mortar waste, excludes scaffolding, grout and reinforcing	D8	220.00	0.182	450.00	S.F.	$1,732.50	$2,812.50		$4,545.00	$6,186.38
079210100050	Caulking & Sealants, backer rod, polyethylene, 1/2″ dia	1 Bric	4.60	1.739	0.23	C.L.F.	$1.40	$15.18		$16.58	$24.84
079210101800	Caulking & Sealants, butyl based, bulk, in place, 77 LF per gallon, 1/2″ x 1/2″	1 Bric	180.00	0.044	22.50	L.F.	$6.98	$38.03		$45.00	$65.47
076513103700	Flexible Flashing, copper, mastic-backed 2 sides, 5 ounce	1 Rofc	330.00	0.024	50.00	S.F.	$126.00	$38.50		$164.50	$204.01
072610100900	Building Paper, polyethylene vapor barrier, standard, .006″ thick, 9′ x 400′ roll	1 Carp	37.00	0.216	4.50	Sq.	$21.06	$35.78		$56.84	$78.76
072610100480	Building Paper, vapor barrier, housewrap, exterior, spun bonded polypropylene, large roll	1 Carp	4,000.00	0.002	450.00	S.F.	$58.50	$31.50		$90.00	$112.51
061636102850	1/2″ gypsum sheathing, weatherproof	2 Carp	1,125.00	0.014	450.00	S.F.	$279.00	$234.00		$513.00	$670.54
040519160570	Adjustable wall ties, anchor and tie, rectangular, mill galvanized, 4-1/8″ wide, 3/16″ wire, 4-3/4″ eye, 4-3/4″ tie (Adjusted by 040519164750)	1 Bric	1.05	7.619	0.17	M	$144.59	$49.30		$193.89	$232.50
040519164750	Wall tie channel slot anchor, for hot dip galvanized, add					C					
054113307400	Partition, galv LB studs, 16 ga x 6″ W studs 16″ O.C. x 16′ H, incl galv top & bottom track, excl openings, headers, beams, bracing & bridging	2 Carp	48.00	0.333	30.00	L.F.	$720.00	$367.50		$1,087.50	$1,349.87
072116200860	Fiberglass insulation, unfaced, batts or blankets for walls or ceilings, 6″ thick, R19, 15″ wide	1 Carp	1,150.00	0.007	405.00	S.F.	$230.85	$105.30		$336.15	$417.15
092910302050	Gypsum wallboard, on walls, standard, taped & finished (level 4 finish), 5/8″ thick	2 Carp	965.00	0.017	442.00	S.F.	$190.06	$269.62		$459.68	$627.52
051223753300	Structural steel member, 100-ton project, 1 to 2 story building, W18x35, A992 steel, shop fabricated, incl shop primer, bolted connections (Adjusted by 051223758492)	E5	960.00	0.083	30.00	L.F.	$1,422.00	$102.00	$51.90	$1,575.90	$1,805.71
054113304340	Partition, galv LB studs, 16 ga x 3-5/8″ W studs 16″ O.C. x 8′ H, incl galv top & bottom track, excl openings, headers, beams, bracing & bridging	2 Carp	66.00	0.242	5.61	L.F.	$56.38	$49.93		$106.31	$140.26
072116200820	Fiberglass insulation, unfaced, batts or blankets for walls or ceilings, 3-1/2″ thick, R11, 15″ wide	1 Carp	1,350.00	0.006	45.00	S.F.	$16.20	$9.90		$26.10	$33.30
051223750360	Structural steel member, 100-ton project, 1 to 2 story building, W8x24, A992 steel, shop fabricated, incl shop primer, bolted connections (Adjusted by 051223758492)	E2	550.00	0.102	15.00	L.F.	$486.00	$61.65	$42.15	$589.80	$689.10
051223758492	Structural steel member, 1 to 2 story building, shop fabricated, for projects 50 to 74 tons, add					L.F.					
092910301550	Gypsum wallboard, on beams, columns, or soffits, taped & finished (level 4 finish), 1/2″ thick	2 Carp	475.00	0.034	13.10	S.F.	$4.72	$16.24		$20.96	$30.40
051223401330	Cross bracing angles, to reinforce structural framing, 5″x5″x3/8″, shop fabricated, incl shop primer, fasteners	E3	2,800.00	0.009	206.00	Lb.	$253.38	$74.16	$8.24	$335.78	$422.31
033053400700	Structural concrete, in place, column, square, min reinforcing, 12″ x 12″, includes forms (4 uses), reinforcing steel, and finishing	C14A	11.96	16.722	0.13	C.Y.	$42.90	$79.95	$7.93	$130.78	$181.99
033053403850	Structural concrete, in place, spread footing, over 5 C.Y., includes forms (4 uses), reinforcing steel & finishing	C14C	81.04	1.382	0.33	C.Y.	$88.58	$16.15	$0.09	$104.82	$123.21
033053404300	Structural concrete, in place, grade wall, 15″ thick x 8′ high, includes forms (4 uses), reinforcing steel, and finishing	C14D	80.02	2.499	4.70	C.Y.	$709.70	$430.05	$42.77	$1,182.52	$1,504.19
							$6,590.80	**$4,837.24**	**$153.08**	**$11,581.11**	**$14,900.02**

Table 2. 6 inch metal studs with batt insulation cost estimate (system 1). Source: Unit. Type: Union. Release: 2007.

LINE NUMBER	DESCRIPTION	CREW	DAILY OUTPUT	LABOR HOURS	QUANTITY	UNIT	EXT. MATERIAL	EXT. LABOR	EXT. EQUIPMENT	EXT. TOTAL	EXT. TOTAL INCL O&P
042113132020	Red brick, veneer, running bond, T.L. lots, 6.75/S.F., 4″ x 2-2/3″ x 8″, includes 3% brick and 25% mortar waste, excludes scaffolding, grout and reinforcing	D8	220.00	0.182	450.00	S.F.	$1,732.50	$2,812.50		$4,545.00	$6,186.38
079210100050	Caulking & Sealants, backer rod, polyethylene, 1/2″ dia	1 Bric	4.60	1.739	0.23	C.L.F.	$1.40	$15.18		$16.58	$24.84
079210101800	Caulking & Sealants, butyl based, bulk, in place, 77 LF per gallon, 1/2″ x 1/2″	1 Bric	180.00	0.044	22.50	L.F.	$6.98	$38.03		$45.00	$65.47
076513103700	Flexible Flashing, copper, mastic-backed 2 sides, 5 ounce	1 Rofc	330.00	0.024	50.00	S.F.	$126.00	$38.50		$164.50	$204.01
072113101940	Extruded polystyrene insulation, rigid, for walls, 25 PSI compressive strength, 2″ thick, R10	1 Carp	730.00	0.011	450.00	S.F.	$445.50	$180.00		$625.50	$773.91
071353100090	Elastomeric Waterproofing, EPDM, plain, 45 mils thick	2 Rofc	580.00	0.028	450.00	S.F.	$463.50	$396.00		$859.50	$1,179.09
061636102850	1/2″ gypsum sheathing, weatherproof	2 Carp	1,125.00	0.014	450.00	S.F.	$279.00	$234.00		$513.00	$670.54
040519160570	Adjustable wall ties, anchor and tie, rectangular, mill galvanized, 4-1/8″ wide, 3/16″ wire, 4-3/4″ eye, 4-3/4″ tie (Adjusted by 040519164750)	1 Bric	1.05	7.619	0.17	M	$144.59	$49.30		$193.89	$232.50
040519164750	Wall tie channel slot anchor, for hot dip galvanized, add					C					
054113307400	Partition, galv LB studs, 16 ga x 6″ W studs 16″ O.C. x 16′ H, incl galv top & bottom track, excl openings, headers, beams, bracing & bridging	2 Carp	48.00	0.333	30.00	L.F.	$720.00	$367.50		$1,087.50	$1,349.87
072116200860	Fiberglass insulation, unfaced, batts or blankets for walls or ceilings, 6″ thick, R19, 15″ wide	1 Carp	1,150.00	0.007	405.00	S.F.	$230.85	$105.30		$336.15	$417.15
092910302050	Gypsum wallboard, on walls, standard, taped & finished (level 4 finish), 5/8″ thick	2 Carp	965.00	0.017	442.00	S.F.	$190.06	$269.62		$459.68	$627.52
051223753300	Structural steel member, 100-ton project, 1 to 2 story building, W18x35, A992 steel, shop fabricated, incl shop primer, bolted connections (Adjusted by 051223758492)	E5	960.00	0.083	30.00	L.F.	$1,422.00	$102.00	$51.90	$1,575.90	$1,805.71
054113304340	Partition, galv LB studs, 16 ga x 3-5/8″ W studs 16″ O.C. x 8′ H, incl galv top & bottom track, excl openings, headers, beams, bracing & bridging	2 Carp	66.00	0.242	5.61	L.F.	$56.38	$49.93		$106.31	$140.26
072116200820	Fiberglass insulation, unfaced, batts or blankets for walls or ceilings, 3-1/2″ thick, R11, 15″ wide	1 Carp	1,350.00	0.006	45.00	S.F.	$16.20	$9.90		$26.10	$33.30
051223750360	Structural steel member, 100-ton project, 1 to 2 story building, W8x24, A992 steel, shop fabricated, incl shop primer, bolted connections (Adjusted by 051223758492)	E2	550.00	0.102	15.00	L.F.	$486.00	$61.65	$42.15	$589.80	$689.10
051223758492	Structural steel member, 1 to 2 story building, shop fabricated, for projects 50 to 74 tons, add					L.F.					
092910301550	Gypsum wallboard, on beams, columns, or soffits, taped & finished (level 4 finish), 1/2″ thick	2 Carp	475.00	0.034	13.10	S.F.	$4.72	$16.24		$20.96	$30.40
051223401330	Cross bracing angles, to reinforce structural framing, 5″x5″x3/8″, shop fabricated, incl shop primer, fasteners	E3	2,800.00	0.009	206.00	Lb.	$253.38	$74.16	$8.24	$335.78	$422.31
033053400700	Structural concrete, in place, column, square, min reinforcing, 12″ x 12″, includes forms (4 uses), reinforcing steel, and finishing	C14A	11.96	16.722	0.13	C.Y.	$42.90	$79.95	$7.93	$130.78	$181.99
033053403850	Structural concrete, in place, spread footing, over 5 C.Y., includes forms (4 uses), reinforcing steel, and finishing	C14C	81.04	1.382	0.33	C.Y.	$88.58	$16.15	$0.09	$104.82	$123.21
033053404300	Structural concrete, in place, grade wall, 15″ thick x 8′ high, includes forms (4 uses), reinforcing steel, and finishing	C14D	80.02	2.499	4.70	C.Y.	$709.70	$430.05	$42.77	$1,182.52	$1,504.19
							$7,420.24	**$5,345.96**	**$153.08**	**$12,919.27**	**$16,661.75**

Table 3. 6 inch metal studs with batt and rigid insulation cost estimate (system 2). Source: Unit. Type: Union. Release: 2007.

LINE NUMBER	DESCRIPTION	CREW	DAILY OUTPUT	LABOR HOURS	QUANTITY	UNIT	EXT. MATERIAL	EXT. LABOR	EXT. EQUIPMENT	EXT. TOTAL	EXT. TOTAL INCL O&P
042113132020	Red brick, veneer, running bond, T.L. lots, 6.75/S.F., 4″ x 2-2/3″ x 8″, includes 3% brick and 25% mortar waste, excludes scaffolding, grout and reinforcing	D8	220.00	0.182	450.00	S.F.	$1,732.50	$2,812.50		$4,545.00	$6,186.38
079210100050	Caulking & Sealants, backer rod, polyethylene, 1/2″ dia	1 Bric	4.60	1.739	0.23	C.L.F.	$1.40	$15.18		$16.58	$24.84
079210101800	Caulking & Sealants, butyl based, bulk, in place, 77 LF per gallon, 1/2″ x 1/2″	1 Bric	180.00	0.044	22.50	L.F.	$6.98	$38.03		$45.00	$65.47
076513103700	Flexible Flashing, copper, mastic-backed 2 sides, 5 ounce	1 Rofc	330.00	0.024	50.00	S.F.	$126.00	$38.50		$164.50	$204.01
072113101940	Extruded polystyrene insulation, rigid, for walls, 25 PSI compressive strength, 2″ thick, R10	1 Carp	730.00	0.011	450.00	S.F.	$445.50	$180.00		$625.50	$773.91
071353100090	Elastomeric Waterproofing, EPDM, plain, 45 mils thick	2 Rofc	580.00	0.028	450.00	S.F.	$463.50	$396.00		$859.50	$1,179.09
061636102850	1/2″ gypsum sheathing, weatherproof 45 mils thick	2 Carp	1,125.00	0.014	450.00	S.F.	$279.00	$234.00		$513.00	$670.54
040519160570	Adjustable wall ties, anchor and tie, rectangular, mill galvanized, 4-1/8″ wide, 3/16″ wire, 4-3/4″ eye, 4-3/4″ tie (Adjusted by 040519164750)	1 Bric	1.05	7.619	0.17	M	$144.59	$49.30		$193.89	$232.50
040519164750	Wall tie channel slot anchor, for hot dip galvanized, add					C					
054113307400	Partition, galv LB studs, 16 ga x 6″ W studs 16″ O.C. x 16′ H, incl galv top & bottom track, excl openings, headers, beams, bracing & bridging	2 Carp	48.00	0.333	30.00	L.F.	$720.00	$367.50		$1,087.50	$1,349.87
092910302050	Gypsum wallboard, on walls, standard, taped & finished (level 4 finish), 5/8″ thick	2 Carp	965.00	0.017	442.00	S.F.	$190.06	$269.62		$459.68	$627.52
051223753300	Structural steel member, 100-ton project, 1 to 2 story building, W18x35, A992 steel, shop fabricated, incl shop primer, bolted connections (Adjusted by 051223758492)	E5	960.00	0.083	30.00	L.F.	$1,422.00	$102.00	$51.90	$1,575.90	$1,805.71
054113304340	Partition, galv LB studs, 16 ga x 3-5/8″ W studs 16″ O.C. x 8′ H, incl galv top & bottom track, excl openings, headers, beams, bracing & bridging	2 Carp	66.00	0.242	5.61	L.F.	$56.38	$49.93		$106.31	
051223750360	Structural steel member, 100-ton project, 1 to 2 story building, W8x24, A992 steel, shop fabricated, incl shop primer, bolted connections (Adjusted by 051223758492)	E2	550.00	0.102	15.00	L.F.	$486.00	$61.65	$42.15	$589.80	$689.10
051223758492	Structural steel member, 1 to 2 story building, shop fabricated, for projects 50 to 74 tons, add					L.F.					
092910301550	Gypsum wallboard, on beams, columns, or soffits, taped & finished (level 4 finish), 1/2″ thick	2 Carp	475.00	0.034	13.10	S.F.	$4.72	$16.24		$20.96	$30.40
051223401330	Cross bracing angles, to reinforce structural framing, 5″x5″x3/8″, shop fabricated, incl shop primer, fasteners	E3	2,800.00	0.009	206.00	Lb.	$253.38	$74.16	$8.24	$335.78	$422.31
033053400700	Structural concrete, in place, column, square, min reinforcing, 12″ x 12″, includes forms (4 uses), reinforcing steel, and finishing	C14A	11.96	16.722	0.13	C.Y.	$42.90	$79.95	$7.93	$130.78	$181.99
033053403850	Structural concrete, in place, spread footing, over 5 C.Y., includes forms (4 uses), reinforcing steel, and finishing	C14C	81.04	1.382	0.33	C.Y.	$88.58	$16.15	$0.09	$104.82	$123.21
033053404300	Structural concrete, in place, grade wall, 15″ thick x 8′ high, includes forms (4 uses), reinforcing steel, and finishing	C14D	80.02	2.499	4.70	C.Y.	$709.70	$430.05	$42.77	$1,182.52	$1,504.19
							$7,173.19	**$5,230.76**	**$153.08**	**$12,557.02**	**$16,211.30**

Table 4. 6 inch metal studs with rigid insulation cost estimate (system 3). Source: Unit. Type: Union. Release: 2007.

LINE NUMBER	DESCRIPTION	CREW	DAILY OUTPUT	LABOR HOURS	QUANTITY	UNIT	EXT. MATERIAL	EXT. LABOR	EXT. EQUIPMENT	EXT. TOTAL	EXT. TOTAL INCL O&P
042113132020	Red brick, veneer, running bond, T.L. lots, 6.75/S.F., 4˝ x 2-2/3˝ x 8˝, includes 3% brick and 25% mortar waste, excludes scaffolding, grout and reinforcing	D8	220.00	0.182	450.00	S.F.	$1,732.50	$2,812.50		$4,545.00	$6,186.38
079210100050	Caulking & Sealants, backer rod, polyethylene, 1/2˝ dia	1 Bric	4.60	1.739	0.44	C.L.F.	$2.68	$29.04		$31.72	$47.53
079210101800	Caulking & Sealants, butyl based, bulk, in place, 77 LF per gallon, 1/2˝ x 1/2˝	1 Bric	180.00	0.044	44.00	L.F.	$13.64	$74.36		$88.00	$128.03
076513103700	Flexible Flashing, copper, mastic-backed 2 sides, 5 ounce	1 Rofc	330.00	0.024	50.00	S.F.	$126.00	$38.50		$164.50	$204.01
072113101940	Extruded polystyrene insulation, rigid, for walls, 25 PSI compressive strength, 2˝ thick, R10	1 Carp	730.00	0.011	450.00	S.F.	$445.50	$180.00		$625.50	$773.91
042210141150	Concrete masonry unit (CMU), back-up, normal weight, tooled joint one side, 2000 psi, 8˝ x 8˝ x 16˝, includes mortar and horizontal joint reinforcing every other course, excludes scaffolding, vertical reinforcing and grout	D8	395.00	0.101	430.00	S.F.	$924.50	$1,492.10		$2,416.60	$3,289.42
040519260060	#5 and #6 reinforcing steel bars, placed vertically, ASTM A615	1 Bric	650.00	0.012	157.50	Lb.	$70.88	$74.03		$144.90	$189.00
040516300250	Grout, concrete masonry unit (CMU) cores, 8˝ thick, 0.258 C.F./S.F., pumped, excludes blockwork	D4	680.00	0.047	71.70	S.F.	$78.15	$111.85	$15.77	$205.78	$272.44
042210162100	Concrete masonry unit (CMU), bond beam, normal weight, 2000 psi, 8˝ x 8˝ x 16˝, includes mortar, grout and 2-#5 horizontal reinforcing bars, excludes scaffolding and vertical reinforcing	D8	300.00	0.133	30.00	L.F.	$124.20	$137.10		$261.30	$345.01
040523130160	Control joint, PVC, 8˝ wall	1 Bric	280.00	0.029	21.50	L.F.	$46.44	$23.44		$69.88	$86.63
092910302050	Gypsum wallboard, on walls, standard, taped & finished (level 4 finish), 5/8˝ thick	2 Carp	965.00	0.017	450.00	S.F.	$193.50	$274.50		$468.00	$638.87
033053404300	Structural concrete, in place, grade wall, 15˝ thick x 8´ high, includes forms (4 uses), reinforcing steel, and finishing	C14D	80.02	2.499	4.86	C.Y.	$733.86	$444.69	$44.23	$1,222.78	$1,555.39
							$4,491.85	**$5,692.11**	**$60.00**	**$10,243.96**	**$13,716.62**

Table 5. 8 inch block with rigid insulation cost estimate. Source: Unit. Type: Union. Release: 2007.

continued from page 42

housewrap (moisture barrier) placed over the exterior sheathing in System 1. A 6˝ deep metal stud, 16 gauge, is spaced 16˝ oc for the structural backup. The 6˝ stud depth was selected due to consideration of limiting the lateral load deflection to less than L/600. Such deflection criterion will allow a maximum crack width of about .015˝ in the brick veneer for typical floor-to-floor dimensions.[4] The 16-gauge thickness was selected due to consideration of pull out of the brick tie fasteners. Six inches of batt insulation (R-19) is placed between the metal studs in Systems 1 and 2. Adjustable brick ties with prongs penetrating the sheathing and engaging the metal stud flange upon fastening are used. The interior side is finished with 5/8˝ drywall. To support the metal studs laterally for wind load, a structural steel frame consists of 15´ high steel columns spaced 30´ oc with perimeter steel beams. Concrete pier and spread footings support steel columns, along with a concrete foundation wall supporting the brick veneer and metal studs.

The loadbearing multi-wythe masonry cavity wall system consists of the following components: brick masonry, brick masonry expansion joints, drainage cavity, flashing and weep holes, rigid insulation, block, block control joints, adjustable brick ties, interior wall board and concrete foundation wall (see Table 5). Brick used meets ASTM C216 specification for face brick, grade SW for severe weathering. Brick expansion joints are placed every 20´ oc. Code[3] requires a minimum 1˝ drainage cavity, but 2˝ is suggested. Flashing and weep holes are placed at the base of the wall and 2˝ of R-10 rigid insulation is used. Moisture barrier and exterior sheathing are not required by Code. Block used meets ASTM C90 specification for loadbearing CMU. The 15´ high block wall is reinforced vertically with steel reinforcement and a reinforced bond beam at the top of the wall to resist the lateral wind load and support the roof gravity loads. Adjustable brick ties with pintles and eyelets welded to the horizontal joint reinforcement are used. The interior side is finished with 5/8˝ drywall. A concrete foundation wall is used to support brick and block wythes.

The bottom line

COST COMPARISON

Tables 2, 3 and 4 estimates for brick veneer and metal stud systems show total costs of $14,900.02, $16,661.75 and $16,211.30 for Systems 1, 2 and 3 respectively. The Table 5 estimate for the loadbearing multi-wythe cavity wall system shows a total cost of $13,716.62. The Table 6 cost comparison summary calculates the brick veneer and metal

[4] Brick Industry Association, "Technical Notes on Brick Construction, 28B Brick Veneer/Steel Stud Walls," Dec 2005: page 4.

SYSTEM	BRICK VENEER/METAL STUD						BRICK/BLOCK	
	BATT INSULATION		BATT & RIGID INSULATION		RIGID INSULATION		RIGID INSULATION	
	COST	COST/SF	COST	COST/SF	COST	COST/SF	COST	COST/SF
1. Brick Veneer	6,186.38	13.75	6,186.38	13.75	6,186.38	13.75	6,186.38	13.75
2. Brick Veneer Expansion Joint	90.31	0.20	90.31	0.20	90.31	0.20	89.77	0.20
3. Flashing	204.01	0.45	204.01	0.45	204.01	0.45	204.01	0.45
4. Rigid Insulation	not req'd	not req'd	773.91	1.72	773.91	1.72	773.91	1.72
5. Moisture and Vapor Barrier	191.27	0.43	1,179.09	2.62	1,179.09	2.62	not req'd	not req'd
6. Sheathing	670.54	1.49	670.54	1.49	670.54	1.49	not req'd	not req'd
7. Ties	232.50	0.52	232.50	0.52	232.50	0.52	in backup cost	in backup cost
8. Backup	1,490.13	3.31	1,490.13	3.31	1,490.13	3.31	4,095.87	9.10
9. Batt Insulation	450.45	1.00	450.45	1.00	not req'd	not req'd	not req'd	not req'd
10. Block Control Joint	not req'd	not req'd	not req'd	not req'd	not req'd	not req'd	172.42	0.38
11. Wall Board	657.92	1.46	657.92	1.46	657.92	1.46	638.87	1.42
12. Perimeter Steel Beam	1,805.71	4.01	1,805.71	4.01	1,805.71	4.01	not req'd	not req'd
13. Perimeter Steel Column	689.10	1.53	689.10	1.53	689.10	1.53	not req'd	not req'd
14. Perimeter Steel X-Bracing	422.31	0.94	422.31	0.94	422.31	0.94	not req'd	not req'd
15. Concrete Pier	181.99	0.40	181.99	0.40	181.99	0.40	not req'd	not req'd
16. Concrete Spread Footing	123.21	0.27	123.21	0.27	123.21	0.27	not req'd	not req'd
17. Concrete Foundation Wall	1,504.19	3.34	1,504.19	3.34	1,504.19	3.34	1,555.39	3.46
TOTAL	$14,900.02	$33.11/SF	$16,661.75	$37.03/SF	$16,211.30	$36.03/SF	$13,716.62	$30.48/SF

Table 6. Cost comparison summary

stud systems at $33.11, $37.03 and $36.03/wall square foot for Systems 1, 2 and 3 respectively. Included in these costs are $7.15/wall square foot for the supporting structural steel frame and the additional concrete footings required. The Table 6 cost comparison summary calculates loadbearing multi-wythe cavity wall system at $30.48/wall square foot. A savings of 8.6% to 21.5%.

SYSTEM COMMENTS

Typically, the metal stud wall systems are designed as non-loadbearing infill in a structural steel frame to resist the applied loads (Figures 9, 10 and 11). From a construction-scheduling standpoint, the metal studs cannot be placed until the structural steel frame has been erected. Before the structural steel is erected, the process of procuring the steel has to be initiated. This process involves material procurement (quantity surveying, placing mill order and steel delivery from the mill to the fabrication shop), development of shop drawings, submittal of shop drawings to the contractor and engineer for approval. Upon shop drawing approval, steel is fabricated, delivered to jobsite and erected. If metal stud *web* mounted ties are considered in lieu of the metal stud *flange* mounted ties used in the cost comparison analysis, the cost of the metal stud wall systems would be even greater. Use of web-mounted ties has the advantage

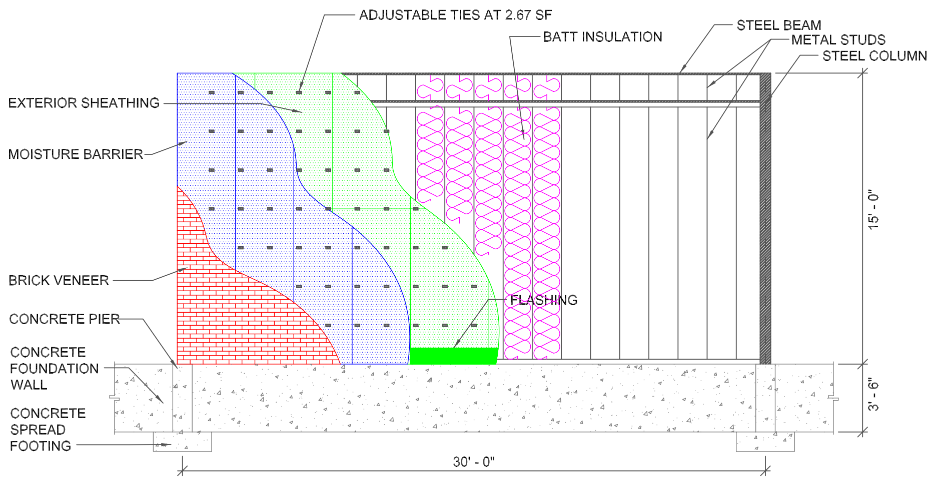


Figure 9. 6 inch metal studs with batt insulation (system 1)

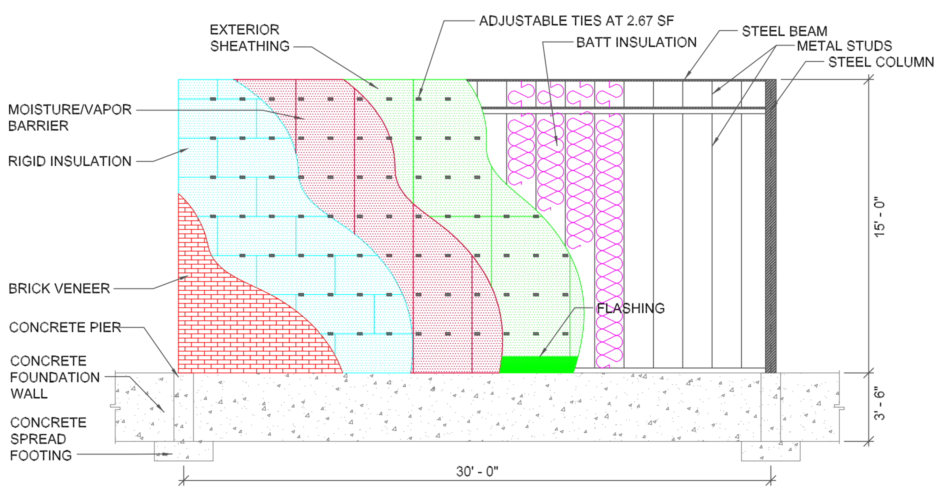


Figure 10. 6 inch metal studs with batt and rigid insulation (system 2)

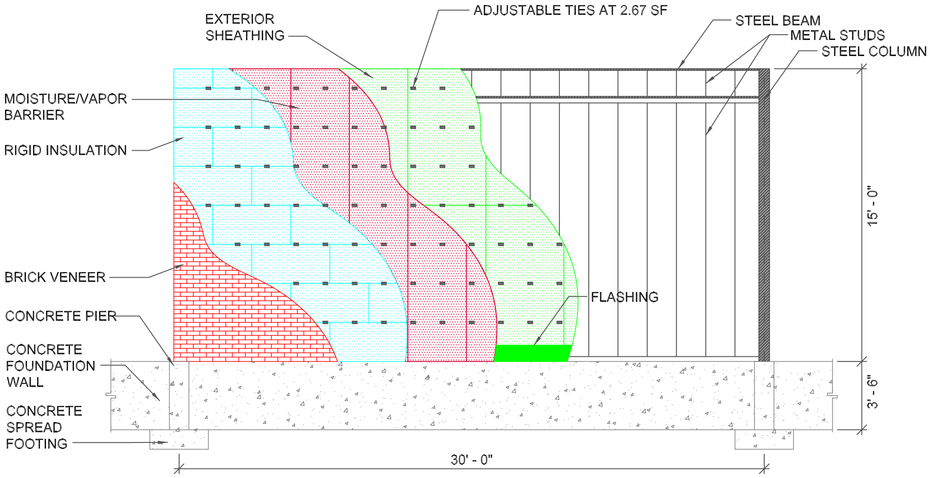


Figure 11. 6 inch metal studs with rigid insulation (system 3)

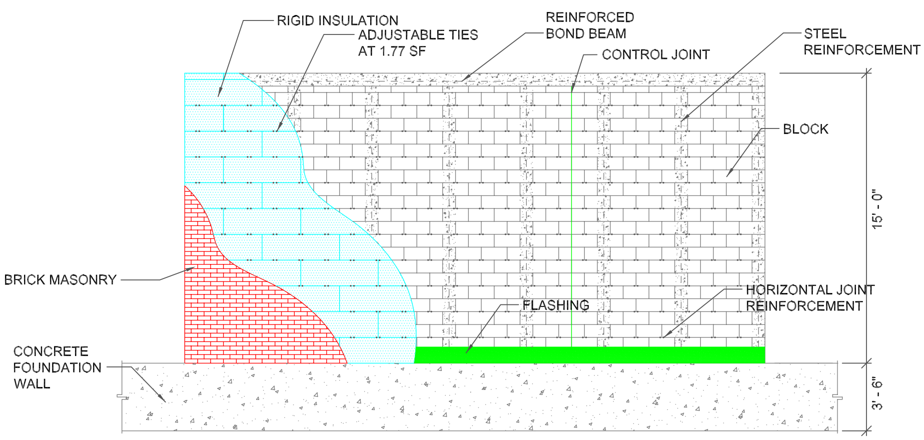


Figure 12. 8 inch block with rigid insulation

SYSTEM	BRICK VENEER/METAL STUD			BRICK/BLOCK
	BATT INSULATION	**BATT & RIGID INSULATION**	**RIGID INSULATION**	**RIGID INSULATION**
DEWPOINT POTENTIAL				
Vapor Barrier	yes	yes	yes	none
Vapor Barrier Location	interior	exterior	exterior	none
Dewpoint	yes	yes	yes	yes
Dewpoint Location	stud cavity	stud cavity	rigid insulation	drainage cavity
Dewpoint Occurrence	summer	winter	summer	winter
COST COMPARISON				
Initial Construction Cost Per SF	$33.11	$37.03	$36.03	$30.48
Increase in Cost, %	8.6	21.5	18.2	---

Table 7. Cost comparison and dewpoint potential summary

of the fasteners screws resisting the lateral load in shear and not-in-tension compared to the flange mounted ties.

The wall system for the loadbearing multi-wythe cavity consists of a brick wythe and a block wythe supported by a foundation wall (Figure 12). Typically, the block wythe is designed to resist the applied loads. The block wythe alone is accomplishing the same task as the metal stud infill, steel beam, steel column and steel X-bracing in resisting the applied loads. This can be an advantage for saving money (initial construction cost) and time (scheduling). If the exterior enclosure package can be let for bid following the foundation package, the procurement of block backup for construction can be immediate. There is no need to lose construction time waiting for structural steel in order for metal stud placement. As evidenced in Figures 9, 10, 11 and 12, the adjustable tie spacing for the brick veneer and metal studs is every 2.67 sf while the brick and block is 1.77 sf. The adjustable tie system for the brick and block is an assembly that is welded to the horizontal joint reinforcement spaced every 16˝ oc in the block. From a structural engineering perspective, the 1.77 sf spacing is a minimum requirement by the MSJC code to allow the brick to share in resisting the lateral wind load with the block.[5] In other words, the brick can be designed as "brick masonry" in lieu of "brick veneer" and can be counted on to resist a portion of the lateral wind load.

According to

According to Joseph O Arumala, M. ASCE, PE, Professor, Construction Management Technology Program, University of Maryland Eastern Shore, "The brick veneer with steel stud backup wall system has been used successfully in a wide range of commercial, industrial, and institutional structures. However, it is recognized that the wall system is vulnerable if liquid water and water vapor condensation are not sufficiently controlled. Most of the reported cases of failures were due to poor material selection, design and construction practices. It is important to pay attention to design, detailing and construction specifications and guidelines in order to minimize the water/moisture problems with the system. To assure safe and sound performance, brick veneer with steel stud backup wall must be properly designed, meticulously detailed and skillfully built under special inspection to control the flow of moisture in and out of the wall cavity and to keep the wall components dry. It is necessary to design and construct the wall envelope to be watertight. However, there is need for design improvements to insure that the wall is kept dry in service. This may mean that the air cavity thickness may be increased to promote drainage and drying. Maintenance is also critically important to ensure the system remains functioning as needed." [6]

Robin D Rund, AIA, CSI, CCS, Ghafari Associates states, "It appears that brick veneer/steel stud back-up walls are not inherently problematic, only that this particular design is susceptible to extreme damage when problems, of the sort that could happen with any wall type, do occur. Improper flashings, copings, vapor retarder placement or any number of design and construction problems can quickly and silently ruin a steel stud back-up wall, while the same problem may have little effect in all-masonry construction…" [7]

Finally, Wagdy Anis, AIA, Shepley Bulfinch Richardson and Abbott states, "Steel is a good conductor of heat, and when framing losses are averaged out with the insulation, the effect is that of a wall that is an average R-1.23 m^2 K/W (R-7)! What is worse, from a functional standpoint, is that the sheathing and other surfaces in the stud cavity are below the dew point of the indoor air. This increases the condensation potential due to diffusion and air leakage, which may cause corrosion and premature failure of the stud system. Consider a strategy whereby all the insulation is outboard of the sheathing — for example, 50 mm (2 in.) of foam plastic (rigid boards or spray foam) insulation of about 1.76 m^2 K/W (R-10). Not only is the insulating value better because the insulation is unbroken, but the stud system remains at almost room temperature, avoiding the possibility of condensation and corrosion either from diffusion or air exfiltration in cold climates…" [8]

For all it's worth

The loadbearing multi-wythe cavity wall system also provides the following advantages and benefits:

- lower initial construction cost
- enhanced construction schedule
- high system performance with single source responsibility [9]
- lower life cycle cost
- lower maintenance cost
- durability
- a structural system
- more effective anchoring system for stone veneer [10]
- excellent fire rating
- thermal resistance
- thermal mass efficiency [11]
- sound resistance
- moisture resistance
- mold resistance
- structural redundancy
- use of regional materials reduces environmental impacts of transportation, and optimize energy performance due to thermal mass, and contribute to LEED points
- manufacturing masonry materials locally and constructing masonry wall systems supports the local economy.

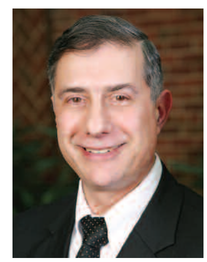
Benefit from designing and constructing the masonry premiere wall system for a lower initial construction cost with an enhanced construction schedule.

- no steel X-bracing is required
- no costly moment steel connections are required
- no complex foundations are required
- no shop drawings are required
- no lead time required for block backup
- no cost increase for block backup.

Life cycle cost analyses have shown that masonry systems over time are the most economical, even more so when operational and insurance costs are factored in. According to Stephen J Kirk and Stephen Garrett, "Analyzing these life-cycle cost data, SH&G found the masonry alternative to be the most cost-effective exterior wall system…" [12]

And if that's not enough, the bottom line based on the initial construction cost analysis and the condensation potential (Table 7), shows the loadbearing multi-wythe cavity wall system to be 8.6 to 21.5% cheaper than the brick veneer and metal stud wall systems! For all it's worth, there is no other wall system that offers so many advantages and benefits at a low initial construction cost!

Dewpoint analyses were calculated by DOW Building Solutions using proprietary software developed to analyze the potential for dewpoint within wall assemblies. The software is available to building owners, designers and contractors. Special thanks to Bill Waddell of DOW, wwaddell@dow.com.



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Prior to joining the MIM, he worked with the Detroit City Engineering Department Inspection Bureau as an associate civil engineer. Zechmeister has also worked as a structural engineer for Albert Kahn Associates and Campbell Associates and as a civil engineer at HF Campbell Co and as a student engineer at the Detroit Metro Water Department. Zechmeister graduated from Wayne State University with a Bachelor of Science in Civil Engineering. dan@mim-online.org, 734-458-8544

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[5] Building Code Requirements for Masonry Structures (ACI 530-02/ASCE 5-02/TMS 402-02) and Specification for Masonry Structures (ACI 530.1-02/ASCE 6-02/TMS 602-02).
[6] The Masonry Society, "Brick Veneer Steel Stud Wall Systems: State-of-the-Art," The Masonry Society Journal, Vol. 25, No. 1, Sept 2007: page 18.
[7] Robin D Rund, "Perception or Reality," The Story Pole, Vol. 33, No. 6, Nov/Dec 2002: page 10.
[8] Wagdy Anis, "Insulation Strategies for Exterior Walls," The Construction Specifier, Aug 2002: page 41.
[9] Jeff Snyder, "Sequencing Exterior Masonry Systems," The Story Pole, Vol. 38, No. 1, Jan/Feb 2007: page 46.
[10] Jeff Snyder, "Backed-Up By Design," The Story Pole, Masonry Resource Guide 2006, Vol. 37, No. 1: page 96.
[11] Peter Damore and Kenneth Neigh, "Insulated Cavity Masonry Wall Design: Maximizing Energy Performance," The Story Pole, Masonry Resource Guide 2008, Vol. 39, No. 1
[12] Stephen J Kirk and Stephen Garrett, "Life-Cycle Costing Reveals Masonry's Long-Term Value," Masonry Construction, Dec 1996: page 557.

Life Cycle Cost

Exterior Wall Systems

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Life Cycle Cost Model ~ Input Data

Project: **Military Housing**
Location: **Austin, TX**
Date: **30-Jun-10**
Item: **Exterior Wall Systems**

KEY: **#** **= Input Needed**

Economic Data		Input:	Notes:	
1	Life Cycle (years):	**70**	Ranges from 10 to 40 years	
2	Discount Rate:	**6%**	Federal Govt. 3-7%, Private industry >10%	
3	Overall Location Factor:	**0.808**	See Means	**This changes automatically**
4	Cost Index (time):	**1.00**	See Means	**2009 Baseline**
5	Energy Escalation per year:	**1%**	Department of Energy (website)	
6	Maintenance Escalation per year:	**0%**	Steven Winter or from Client	
7	Cost of Energy ($ / kwh)	**0.120**	Per Local Utility	
8	Seismic / Wind Premium:	**Level A**		
9	Framing Premium:	**2**		
10	Currency Rate:	**1.00**	US	

Non-Monetary Criteria - Weighting		Add Weight Below:	(Total of 100 Points)
1	Image / Aesthetics	**20**	
2	Color Rendition	**5**	
3	Environmental Sustainability	**20**	
4	Obsolescence Avoidance	**0**	
5	Operational Effectiveness	**15**	
6	Durability	**35**	
7	Future Extendability	**5**	
	Total (not to exceed 100 points)	**100**	

Non-Monetary Criteria - Scoring		Image	Color	Env	Obs	Oper	Dur	Fut
14	Modular on 6" Metal Stud, with rigid insulation	**8**	**9**	**6**	**9**	**6**	**6**	**4**
32	Insulated Archictural Precast 3/3/3	**8**	**6**	**6**	**8**	**6**	**8**	**2**
44	Modular / Block Wall 4" Spray Foam (R=30.6)	**9**	**8**	**10**	**9**	**7**	**10**	**2**

Score Key: Excellent = 9-10, Very Good = 7-8, Good = 5-6, Fair = 3-4, Poor = 1-2

Ranking Worksheet

Project: **Military Housing**

Item: **Exterior Wall Systems**

Total Benefit to Cost Ranking

Alternatives:		Benefit Total	Life Cycle Cost / WSF	Benefit to Cost Ratio	Ranking
44	Modular / Block Wall 4" Spray Foam (R=30.6)	885	$24.87	35.6	1
14	Modular on 6" Metal Stud, with rigid insulation	645	$32.36	19.9	2
32	Insulated Archictural Precast 3/3/3	690	$49.37	14.0	3

Total Benefit Ranking

Alternatives:		Benefit Total	Ranking
44	Modular / Block Wall 4" Spray Foam (R=30.6)	885	1
32	Insulated Archictural Precast 3/3/3	690	2
14	Modular on 6" Metal Stud, with rigid insulation	645	3

Total Cost Ranking

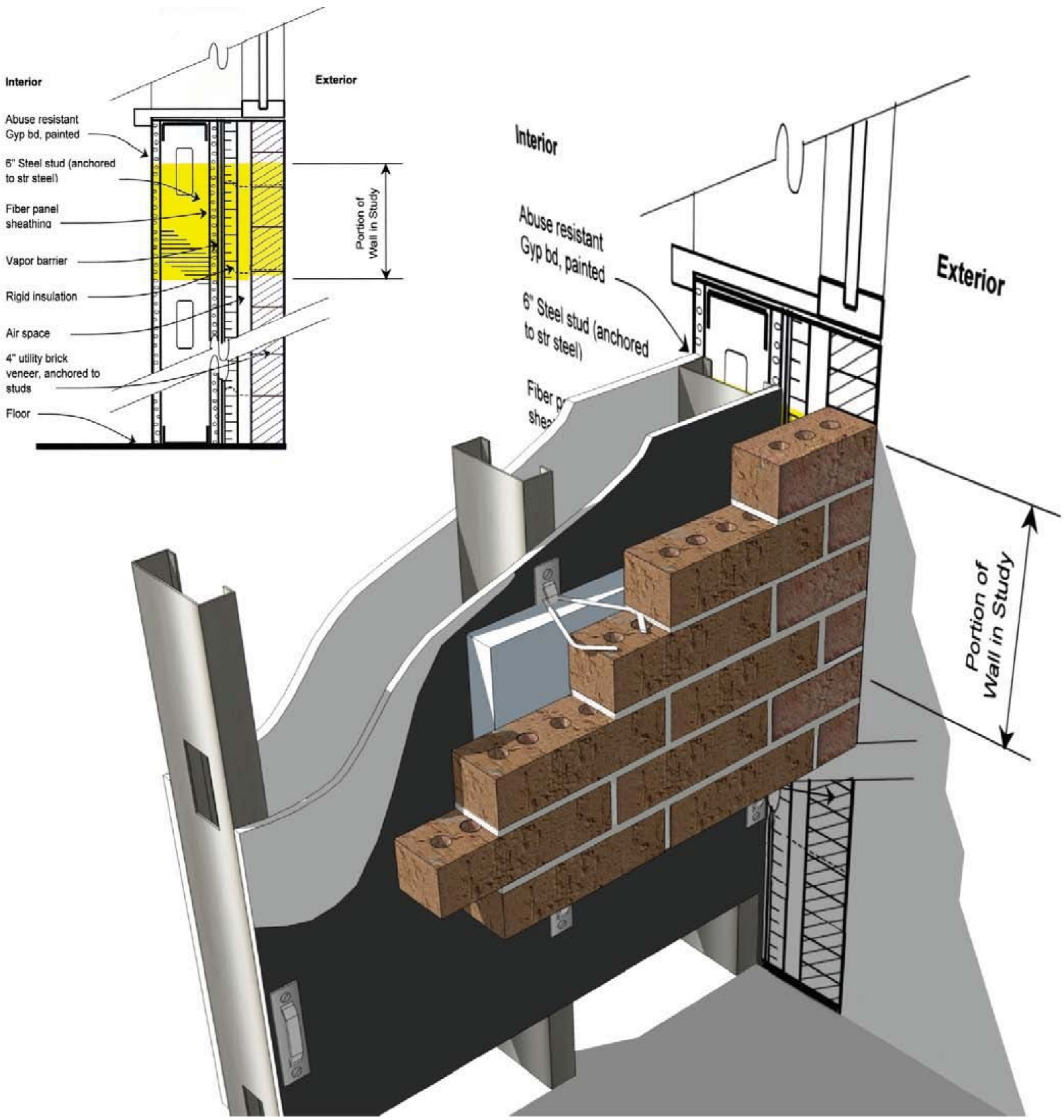
Alternatives:		Life Cycle Cost / WSF	Ranking
44	Modular / Block Wall 4" Spray Foam (R=30.6)	$24.87	1
14	Modular on 6" Metal Stud, with rigid insulation	$32.36	2
32	Insulated Archictural Precast 3/3/3	$49.37	3

Sketch Worksheet

Project: **Military Housing**

Item: **Exterior Wall Systems**

Alternative 14: **Modular on 6" Metal Stud, with rigid insulation**



Total Life Cycle Costs / Wall Square Foot (Present Worth) **$32.36**

LIFE CYCLE COST ANALYSIS (LCCA)

Project: **Military Housing**
Item: **Exterior Wall Systems**
Alternative 14: **Modular on 6" Metal Stud, with rigid insulation**

Description:			**Alternative 14:**
Location =	**Austin, TX**		
Project Life Cycle =	**70**	**Years**	
Discount Rate =	**6.00%**		
Present Time =	**Date of Occupancy**		

INITIAL COSTS	**Quantity**	**UM**	**Unit Price**	**Adj. Factor (by CSI)**	**CSI Div**	**Est.**	**PW**
4x2 2/3x8 standard brick (6.7	50,000	WSF	$10.10	0.669	4	337,844	337,844
Std Brick Tie / Foam & Metal	50,000	WSF	$1.25	0.669	4	41,813	41,813
2" rigid Insulation	50,000	WSF	$1.84	0.669	4	61,548	61,548
1/2" Gypsum, weatherproof	50,000	WSF	$1.33	0.754	6	50,141	50,141
Air Barrier Allowance	50,000	WSF	$2.25	0.754	6	84,825	84,825
6" Mtl Stud, 14 GA-16" OC	50,000	WSF	$3.31	0.754	6	124,787	124,787
5/8" Abuse res board, L4	50,000	WSF	$2.21	0.686	9A	75,803	75,803
Interior paint	50,000	WSF	$0.52	0.600	9B	15,600	15,600
Scaffold allowance	50,000	WSF	$1.50	0.669	4	50,175	50,175
Seismic / Wind Premium:	Masonry		2%	Level A		10,094	10,094
Currency Conversion	US		1.00			0	0
Structural Premium	Steel		$7.00	2		349,999	349,999
Total Initial Cost							**1,202,627**

REPLACEMENT COST/ SALVAGE VALUE Description	**Cycle (yrs)**	**Qty**	**PW Year**	**PW Factor**	**Cur $**	**Est.**	**PW**
Clean & Reseal Clay Brick	50	1	50	0.0543	1.00	41,271	2,240
Repair Brick	50	1	50	0.0543	1.00	12,404	673
Repoint (5% surface) Clay Bı	50	1	50	0.0543	1.00	9,186	498
Refinish Gypsum Wallboard	6	11	35	0.1301	1.00	138,909	18,072
Repair Gypsum Wallboard	6	11	35	0.1301	1.00	60,118	7,821
							0
							0
Salvage Value Max Life:	70	Years	70	0.0169		0	0
Total Replacement/Salvage Costs							**29,304**

ANNUAL COSTS Description	**Escl. %**	**PWA**	**Cur $**	**Est.**	**PW**
Energy / Fuel Annual Costs	1.0%	19.514	1.00	19,786.98	386,120
Maintenance & Repair (see above)	0.0%	16.385			0
	0.0%	16.385			0
	0.0%	16.385			0
Total Annual Costs (Present Worth)					**386,120**

Total Life Cycle Costs (Present Worth)				**1,618,050**
Total Life Cycle Costs / Wall Square Foot (Present Worth)				**32.36**
Total Life Cycle Costs (Annualized)	**0.0610**	**PP Factor**	**98,755**	**Per Year**

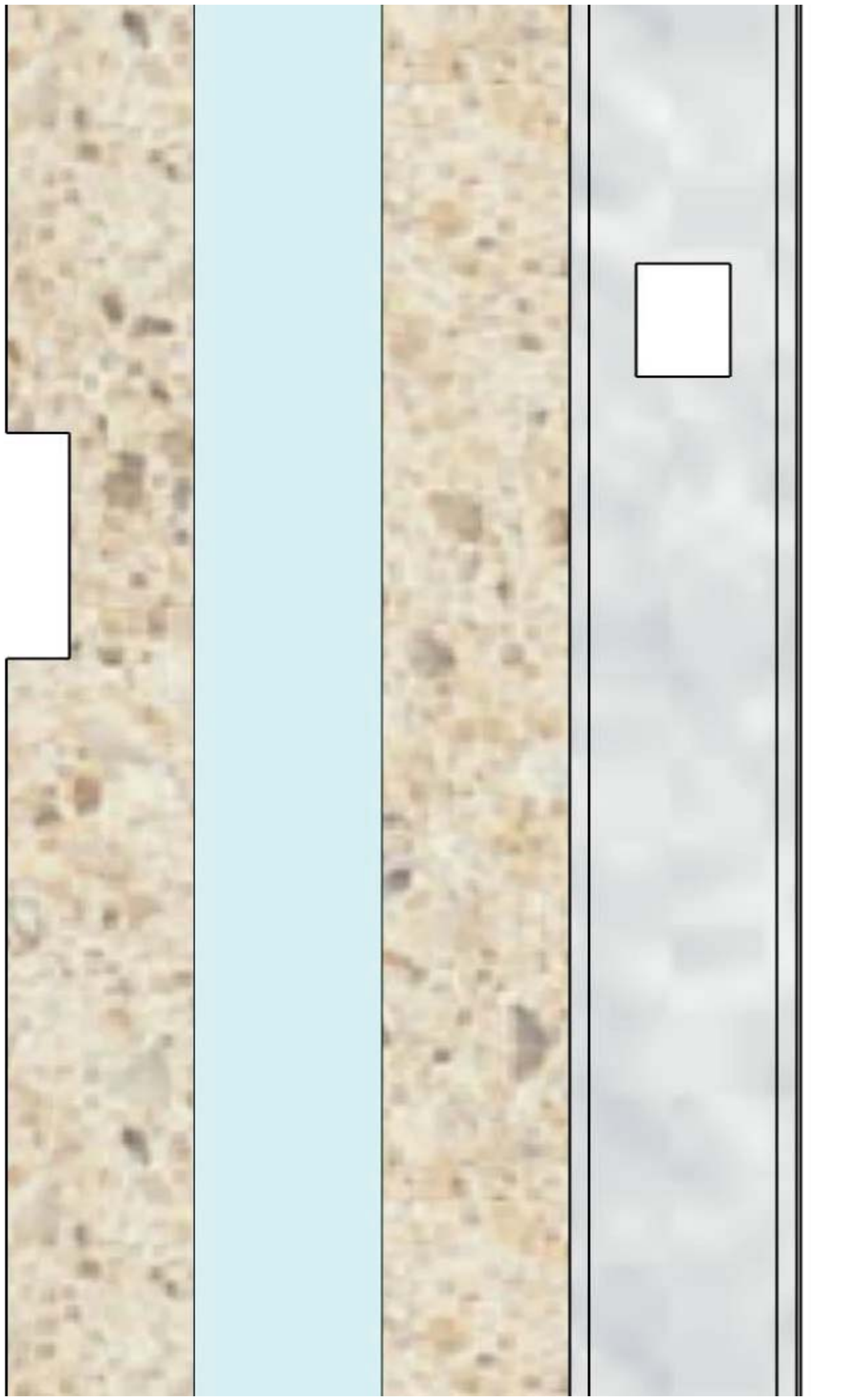
PW: Present Worth
PWA: Present Worth of Annuity
PP: Periodic Payment

Sketch Worksheet

Project: **Military Housing**

Item: **Exterior Wall Systems**

Alternative 32: **Insulated Archictural Precast 3/3/3**



Total Life Cycle Costs / Wall Square Foot (Present Worth) **$49.37**

LIFE CYCLE COST ANALYSIS (LCCA)

Project: **Military Housing**
Item: **Exterior Wall Systems**
Alternative 32: **Insulated Archictural Precast 3/3/3**

Description:		**Alternative 32:**
Location =	**Austin, TX**	
Project Life Cycle =	**70 Years**	
Discount Rate =	**6.00%**	
Present Time =	**Date of Occupancy**	

INITIAL COSTS	**Quantity**	**UM**	**Unit Price**	**Adj. Factor (by CSI)**	**CSI Div**	**Est.**	**PW**
Insul Arch Precast Panl	50,000	WSF	$42.00	0.695	3	1,459,496	1,459,496
Air Barrier Allowance	50,000	WSF	$2.25	0.808		90,900	90,900
Backer Rod, Joint Sealant	50,000	WSF	$2.94	0.669	4	98,343	98,343
Steel angle sub frame, 4x6"	50,000	WSF	$0.00	0.885	5	0	0
Vapor Barrier, 4 mil	50,000	WSF	$0.17	0.669	4	5,787	5,787
4" Mtl Stud, 14 GA-16" OC	50,000	WSF	$2.90	0.754	6	109,330	109,330
	50,000	WSF	$0.00	0.731	7	0	0
5/8" Abuse res board, L4	50,000	WSF	$2.21	0.686	9A	75,803	75,803
Interior paint	50,000	WSF	$0.52	0.600	9B	15,600	15,600
Seismic Premium	Steel		0%	Level A		0	0
Currency Conversion	US		1.00			0	
Structural Premium	Steel		$7.50	2		374,999	374,999
Total Initial Cost							**2,230,256**

REPLACEMENT COST/ SALVAGE VALUE Description	**Cycle (yrs)**	**Qty**	**PW Year**	**PW Factor**	**Cur $**	**Est.**	**PW**
Clean & Reseal Concrete	50	1	35	0.1301	1.00	38,493	5,008
Repair caulk joints	25	2	25	0.2330	1.00	91,512	21,322
	0	0	35	0.1301	1.00	0	0
Refinish Gypsum Wallboard	6	11	35	0.1301	1.00	138,909	18,072
Repair Gypsum Wallboard	6	11	35	0.1301	1.00	60,118	7,821
							0
Salvage Value Max Life:	70	Years	70	0.0169		0	0
Total Replacement/Salvage Costs							**52,223**

ANNUAL COSTS Description	**Escl. %**	**PWA**	**Cur $**	**Est.**	**PW**
Energy / Fuel Annual Costs	1.0%	19.514	1.00	9,533.73	186,039
Maintenance & Repair (see above)	0.0%	16.385			0
	0.0%	16.385			0
	0.0%	16.385			0
Total Annual Costs (Present Worth)					**186,039**

Total Life Cycle Costs (Present Worth)	**2,468,519**
Total Life Cycle Costs / Wall Square Foot (Present Worth)	**49.37**

Total Life Cycle Costs (Annualized)	**0.0610**	**PP Factor**	**150,661**	**Per Year**

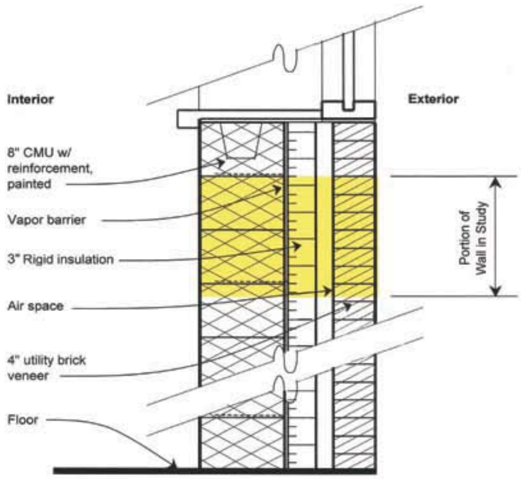
PW: Present Worth
PWA: Present Worth of Annuity
PP: Periodic Payment

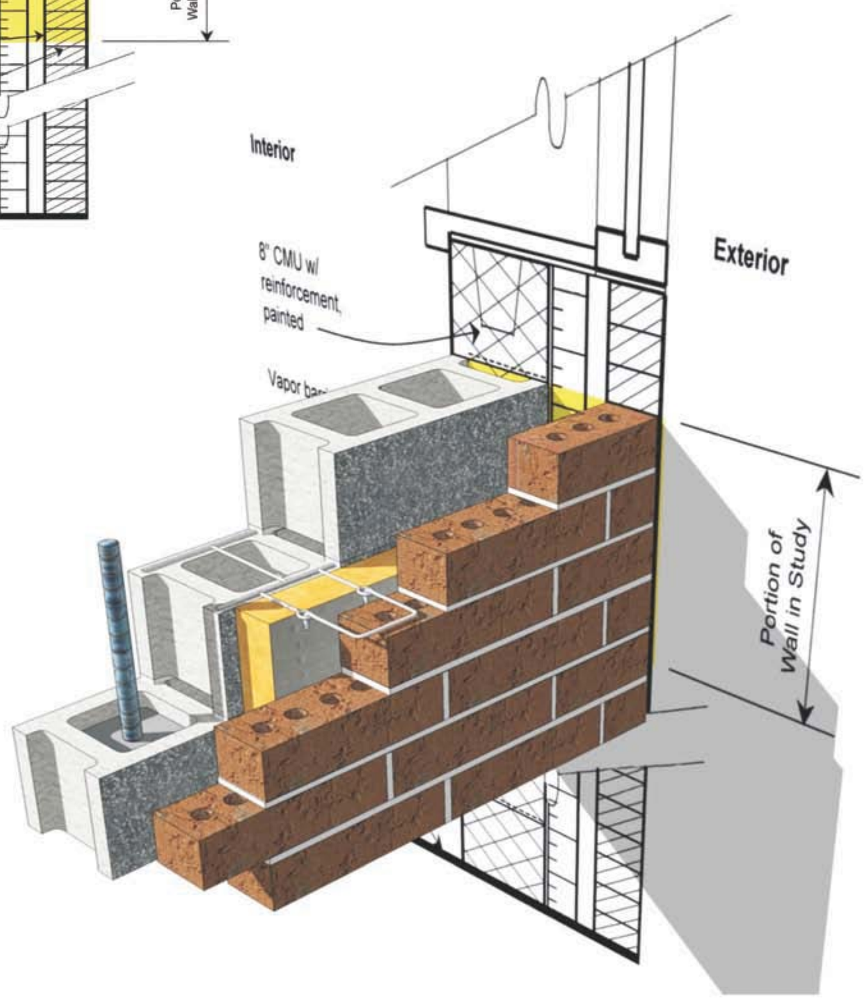
Sketch Worksheet

Project: **Military Housing**

Item: **Exterior Wall Systems**

Alternative 44: **Modular / Block Wall 4" Spray Foam (R=30.6)**





Total Life Cycle Costs / Wall Square Foot (Present Worth) **$24.87**

LIFE CYCLE COST ANALYSIS (LCCA)

Project: **Military Housing**
Item: **Exterior Wall Systems**
Alternative 44: **Modular / Block Wall 4" Spray Foam (R=30.6)**

Description:		**Alternative 44:**
Location =	**Austin, TX**	
Project Life Cycle =	**70 Years**	
Discount Rate =	**6.00%**	
Present Time =	**Date of Occupancy**	

INITIAL COSTS	Quantity	UM	Unit Price	Adj. Factor (by CSI)	CSI Div	Est.	PW
4x2 2/3x8 standard brick (6.75	50,000	WSF	$15.70	0.669	4	525,163	525,163
4" Thick spray on insultn	50,000	WSF	$3.13	0.669	4	104,698	104,698
(Insul-air & vapor barrier)	50,000	WSF	$0.00	0.731	7	0	0
8" CMU backup w/ reinf.	50,000	WSF	$11.05	0.669	4	369,621	369,621
	50,000	WSF		0.669	4	0	0
Interior paint	50,000	WSF	$0.52	0.600	9B	15,600	15,600
Scaffold allowance	50,000	WSF	$1.50	0.669	4	50,175	50,175
Seismic Premium	Masonry		2%	Level A		17,896	17,896
Currency Conversion	US		1.00			0	0
Structural Premium	Masonry		$0.00	2		0	0
Total Initial Cost							**1,083,154**

REPLACEMENT COST/ SALVAGE VALUE Description	Cycle (yrs)	Qty	PW Year	PW Factor	Cur $	Est.	PW
Clean & Reseal CMU	50	1	35	0.1301	1.00	39,744	5,170
Repair CMU	50	1	50	0.0543	1.00	6,552	355
Repoint (5% surface) CMU	50	1	35	0.1301	1.00	5,240	681
Refinish CMU, Paint Int.	10	7	35	0.1301	1.00	143,407	18,657
Repair CMU Interior	25	2	25	0.2330	1.00	6,755	1,573
							0
							0
Salvage Value Max Life:	70	Years	70	0.0169		0	0
Total Replacement/Salvage Costs							**26,436**

ANNUAL COSTS Description	Escl. %	PWA	Cur $	Est.	PW
Energy / Fuel Annual Costs	1.0%	19.514	1.00	6,854.31	133,754
Maintenance & Repair (see above)	0.0%	16.385			0
	0.0%	16.385			0
	0.0%	16.385			0
	0.0%	16.385			0
Total Annual Costs (Present Worth)					**133,754**

Total Life Cycle Costs (Present Worth)				**1,243,343**
Total Life Cycle Costs / Wall Square Foot (Present Worth)				**24.87**
Total Life Cycle Costs (Annualized)	**0.0610**	**PP Factor**	**75,885**	**Per Year**

PW: Present Worth
PWA: Present Worth of Annuity
PP: Periodic Payment

Notes

Interior Partitions

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Life Cycle Cost Model ~ Input Data

Project: Education Building
Location: Austin, TX
Date: 24-Mar-10
Item: Interior Load Bearing Partition Systems

KEY: # = Input Needed

Economic Data		Input:	Notes:	
1	Life Cycle (years):	50	Ranges from 10 to 40 years	
2	Discount Rate:	6%	Federal Govt. 7%, Private industry >10%	
3	Overall Location Factor:	0.808	See Means	This changes automatically
4	Cost Index (time):	1.00	See Means	2010 Baseline
5	Energy Escalation per year:	0.0%	Department of Energy (website)	
6	Maintenance Escalation per year:	0.0%	Steven Winter or from Client	
7	Differential Escalation	0%	Difference between inflation and construction escalation	
8	Currency Rate:	1.00	US	

Non-Monetary Criteria - Weighting		Add Weight Below:	(Total of 100 Points)
1	Image / Aesthetics	25	
2	Color Rendition	10	
3	Environmental Sustainability	5	
4	Obsolescence Avoidance	5	
5	Operational Effectiveness	10	
6	Durability	40	
7	Future Extendability	5	
	Total (not to exceed 100 points)	100	

Non-Monetary Criteria - Scoring		Image	Color	Env	Obs	Oper	Dur	Fut
1	8" CMU	6	7	8	10	9	9	5
3	8" Ground Face CMU, integrally colored	9	9	8	10	9	9	3
9	Abuse resistant Gyp Bd on 6" Metal Stud	7	8	6	7	7	3	9

Score Key: Excellent = 9-10, Very Good = 7-8, Good = 5-6, Fair = 3-4, Poor = 1-2

Ranking Worksheet

Project: **Education Building**

Item: **Interior Load Bearing Partition Systems**

Total Benefit to Cost Ranking

Alternatives:		Benefit Total	Life Cycle Cost per Wall SF	Benefit to Cost Ratio	Ranking
1	8" CMU	785	$8.73	89.9	1
9	Abuse resistant Gyp Bd on 6" Metal Stud	555	$13.97	39.7	2

Total Benefit Ranking

Alternatives:		Benefit Total	Ranking
1	8" CMU	785	1
9	Abuse resistant Gyp Bd on 6" Metal Stud	555	2

Total Cost Ranking

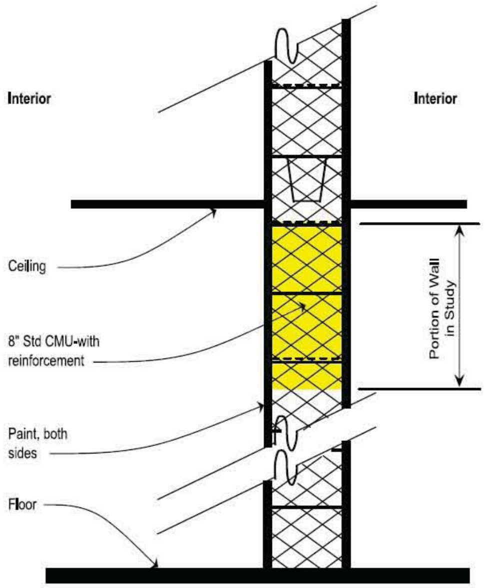
Alternatives:		Life Cycle Cost per Wall SF	Ranking
1	8" CMU	$8.73	1
9	Abuse resistant Gyp Bd on 6" Metal Stud	$13.97	2

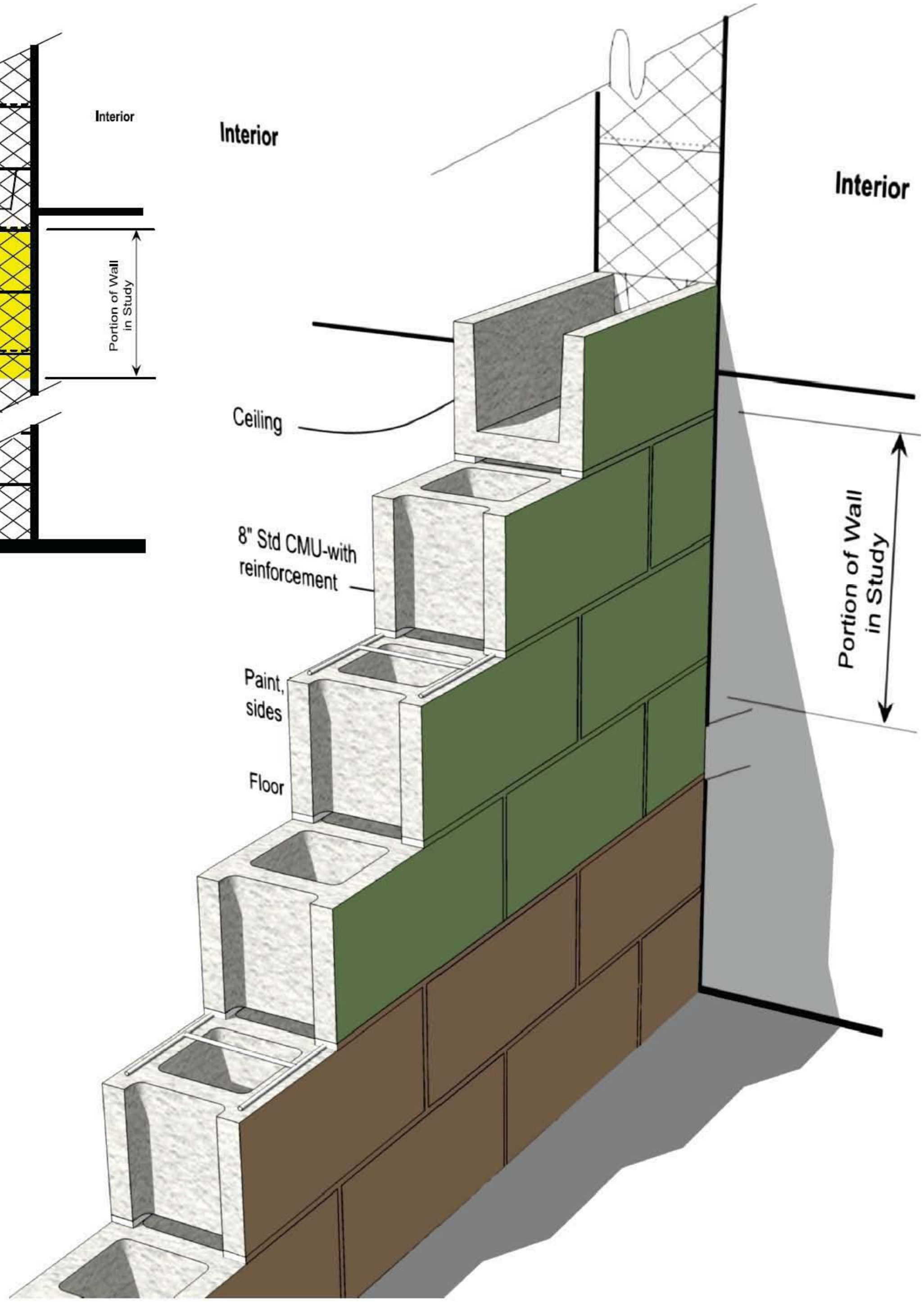
Sketch Worksheet

Project: **Education Building**

Item: **Interior Load Bearing Partition Systems**

Alternative 1: **8" CMU**





Total Life Cycle Costs / Wall Square Foot (Present Worth) **$8.73**

LIFE CYCLE COST ANALYSIS (LCCA)

Project:	**Education Building**
Item:	**Interior Load Bearing Partition Systems**
Alternative 1:	**8" CMU**

Description:			**Alternative 1:**
Location =	**Austin, TX**		
Project Life Cycle =	**50**	**Years**	
Discount Rate =	**6.00%**		
Present Time =	**Date of Occupancy**		

INITIAL COSTS	**Quantity**	**UM**	**Unit Price**	**Adj. Factor (by CSI)**	**CSI Div**	**Est.**	**PW**
8" CMU reinforced	10,000	WSF	$10.32	0.669	4	69,043	69,043
Interior paint	20,001	WSF	$0.52	0.600	9B	6,240	6,240
				0.808		0	0
				0.808		0	0
				0.808		0	0
				0.808		0	0
				0.808		0	0
				0.808		0	0
Currency Conversion	US		1.00			0	0
Does not include any structural steel costs						0	0
Total Initial Cost							**75,283**

REPLACEMENT COST/ SALVAGE VALUE **Description**	**Cycle (yrs)**	**Qty**	**PW Year**	**PW Factor**	**Cur $**	**Est.**	**PW**
Refinish CMU, Paint	8	6	25	0.2330	1.00	37,789	8,804
Minor Repair CMU	16	3	25	0.2330	1.00	8,097	1,886
Finish Repaired CMU	16	3	25	0.2330	1.00	5,861	1,365
							0
							0
							0
Salvage Value							0
Total Replacement/Salvage Costs							**12,055**

ANNUAL COSTS **Description**	**Escl. %**	**PWA**	**Cur $**	**Est.**	**PW**
Maintenance & Repair (see above)	0.0%	15.7619	1.00		0
	0.0%	15.7619	1.00		0
	0.0%	15.7619	1.00		0
	0.0%	15.7619	1.00		0
	0.0%	15.7619	1.00		0
	0.0%	15.7619	1.00		0
Total Annual Costs (Present Worth)					**0**

Total Life Cycle Costs (Present Worth)				**87,338**
Total Life Cycle Costs / Wall Square Foot (Present Worth)				**8.73**
Total Life Cycle Costs (Annualized)	**0.0634**	**PP Factor**	**5,541**	**Per Year**

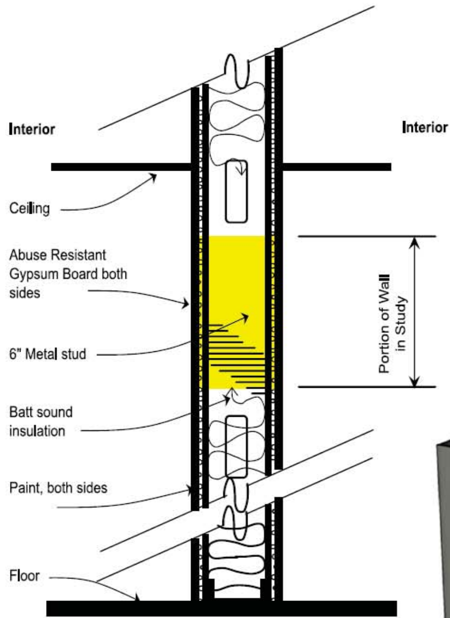
PW: Present Worth
PWA: Present Worth of Annuity
PP: Periodic Payment

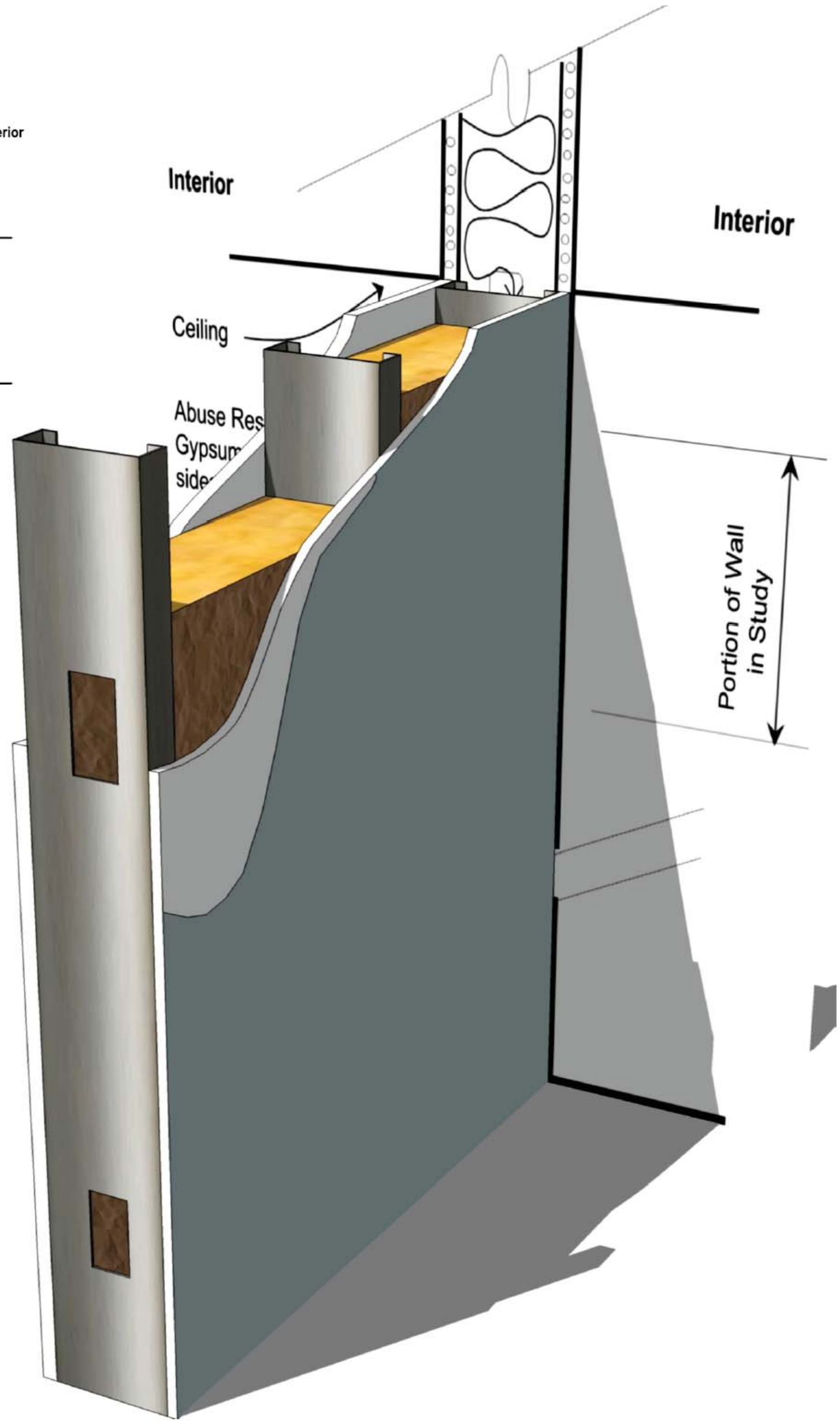
Sketch Worksheet

Project: **Education Building**

Item: **Interior Load Bearing Partition Systems**

Alternative 9: **Abuse resistant Gyp Bd on 6" Metal Stud**





Total Life Cycle Costs / Wall Square Foot (Present Worth) **$13.97**

LIFE CYCLE COST ANALYSIS (LCCA)

Project: **Education Building**
Item: **Interior Load Bearing Partition Systems**
Alternative 9: **Abuse resistant Gyp Bd on 6" Metal Stud**

Description:		**Alternative 9:**
Location =	**Austin, TX**	
Project Life Cycle =	**50 Years**	
Discount Rate =	**6.00%**	
Present Time =	**Date of Occupancy**	

INITIAL COSTS	**Quantity**	**UM**	**Unit Price**	**Adj. Factor (by CSI)**	**CSI Div**	**Est.**	**PW**
6" Steel Stud-18 GA	10,000	WSF	$3.18	0.754	6	23,978	23,978
5/8" Abuse res board	20,001	WSF	$2.21	0.686	9A	30,322	30,322
3 1/2" Acoustic insulation	10,000	WSF	$0.71	0.731	7	5,190	5,190
Interior paint	20,001	WSF	$0.52	0.600	9B	6,240	6,240
Structural Steel Frame	10,000	WSF	$7.50	0.808		60,600	60,600
				0.808		0	0
				0.808		0	0
				0.808		0	0
Currency Conversion	US		1.00			0	0
				0.808		0	0
Total Initial Cost							**126,331**

REPLACEMENT COST/ SALVAGE VALUE Description	**Cycle (yrs)**	**Qty**	**PW Year**	**PW Factor**	**Cur $**	**Est.**	**PW**
Refinish Gyp Bd Wall Finish	6	8	25	0.2330	1.00	28,760	6,701
Minor Gyp Bd Repair	6	8	25	0.2330	1.00	18,335	4,272
Finish Repair Work	6	8	25	0.2330	1.00	10,159	2,367
							0
							0
							0
							0
Salvage Value							0
Total Replacement/Salvage Costs							**13,340**

ANNUAL COSTS Description	**Escl. %**	**PWA**	**Cur $**	**Est.**	**PW**
Maintenance & Repair (see above)	0.0%	15.762	1.00		0
	0.0%	15.762	1.00		0
	0.0%	15.762	1.00		0
	0.0%	15.762	1.00		0
	0.0%	15.762	1.00		0
	0.0%	15.762	1.00		0
Total Annual Costs (Present Worth)					**0**

Total Life Cycle Costs (Present Worth)	**139,671**
Total Life Cycle Costs / Wall Square Foot (Present Worth)	**13.97**

Total Life Cycle Costs (Annualized)	**0.0634**	**PP Factor**	**8,861**	**Per Year**

PW: Present Worth
PWA: Present Worth of Annuity
PP: Periodic Payment

LIFE CYCLE COST ANALYSIS (LCCA)

Economic Terms

Life Cycle Cost Analysis*	An economic assessment of an item, system, or facility and competing design alternatives considering the time value of money.
Life Cycle Cost*	The total cost of ownership over a study period or "life cycle." May include initial construction costs, replacement costs, energy costs, maintenance costs, and salvage values
Life Cycle (Study Period)*	The length of time over which an investment is analyzed.
Discount Rate**	The 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 (present time).
Discount Factor**	A multiplicative number (calculated from a discount formula for a given discount rate and interest period) that is used to convert costs and benefits occurring at different times to a common time. See references below for the various discount formulas.
Present Worth* (Net Present Value)	Economic method that requires conversion of costs and benefits by discounting future cash flows to a baseline date (present time).
Present Worth of Annuity*	Economic method that requires conversion of costs and benefits by discounting annual cash flows to a baseline date (present time).
Periodic Payment*	Economic method that requires conversion of present worth costs and benefits to an equivalent annual series of cash flows.
Escalation (Inflation)*	A continuing rise in the general price levels, caused usually by an increase in the volume of money and credit relative to available goods.
Replacement Life* (Useful Life)	The life of a system or component (usually expressed in years) for which it is cost effective to utilize before being replaced.
Economic Approach*	The approach taken with regard to inflation. "Current dollars" indicates prices in the LCC include inflation to the year of expenditure.
Time Value of Money*	The time-dependent value of money stemming both from changes in the purchasing power of money (that is, inflation or deflation), and from the real earning potential of alternative investments over time.
Location Factor	The relative difference in constructions cost between cities in the USA. A 1.00 factor is the "average" cost of construction for all cities in the USA. For this study, RS Means was used as the source of the location factor.
Straight line depreciation	The simplest and most commonly used, straight line depreciation is calculated by taking the purchase or acquisition price of an asset subtracted by the salvage value divided by the total productive years the asset can be reasonably expected to benefit the company [called “useful life” in accounting jargon].

Source

* Stephen Kirk & Alphonse Dell'Isola, *Life Cycle Costing for Facilities* , Reed Construction Data, 2003

**ASTM E833-91a, *Standard Terminology of Building Economics* , May 1991

Understanding Your Life Cycle Cost Report

Input Sheet

In order to generate a report for your project we must first gather enough information to fulfill the spreadsheet requirements.

A location must be established. The spreadsheet will use the location to adjust several of the costs so they are accurate for that region. There are over 25 cities from throughout the US and Canada currently in the system.

The Life Cycle duration is the time span for which the study will consider the economic impact of the various input options. For example, we know that a school or hospital will physically last more than thirty or forty years, however, in most cases we do not necessarily want to consider the economic impact today's decisions beyond some specific time span. At some point it becomes difficult to predict the future beyond a certain number of years. The spreadsheet will accommodate durations from 10 to 40 years in 5 year increments.

Because we are looking at value, in dollars, across a span of several years we must deal with the fact that a dollar today is worth more than a dollar will be several years from now. For investments, interest will provide for a growth rate, while borrowing money results in a discount rate. Although adjustable, we typically leave the discount rate at 7% for government work as established by the federal government while private industry is slightly higher.

Energy escalation factor accounts for the fact that energy costs inflate faster than general inflation so we add an additional inflation factor to help balance that figure.

Maintenance inflation factors also increase somewhat faster than average costs so we add an additional 1% for inflation there as well.

Not every factor an owner will want to consider is purely about money. In fact, considerations such appearance, green or environmental impact or ability to withstand abuse from heavy wear might be very important to an owner or, maybe some combination of all three.

One of the most powerful features of this life cycle cost analysis system is the ability to place a comparative value on these types of non-monetary factors so they might be considered as a part of the overall equation.

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.

This is accomplished in a two-part system of weights and scores. Weighting values are established without regard to any specific wall or floor system. A choice is simply made based on desires of the owner: "I want a highly durable wall" or "this floor needs to look really good and it needs to be as environmentally friendly as possible". However most of the time owners want a combination of these choices so we assign a weight to each of them. Using 100 as a maximum value we might look at the requirements above and weight them as follows: 50 for durability because it is really important and 25 apiece for appearance and environmental factors. These weights will have a significant impact on the final rankings of the selected walls or floors.

There are seven criteria available for consideration within the system:

Image / Aesthetics is all about appearance. How good does it need to look?

Color Rendition refers to the ability of the system to take and hold color throughout its lifespan.

Environmental sustainability deals with constructing using materials that are environmentally friendly and don't require maintenance that is harmful to the environment.

Obsolescence avoidance is a response to the time factor. How well will this wall or floor stand up to changes in building codes, acceptable performance to changing demands and so forth or will the wall or floor simply become obsolete and minimally usable.

Operational effectiveness refers to the ability of the building to function for maximum productivity. This is extremely important, for example, in hospitals where staffing costs are very high and always will be. Wall and floor systems that are durable and easy to clean help to reduce janitorial and cleaning costs. Staff efficiency should be an important design consideration.

Durability is the ability of the wall or floor to withstand exposure to the elements, heavy use or even abuse.

Future extendibility refers the ability or need to accommodate

changes to the building during its lifespan. For example, in leased office space the interior wall systems might be substantially altered with each new tenant build out, but in an elementary school they might remain exactly as they were originally built for the entire life of the building.
If weighting values define the desires of the owner for certain characteristics to be present in their projects and we also need a way to illustrate how well each wall or floor system meets these same criteria. This is accomplished by determining a score for each of the criteria, image, color rendition, environmental sustainability and so forth, for each wall or floor system in the library of options.

To determine the scores for various wall and floor system a committee debated the relative merits of each wall or floor system and assigned a value of 1 through 10, 10 being the highest value, for each criteria. Five was considered to be average performance, with values above five indicating above average rating for that criteria and values below 5 indicating a below average rating. For example: maintenance data indicates that drywall faced partition walls in schools require more frequent cycles repainting and sustain more nicks and damaged areas that require repairs than do walls constructed of painted cement masonry units (cmus). This affects scores in two areas, clearly cmu walls are more durable so would score higher on that criteria but painting can release fumes or vapors into the environment and disposal of paint containers, rags, brushes etc. also have an environmental impact so the score for the environmental criteria is impacted as well. Other factors like image can be evaluated as well, for example, If one compared painted cmu walls to integrally colored burnished block walls one can easily see the burnished block walls is far more refined and architectural in appearance and will rate higher than painted cmu in the criteria of image.

LCC reports are specific to building type so some of the scoring criteria may be affected by that as well. For example, future extendibility has to do with the ability of the floor or wall to accommodate changes to the building resulting change in use. For applications such as exterior wall systems for school buildings we have rated that criteria very low for both weighting and scoring because exterior of schools rarely change once the building is completed. If that factor is important to a specific project then that value would need to be adjusted to reflect the owners wishes.

During the input process weighting values may be adjusted so long as they add up to 100 points. Scoring values of individual walls are only adjustable by request to the committee because we have the background information and access to the data that was used to determine the current scores.

Filling out the Input Sheet

Required inputs into the system include: building type, date, location and duration of the study. There are carefully selected default values for the other possible economic data inputs. They can be adjusted if one wishes but it is not necessary to do so to obtain an accurate report.

There are default weighting values as well, based on building type, or one can enter values of their own choice so long as they add up to a total of 100 points.

Scoring values are only adjustable by request as explained above.

One must now choose the walls or floors to be compared. There are a couple simple rules: In order to have a comparison at least two choices are necessary, although the report will accommodate up to 8 options; and, the choices must be from the same library of options. There are three libraries: Exterior walls, Interior partition walls and Floors.

For the most effective report, chose systems that are logical to compare against one another.

Outputs

Ranking Worksheet

The first output sheet is the ranking sheet.

The ranking sheet will show the comparisons between your choices ranked in three different ways: by cost to benefit ratio, by total benefit, and by total cost.

Cost to benefit ratio may be the most useful of the three rankings. It is derived by dividing the total benefit by the total cost and expressing the result as a ratio.

Remember all those weights and scores? The weights defined what your expectations were for floor or wall performance and the scores rated how well each wall or floor meet those same criteria. By multiplying the weight for a single criteria by the score for that criteria we can tell how well that wall or floor meet your expectation or in other words how much benefit that option brings to the project. So we would multiple weight of image by score of image and so forth for each of the seven criteria. By adding all those values together we have defined, mathematically, the total benefit of that option.

If we now divide that total benefit by the total cost we now have a benefit to cost ratio.

A good way to view this figure is "bang for the buck". An option that doesn't do a good job of meeting the requirements as defined by the weighting values won't score well but neither will an option that costs a lot more for only a few little more benefit. Options that provide a lot of benefit for a good price will almost always rank at the top of the list.

This is the ranking that should, in most cases, receive the most consideration.

The total benefit chart ranks results solely by weights and scores with no regard to cost and the total cost chart shows the options ranked by least expensive to most expensive with no regard to benefit.

Individual Alternative Reports

Initial Costs

Individual costs reflect the cost necessary to construct the wall or floor system. It will include: material, labor, and equipment as well as typical overhead and profit. The costs are obtained from the latest version of the R.S. Means Co. "Building Construction Cost Data" guide, the most widely recognized costing reference in the design and construction industries. There are a few exceptions, usually new materials that are not specifically called out in Means. Those exceptions are identified.

We know that there are different costs for constructing similar systems based on location. If you recall, we selected a specific city as a base location for the study. On the first sheet of your report, the Input Sheet, line 3, indicates the "Overall Location Factor", which is the multiplying factor for that location. Numbers less than 1.0 indicate lower costs than the national average while numbers in excess of 1.0 for example, 1.07, indicate a higher than average cost, in this case 7% higher. But, what is the "national average" anyway?

A few years back R.S. Means developed a very sophisticated computer program that analyzed thirty different major construction markets from all areas of the US. Included was a factor that allowed them to weight each location by volume of work type based on nine different project models. Using this program RS Means determines what a national average (score of 1.0) would be without respect to any one given location. This same program that is used to analyze data for the over 700 locations throughout the US and Canada to determine the Overall Location Factor.

Even with that considerable effort, RS Means still provides additional data that allows us to become even more accurate. In this case we have the data to adjust the construction cost to specific trade groups within specific locations. This allows us to adjust the specific material installation cost to the exact trade installing that material at that location. These are the adjustment factors that you will see listed in your report under Initial Costs. Because IMI is international in scope we have been able to coordinate information from offices throughout the US and Canada to verify that the numbers are in fact, reasonably accurate. Remember there is really no exact square foot cost figure for a wall or floor system, if there were, we wouldn't need to bid work out, the price would be constant.

A couple of other notes on initial costs: in order to be more realistic, we have priced the cost based on constructing, maintaining and operating 100 square foot of wall and divided back at the end to arrive at a square foot cost. The portion of the wall included in the study is identified on the accompanying illustration. The second item is the Present Worth (PW) analysis. Because all of these costs occur at the beginning of the project, as opposed to operational and maintenance costs which occur throughout the selected time span, they are in present dollars.

Since we have brought up the issue of Present Worth (PW) we might as well deal with it now. Because we are looking at a series of accumulated costs across time we need to get some fixed point of reference for time in order to calculate a single figure we can use for comparison. We know that cost go up and inflation and other factors affect the value of a dollar. In fact, in a 40 year study the affect can be considerable. There are really only two points that are logical to do this: at the beginning of the project or at the end. Life cycle cost studies are typically done not long before the project begins. Initial cost data, a big chunk of the cost is pretty much known at that point and that cost is in today's dollars. Logically it just makes sense to relate everything back to current time when the study is being done. Life Cycle Cost studies are, therefore, commonly done in present worth.

There are standard reference tables used by accountants to determine the multiplier factors for developing present worth values. Find the correct reference table based on the discount rate (Line 2, on the Input Sheet) and look up the desired information. Copies of these tables can be found in the Appendix of <u>Life Cycle Costing for Facilities</u> by Alphonse J. Dell'Isola, PE, CVS and Stephen J. Kirk, FAIA, CVS.

Replacement Cost / Salvage Value

This category of costs deals with large periodic maintenance issues or total replacement of a system, like a roof or major HVAC update. In our case this is usually cleaning or repointing masonry, caulking, painting or removal and replacement of carpet or resilient flooring systems. Because these costs occur at fixed intervals they are calculated in sections. For example, if walls were repainted every 8 years for 40 years we would have cost occurring at year 8, 16, 24, 32 and 40 or 5 cycles. We would calculate these costs, allowing for inflation, at each of these intervals, adjust for PW and add the resulting five values to determine the total adjusted cost of painting walls for 40 years.

Annual Costs

If replacement costs are viewed as a series of events, like a sequence of photographs, think of annual cost as being more like a movie, continuously moving foreword. The costs of energy, day to day cleaning and maintenance plotted out on a graph would be steadily arcing upward over an extended time period. Present Worth of Annuity (PWA) will provide a more accurate method of looking at these costs. PWA multiplier factors are again taken for standard accounting reference tables. PWA is located in a different column but on the same table in <u>Life Cycle Costing for Facilities</u> for any given discount interest rate.

We have now accounted for all the costs associated with our life cycle cost study. Total Life Cycle Costs, in present worth are accumulated and reported at the bottom of the sheet. This figure will match the Life Cycle Cost figure in the second column of your Ranking Worksheet back at the beginning of your report.
One last figure is provided in the report: Annualized Total Life Cycle Cost. By annualizing the total costs, based on the life of the study we can look at the total cost per square foot in a manner that is somewhat analogues to comparing monthly car payments or mortgage payments. These are calculated using a Periodic Payment factor taken from the same reference tables as the present worth and present worth of annuity factors.

Resources

Here is a list of masonry resources:

Masonry Institute of Michigan (MIM)

- Generic Specification for **MULTI-WYTHE MASONRY ASSEMBLIES (CAVITY WALL: VENEER WYTHE W/CMU BACKUP)**
  - http://www.mim-online.org/ArchDetails/Vol%202/specs/042700-00.pdf
- Generic Specification for **CONCRETE MASONRY ASSEMBLIES (SINGLE WYTHE CMU)**
  - http://www.mim-online.org/ArchDet ails/Vol%201/specs/specs-042200.pdf
- Generic Multi-Wythe Wall Design Details (click on menu links on left side of screen)
  - http://www.mim-online.org/ArchDetails/Vol%202/8-multi-re/8-multi-re-index.htm
- Generic Single Wythe Wall Design Details
  - http://www.mim-online.org/ArchDetails/Vol%201/8-un/ALL_SINGLE_WYTHE_8_INCH.pdf
- FREE project plan/specification reviews, please contact kelly@mim-online.org
- FREE technical inquiry assistance, please contact kelly@mim-online.org
- Pre-Construction Masonry Conference agenda (see attachment)
- Presentations (AIA/CES credits available), please contact michelle@mim-online.org:
  - Loadbearing Masonry's Bottom Line
  - Special Inspection for Structural Masonry
  - For other topics visit http://www.mim-online.org/AEpresentations.html

International Masonry Institute (IMI)

- Loadbearing and Hybrid Details
  - http://www.imiweb.org/design_tools/masonry_details/index.php

Brick Industry Association (BIA)

- Technical Notes on Brick Construction
  - http://www.gobrick.com/html/frmset_thnt.htm

National Concrete Masonry Association (NCMA)

- e-TEK Manual
  - http://www.ncmaetek.org/etek/homefrm_map.cfm?spdm=cemexusa.com

Indiana Limestone Institute (ILI)

- ILI Technote Series
  - http://iliai.com/index.php?pageId=139
- ILI Handbook (FREE download)
  - http://iliai.com/index.php?pageId=41

Portland Cement Association (PCA)

- Designer and Specifier's Site
  - http://www.cement.org/masonry/notebook.asp

Cast Stone Institute (CSI)

- Technical Resources
  - http://www.caststone.org/techcover.html

Masonry Executives Council

- http://www.masonrysystems.org/

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- Licensed Professional Engineer in the Province of Ontario since 1982
- Principal of Building Science Corporation in Waterloo, Ontario
- One of the world's foremost authorities on energy efficient construction techniques
  - expert in the areas of rain penetration, air barriers, vapor barriers, air quality, durability and construction technology
  - specializes in rain damage and mold and microbial contamination of buildings
- ASTM (American Society for Testing and Materials)
  - past chairman of ASTM E241
- ASHRAE
  - contributor and reviewer of Chapters 21 and 22 of ASHRAE Fundamentals
  - voting member
    - ASHRAE Standard 62
    - ASHRAE Technical Committee 4.4 – *Building Materials and Building Envelope Performance*
- Author of numerous books and technical papers on building construction, building science, indoor air quality and durability