Thermal Performance Evaluation of Innovative Metal Building Roof Assemblies

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Disclaimer

- MBMA does not promote the use of any particular type or combination of insulations to meet the codes
- The roof systems shown are still in development and may not be appropriate for use at this time
Anatomy of a Metal Building

Conditioned vs Semi-Heated Space

Cool Roofs

Roof/Wall Insulation

Roll-up Doors & Loading Docks

Air Leakage Component / Building

Fenestration windows/skylights

Opaque Doors
Metal Building Applications

Sports Facility

Health Care Facility

Community Facility

Aircraft Hangar

Restaurant

Office Building
Introduction – Why This Work Was Needed

- The demand for increased energy efficiency in commercial building energy codes & standards
  - I-Codes
    - International Energy Conservation Code (IECC)
    - International Green Construction Code (IgCC)
  - ASHRAE
    - 90.1 – Energy Standard for Buildings Except Low-Rise Residential Buildings
What Drives Code Development?

• Building Codes
  – IBC, NFPA 5000 are life-safety codes
  – Minimum standards are set to protect loss of life

• Energy Codes
  – IECC, ASHRAE 90.1 set minimum requirements for energy conservation → this is not a life-safety issue
  – Minimums can be set in two ways:
    1. Economic Justification (i.e. cost effectiveness)
    2. Legislative Mandates (the law)
Construction is Getting More Complicated

• In order to meet the coming energy codes, multiple layers of various insulation types will be required
  – Example is fiberglass insulation in walls with rigid board on the exterior

• The demand for greater efficiency has pushed insulation levels beyond the cavity depth

• Education of design professionals, building officials and contractors is needed to ensure that performance levels are being achieved
Assembly U-Factors vs R-Values

• U = Thermal Transmittance
  • Measured in Btu/h*ft^2*°F
• U is the reciprocal of R  (U = 1/R)
  – Technically true, but for insulation only
  – Assemblies are comprised of many R’s that vary
• So really, U-Factor = 1/R_{Total}
• How are U-Factors derived?
  – For MBS - Only from hot box tests or computer modeling
  – You can not add R-values of insulation unless they are continuous and uncompressed
More About U-Factors

- Lower U-Factors have better performance
- Higher U-Factors have worse performance
- Therefore, U-0.04 is better than U-0.05
  - How much better?
    - U-0.04 = R-25
    - U-0.05 = R-20

- Why should we use U-Factors?
  - R-values don’t tell the whole story
  - U-Factors allow flexibility in what you can provide
  - Codes & standards are moving toward U-Factors
    - 2009 IECC added U-Factors, ASHRAE always had them
    - Advantage of using U-factors:
      - COMcheck has trade-off capabilities for roofs and walls
      - You can use U-factors to trade-off roof and wall insulation as well as fenestration performance
Evaluation of Metal Roofing Systems
Scope of Work

- Cooperative Research with ORNL & MBMA
  - MBMA provided design concepts and donation of materials and labor
- Promising roofing systems with improved thermal performance over the levels accepted in the ASHRAE 90.1 standard
  - Evaluation in the Large Scale Climate Simulator (LSCS)
    - ASTM C1363
  - Up to 10 systems
  - Evaluation at winter and summer conditions
  - U values of 0.040 (R-25) or better
- Identify more cost-effective ways of constructing “next generation” metal roofing systems with improved thermal performance
Why This Work is Needed

• Codes & standards developing entities are pushing for higher insulation assemblies
  – ASHRAE 90.1, IECC
  – ASHRAE 189.1, IgCC, LEED

• Current code requirements have already “maxed out” the known performance of common systems

• Some of the “high” performance systems in codes were developed using R-values long ago and may not be the best option now
### TABLE 502.2(2)
**BUILDING ENVELOPE REQUIREMENTS—OPAQUE ASSEMBLIES**

<table>
<thead>
<tr>
<th>ROOFS</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>R-19</td>
<td>Standing seam roof with single fiberglass insulation layer.</td>
</tr>
<tr>
<td></td>
<td>This construction is R-19 faced fiberglass insulation batts draped perpendicular over the purlins.</td>
</tr>
<tr>
<td></td>
<td>A minimum R-3.5 thermal spacer block is placed above the purlin/batt, and the roof deck is secured to</td>
</tr>
<tr>
<td></td>
<td>the purlins.</td>
</tr>
<tr>
<td>R-13 + R-13</td>
<td>Standing seam roof with two fiberglass insulation layers.</td>
</tr>
<tr>
<td>R-13 + R-19</td>
<td>The first $R$-value is for faced fiberglass insulation batts draped over purlins.</td>
</tr>
<tr>
<td></td>
<td>The second $R$-value is for unfaced fiberglass insulation batts installed parallel to the purlins.</td>
</tr>
<tr>
<td></td>
<td>A minimum R-3.5 thermal spacer block is placed above the purlin/batt, and the roof deck is secured to</td>
</tr>
<tr>
<td></td>
<td>the purlins.</td>
</tr>
<tr>
<td>R-11 + R-19 FC</td>
<td>Filled cavity fiberglass insulation.</td>
</tr>
<tr>
<td></td>
<td>A continuous vapor barrier is installed below the purlins and uninterrupted by framing members.</td>
</tr>
<tr>
<td></td>
<td>Both layers of uncompressed, unfaced fiberglass insulation rest on top of the vapor barrier and are</td>
</tr>
<tr>
<td></td>
<td>installed parallel, between the purlins. A minimum R-3.5 thermal spacer block is placed above the</td>
</tr>
<tr>
<td></td>
<td>purlin/batt, and the roof deck is secured to the purlins.</td>
</tr>
</tbody>
</table>

**WALLS**

<table>
<thead>
<tr>
<th>ROOFS</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>R-16, R-19</td>
<td>Single fiberglass insulation layer.</td>
</tr>
<tr>
<td></td>
<td>The construction is faced fiberglass insulation batts installed vertically and compressed between the</td>
</tr>
<tr>
<td></td>
<td>metal wall panels and the steel framing.</td>
</tr>
<tr>
<td>R-13 + R-5.6</td>
<td>The first $R$-value is for faced fiberglass insulation batts installed</td>
</tr>
<tr>
<td>R-19 + R-5.6</td>
<td>perpendicular and compressed between the metal wall panels and the steel framing. The second rated</td>
</tr>
<tr>
<td></td>
<td>$R$-value is for continuous rigid insulation installed between the metal wall panel and steel framing,</td>
</tr>
</tbody>
</table>
Single Layer of Fiberglass
Double Layer Fiberglass
Filled Cavity

- Thermal Spacer Block
- Long Tab Lap Location
- Panel Clip
- Standing Seam Roof Panel
- Unfaced Insulation
- Faced Long Tab Insulation Installed (Parallel to Purlins)
- Exposed Purlin
- Steel Banding Perpendicular Beneath Purlins
Liner System
The Experiments
Steady-State Guarded Hot Box Evaluation in LSCS (ASTM C1363)

- Standing-seam metal roofs (SSR) with purlins 4 ft oc
- LSCS provides controlled conditions above & below roof test sections
- Test module 12.5 ft square with metering area of 8 ft square
- Completed 4 test modules
One Basis of Comparison

• To make an apples-to-apples comparison, we make the following comparison:

\[
\frac{\sum R_{\text{measured}}}{\sum R_{\text{rated}}}
\]

• For example, R-13 fiberglass between 2x4 stud wall spaced 16” o.c. \((U_{\text{ASHRAE}} = 0.089)\)

\[
1 / 0.089 = R_{\text{total}} = 11.2
\]

\[
11.2 / 13 = 86.4\%
\]
The Assemblies
MBMA – Module 1

- 3” stand off panel clips (specially fabricated for this experiment)
- R-13 over the purlins and R-25 between purlins with 2-5/8” expanded polystyrene thermal blocks between clips
- 1.25” faced polyiso board below the purlins

Result:
U-0.027 (R-37.17)

R-37.2/R-46 = 81% Efficient
MBMA – Module 2

- 1 3/8” stand off panel clips (standard clips)
- R-13 over the purlins and R-25 between purlins with 5/8” expanded polystyrene thermal blocks between clips
- 1.25” rigid board at the bottom of the purlins

Results:
U-0.030 (R-33)

R-33/R-46 = 72% Efficient
MBMA – Module 3

- 1 3/8” stand off panel clips
- 3/8” reflective insulation over the purlins and R-25 between purlins with 1” thermal blocks between clips
- 1.25” rigid board at the bottom of the purlins

Results:

- \( U \) 0.033 up
- \( U \) 0.038 down
- \( R \) -30.6 up
- \( R \) -26 down

\( R = 31/R = 36.13 = 85\% \) Efficient
MBMA - Module 4

- Twin skin – two metal panels used, first one is metal liner over purlins
- 12” Tall roof standoff clip raises roof surface above purlins
- Zero clearance roof clip attaches to hat channels
- R-30 + R-13 fiberglass laid on top of metal liner panel

Results:
U-0.032 (R-31)

R-31/R-43 = 72% Efficient
Future Plans

- Continue this collaborative work to evaluate additional modules
- Possible further investigations on parameters of the first four modules
- Improved metal building walls are also of interest to MBMA
In Closing...

• These experiments show the potential for improving metal building roof thermal performance

• Additional work is currently being done by several stakeholders, so the data is expanding

• These experiments are for R&D purposes, and may not be viable for immediate use
  – The following are among the things not investigated in this study
    • Structural performance
    • Fire resistance
    • Durability
    • Constructability on full-scale buildings