Structural and Hygrothermal Analysis of Hybrid Wall Systems

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Introduction

• Proposed that Hybrid Assemblies would help meet the U.S. Department of Energy home energy use reductions of 30-50%

• Research Focus on Hybrid Wall Systems
  • Combinations of materials and approaches provide optimum performance
  • No single manufacturer provides all necessary components
  • Integration of materials and manufacturers is key
Outline

1. Design and Hypothesis
2. Identification of hybrid wall assemblies
3. Hygrothermal analysis
4. Laboratory structural testing
5. Summary of testing results
6. Development of Recommendations
Design

Hybrid walls will utilize a combination of

- 1.5” to 3” exterior board foam insulation
- Diagonal metal strapping
- 2x6 Advanced Framing (24” oc +)
- 1.5” closed cell spray polyurethane foam
- Cellulose or fibrous cavity fill insulation
- *No wood based structural sheathing*
Hypothesis

Hybrid walls can provide effective:

- Thermal control
- Air control
- Vapour control
- Water control (drainage plane)

- And Structure!
# Hybrid Wall Assemblies

<table>
<thead>
<tr>
<th></th>
<th>Standard Wall</th>
<th>Exterior Insulated Wall</th>
<th>Hybrid Wall 1</th>
<th>Hybrid Wall 2</th>
<th>Hybrid Wall 3</th>
<th>Hybrid Wall 4</th>
<th>Hybrid Wall 5</th>
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Costs - Incremental

- Industry average costs (RSMeans CostWorks 2011)
- Production builders may have better prices

![Bar Chart: Incremental Construction Cost]

- Standard Wall: $0.00
- Exterior Insulated Wall: $1.66
- Hybrid Wall 1 (1.5" XPS/Cell): $2.30
- Hybrid Wall 2 (1.5" XPS/Fiber): $2.39
- Hybrid Wall 3 (1.5" FFPIC/Cell): $2.20
- Hybrid Wall 4 (1.5" FFPIC/Fiber): $2.29
- Hybrid Wall 5 (3" FFPIC/Cell): $5.17
Thermal Analysis

*Therm 5 – Thermal Comparison*

**Exterior**
- Ext Insulation
- ccSPF
- Cavity Fill Insulation
- Drywall

**Interior**

Air Leakage Condensation Plane
Hygrothermal Analysis

WUFI

*Most advanced commercially available hygrothermal moisture modeling program*

Modeling

- Two Base Walls
- Five Hybrid Walls
- Two Exterior Climates
- Two Interior Humidity Cases
- One Interior Temperature Profile

Looking to compare Temperature and Dew Point profiles
Hygrothermal Analysis

Criteria Monitored

- Condensation Plane Temperature
- Interior Temperature and Relative Humidity

Calculations

- Interior Air Dew point

Comparisons and Risk

- Air leakage condensation risk
- Air leakage must be present
- Duration, repetition, alternating drying
Air leakage condensation - air leakage must be present

Credit – J.Smegal, BSCI
Standard Wall - 2x6 Advanced Frame, OSB Sheathing

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Hybrid Wall 1 - 1.5” XPS, 1.5” ccSPF, Cellulose

Hybrid Wall 1 in Minneapolis

Condensation Surface Temperature (F)  Interior Dew Point Temperature (F)  Hours of Possible Condensation

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Risk Comparison - Minneapolis

![Graph showing risk comparison for different wall types in Minneapolis.](#)

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Hygrothermal Summary

- Hybrid Walls greatly reduce air leakage condensation risk
- Hybrid Wall 5 reduced risk the most
- Hybrid Wall 3 reduced risk the second most

- Hybrid walls do not have a moisture sensitive condensation plane!
Structural Analysis

ASTM E72 Testing
Standard Test Methods of Conducting Strength Tests of Panels for Building Construction

Build and Test

- Base Case Code Accepted Wall (OSB)
- Base Case Strapping Only Wall (no ccSPF)
- Hybrid Walls
Structural Analysis

Comparison and Analysis

• Base Case Test 0 – 3 Walls
• Base Case Test 1 XPS w/ Strapping Only – 3 Walls
• Hybrid Test 2 with XPS Exterior Insulation – 3 Walls
• Hybrid Test 3 with ffPIC Exterior Insulation – 3 Walls

No Cellulose or Fiberglass

No Drywall

No Exterior Finish
ASTM E72 Racking Testing
ASTM E72 Racking Testing

Deflection as a result of loadings

- Ram locates wall and zeros its displacement measurement
- Loadings applied 395 lbs/minute
- Loading to 790lbs
  - Release loading
- Loading to 1570 lbs
  - Release loading
- Loading to 2360 lbs
  - Release loading
- Load to failure (4” deflection or 30,000 lbs)
Base Case OSB Wall
Base Case OSB Wall – Code Approved

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Base Case 1 – XPS Exterior Insulation
Base Case 1 – XPS Exterior Insulation
Base Case 1 – XPS Exterior Insulation
Base Case 1 – XPS Exterior Insulation
Base Case 1 – XPS Exterior Insulation
Base Case 1 – XPS Exterior Insulation
Base Case 1 – XPS Exterior Insulation

![Graph showing force applied vs. displacement for different wall configurations with XPS exterior insulation.](graph.png)
Hybrid Test 2 – XPS Exterior Insulation
Hybrid Test 2 – XPS Exterior Insulation
Hybrid Test 2 – XPS Exterior Insulation
Hybrid Test 2 – XPS Exterior Insulation
Hybrid Test 2 – XPS Exterior Insulation
Hybrid Test 2 – XPS Exterior Insulation
Hybrid Test 2 – XPS Exterior Insulation
Hybrid Test 3 – Foil Faced Polyiso Exterior Insulation
Hybrid Test 3 – Foil Faced Polyiso Exterior Insulation
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Hybrid Test 3 – Foil Faced Polyiso Exterior Insulation
Racking Test Summary

Force Applied (lbs)

Displacement (in)

Wall A - v1
Wall A - v2
Wall A - v3
Wall B - v1 - XPS+SPF
Wall B - v2 - XPS+SPF
Wall B - v3 - XPS+SPF
Wall C - v1 - PIC+SPF
Wall C - v2 - PIC+SPF
Wall C - v3 - PIC+SPF
Std Wall w/ OSB v1
Std Wall w/ OSB v2
Std Wall w/ OSB v3
Future System

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Conclusions

Thermal

- All Hybrid walls outperform Base Cases
- Hybrid Wall 5 highest R-Value
- Hybrid Wall 3 and 4 Second Highest R-Value

Hygrothermal

- All Hybrid walls outperform Base Cases
- Hybrid Wall 5 Lowest Condensation Risk
- Hybrid Wall 3 and 4 Second Lowest
- Hybrid Wall 3 – 98% Reduction in Risk
Structural

- XPS and Strapping Capacity ~ 2000lbs @ 3.5”
- 7/16” OSB Capacity ~ 4000 lbs @ 2.5”
- XPS and ccPSF Capacity ~ 6000 lbs @ 2”
- ffPIC and ccSPF Capacity ~ 6000 lbs @ 1.5”
- Future Wall Systems ~ 9000 lbs @ 2.5”

- Hybrid Walls 3 and 4 use ffPIC
Hybrid Wall 3 – Best Overall Performer

- 1.5” ffPIC Exterior Insulation
- 26 Gauge Diagonal Metal Strapping
- 2x6 Advanced Framing (24 oc.)
- 1.5” ccSPF Insulation
- 3” Cellulose Cavity Fill Insulation
- Drywall

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