High Performance Building Materials for Passive House Construction
475 enables building energy efficiency improvements required to dramatically reduce energy demand and address our climate crisis.
Exterior air sealing & vapor control
Interior air sealing & vapor control
Wood fiber insulation boards/WRB
Heat Recovery Ventilation

- >90% efficient
- Very quiet
- Through wall/Ductless HRV
Quality Control: PHI Software & Retrotec Testing
High Performance Building Materials for Passive House Construction
Learning Objectives:

1. Outline meaning and characteristics of high performance materials.
2. Describe the principles of Passive House, and its impacts on construction.
4. Outline steps for how material utilization strategies can be optimized for affordability, comfort and durability.
What makes Passive House different?

Integrated Goals & Methodology:

1. Focus on Passive Elements:
   - Orientation
   - Massing
   - Insulation
   - Airtightness
   - Windows
   - Doors
   - Passive Heat Gains

2. Fixed Performance Goals:
   - **Heating**: 4.75Kbtu/sf2*yr demand or 3.17 btu/hr*sf peak load
   - **Cooling & Dehumidification**: 4.75Kbtu/sf2*yr + climate specific dehumidification
   - **Primary Energy**: ~38Kbtu/ft2*yr
   - **Airtightness**: Tested limit 0.6 ACH50

3. Calculated Energy Balance:
   - Passive House Planning Package (PHPP)

   “Peak Load Equivalent”
   For 1,000 sq ft house

   Peak load is the original “Source EUI” metric. The calculation now is for Primary Energy Renewable (PER) and is no longer directly comparable to EUI but still roughly corresponds to this original number for Passive House Classic certification.

PHIUS+ Separate set of targets and uses WUFI Passive
Verification of the Methodology

2000:

250 dwelling units in 14 different building projects as Passive House Buildings
Delivers comfort with dramatic energy savings:

Approx **90%** reduction in heating & cooling

Up to **75%** reduction in total energy usage.
Supports renewables transition:

- **Path to Net-Zero Buildings & more.**
- Allows switching to all electric buildings.
- More even utility demand profile.
- Primary Energy Renewable (PER) Calculation optimizes building energy use for 100% renewable grid.
Bold Implementation

**BRUSSELS, 2015:** All buildings, private, public, new and retrofitted *mandated* Passive House performance.

**EUROPE, 2020:** Nearly zero-energy buildings.

**NYC** (& Vancouver...)
Not Typical “Cost-Plus” Paradigm

Brussels: City Block Multi-Use Complex – Competitive Design-Build Bids

eu 1,225/m² vs. eu 1,362/m² average
Not Typical “Cost-Plus” Paradigm

PHFA Multifamily Housing Around Philadelphia
Region = 17 Buildings

$206/sf vs. $208/sf average
Complex Buildings in Varied Climates
Retrofit of Existing Buildings
Five key principles:

1. Climate Specific Insulation Levels
2. Thermal Bridge Free Connections
3. High-Performance Windows/Doors
4. Airtightness
5. High Efficiency Heat Recovery Ventilation
Win-win

A very low energy building via optimized methods produces:

1. Comfort
2. Health
3. Affordability
4. Efficiency
5. Predictability
6. Security
7. Resiliency
8. Climate Mitigation
9. Renewables Transition
Universe of Critical Materials Support
(or don’t support) Passive House Construction
High Performance General Criteria

Toxicity  Performance  Robustness
Figure 4: Theoretical contribution of air transport through OSB to global $n_{50}$-value

Airtightness Budget
OSB leaky?
Does it leak?
## Airtight per ASTM E2178

<table>
<thead>
<tr>
<th>Material</th>
<th>Thickness (minimum)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plywood</td>
<td>3/8 in.</td>
</tr>
<tr>
<td>Oriented strand board</td>
<td>3/8 in.</td>
</tr>
<tr>
<td>Extruded polystyrene insulation board</td>
<td>½ in.</td>
</tr>
<tr>
<td>Foil-faced urethane insulation board</td>
<td>½ in.</td>
</tr>
<tr>
<td>Exterior gypsum sheathing or interior gypsum board</td>
<td>½ in.</td>
</tr>
<tr>
<td>Cement board</td>
<td>½ in.</td>
</tr>
<tr>
<td>Built up roofing membrane</td>
<td></td>
</tr>
<tr>
<td>Modified bituminous roof membrane</td>
<td></td>
</tr>
<tr>
<td>Fully adhered single-ply roof membrane</td>
<td></td>
</tr>
<tr>
<td>A Portland cement/sand parge, stucco, or gypsum plaster</td>
<td>½ in.</td>
</tr>
<tr>
<td>Cast-in-place and precast concrete</td>
<td></td>
</tr>
<tr>
<td>Sheet metal</td>
<td></td>
</tr>
<tr>
<td>Closed cell 2 lb/ft³ nominal density spray polyurethane foam</td>
<td>1 in.</td>
</tr>
</tbody>
</table>
Application

working in cold and wet conditions

Worse

• Spray Foam & Butyl Based adhesives:
  • 25 to 40 degree temp limit
  • Low moisture required
  • Clean surfaces

Better

Pressure Sensitive Acrylic (PSA) Adhesives

• Molecular bonding
• 1 hour setup

Caulking Adhesive

• 48 hour setup
• 15 degree temp limit
• Moisture tolerant

Credit: Journal of Light Construction, Trouble Shooting Spray-Foam Insulation by Mason Knowles, Sept 2010
Is it tough?

Is it meant to be a sacrificial layer?

Vs. SHARP

Vs.
Longevity

Flexibility – Materials can’t embrittle over time.
Longevity

Flexibility – Materials can’t delaminate or tear over time.

Vs.

...it doesn’t tear
air tightness not compromised
Is it Green?

In production, life time usage & disposal
Can it Multitask?

- Water control?
  - WRBs
- Vapor control?
  - Vapor open vs. vapor closed/retarding/variable
- Thermal control?
  - Board insulations
Most Critical Components are Certified

Component Database

Opaque building envelope
- Wall and construction systems
- Façade anchors
- Floor slabs
- ICF for roof parapets
- Flue systems
- Balcony connections
- Attic staircases
- Airtightness systems

Building services
- Compact heat pump units
- Ventilation systems (capacity < 600 m³/h)
- Ventilation systems (capacity > 600 m³/h)
- Drain water heat recovery

Transparent building envelope
- Windows
- Roof windows
- Skylights
- Curtain wall systems
- Glass roofs
- Openable glass roof elements
- Shutters
- Entry doors
- Sliding doors
- Glazing
- Spacers
CERTIFICATE
Certified Passive House Component
Component-ID: 1106as03 valid until 31st December 2017
Passive House Institute
Dr. Wolfgang Feist
64283 Darmstadt
Germany

Category: Airtightness Systems / Surface Air sealing
Manufacturer: pro clima
Norddickingsche Produkte GmbH
Reisstiege 61
56723 Schwetzingen, Germany

Product System: pro clima INTELLO

Description: System for surface air sealing

System Components: Airtight membrane „INTELLO“
Self-adhesive Tape „TESCON VIA“
Self-adhesive Tape „CERTISOL SOLID SL“

This certificate was awarded based on the following criteria:
Tested under standard boundary conditions the system meets the listed requirements:

<table>
<thead>
<tr>
<th>Component</th>
<th>Metric</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glass</td>
<td>pHA</td>
<td>0.01 m³/(h·Pa)</td>
</tr>
<tr>
<td></td>
<td>pHB</td>
<td>0.10 m³/(h·Pa)</td>
</tr>
<tr>
<td></td>
<td>pHC</td>
<td>0.15 m³/(h·Pa)</td>
</tr>
</tbody>
</table>

The manufacturer supplies convenient and comprehensive instructions for use and sealing recommendations for all system components. Adhering to these recommendations the system can greatly simplify the execution of an airtight building. The complete Certification Report may also be downloaded at www.passiv.de.

Ventilation system (capacity > 600 m³/h)
Adconair 76 03 01

Component ID: 01945603
Manufacturer: Adconair GmbH
Airflow range: 11000 m³/h
Available external pressure: 250 Pa
Sound level of unit: 57.0 dBA
Climate zones: Cool, temperate

Download certificate (e, d, C)

Glass roof
LAMILUX CI-System Glasarchitektur PR60 energysave (Glasdach)

Component ID: 01598203
Manufacturer: LAMILUX Heinrich Stranz GmbH
Category: Glass Roof
Material: Aluminium
Efficiency class: pHA
Spacer: Super Spacer TriSeal / Ti-Spacar Premium
Climate zones: Cool, temperate
Examine in Plan & Section
Specialized Drawings

01 SECTION EAST

02 SECTION WEST

1c CONDITIONED CELLAR - INBOARD INSULATION
FULL SCALE / PRINT AT: 1 1/2" = 1'-0"
Simplify Wherever Possible

- Continuous wind-tight weather barrier
- Continuous air barrier with vapor control
- Ledger supporting 2nd floor framing

Exterior

Interior

Credit: Gregory La Vardera, Lamidesign.com
Sequence for continuity

Step One

Step Two

Credit: Ed May, http://bldgtypblog.blogspot.com/
Sequence
Minimize Penetrations
Wire and pipe penetration sealing

Allow for **room** to gasket properly

Credit: Ed May, BldgTYp

Credit: Roger Lin, Southern Exposure Homes
Clip/Post/Joist penetration sealing
Construction Planning

• Team meeting
  – Supervisors/foremen must buy in and take responsibility (all trades)
  – Identify few personnel to execute bulk of airsealing

• Training
  – Passive House Tradesperson Training for key personnel

• Sequencing
  – Do not impede or cover the air barrier

• 1st Blowerdoor test
  – As early in process as possible.
Commission & test critical components

• Airtightness
• Doors & Windows
• Ventilation flow rates
• Heating & Cooling systems

Measure and collect data...

Make sure everything is running smooth...
Protect critical components

Service Cavity & Vented Rain Screen
Critical Aspects/Principles

• Airtightness
• Vapor Control
• Well Insulated
• High-performance windows
• Fresh air ventilation
....and Key Themes

- Continuity
- Integration
- Lower toxicity (not PH specific)
- Inspection & Testing
- Commissioning
- Training
- Teamwork
- Affordability via Optimization
Critical Aspects/Principles

- **Airtightness**
- Vapor Control
- Well Insulated
- High-performance windows
- Fresh air ventilation
Measure Airtightness
Air Control Progression

- Historic: 5 ACH50
- 2012 IECC (zones 4-8): 3 ACH 50
- US Bldg Science: ACH 50
- 1.5
- Passive House Certification: 0.6 ACH 50
Airtightness

Driving Force for Performance
Air Control

• Second only to water control.
• Disproportionately effects:
  – **Indoor air quality**: control the air to control the quality
  – **Comfort**: drafts are uncomfortable
  – **Air transported wetting**: a bigger liability than diffusion wetting
  – **Heat loss/thermal bypass**
Thermal bypass describes heat loss that gets around intended thermal insulation, including: windwashing, air infiltration, and convective loops.

Thermal Performance of Leaky vs. Airtight enclosures: Factor of 4.8 or a 79% reduction in performance

Credit: Mark Siddall, Building Green Magazine
Why Inboard Airtightness is Better

1. Keeps conditioned air within the conditioned space.
2. Better protection against condensation risk.
3. Places the components of this most important control layer in a climate controlled location.
4. Leaks can often be more readily found and easier to repair.
5. The air control layer can/should double as a vapor control layer.
Critical Aspects/Principles

- Airtightness
- Vapor Control
- Well Insulated
- High-performance windows
- Fresh air ventilation
Vapor Control

- Airtightness
- Vapor Control
- Warm surface temperatures
- High-performance windows
- Fresh air ventilation
Avoid Sweating
Poorly insulated walls are often heated dry.

Well built assemblies dry through vapor diffusion.
(or they don’t dry)
Outside | Winter | Inside
--- | --- | ---
Vapor open | | Vapor Closed (retarding/variable) How variable?

Drying Outward in Winter

Minimize potential Wetting from Inside
Drying Inward in Summer

Outside
Vapor open

Summer

Inside
Vapor Open (retarding/variable)
How variable?

Drying Inward in Summer

Vapor Drive

Drying In

www.foursevenfive.com | 800-995-6329
Vapor open sheathing at Exterior
Membranes: Mechanically Fastened

Exterior and Interior

**Exterior** Airtight Membranes
Pro Clima: SOLITEX, FRONTA QUATTRO, FRONTA HUMIDA & INTESANA, etc
Siga: Majcoat (no reinforced option, less water proof)

**Not**
Siga Majvest
Tyvek
Greenguard
Hydrogap
Delta Foxx
Typar etc

**Interior** Airtight Membranes
Pro Clima: DB+, DA, INTELLO Plus
Certainteed: Membrain (no reinforced option)
Siga: Majpell (no reinforced option, not vapor variable)
Polyethelene (vapor closed)
Water penetration due to reduced surface tension

Conventional technology: PE /PP membrane: (micro)porous

Water can penetrate the structure due to the reduced water tension caused by:

- Wood preservatives (salts and detergents)
- Chainsaw oil
- Materials contained in the wood (resins, oils or terpentines)
- Not completely airtight (porous)

New technology: TEEE membrane: nonporous and monolithic

Nonporous structures are always watertight and are not affected by:

- Wood preservatives (salts and detergents)
- Chainsaw oil
- Materials contained in the wood (resins, oils or terpentines)
- Completely airtight
High quality exterior membranes

Functions:

Top Layer:
Protection of the membrane from the outside at installation process (during the installation of the battens and subsequent roofing).

Membrane:
WRB: Waterproof against driving rain, Monolithic Actively vapor open (temp roof, roof underlayment and WRB)

Bottom layer:
Protection of the membrane against irregularities in the substrate (rafters or timber shuttering)
Active vapor open TEEE

Condensation on PE / PP micro-porous membrane
- Pores filled = vapor closed

Looks like a Leaky Building ???

Dry surface on TEEE nonporous monolithic membrane
- remains vapor open, protects building
Tapes

Acrylic, butyl.....

Acrylic Options:
Pro Clima: TESCON Vana, Profil, CONTEGA and more
3M, Siga, ZIP

Bitumen/Butyl Options:
Pro Clima, EXTOSEAL ENCORS (butyl/acrylic)
WR Grace, Vycor (primer required) asphalt base

Primers must match profile of adhesive

Note: Expanding/Impregnated Foam cannot be practically installed airtight in our experience
Tapes

Adhesion must hold
Slippage doesn’t provide confidence or durability

Pro Clima primer on masonry tile with Contego Exo
- forced to failure: internal delamination of tape
Tapes
Address Penetrations
Tapes
Address Penetrations
(blind taping for concealed hinges)
Caulking Sealant

Acrylic, can be tricky

Pro Clima: CONTEGA HF  
Contega Classic

Siga primur
Tremco acoustical
Gaskets

EPDM Rubber for wires, pipes and ducts
Pro Clima KAFLEX
Pro Clima ROFLEX

Plastic Electric Boxes
Pro Clima INSTAA Boxes
LESSCO

Liquid pipe sealing
Pro Clima WYFLEXA or CONTEGA HF
Zip Liquid Flash
Prosoco Fast Flash
Insulations

Mineral wool:
Roxul
Urea-extended phenol formaldehyde binder - very low ppm (Greenguard)
No flame retardants

Fiberglass:
Typically with phenol formaldehyde binder
Dense pack: Jet Stream Ultra binder free by Knauf
Below: JM Spider with hydrolyzed polyester binder

Alex Wilson, BuildingGreen
Insulations

Cellulose:
Check for Aluminum Sulfates
15% Borates for fire, pest and mold prevention.

Woodfiber Board:
Gutex & Agepan
High recycled content, check % of PU binder
As risks increase: Intelligent Vapor Retarders....

prevent wetting and promote drying
building drying reserves, for maximum protection
Cornell Tech
Panelized System Continuous Envelope
• Airtightness
• Vapor Control
• **Well Insulated**
• High-performance windows
• Fresh air ventilation
Warm Surface Temperatures

Continuation insulation

Thermal Bridge Free

Insulation levels are climate specific, like sleeping bags
Comfort Criteria and Safety from Condensation
Thermal Breaks at the Foundation

Junction with no insulation block in the brickwork. $\Psi = 0.27 \text{ W/m} \cdot \text{K}$

Junction including an insulation block in the brickwork. $\Psi = 0.02 \text{ W/m}$
Parapet Walls
Thermal Break at the Rain Screen
Thermal Break at Balcony
Critical Aspects/Principles

- Airtightness
- Vapor Control
- Well Insulated
- High-performance windows
- Fresh air ventilation
High-Performance Windows

Comfort drives performance
Comfort drives performance

Typical **Double Glazing**

- 68°F → 59°F → 6°F → discomfort

**PH Windows**

- 68°F → 64°F min. → 6°F → comfort
Spacers Matter, Frames Matter

- Standard Aluminum: 49 ºF
- Stainless-steel: 53 ºF
- Superspacer: 55 ºF

Passive House Academy
Window Placement Matters

$U_{w, installed} = 0.151 \text{ Btu/hr.ft}^2\text{.°F}$

$R_{w, installed} = 6.62 \text{ hr.ft}^2\text{.°F/Btu}$

$T_{si} = 58.9 \text{ °F}$

$\psi_{install} = 0.011 \text{ Btu/hr.ft.°F}$

$T_{si} = 58.9 \text{ °F}$

$\psi_{install} = 0.010 \text{ Btu/hr.ft.°F}$

$T_{si} = 59.1 \text{ °F}$

$\psi_{install} = 0.006 \text{ Btu/hr.ft.°F}$

$T_{si} = 59.0 \text{ °F}$

$\psi_{install} = 0.010 \text{ Btu/hr.ft.°F}$

$T_{si} = 59.3 \text{ °F}$

$\psi_{install} = 0.071 \text{ Btu/hr.ft.°F}$

$T_{si} = 59.2 \text{ °F}$

$\psi_{install} = 0.118 \text{ Btu/hr.ft.°F}$

$T_{si} = 59.2 \text{ °F}$

$\psi_{install} = 0.010 \text{ Btu/hr.ft.°F}$

$U_{w, installed} = 0.148 \text{ Btu/hr.ft}^2\text{.°F}$

$R_{w, installed} = 6.76 \text{ hr.ft}^2\text{.°F/Btu}$

Passive House Academy
Skylight Integration....

Lamilux FE Energysave with AK40 curb
(16” high – 4’ wide insulated fiberglass curb)

Installed U-value 0.15 (R-7)
Critical Aspects/Principles

- Airtightness
- Vapor Control
- Well Insulated
- High-performance windows
- Fresh air ventilation
Fresh Air Ventilation

- Supply to every served space: living rooms, bedrooms, etc...
- Exhaust from every service space: bathrooms, kitchens, etc...
- Individual unit control
- Humidity control
Centralized vs. Decentralized

- Central Units: at top/bottom/middle of building with risers
- Semi-Central Units: at each floor
- Semi-Decentralized Units: at each apartment
- Decentralized Units: at each room

Central & Semi-Central (Ventacity, Swegon)
Semi-Decentralized (Zehnder)
Decentralized (Lunos)
Humidity and HRV vs. ERV (for Multifamily)

- **HRV** only recovers heat energy – **good for lowering humidity in winter**
- **ERV** recovers humidity/latent energy – maintaining indoor humidity levels & **good for preventing moisture loading in summer**.

**Suggested Solution:**
- Address summer humidity with active cooling.
- Address winter humidity with HRV system.
Lower Toxicity

Consider Chemical Risks

- Occupational Health
- Occupant Health
- Biosphere Health
  - Chemical sensitization
  - Respiratory ailments
  - Neurological ailments
  - Cancer
Work to Lower Toxicity

- No/low VOCs
- In manufacture, application, life and disposal
- Toward natural building.
- “Less is Best”

- International Living Future Institute: Red List
- USGBC LEED
- BuildingGreen: Greenspec
- Healthy Building Network: Pharos Project
- Declaration EPD: ISO 14025
- California EPA Air Resources Board
- Perkins & Will’s Precautionary List
Training, Documentation, Verification & Orientation

Predictability Relies on Process....

Trained Professionals: Architects, Engineers, Builders Consultants (PH certified)

Integrated Design

Onsite Verification

Occupant Orientation

Third Party VeriPHy

Airtightness Testing Plan

MEP Commissioned accordingly

Certification:
Signage more numerous than “No Smoking”

AIRTIGHT BUILDING

NO DRILLING AIRTIGHT CONSTRUCTION

NO CUTTING AIRTIGHT MEMBRANES

REPORT ALL PENETRATIONS TO SUPERVISOR
Verify materials for continuity

Manufacturers
Airsealing system /Performance requirements
Airtight materials (membranes, sheathing)
Air-sealing tapes
Adhesives

Accessories
Tape primers
Gaskets for pipes, cables and ducts
Outlet airtight enclosures
Summary

1. Robust (next generation) materials & components
2. Less toxic materials too
3. Fully integrated
4. Forming continuous control layers (predictability)
5. With simplified detailing
6. Sequenced
7. Protected
8. Tested & Commissioned
9. With trained workforce
10. Providing optimized function and affordability
475 Can Help!
info@foursevenfive.com

Knowledge and Resources

475 CAD Details

Free eBooks
Thank You!