TREMCO Barrier Solutions

Aug 5, 2014
Lstiburek Summer Camp

Technology, Chemistry, & Benefits of Liquid-Applied Water-Resistive Barriers

Makers of TUFF-N-DRI® and WATCHDOG WATERPROOFING ®

TUFF-N-DRI WATCHDOG WATERPROOFING

Tremco Barrier Solutions Speaker & Background

- **Dr. Jim Wells PhD. - Technical Director, Tremco Barrier solutions (TBS)**
  - Graduated & Taught Engineering at Purdue
    Aeronautics, Astronautics and Engineering Sciences
  - Vs Joe at University of Toronto
    Aerospace and Engineering Sciences …the better school?

Tremco Barrier Solutions Speaker & Background

Astronaut Score:

- **Purdue 23**: Gus Grissom, Neil Armstrong, Gene Cernan, John Glenn, plus 22 more…
- **U of T 2**: Roberta Bondar, Julie Payette

Tremco Barrier Solutions Speaker & Background

- **Dr. Jim Wells PhD. - Technical Director, TBS**
  - Graduated & Taught Engineering at Purdue
    Aeronautics, Astronautics & Engineering Sciences
  - Over 30 years R&D in Construction Products
    - Owens Corning: Insulation & Roofing Systems -15 years
    - Koch & Tremco Residential Barrier Systems – 18 years

Technology and Chemistry of Liquid-Applied WRB - Agenda

- **History**
- **Testing**
- **Technology**
- **Application & Details**
- **Benefits**
- **Performance and Models**

Water-Resistive Barriers (WRB) A Brief History

- In the beginning, God created the heavens and the earth
- Some years passed → USA + wood frame construction
- 15 lb. felt paper
  - 1803 patent by J.J. Fuller "Improved Fabric for Roofing"
  - Widely used to roof shacks during California Gold Rush
- Polymer sheets, early 1980s to present
  - Spun-bond polyolefin (polyethylene): Tyvek®
  - Perforated polyolefin films: Typar®
  - Permeable polymer films: TEEE (Thermoplastic Elastomer Ether Ester)
- Liquid-applied WRB: formed in-situ permeable membranes

Water-Resistive Barriers (WRB) Testing Requirements

- **15 lb. felt paper**
  - Original weight (organic felt): 15 lb/100ft^2
  - Current requirements (organic felt)
    - Weight minimum: Type I = 11.5, Type II = 26 lbs/100 ft^2
    - ASTM D226 specification
  - Material characterization only – no performance testing
    - Allowed to leak water under pressure
  - The only WRB specified in building codes

    "**R703.2 Water-resistive barrier. "**One layer of No. 15 asphalt felt, free from holes and breaks, complying with ASTM D 226 for Type 1 felt or other approved water-resistive barrier shall be applied over studs or sheathing of all exterior walls."

Water-Resistive Barriers (WRB) Testing Requirements

- **Polymer sheets**
  - One of the "other approved water-resistive barriers"
  - ICC-ES Acceptance Criteria AC38
  - One of the older acceptance criteria
  - Very simple tests, easy to pass
    - Freezer paper from the grocery meets all requirements
  - Material characterization only – no performance testing
    - No tensile, tear, or puncture
    - No seam adhesion/integrity
    - Allowed to leak water under pressure

Water-Resistive Barriers (WRB) Testing Requirements

- **Liquid-applied**
  - One of the "other approved water-resistive barriers"
  - ICC-ES Acceptance Criteria AC212
  - One of the newest acceptance criteria
  - Very demanding tests, difficult to pass
  - Material and system performance testing
  - Not allowed to leak

Water-Resistive Barriers (WRB) Testing Requirements

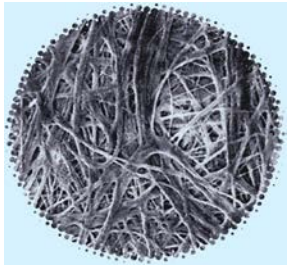
- **Liquid-applied Acceptance Criteria – AC212**
- **AC212 "Torture Testing"**
  - **Water-vapor Transmission: ASTM E96 Wet Method**
  - **Water-resistance: 14 days: 100 F, 100% RH condensing vapor**
  - **Tensile Bond: to multiple substrates & flashing materials**
  - **Freeze-thaw: 10 Cycles (8 hr at 120 F, 8 hr in water, 16 hr at -20 F)**
  - **Structural, Racking and Restrained Environmental Conditioning:**
    - 8' x 8' panel with vertical and horizontal joints, evaluated for cracking
  - **Structural, Racking and Restrained Env. Cond. And Water Penetration**:
    - Must not crack or leak with 2.86 psf air pressure difference w/ water spray
  - **Weathering:** (samples include joint treatment)
    - 21 days (10 hrs/dry) concentrated UV exposure at 140 F
    - 25 days: 3 hrs at 120 F, 3 hrs water soak, 18 hrs air drying
    - Hydrostatic pressure test: 22 inches of water- 5 hours, must not leak (>200 mph wind)

Water-Resistive Barriers (WRB) Technology & Chemistry

- Water Transmission through walls
  - Through Holes (macro or micro)
    - Liquid, i.e. a leak
    - Vapor in bulk air movement, i.e. infiltration & exfiltration
  - Through Solids (molecular porosity)
    - Liquid by capillarity
    - Vapor by diffusion - Permeance

Water-Resistive Barriers (WRB) Technology & Chemistry

- HDPE fine fiber network – microscopic porosity
- Surface tension of pure water prevents leaks
- Surfactants reduce surface tension and let water leak through holes
- Water vapor can always go through the holes



Typical fiber diameter 1 – 10 µm (10^{-6} m)

Water-Resistive Barriers (WRB) Technology & Chemistry

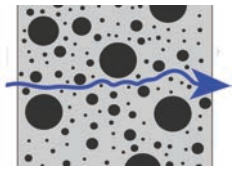
Figure 1

- "non-wetable" surface
- water repellant surface
- hygrophobic surface
- water more attracted to itself than to surface
- surface energy of water greater than surface energy of surface
- water "beads up"
- "greasy" surface
- high contact angle "θ"

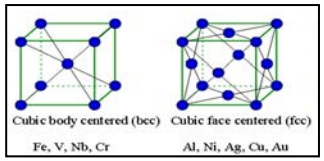
- "wetable" surface
- non-water repellant surface
- hygroscopic surface
- water more attracted to surface than itself
- surface energy of surface greater than surface energy of water
- water "spreads up"
- "non-greasy" surface
- low contact angle "θ"

Liquid-Applied WRB Technology & Chemistry

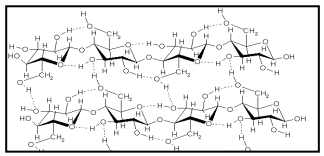
- Polymer/asphalt membrane – molecular porosity only (diffusion)
- There are no holes to allow liquid water leaks
- Surfactants have no effect, no holes – no water leaks
- Water vapor goes through the polymer molecular 'pores' without holes
  Ex: a balloon



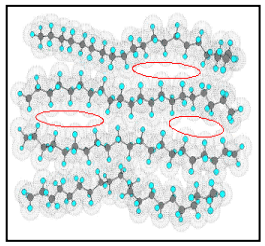
Liquid-Applied WRB Technology & Chemistry



Crystalline – metal examples



Highly crystalline polymer–low free volume



Amorphous polymer–more free volume

Images: www.subtech.com, University of Cambridge, The Nippon Synthetic Chemical Industry Co

Liquid-Applied WRB Technology & Chemistry

- Molecular Level Permeance
  - Molecular free volume
  - Chain branches and cross-linking hinders
- Diffusing molecules
  - Size matters:
    - H_2O ~ 1.7 Å, O_2 ~ 2.9 Å, N_2 ~ 3.2 Å **(1 x 10^{-10} m)**
  - Velocity matters:
    - statistically distributed
    - temperature dependent
  - Concentration matters (net vapor pressure)
  - Water Vapor: Phychrometric chart/app for vapor pressure

Liquid-Applied WRB Application & Details

- A system is fundamentally better if it's more
  - Simple
  - Repeatable
  - Reliable
  - Lasting

Liquid-Applied WRB Application & Details

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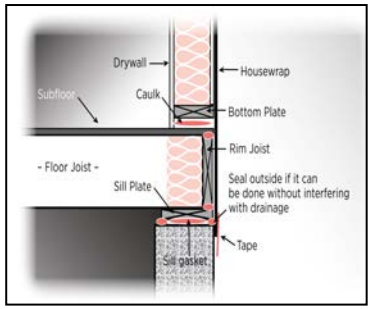

Interior Sealing: Rim & Band Joists

Air Sealing, Building America Best Practice Series, PNNL & ORNL, 2010

Liquid-Applied WRB Application & Details

• Liquid-applied - moisture and air control - the next generation in wall moisture and air control

DuPont

Liquid-Applied WRB Application & Details

- Liquid-applied - moisture and air control

(Enviro-Dri)

(Sto)

Liquid-Applied WRB Application & Details

- Exterior simple geometry
- Simple repeatable application
- Power roll or spray
- Application Temperature: 0 to 130 °F
- Rapid cure: minutes to a few hours
- Fits typical construction schedule
- After framing, generally before roofing

Liquid-Applied WRB Application & Details

Liquid-Applied WRB Application & Details

Water-Resistive Barriers (WRB) Benefits

- Air- and water-barrier in one application
- More reliable, lower air infiltration
  - reliably meet < 3.0 ACH50
- Beneficial energy performance trade-offs
- Enhanced moisture protection
  - Fully and permanently attached protection during/post construction
  - Permeable for effective vapor transport
  - Simple, uniform exterior protection plane
- Less complexity – more reliability

Water-Resistive Barriers (WRB) Benefits

Water-Resistive Barriers (WRB) Benefits

Sheet-applied protection during and after construction

Water-Resistive Barrier Benefits
Permeability and Air Leakage

Beneficial Energy Trade-offs

Equal $ Energy Savings Insulation vs. ACH_{50}		
Ceiling R-value R-38 to R-49	or	**ACH_{50}** 3.0 to 2.8
Frame Wall R-value R-15(2x4) to R-20(2x6)	or	**ACH_{50}** 3.0 to 2.1
R-20(2x6) to R-20(2x6)+R-5	or	3.0 to 2.2
Window U-value U 0.35 to U 0.32	or	**ACH_{50}** 3.0 to 2.7

To Avoid Ceiling+Wall or Ceiling+Window Costs, Reduce ACH_{50} from 3.0 to 1.8 - 2.0

Water-Resistive Barrier Benefits
Permeability and Air Leakage

- **Better Moisture Protection and Air Leakage Control**
- ***Uncontrolled air movement can introduce over 100 times the moisture into walls than diffusion!***
- **Moisture Control Priorities**
  - Stop liquid water leaks – follow instructions, details
  - Stop uncontrolled air movement
  - Maintain permeability for drying incidental moisture
  - Wood frame construction –(*hygric buffering*)
- **Is it Too tight? In what sense?**
  - Uncontrolled air movement: the goal is zero
  - Vapor diffusion: prudent for more forgiving walls

Water-Resistive Barrier Benefits
Permeability and Air Leakage

- **More predictable moisture dynamics**
- **Stop the air; only diffusion is left**
- **Conditions for vapor diffusion**
  - Water vapor pressure difference
    - **Net** vapor flow is **always** from high to low water vapor pressure
  - Vapor permeable transmission medium
    - Vapor can flow through permeable solid materials
- **Factors that Determine Amount and Rate**
  - Size of the vapor pressure difference
    - Determined by temperature and humidity differences
  - Permeability of the material
    - Many values are strongly humidity dependent

Water-Resistive Barrier Benefits
Permeability and Air Leakage

- **What amount flows in what length of time?**
- **Equation for vapor transport**
- **$W = 0.000053 * A * P * T * \Delta VP$**

  W = weight of water (pounds)
  A = transport area (ft^2)
  P = permeability of transport medium (US perms)
  T = time (hours)
  ΔVP = difference in vapor pressure of water vapor in inches of mercury
- **P and ΔVP values change with Temp and RH**

Performance and Models
Comments and Cautions

- 1-Dimensional Models
  - Dewpoint, seriously flawed and limited
  - WUFI 1-D, much better but still very limited
- 2-Dimensional Models
  - WUFI 2-D, better but still limited geometrically
- 3-Dimensional Models
  - Spreadsheet-based Quasistatic, very useful
  - NRC-CNRC, hyglRC-C fully 3D FEA, the real deal

Building Better Homes
Envelope Moisture and Air Control

Liquid-Applied
Weather-Resistant Barrier Systems

- Protection from foundation to roof line
- Code-approved water-resistive barriers
- The next generation in infiltration and moisture control
- Reliable lasting performance, during and after construction
- Helps builders to reliably obtain maximum value from their construction dollars

Awards

Project of the Year – The Puyallup Longhouse's the Place of Hidden Waters:
This LEED Platinum certified housing project is a culturally and environmentally responsive new model for the Puyallup Tribe in the Pacific NW.

StreetScape Development (Libertyville, IL) DOE Challenge Homes Winner, EPA Indoor airPlus

Dwell Development (Seattle, WA) DOE Challenge Winner, EPA Indoor airPlus

•Thank You

Sheet-applied WRB Performance and Issues

- **Even without installation issues, felt and wraps leak water**
- **Surfactants make wraps leak, that don't leak pure water**
  - Lowers the surface tension of water, flows through smaller spaces; an example is clean water vs. soapy water on car wax
  - Many sources: soluble resins from cedar, siding, paints, **stucco & mortar additives**, and power-washing
- **All wraps leaked through the sheet w/ "real-world" wetting**
  - **Wraps tested with 3.5" water solution for 2 hours (70 mph wind)**
  - Some wraps lost 10%, some 80% in 15 minutes, some 100% in 2 hrs (0 mph wind)
  - 15-pound felt lost 30%
  - Liquid-applied WRBs must pass 22" water column for 5 hours (NO Leaks)
- **Wraps also have water-condensing issue**
  - Hot sun drives water vapor through high-perm wrap,
  - Vapor trapped between wrap and lower perm sheathing condenses
  - Condensed water wets the sheathing but can't exit through wrap
- **http://bct.nrc.umass.edu/index.php/publications/by-title/housewraps-felt-paper-and-weather-penetration-barriers**

Liquid-Applied WRB Technology & Chemistry

Sheets or Adhesive Sheets: flexibility/conformability helps with contact area but has limits

Liquid & Fabric: Liquid flows into surface irregularities creating greater contact area and may create mechanical interlock