Intertek

Building Better Together.

Design Phase Building Envelope Commissioning

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Learning Objectives

- Understand the key attributes that dictate proper design based on the environment.
- Discuss common disconnects between MEP engineers, energy modelers and architectural design professionals and tactics for achieving success.
- Learn how to break down and evaluate drawings into isolated performance layers.
- Understand how initial and operating costs can be reduced based on efficient envelope design.
- Learn how to track design review comments to resolution.

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Successful Design

- Achieve environment separation
  - Understand the Environment
  - Prevent equilibrium
- Meet durability/sustainability requirements
- Fulfils desired use
- Simple
- Redundant
- Constructible

Environmental Separation

Building enclosures are designed to separate interior from exterior.

Understand the Environment

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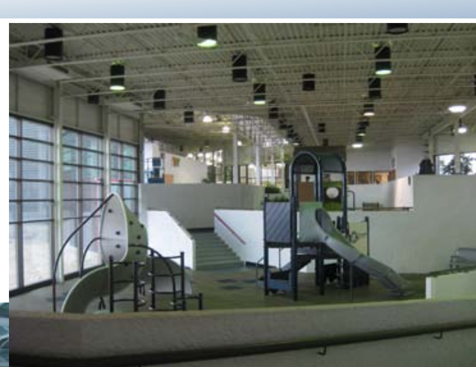
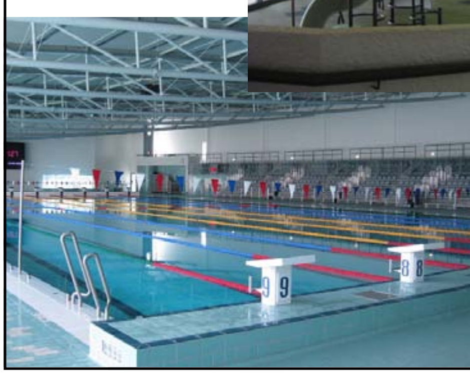
Understanding the Interior Ambient Conditions



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Understand the Environment

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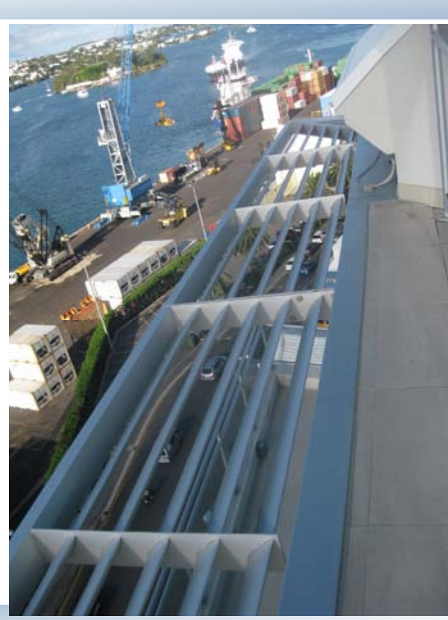
Shading



Understand the Environment

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Becx
becxverhuur.nl
24H service

Understand the Environment

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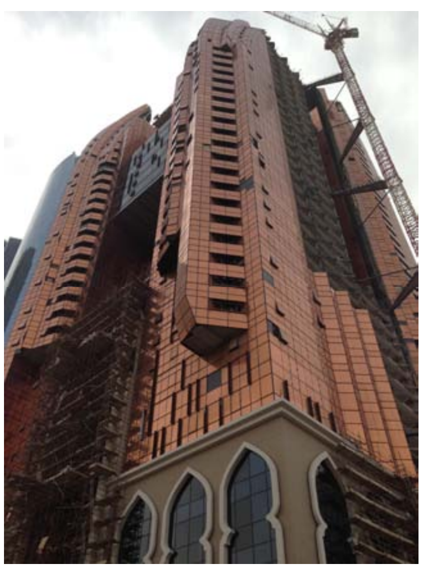
Understand the Environment



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Understand the Environment

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Understand the Environment

Consequence of Poor Environmental Separation

Consequence of Poor Environmental Separation

Successful Design

- Achieve environment separation
  - Understand the Environment
  - Prevent equilibrium
    - Understand Barriers/Code Requirements
- Meet durability/sustainability requirements
- Fulfils desired use
- Simple
- Redundant
- Constructible

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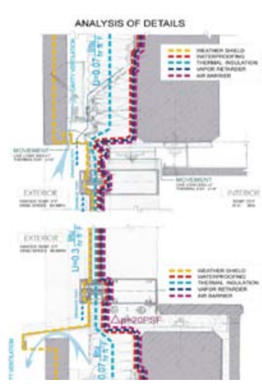
Create Environment Separation

Building enclosures are designed to control multiple loadings.

Control layers include:

1. Water control layer
2. Air control layer
3. Vapor control layer
4. Thermal control layer
5. Acoustical
6. Fire



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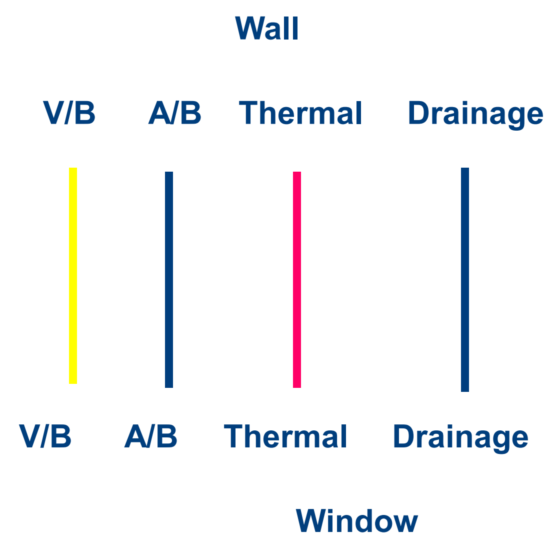
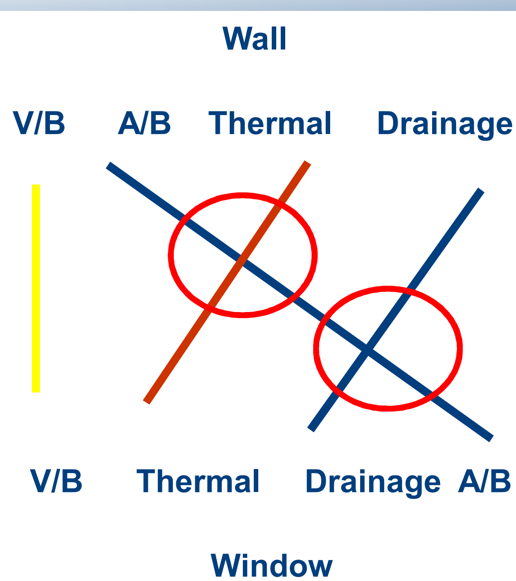
Create Environment Separation



Create Environment Separation



Common Elements

Sources: NIBS www.wbdg.org; nexusfocus.com; www.greenbuildingadvisor.com; www.wbdg.org; www.huggettbetten.com

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Fluid-Applied

- Asphalt
- Acrylic
- STPE
- Silicone

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Self-Adhered Sheet

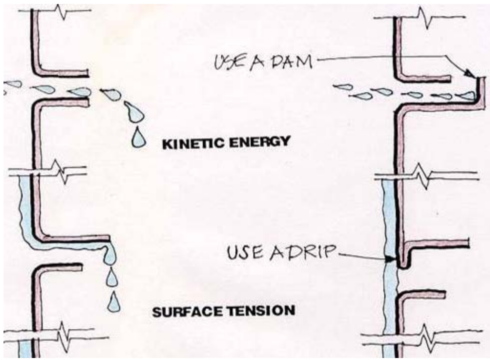
May include:

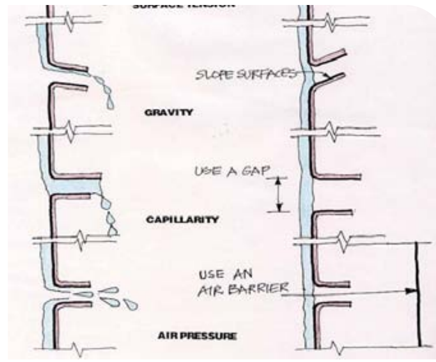
- Rubberized asphalt
- Cross-laminated HDPE film
- Polypropylene
- Other polymers

Other

- Board
- Spray polyurethane foam
- Insulated metal wall panels

Modes of Bulk Water Transport





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Energy Usage vs. Air Leakage

2007:

US Army Corps of Engineers

Air barrier material air permeance not to exceed 0.004 cfm/ft^2 at 0.3” wg (1.57 psf) (0.02 L/sm^2 @ 75 Pa)

Whole building’s air leakage rate must not exceed 1.25 L/sm^2 @ 75 Pa (0.25 cfm/ft^2 at 1.57 psf) when tested according to ASTM E779

TABLE 2. AIR TIGHTNESS STANDARDS COMPARISON (FOR A FOUR-STORY BUILDING, 120 x 110Ft., N=0.65)			
Country	Source	Requirement*	Cfm/sq.ft. at 75 Pa.
U.S.	ASHRAE 189.1-2009		0.40
UK	TS-1 Commercial Best Practice	5 m3/h/m2 at 50 Pa.	0.36
U.S.	LEED	1.25 sq. in. EqLA @ 4 Pa. / 100 sq. ft.	0.30
Germany	DIN 4108-2	1.5 1/h at 50 Pa.	0.28
UK	TS-1 Commercial Tight	2 m3/h/m2 at 50 Pa.	0.14
Canada	R-2000	1 sq. in. EqLA @10 Pa. /100 sq. ft.	0.13
Germany	Passive House Std	0.6 1/h at 50 Pa.	0.11

*USACE requirement is 0.25 cfm/sq. ft. at 75 Pa.

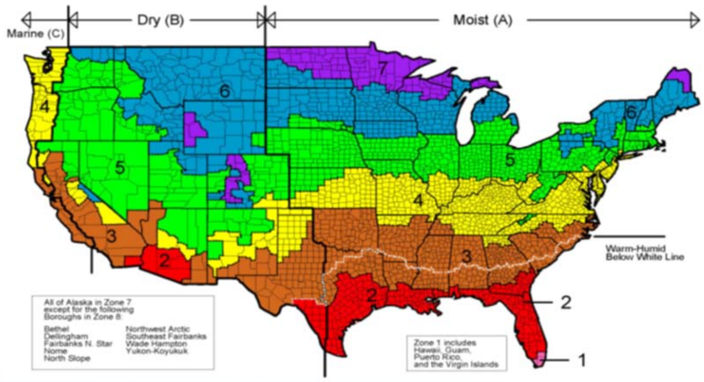
Credit: Journal of Building Enclosure Design Summer 2011 "Improvement of Air Tightness in U.S. Army Buildings" pgs. 11-13

	IECC	ASHRAE
Continuous AB	✔	✔
Continuous AB in Zones 1-3 (Southern States)		✔
Continuous AB in Semi-heated spaces	✔	
Construction Document Requirements		✔
Materials: air permeability ≤0.004 cfm/ft^2	✔	✔
Assemblies: air permeability ≤0.04 cfm/ft^2	✔	✔
Whole Building: air permeability ≤0.4 cfm/ft^2	✔	
Joints/seams resist negative/positive pressure	✔	✔
Joints, seams, transitions, and penetrations sealed	✔	✔
Fenestration Air Leakage Requirements	✔	✔
Door Air Leakage Requirements	✔	✔
Vestibule Requirements	✔	✔

New Air Leakage Requirements

Continuous Air Barrier shall be provided

- **IECC: except Zones 1-3**
- **ASHRAE: except semi-heated spaces in Zones 1-6**



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Fenestration Air Requirements

TABLE C402.4.3
MAXIMUM AIR INFILTRATION RATE
FOR FENESTRATION ASSEMBLIES

FENESTRATION ASSEMBLY	MAXIMUM RATE (CFM/FT²)	TEST PROCEDURE
Windows	0.20[a]	AAMA/WDMA/ CSA101/I.S.2/A440 or NFRC 400
Sliding doors	0.20[a]	
Swinging doors	0.20[a]	
Skylights – with condensation weepage openings	0.30	
Skylights – all other	0.20[a]	
Curtain walls	0.06	NFRC 400 or ASTM E 283 at 1.57 psf (75 Pa)
Storefront glazing	0.06	
Commercial glazed swinging entrance doors	1.00	
Revolving doors	1.00	
Garage doors	0.40	ANSI/DASMA 105, NFRC 400, or ASTM E 283 at 1.57 psf (75 Pa)
Rolling doors	1.00	

For SI: 1 cubic foot per minute = 0.47L/s, 1 square foot = 0.093 m^2.

a. The maximum rate for windows, sliding and swinging doors, and skylights is permitted to be 0.3 cfm per square foot of fenestration or door area when tested in accordance with AAMA/WDMA/CSA101/I.S.2/A440 at 6.24 psf (300 Pa).

IECC 2012

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What is an Air Barrier?

What is an Air Barrier?

Materials with air permeability ≤0.004 cfm/ft²

Compliant Materials

- Plywood ≥ 3/8 in. thick
- Oriented Strand Board ≥ 3/8 in. thick
- Extruded Insulation Board ≥ 1/2 in. thick
- Foil-back Insulation Board ≥ 1/2 in. thick
- Closed-cell spray foam (min. density of 1.5 pcf and thickness ≥ 1-1/2 in.)
- Open-cell spray foam with density 0.4-1.5 pcf and thickness ≥ 4-1/2 in.
- Exterior or interior gypsum board ≥ 1/2 in.
- Cement board ≥ 1/2 in.
- Built-up roofing membrane
- Mod-bit roofing membrane
- Fully-adhered single-ply roofing membrane
- Portland cement/sand parge or gypsum plaster ≥ 3/8 in. thick
- Cast-in-place or precast concrete
- Fully grouted concrete block masonry
- Sheet steel or aluminum

Not All Air Barriers are Equal

Stucco: Air Vs. Flashing Requirements

- **Considered air barrier per C402.4.1.2.2**
- **Must be flashed per 1405.4 IBC 2012**
  - **Weeps in assembly compromise air performance of assembly**

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HVAC or building Envelope?

Air intake, but interior room forms the duct.

Floor is waterproofed with roofing membrane.

Room hemorrhages air.

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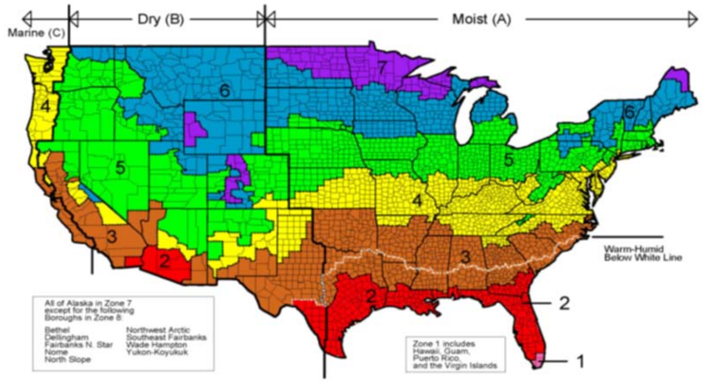
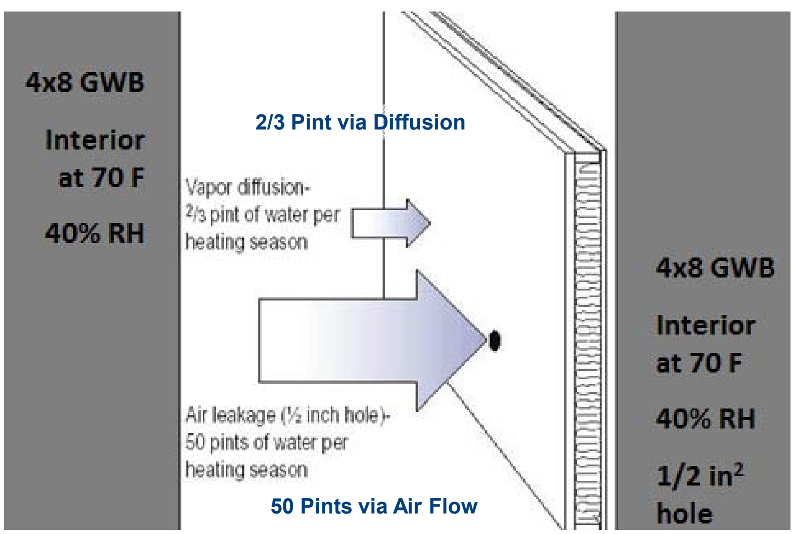
Vapor Barriers

Per IBC 2012

- Class I or II vapor retarders provided on interior side of frame wall in Zones 5-8 and Marine 4
- Class III permitted conditionally



Moisture Transport



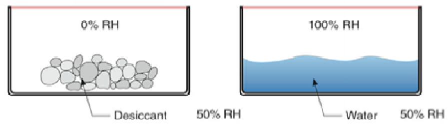
Vapor Retarder Class (IBC)

VAPOR RETARDER CLASS. A measure of a material or assembly's ability to limit the amount of moisture that passes through that material or assembly. Vapor retarder class shall be defined using the desiccant method of ASTM E 96 as follows:

Class I: 0.1 perm or less.

Class II: 0.1 < perm ≤ 1.0 perm.

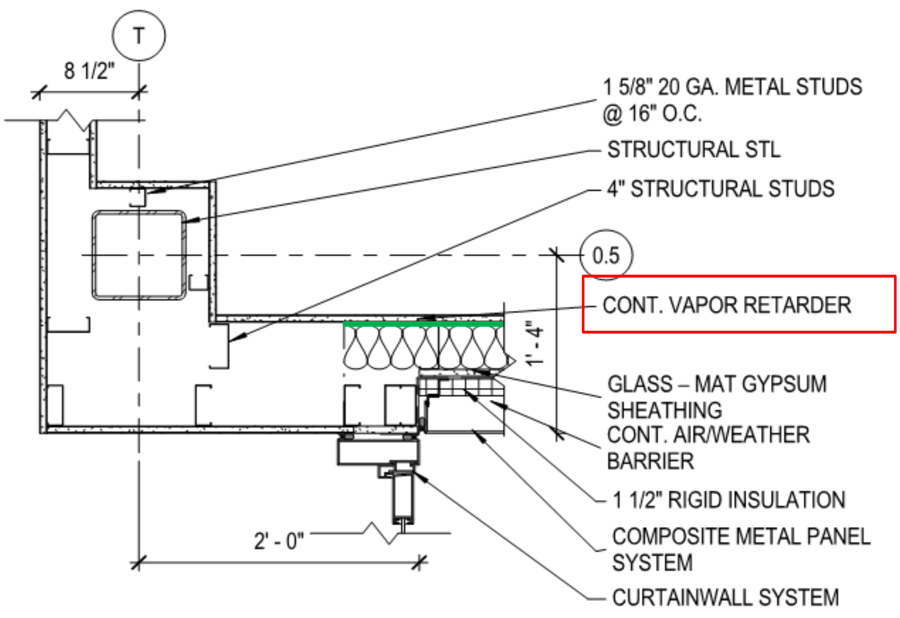
Class III: 1.0 < perm ≤ 10 perm.



ASTM E96

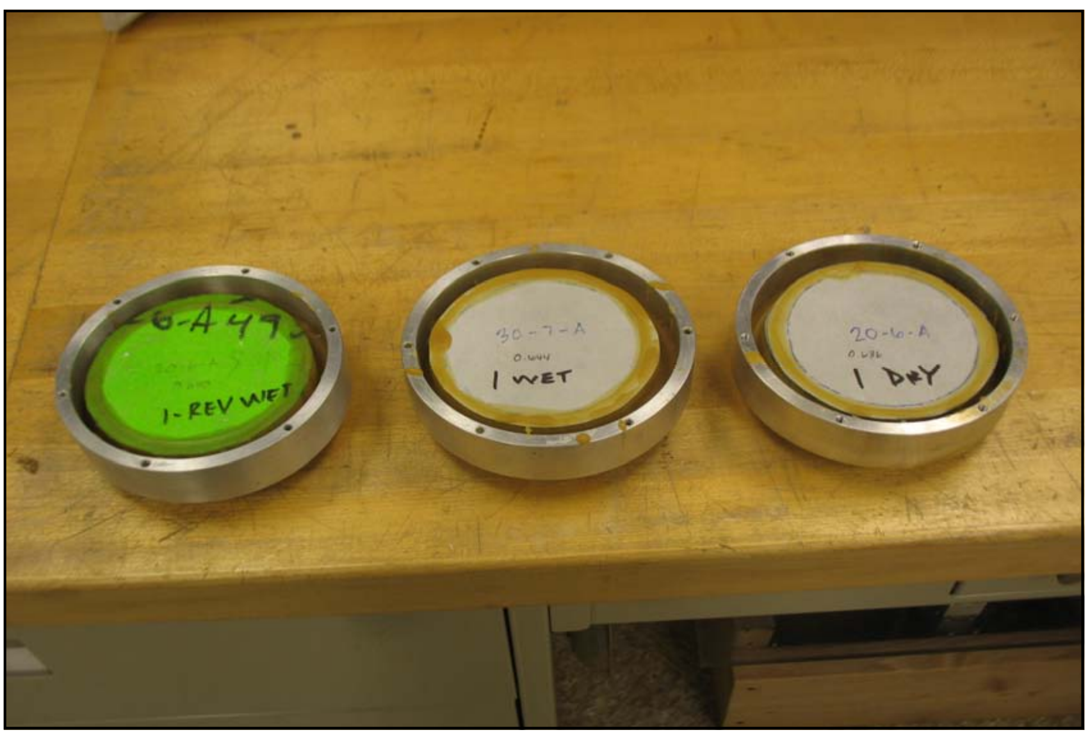
Wet Cup

Dry Cup

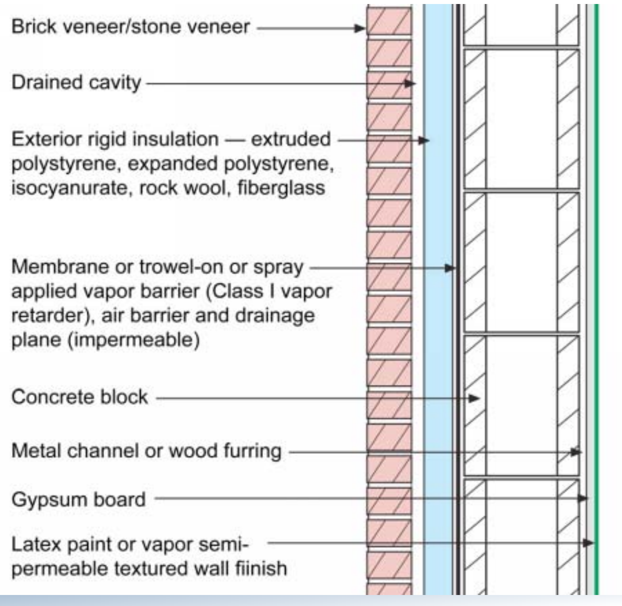


DETAIL


Blueskin


1-REV WET
30-7-A
0.444
1 WET
20-6-A
1 DRY

Enclosure Design



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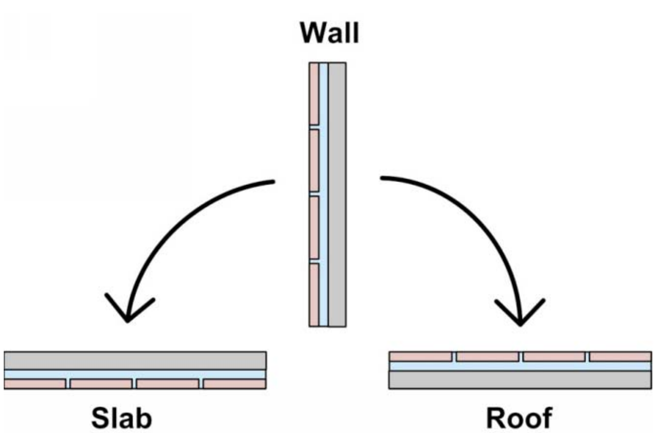
Enclosure Design



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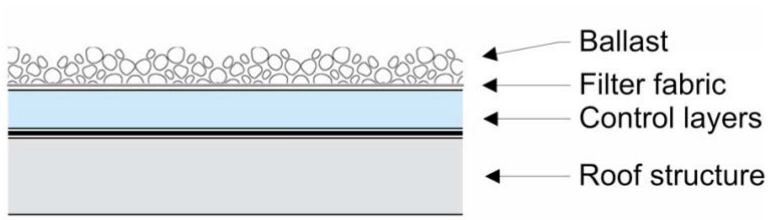
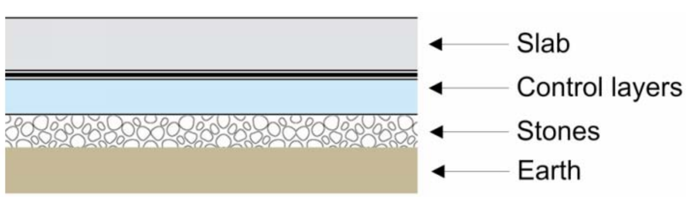
Enclosure Design



Enclosure Design



Successful Design

- Achieve environment separation
- Meet durability/sustainability requirements
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Require Letters of Compatibility

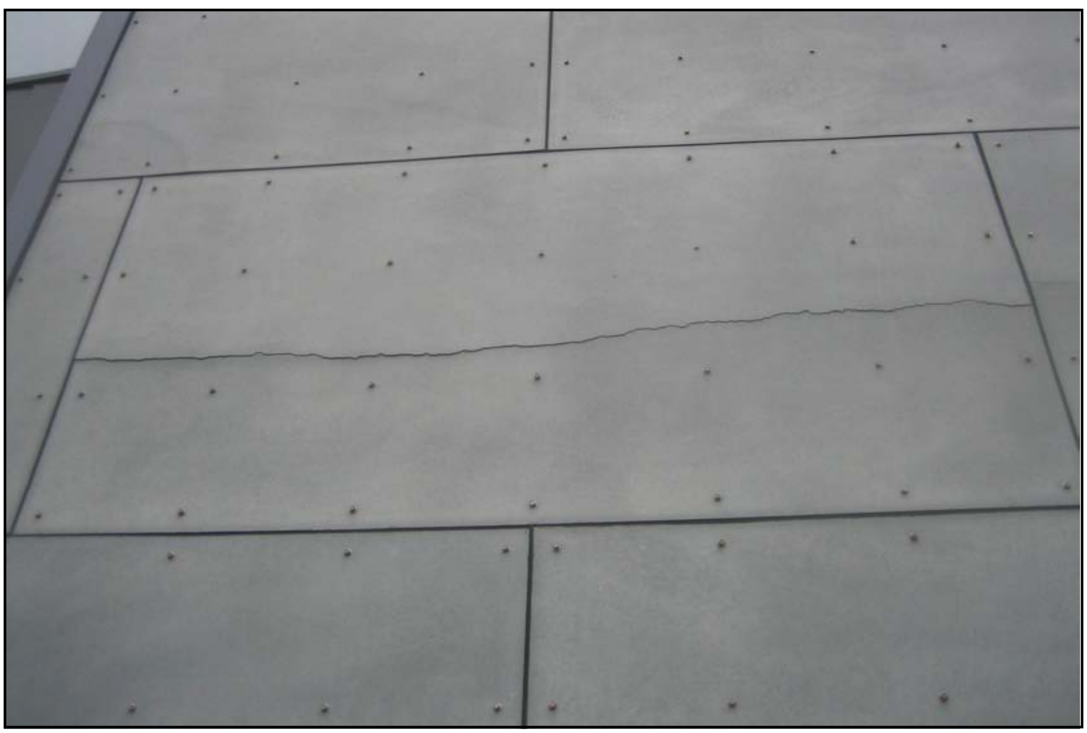
You would think two sealants made by the same MFG would not turn color.

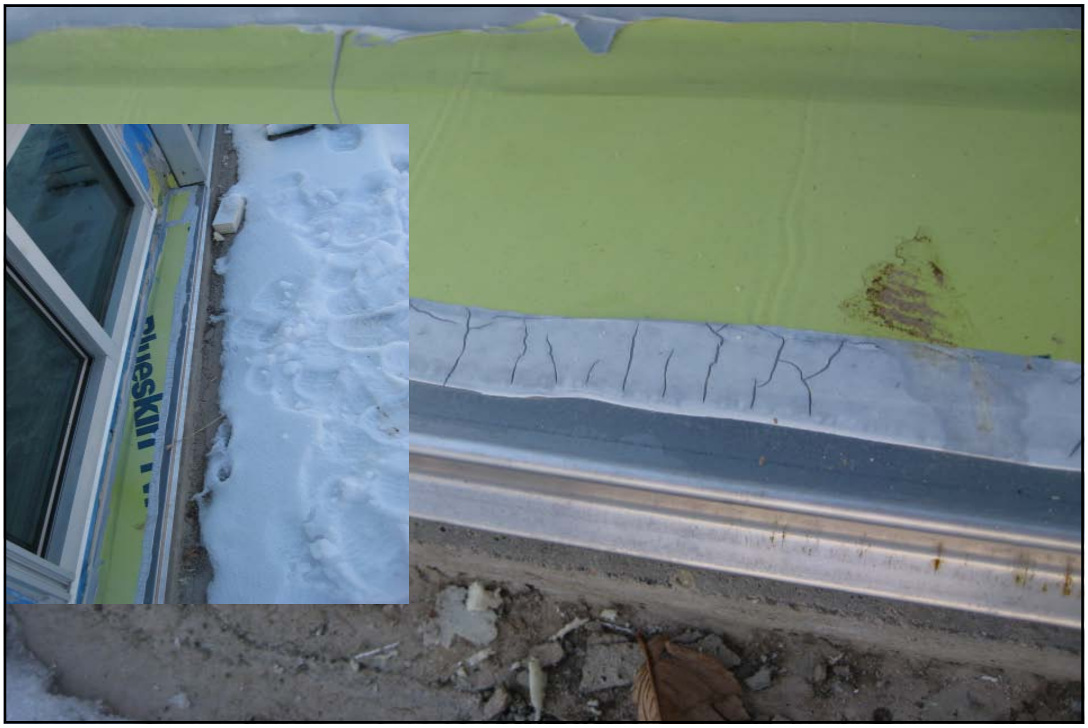
Clear silicone turns yellow when exposed to light. White turns yellow when exposed to clear!

Identify Compatibility Concerns in the Design

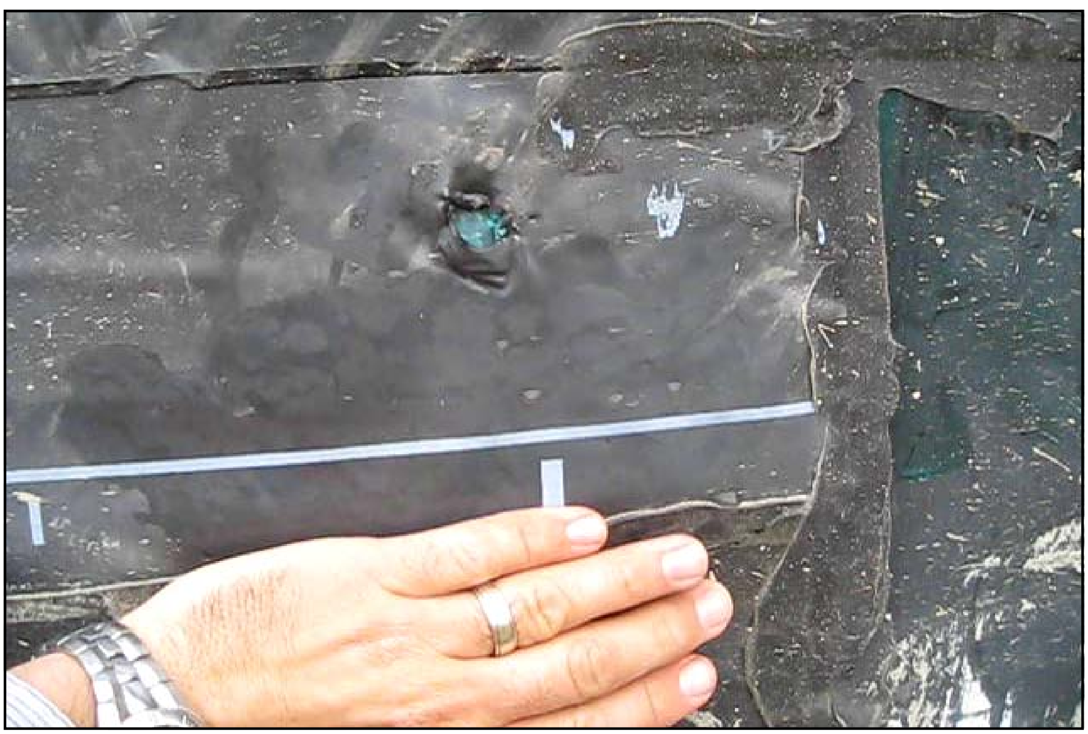
Example of staining due to leading edge of asphaltic membrane touching the sealant.

Installer was warned to hold back the leading edge and ignored it.






Material Selection



Sustainability Drivers

Successful Design

- Achieve environment separation
- Meet durability/sustainability requirements
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How Important are Aesthetics?

Successful Design

- Achieve environment separation
- Meet durability/sustainability
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Successful Design

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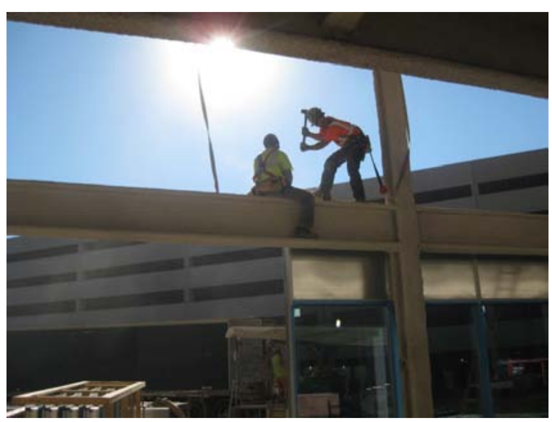

BECx Design Based Phases

- Programming
- Pre-Design
- Design

Energy Modeling & BECx

- Typically, performed in programing phase.
- Used to validate design and evaluation options.
- Scope of analysis is beyond MEP.
- Model comparison with actual performance is increasing.
- Most projects have modeling requirements.
- Modeling is dictating some design decisions.

eQUEST DOE-2 Carrier turn to the experts ENERGY STAR

Energy Modeling and BECx

Building envelope's energy contribution

Solar Heat Gain

U-Factor

Air Leakage

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Energy Modeling and BECx

Solar Heat Gain

<u>SHGC</u>
Transmittance
Reflectance
Absorbtance
Emittance

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Energy Modeling and BECx

BECx
- Overview
- **Pre-Design**
- Design
- Pre-constr.
- Construction
- O&M

Energy Modeling & BECx

ASHRAE Research Project Report RP-1365

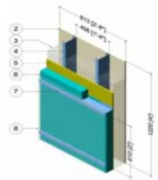
THERMAL PERFORMANCE OF BUILDING ENVELOPE DETAILS FOR MID- AND HIGH-RISE BUILDINGS

ASHRAE 1365-RP's objective was to provide thermal performance data of 40 common building envelope details for mid- and high-rise construction. The goal of the project was to develop procedures and a catalogue that will allow designers quick and straightforward access to information but with sufficient complexity and accuracy to reduce uncertainty in the thermal performance of building envelope components.

Energy Modeling & BECx

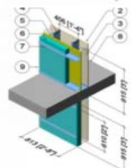
5.2 Thermal Transmittance

The basis of calculation and reporting of thermal transmittances is established by three categories of thermal anomalies as summarized below.



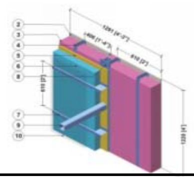
Clear Field Anomalies – thermal bridges uniformly distributed by a sufficient amount such that they can be assumed to modify the thermal transmittance of the assembly and are considered not practical to account for on an individual basis for whole building calculations.

Examples are brick ties, girts supporting cladding, and structural framing. A steel stud assembly with horizontal z-girts is shown to the left as an example.



Linear Anomalies – thermal bridges that are continuous and/or uniformly distributed typically along a considerable portion of a building perimeter or height in one dimension.

Examples are shelf angles, slab edges, balconies, corner framing, parapets, and window interfaces. A steel stud assembly with a structural concrete slab bypassing the wall assembly is shown to the left as an example.

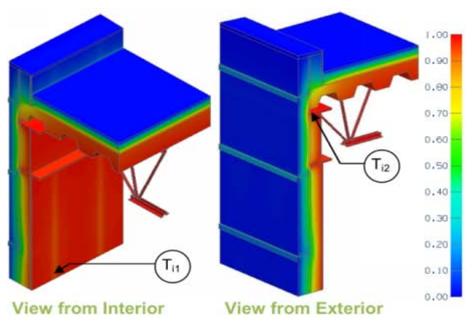


Point Anomalies – thermal bridges that are countable points and are considered feasible to account for on an individual basis for whole building calculations.

Examples are three way corners, structural steel penetrations through insulation, ducts. A steel stud assembly with a structural steel beam (to support a canopy, sign, etc.) bypassing the wall assembly thermal insulation is shown to the left as example.

Reference
ASHRAE 1365 RP

Energy Modeling & BECx



Thermal Performance Indicators

Assembly 1D (Nominal) R-Value	R_{1Dr}, R_{1Dw}	Two base assemblies : r = roof w = wall (Detail 11)
Transmittance / Resistance without Anomaly	U_{or} R_{or} U_{ow} R_{ow}	"clear field" U- and R-values. Separate values presented for the two base assemblies
Surface Temperature Index[1]	T_i	0 = exterior temperature 1 = interior temperature
Linear Transmittance	ψ	Incremental increase in transmittance per linear length of parapet

[1]Surface temperatures are a result of steady-state conductive heat flow with constant heat transfer coefficients. Limitations are identified in final report.

Nominal (1D) vs. Assembly Performance Indicators

Base Assembly – Wall

Wall Exterior Insulation 1D R-Value (RSI)	R_{1D} $ft^2 \cdot hr \cdot {}^oF$ / Btu (m^2 K / W)	R_{ow} $ft^2 \cdot hr \cdot {}^oF$ / Btu (m^2 K / W)	U_{ow} Btu/$ft^2 \cdot hr \cdot {}^oF$ (W/m^2 K)
R-5 (0.88)	R-19.2 (3.38)	R-13.40 (2.36)	0.075 (0.42)
R-10 (1.76)	R-24.2 (4.26)	R-16.28 (2.87)	0.061 (0.35)
R-15 (2.64)	R-29.2 (5.14)	R-18.49 (3.25)	0.054 (0.31)
R-20 (3.52)	R-34.2 (6.02)	R-20.50 (3.61)	0.049 (0.28)
R-25 (4.40)	R-39.2 (6.90)	R-22.14 (3.90)	0.045 (0.26)

Base Assembly – Roof

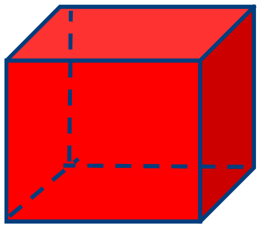
R_{1D} $ft^2 \cdot hr \cdot {}^oF$ / Btu (m^2 K / W)	R_{or} $ft^2 \cdot hr \cdot {}^oF$ / Btu (m^2 K / W)	U_{or} Btu/$ft^2 \cdot hr \cdot {}^oF$ (W/m^2 K)
R-21.2 (3.74)	R-21.0 (3.69)	0.048 (0.27)

Reference ASHRAE 1365 RP

Energy Modeling & BECx

Whole building air test results (ASTM E 779) are expressed as air flow through the wall, roof, and floor, not just the façade.

CFM/SF rates must be adjusted accordingly (sometimes doubles flow the flow rate).



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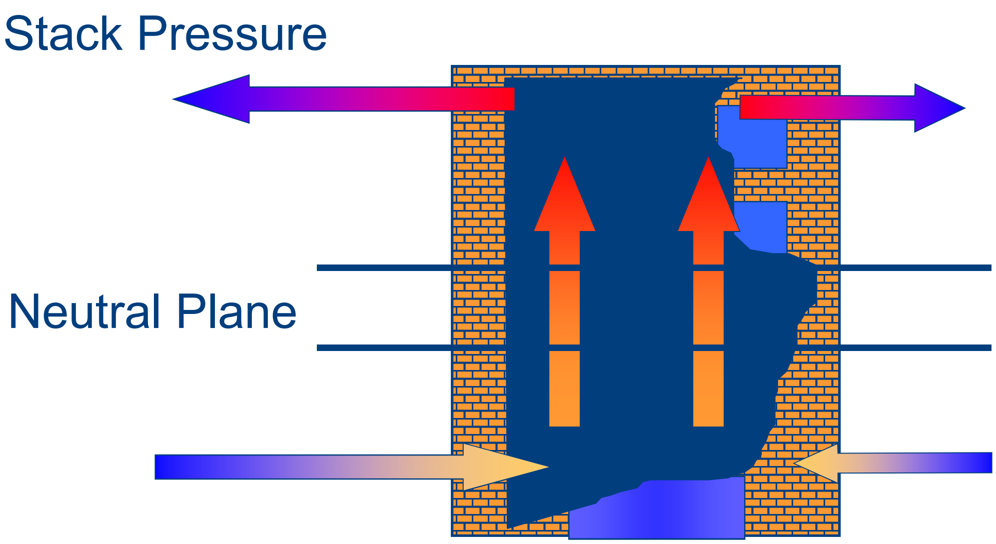
What about Stack Effect?



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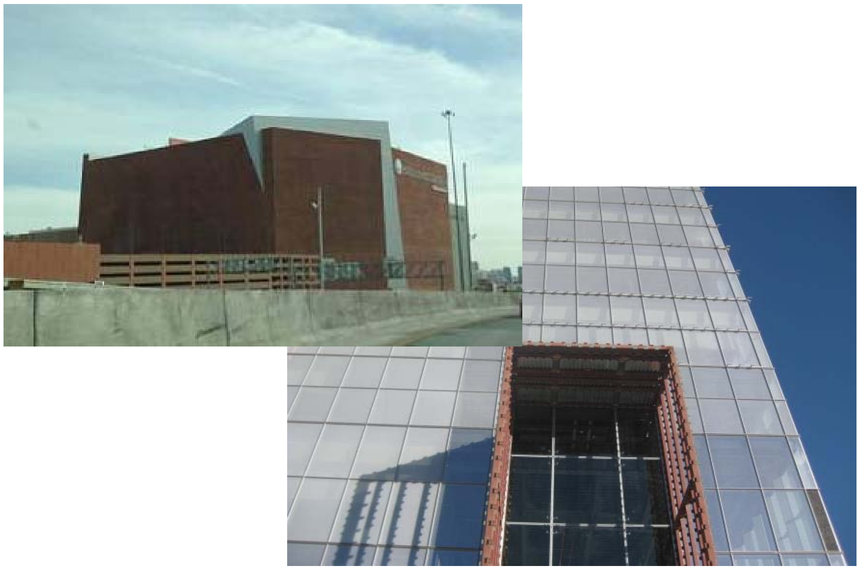
Window to Wall Ratio

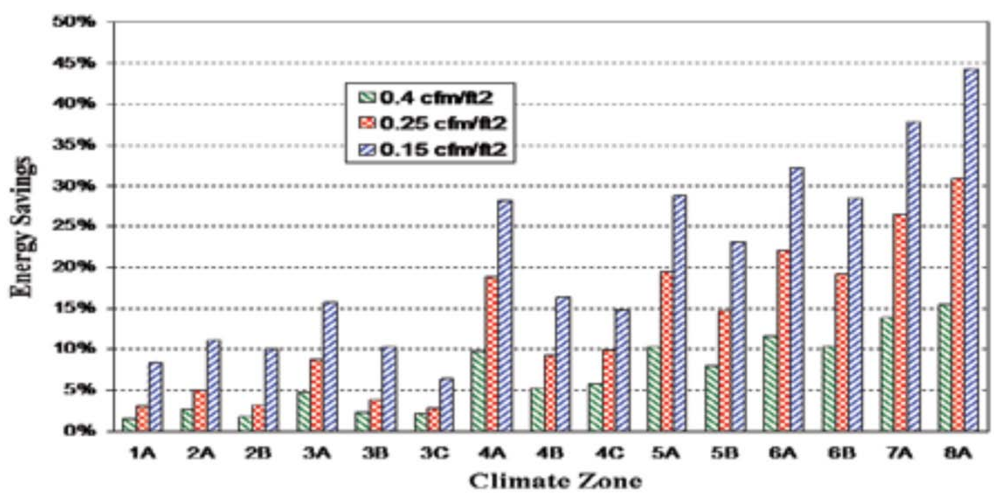


Oak Ridge National Lab - Study

Finding relating to energy modeling and air leakage:

- Current modeling software, such as Energy Plus, doesn't do a good job at accounting for energy loses due to air leakage.
  - Calculations are based on conductive losses that show smaller temperature changes than the rapid temperature changes due to air leakage.
  - There is no interactive term within simulation tools and the magnitude of this term is currently unknown.
- Current models appear to underestimate the energy loss due to air leakage.
- Past studies focus on lower R-value walls (minimizes energy loss due to leakage compared to higher R-values).

Energy Usage vs. Air Leakage

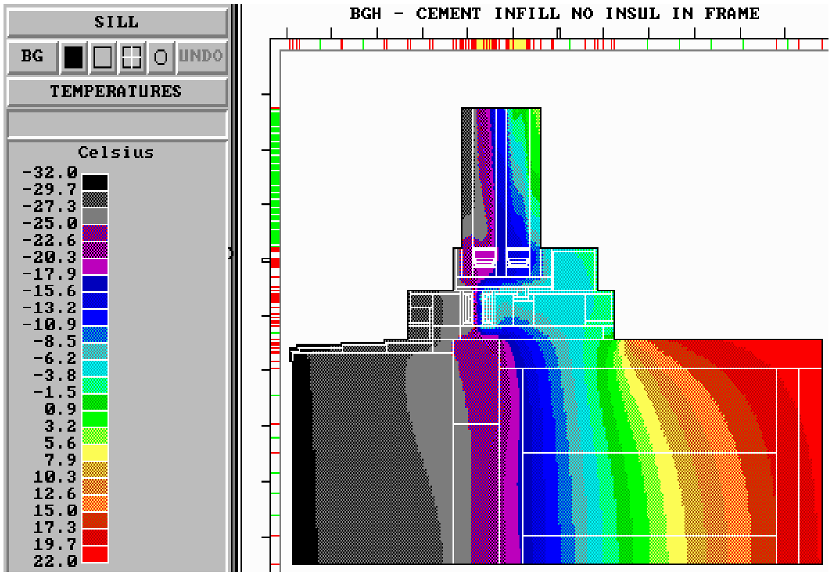


Credit: Journal of Building Enclosure Design Summer 2011 "Improvement of Air Tightness in U.S. Army Buildings" pgs. 11-13

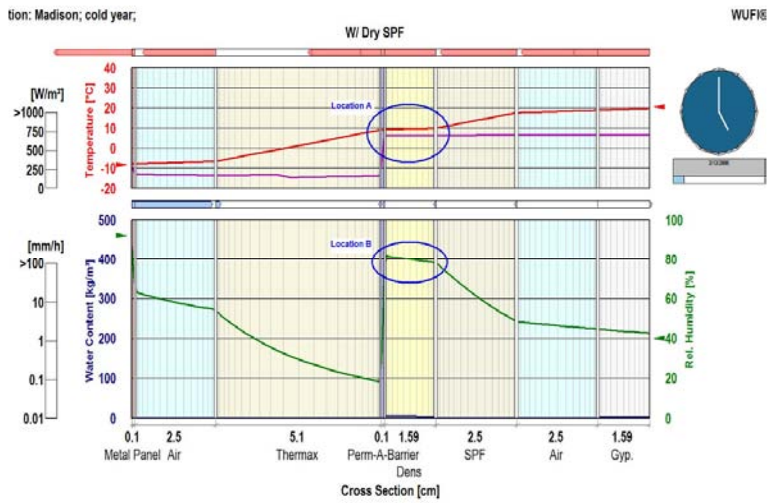
Pre-Design Phase

- Work with Building Owner to develop Owner's Project Requirements (OPR)
- Evaluate design concepts against OPR and Architect of Record's design intent
- Perform hygrothermal computer modeling (WUFI & Therm)
- Basis of Design
- Development and acceptance of initial Commissioning Plan

Thermal Modeling



Enclosure Design



Enclosure Design

DATE:
FILE:

PROJECT:
SUBJECT:
LOCATION:
WALL:

Inside Temperature (T_{inside}):	72	°F
Outside Temperature ($T_{outside}$):	0	°F
Relative Humidity (Φ):	38	%

Total Wall R-Value (R_{tot}) =	23.869	h-ft²-°F/Btu
Total Wall U-Value (U_{tot}) =	0.04	Btu/h-ft²-°F
Heat Flow (Q) =	3.02	Btu/h-ft²
Dew Point Temperature (T_{dp}) =	44.99	°F

Wall Sections

Description	R-Value	T_o (°F)	T_i (°F)	Φ_{max} (%)
Outside Air Film	0.17	0.0	0.5	5.8
1/2" UHPC panel	0.104	0.5	0.8	5.9
Air Space	1.2	0.8	4.4	7.0
2" mineral wool insulated sheathing	7.875	4.4	28.2	19.6
Vapor Barrier	0	0.8	28.2	19.6
7/16" OSB	0.62	28.2	30.1	21.1
10" mtl studs w/2" cell spray-on	12.66	30.1	68.3	88.0
5/8" gyp board	0.56	68.3	69.9	93.3
Inside Air Film	0.68	69.9	72.0	100.0

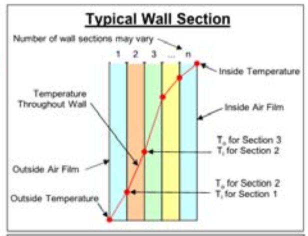
Notes

1. Φ_{max} is the relative humidity at which condensation may occur on the inside surface of the wall section.
2. The Φ_{max} value appears red if it is lower than the room humidity and there is no "Vapor Barrier" between the section inside surface and the inside of the room. This indicates there may be condensation in the wall on that surface.

Cell Color Legend

Information that must be input by the user.
Typical values that may be changed if needed.
Values that are calculated automatically.

Typical Wall Section



Formulas

$$Q = U_{tot}\left(T_{inside} - T_{outside}\right) \qquad U_{tot} = \frac{1}{R_{tot}}$$

$$R_{tot} = \Sigma R_{section}$$

All the temperatures in the following equations are in °C and are converted to/from °F as needed in this spreadsheet.

$$T_{dp} = \frac{237.7 \log\left(\frac{P_s \phi}{611}\right)}{7.5 - \log\left(\frac{P_s \phi}{611}\right)} \qquad \phi_{max} = \frac{P}{P_s}100$$

$$P_s = 6.11\text{x}10^{\frac{7.5T_{inside}}{237.7+T_{inside}}}$$ Saturated Vapor Pressure

$$P = 6.11\text{x}10^{\frac{7.5T_i}{237.7+T_i}}$$ Actual Vapor Pressure

Design Phase

- Review design against OPR and BOD
- Review construction sequencing and scheduling
- Write BECx and functional performance testing specifications
- Draft BECx plan

Design Phase

BECx Specification:

SECTION 019115
BUILDING ENCLOSURE COMMISSIONING REQUIREMENTS

PART 1 GENERAL

1.01 SECTION INCLUDES

A. The work under this Section is subject to requirements of the Contract Documents, including the Owner's General Conditions and articles of the Construction Manager's General Conditions.

B. This section includes the commissioning requirements for the Building Enclosure systems. Refer to Section 019117 for Building Enclosure Functional Performance Testing.

1. The commissioning requirements for the Building Enclosure systems given in this section are entirely separate from, and in addition to, the General Commissioning Requirements for this project. The General Contractor (GC), Subcontractors, and Suppliers are required to participate in both commissioning processes as required and any supplemental General Commissioning requirements.

1.02 DESCRIPTION

A. Building Enclosure Commissioning (BECx) is a systematic process of ensuring all building enclosure systems responsible for environmental separation perform interactively according

Design Phase

FPT Specification:

SECTION 019117
BUILDING ENCLOSURE FUNCTIONAL PERFORMANCE TESTING REQUIREMENTS

PART 1 GENERAL

1.01 SECTION INCLUDES

A. This section includes the functional performance testing requirements for the Building Enclosure systems. Refer to Section 019115 for Building Enclosure Commissioning Requirements

1.02 RELATED DOCUMENTS

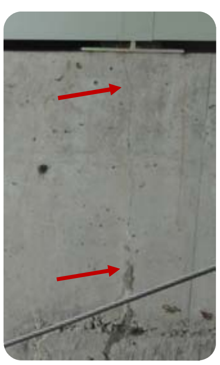
A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and other Division 01 Specification Sections, apply to this Section. Divisions 03, 04, 07, 08 and 09 Specification Sections also apply to this section. Where conflicts arise regarding building enclosure testing, this Section shall supersede other Sections where contradictions occur.

1.03 TESTING AGENCY

A. The Owner will retain a Building Enclosure Testing Agent (BETA), which may be the same entity as the Building Enclosure Commissioning Agent (BECA). In such cases, the BECA

Functional Performance Testing

Typical Failures:



Concrete cracks

Z-girt fasteners

Brick ties

Functional Performance Testing

Typical Failures:

Curtain wall gaskets

Perimeter seal

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Functional Performance Testing

Typical Failures:

Stem wall connection

Mullion intersection

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Functional Performance Testing

Typical Failures:

Unsealed holes

Roof-to-wall interface

Functional Performance Testing

Performance Requirements

- Building Enclosure Functional Performance Testing Specification Section
- This Section shall supersede other Sections where contradictions occur

Component	Performance Criteria: Air	Performance Criteria: Water
Curtain Wall/ Fenestrations/ Skylights	ASTM E 1186 (4.2.7) – No major air leaks. A major leak is defined as air and smoke are visible and easily detectable by hand within one inch of the leak location(s)	AAMA 501.1/ ASTM E 1105 - No uncontrolled water leakage when tested under a pressure difference of 8.0 lbf/sq. ft
	ASTM E 783 – Maximum air leakage of .09 cfm/ft at an air pressure differential of 6.24 psf	
Air Barrier Assemblies	ASTM E 1186 (4.2.6) – Pass/fail criteria shall be no bubbles observed in the leak detection liquid.	AAMA 501.1/ ASTM E 1105 - No uncontrolled water leakage when tested under a pressure difference of 8.0 lbf/sq. ft
	ASTM E 783 – Maximum air leakage of .04 cfm/ft at an air pressure differential of 1.57 psf	
	ASTM E 1186 (4.2.7) – No major air leaks. A major leak is defined as air and smoke are visible and easily detectable by hand within one inch of the leak location(s)	
Roofing Systems	ASTM E 1186 (4.2.6) – Pass/fail criteria shall be no bubbles observed in the leak detection liquid.	ASTM D5957 – No leaks through membrane/roof deck after 48 hours of 2.5" ponded water.

C. Water leakage is only acceptable if ALL of the following conditions are satisfied:

1. Water is contained and drained to the exterior.
2. There is no wetting of a surface that is visible to the building occupants.
3. There is would be no staining or other damage to the completed building or finishes.

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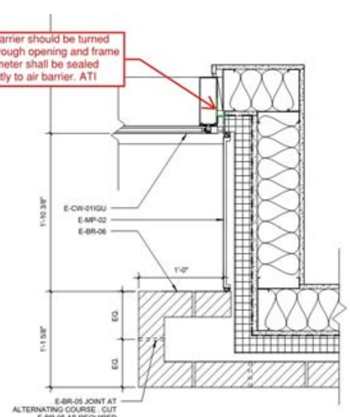
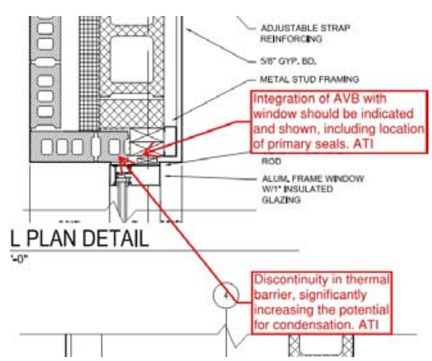
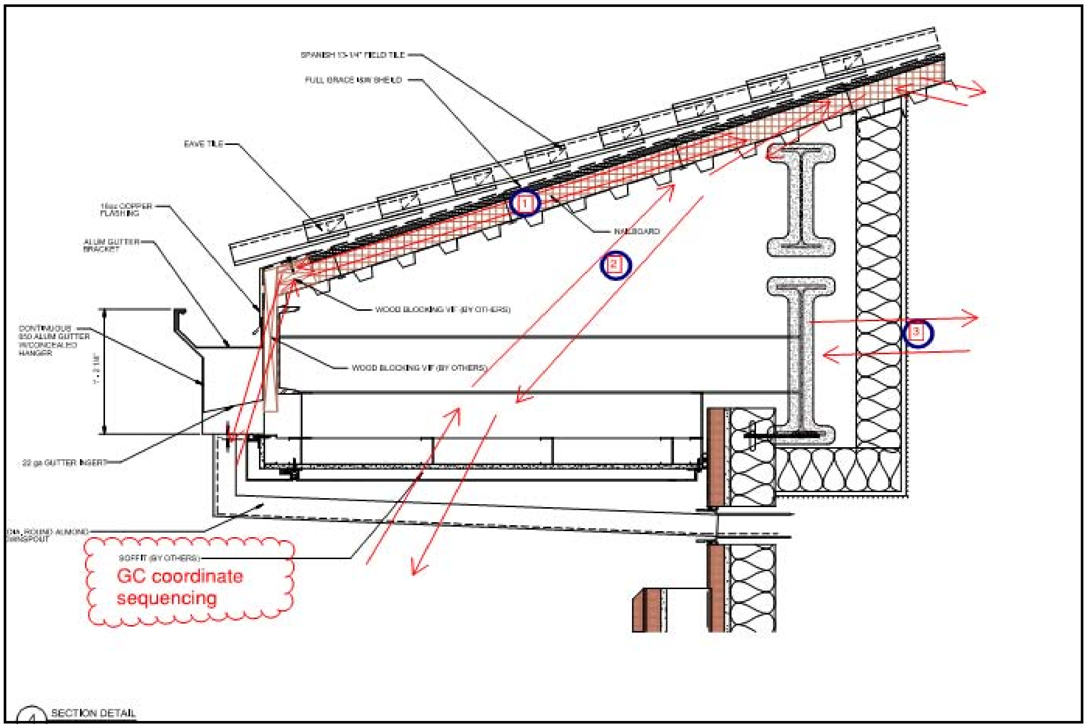
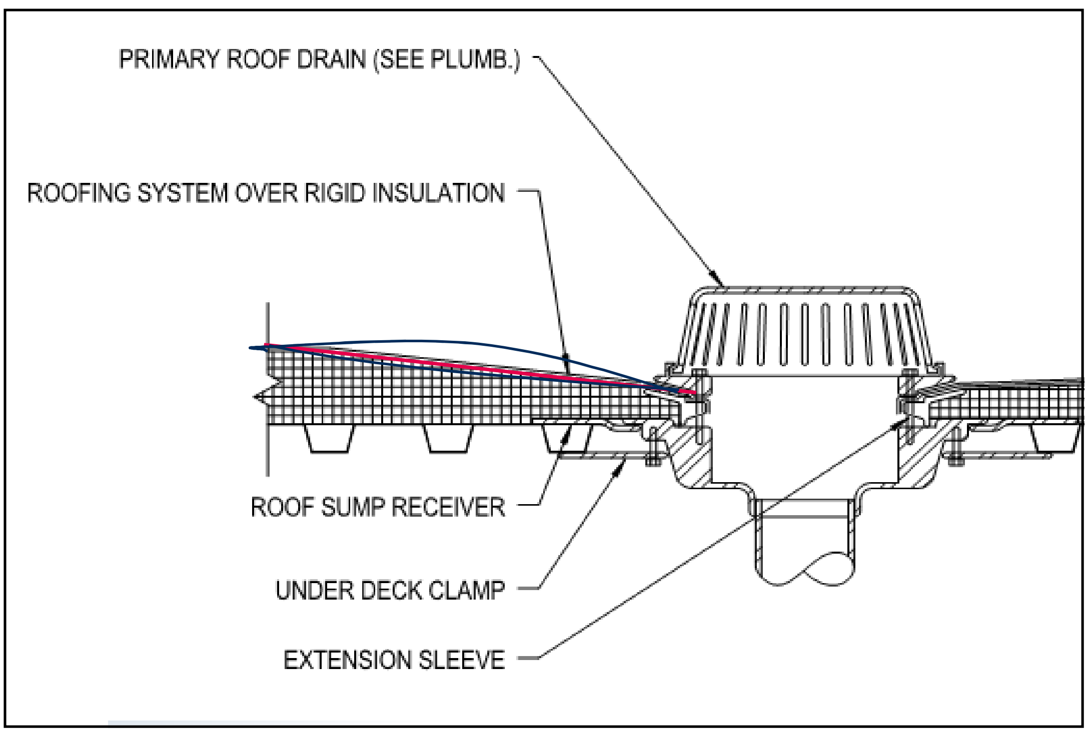
Design Phase

Design Review Examples:

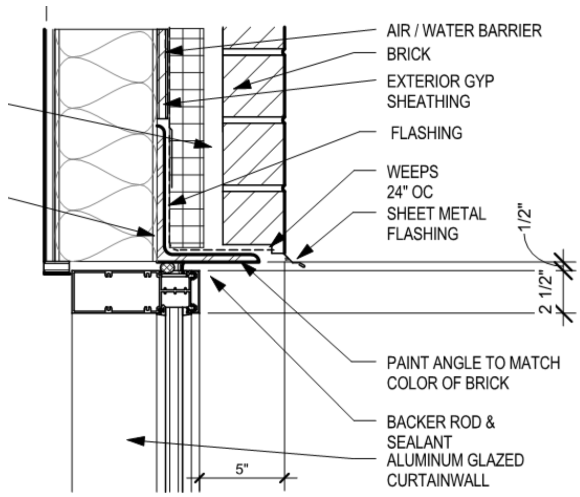





SPANISH 13-1/4" FIELD TILE
EAVE TILE
16oz COPPER FLASHING
ALUM GUTTER BRACKET
NAILBOARD
WOOD BLOCKING VIF (BY OTHERS)
WOOD BLOCKING VIF (BY OTHERS)
22 ga GUTTER INSERT
SOFFIT (BY OTHERS)
GC coordinate sequencing
1
2
3
SECTION DETAIL


PRIMARY ROOF DRAIN (SEE PLUMB.)
ROOFING SYSTEM OVER RIGID INSULATION
ROOF SUMP RECEIVER
UNDER DECK CLAMP
EXTENSION SLEEVE

Head Detail



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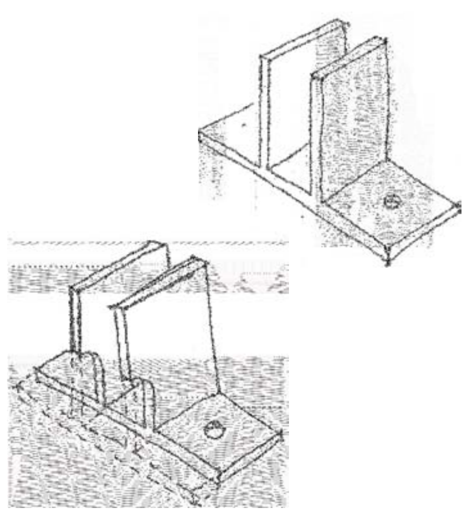
Typical Interface Concerns



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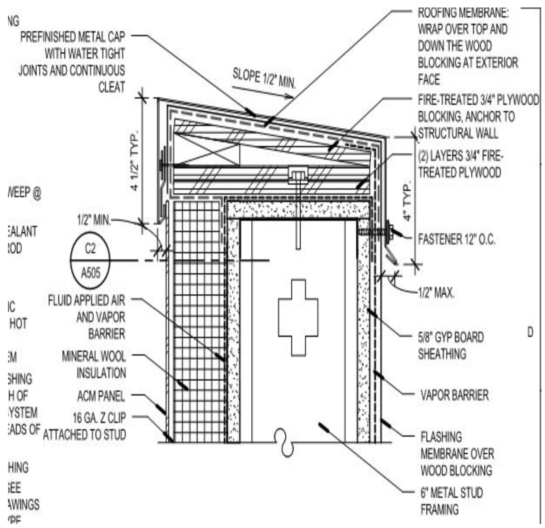
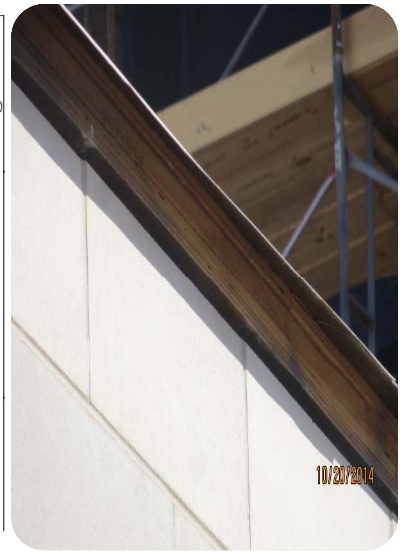
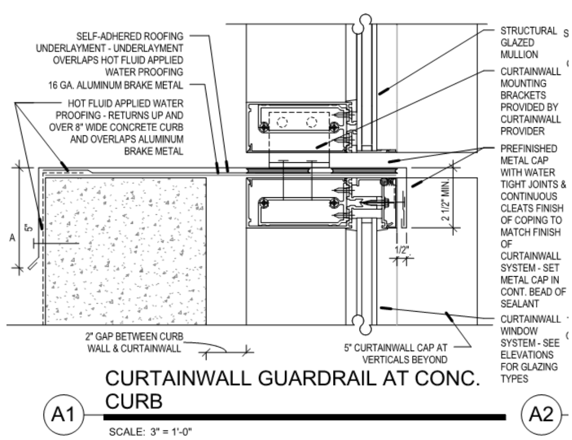
Parapet Cap

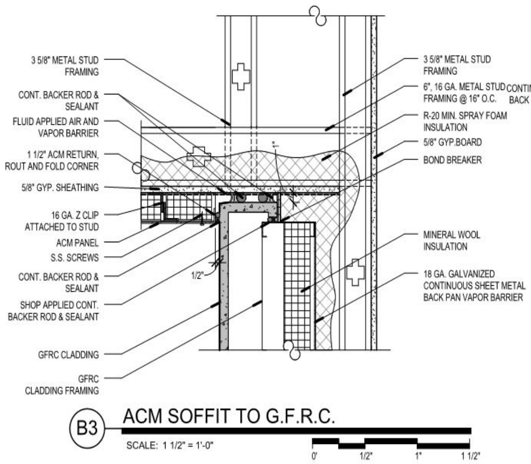




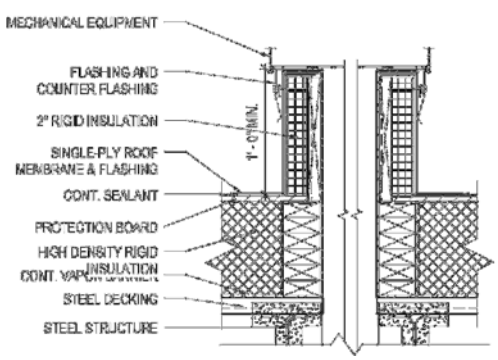
Extended Curtain Wall



Soffits



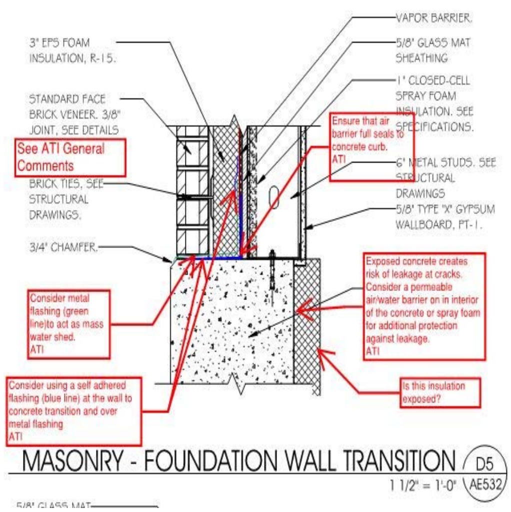
Mechanical Equipment

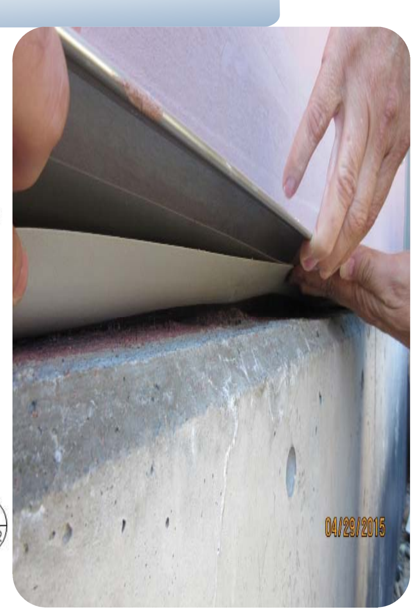


Typical Interface Concerns

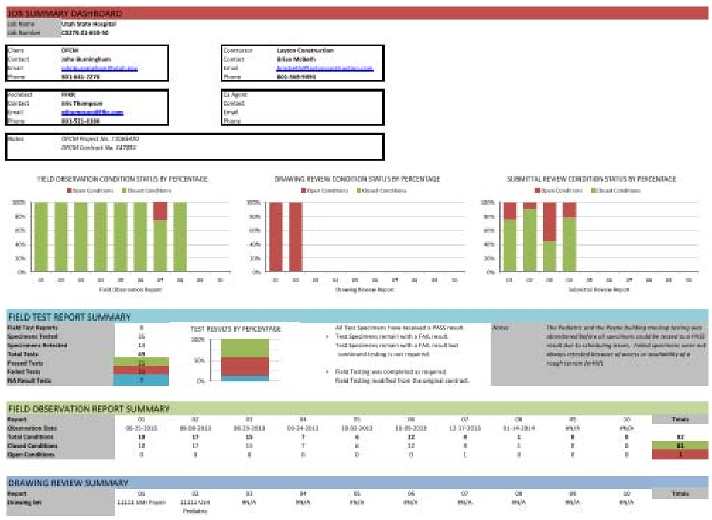
Penetrations

Wall to Foundation





Tracking Non-Compliance



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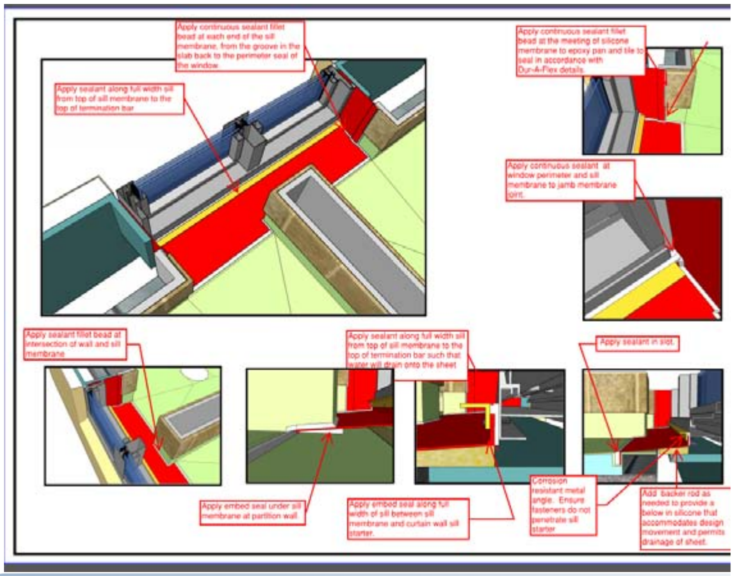
Detailed, Functional Design



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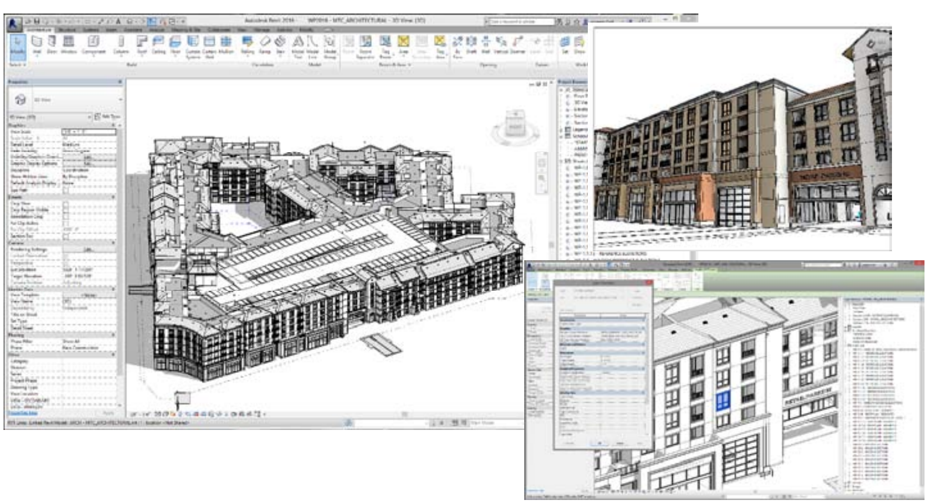
Consulting/Design QA

Revit Model



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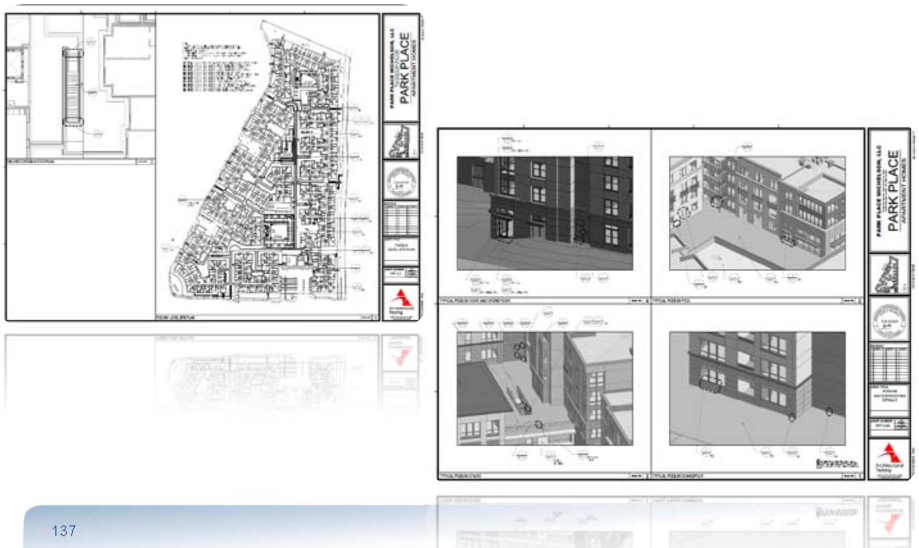
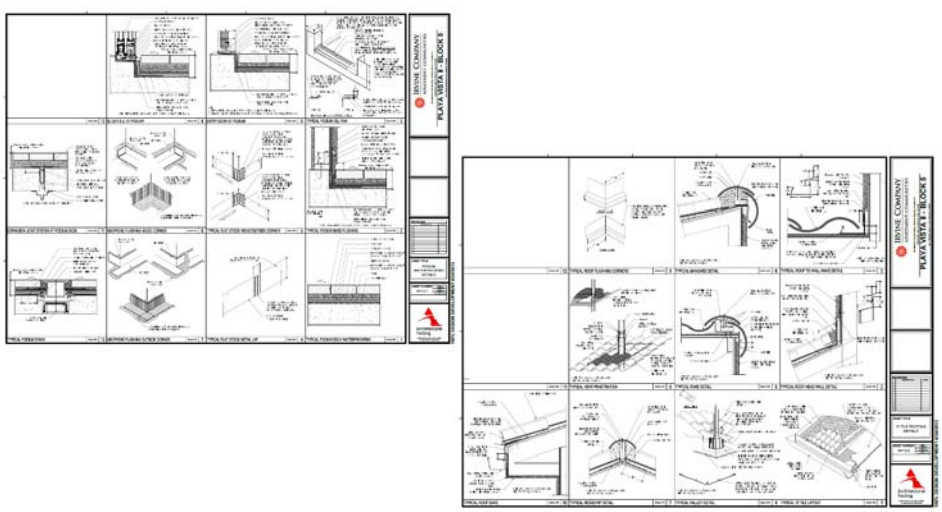
Consulting/Design QA

Building Enclosure Details Set



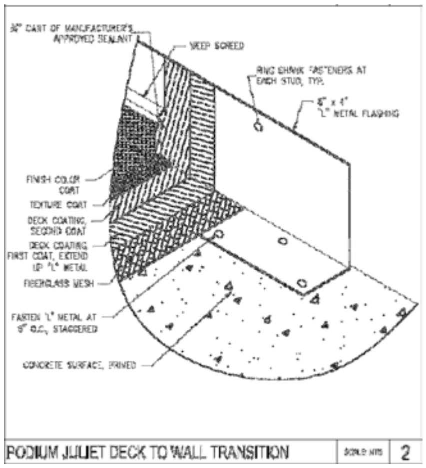
Consulting/Design QA

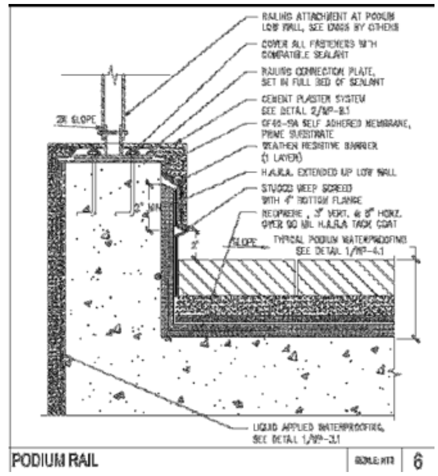
Building Enclosure Details Set



Consulting/Design QA

Building Envelope Details Set





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