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WHAT'S NEXT?
EVOLUTION OF THE BUILDING ENCLOSURE AND FUTURE TRENDS

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WHAT'S NEXT?
EVOLUTION OF THE BUILDING ENCLOSURE AND FUTURE TRENDS

Learning Objectives:

- Understand the evolution of building enclosures, and current accelerating trends.
- Recognize this evolution on previously segmented industries, and their ongoing unification.
- Understand challenges associated with properly integrating enclosure components and systems.
- Acknowledge holistic approaches to achieving code compliance and meeting owner expectations.

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Topics

1. Building Code Requirements and Industry Standards
2. Speed to Market | Integrated Project Delivery | Delegated Design
3. Factory Fabrication of Building Materials and Systems
4. Field Quality Control Testing
5. Building Enclosure Commissioning (BECx)

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Building Code Requirements and Industry Standards

Topic 1

Evolution

- Building Code Requirements and Industry Voluntary Standards
  - ASHRAE
  - ICC Codes (IBC and IECC)
  - CABO MEC
  - BOCA
  - UBC
  - ASTM

Evolution: Vapor Retarders

1970s

1976 UBC: Vapor barriers required in built-up roof construction in cold climates

1979 UBC: No change from 1976 requirements

Evolution: Vapor Retarders

1980s

1981 BOCA: No reference to vapor retarders/barriers

1982 UBC: 1976 requirements and reference to vapor barriers in insulation requirements

1985 UBC: No change from 1982 requirements

1987 BOCA: "Vapor-type barrier" indicated for the interior of exterior walls where cavity is not adequately ventilated

1988 UBC: *Vapor retarder* first introduced as a defined term. Vapor barrier requirements/references largely unchanged from 1985

1989 ASHRAE 90.1: Vapor retarders recommended for consideration to prevent moisture from collecting within the envelope

Evolution: Vapor Retarders

1990s

1990 BOCA: Vapor barrier/retarder indicated for use in crawl and roof spaces, and for the interior of exterior walls where cavity is not adequately ventilated

1991 UBC: No change from 1988 requirements

1992 CABO MEC: Vapor retarder required on warm-in-winter side of insulation for unventilated walls/floors/ceilings, except in hot and humid climates.

1993 BOCA:
-*Vapor retarder* first introduced as a defined term
- No change from 1990 requirements

1994 UBC: No change from 1991 requirements

1996 BOCA: Interior vapor retarder required to cover cavity for wood-framed exterior walls utilizing thermal insulation.

1997 UBC: No change from 1994 requirements

1998 IECC: Vapor retarder required on warm-in-winter side of insulation for unventilated framed walls/floors/ceilings, except for climate zones 1-7 (note: climate zones numbered 1-19 at this time).

Evolution: Vapor Retarders

2000s

2000 IBC: Approved interior noncombustible vapor retarder required for exterior walls

2000 IECC: Largely unchanged from 1998 requirements

2003 IBC: Approved vapor retarder required for exterior walls

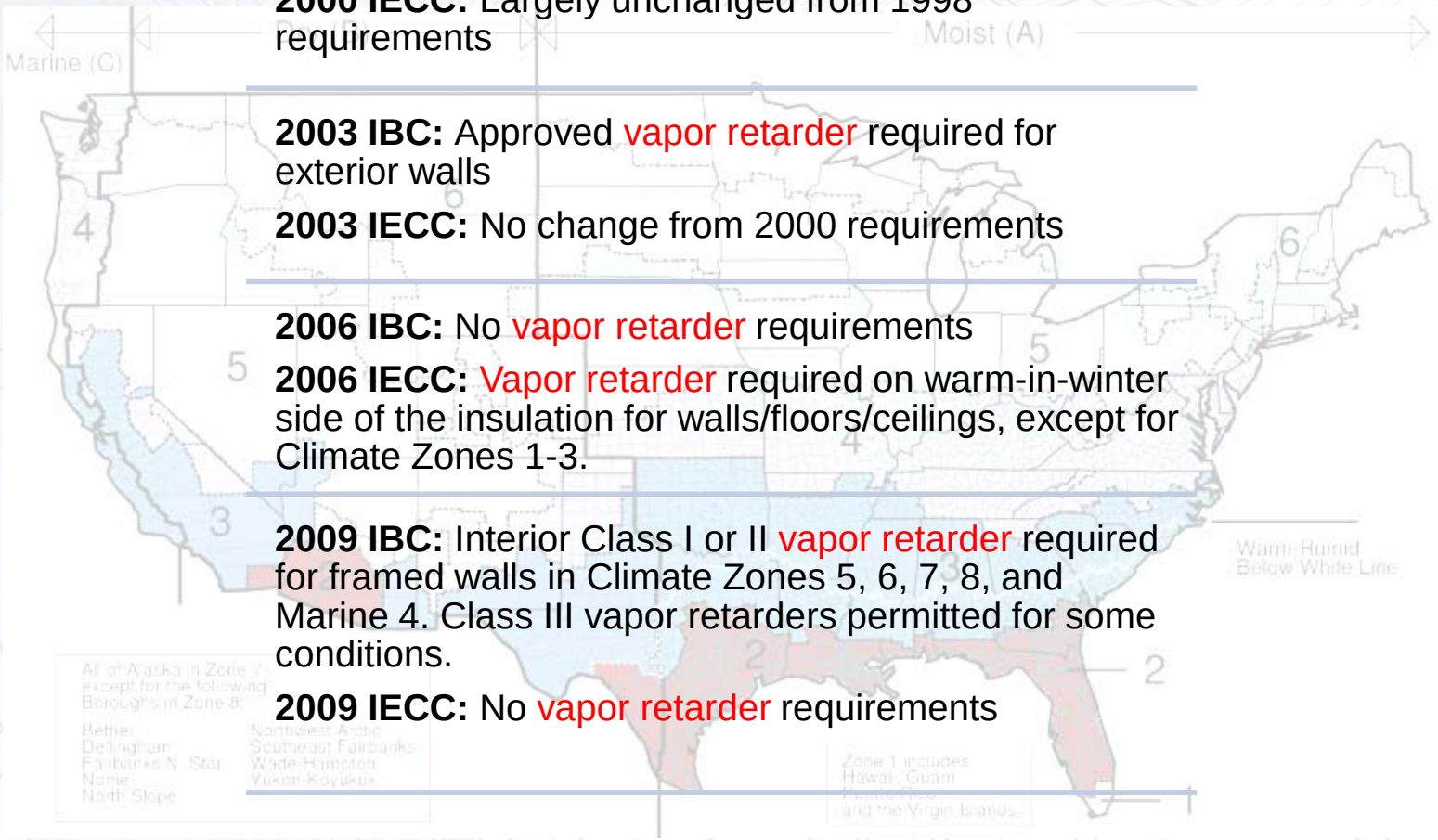
2003 IECC: No change from 2000 requirements

2006 IBC: No vapor retarder requirements

2006 IECC: Vapor retarder required on warm-in-winter side of the insulation for walls/floors/ceilings, except for Climate Zones 1-3.

2009 IBC: Interior Class I or II vapor retarder required for framed walls in Climate Zones 5, 6, 7, 8, and Marine 4. Class III vapor retarders permitted for some conditions.

2009 IECC: No vapor retarder requirements



Evolution: Vapor Retarders

2010s

2012 IBC: Interior Class I or II vapor retarder required for framed walls in Climate Zones 5, 6, 7, 8, and Marine 4.

2012 IECC: No vapor retarder requirements

2015 IBC: 2012 requirements, plus: Class I or II vapor retarders not allowed at interior of framed walls in Climate Zones 1 and 2, and Class I vapor retarders not allowed at interior of framed walls in Climate Zones 3 and 4.

2015 IECC: No vapor retarder requirements

2018 IBC: 2015 requirements, plus: Class I vapor retarders allowed for exterior walls in Climate Zone Marine 4.

2018 IECC: No vapor retarder requirements

Evolution: Air Barrier

2000s

2001 ASHRAE 90.1: Areas of the building envelope indicated to be sealed, caulked, gasketed, or weather-stripped to minimize air leakage.

2004 ASHRAE 90.1: No change from 2001 requirements

2007 ASHRAE 90.1: No change from 2001 requirements

2009 IECC: *Air Barrier* term introduced, but no air barrier requirements

AIR BARRIER. Material(s) assembled and joined together to provide a barrier to air leakage through the building envelope. An air barrier may be a single material or a combination of materials.

Evolution: Air Barrier

2010s

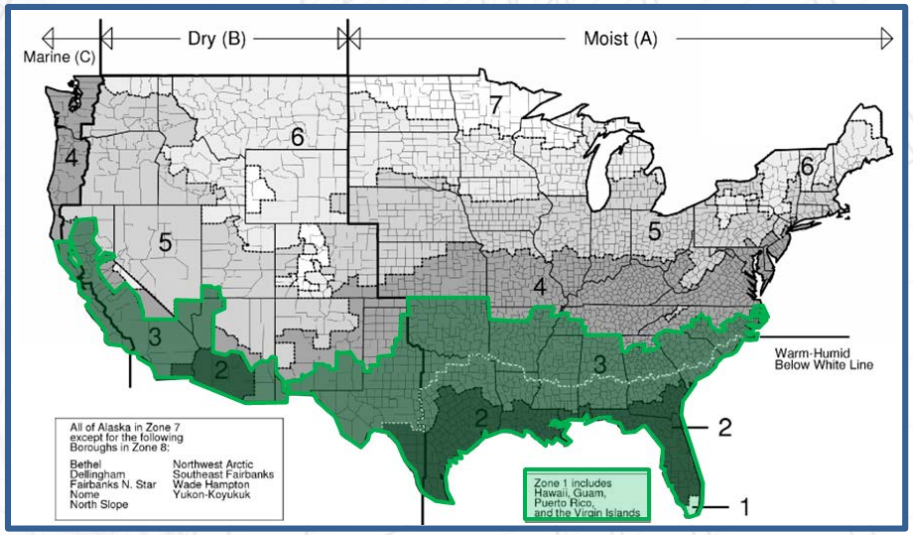
2010 ASHRAE 90.1:

- Continuous air barrier first introduced as defined term

- Continuous air barrier required, except in semi-heated spaces in Climate Zones 1-6, and in single-wythe CMU buildings in Climate Zone 2B.

- First inclusion of identified acceptable materials/ assemblies for continuous air barriers

2012 IECC: Continuous air barrier required, except in Climate Zones 1, 2, and 3



Evolution: Air Barrier

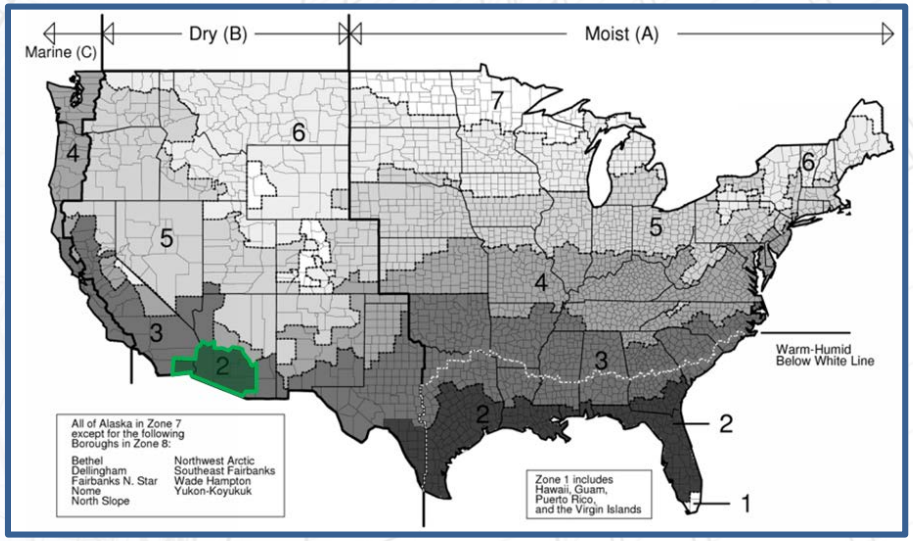
2010s

2013 ASHRAE 90.1: No change from 2010 requirements

2015 IECC:

- Continuous air barrier required, except in Climate Zone 2B

- Testing per ASTM E779 (fan pressurization test for whole building air leakage) introduced as a performance compliance option over prescriptive requirements for air barriers



Evolution: Air Barrier

2010s

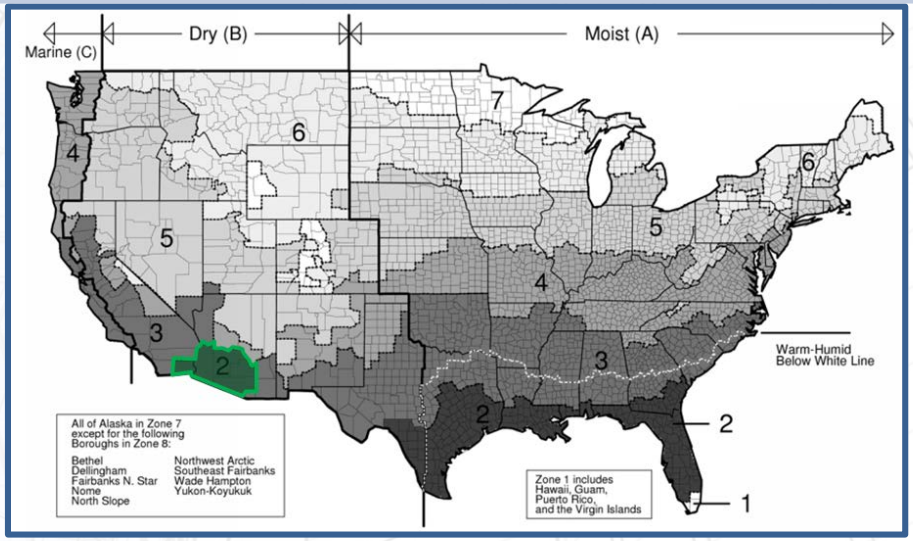
2016 ASHRAE 90.1:

- Continuous air barrier required, except in semi-heated spaces in Climate Zones 0-6, and in single-wythe CMU buildings in Climate Zone 2B.

- Clarification added that continuous air barrier is to extend over all surfaces of the building envelope (at the lowest floor, walls, and roof)

-Option added for continuous air barrier compliance via whole building pressurization testing

2018 IECC: No change from 2015 requirements



Evolution: Whole Building Air Leakage Testing

1990s

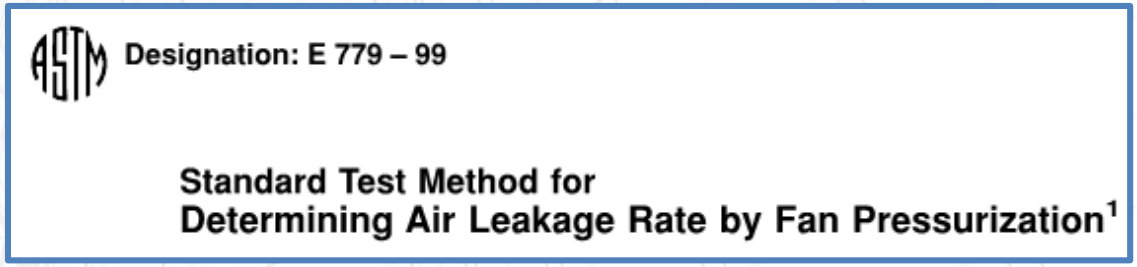
1996 ASTM: ASTM E1827 *Standard Test Methods for Determining Airtightness of Buildings Using and Orifice Blower Door* introduced

1999 ASTM: ASTM E779 *Standard Test Method for Determining Air Leakage Rate by Fan Pressurization* introduced

Designation: E 1827 – 96

An American National Standard

Standard Test Methods for
Determining Airtightness of Buildings Using an Orifice
Blower Door[1]



Designation: E 779 – 99

Standard Test Method for
Determining Air Leakage Rate by Fan Pressurization[1]

Evolution: Whole Building Air Leakage Testing

2010s

2015 IECC: Option added for testing per ASTM E779 (whole building pressurization testing) in lieu of prescriptive requirements for the thermal envelope, including continuous air barrier requirements

2016 ASHRAE 90.1: Option added for continuous air barrier material/assembly compliance via whole building pressurization testing

2018 IECC: No change from 2015 requirements

C402.5 Air leakage—thermal envelope (Mandatory). The *therm*
C402
shall
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with
rate c
cfm/f
testin
C402

5.4.3.1.3 Testing, Acceptable Materials, and Assemblies

The *building* shall comply with whole-*building* pressurization testing in accordance with Section 5.4.3.1.3(a) or with the *continuous air barrier* requirements in Section 5.4.3.1.3(b) or 5.4.3.1.3(c).

a. Whole-*building* pressurization testing shall be conducted in accordance with ASTM E779 or ASTM E1827 by an independent third party. The measured air leakage rate of the *building envelope* shall not exceed 0.40 cfm/ft^2 under a pressure differential of 0.3 in. of water, with this air leakage rate normalized by the sum of the above and below-*grade building envelope* areas of the *conditioned* and *semiheated space*.

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Speed to Market

Integrated Project Delivery

Delegated Design

Topic 2

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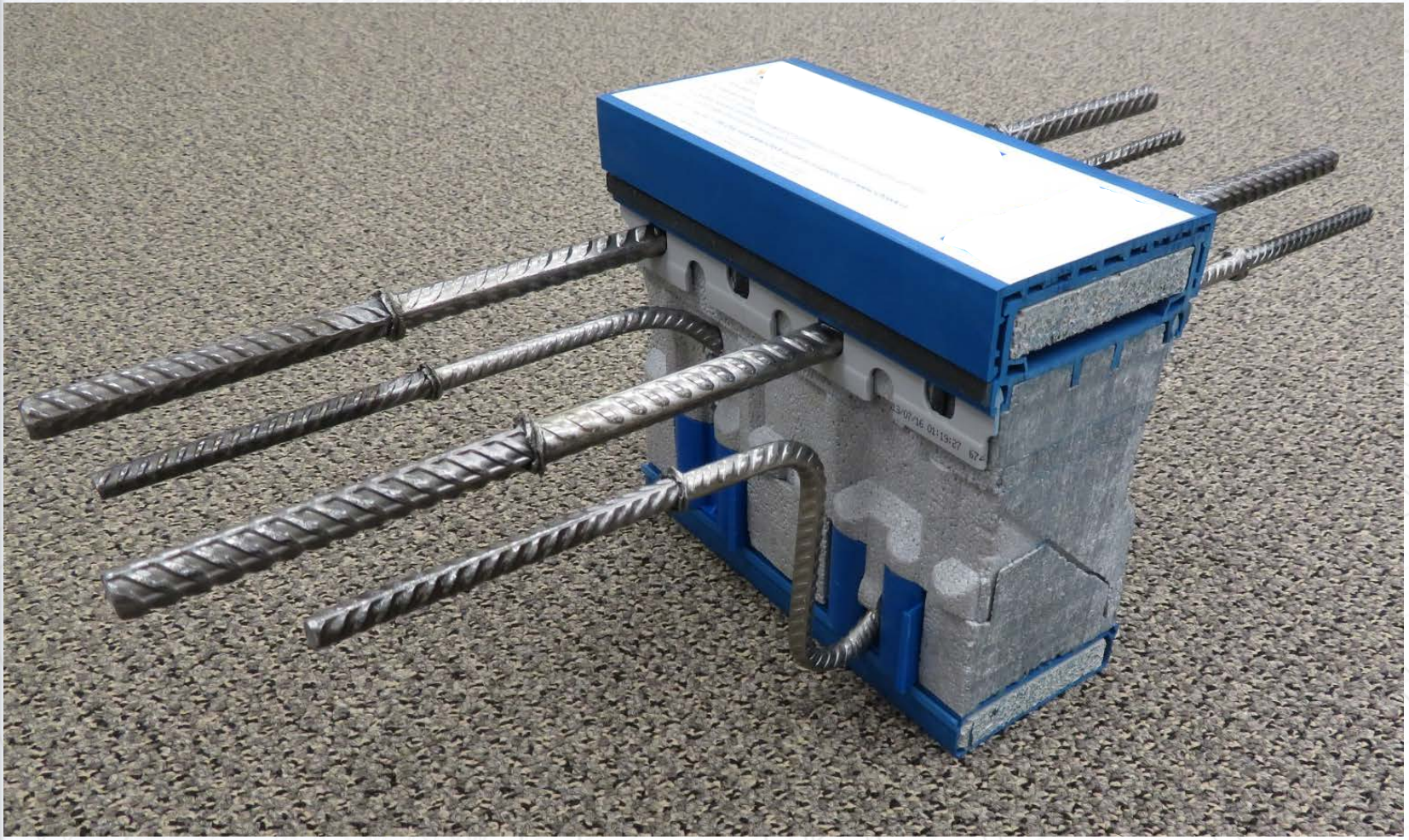

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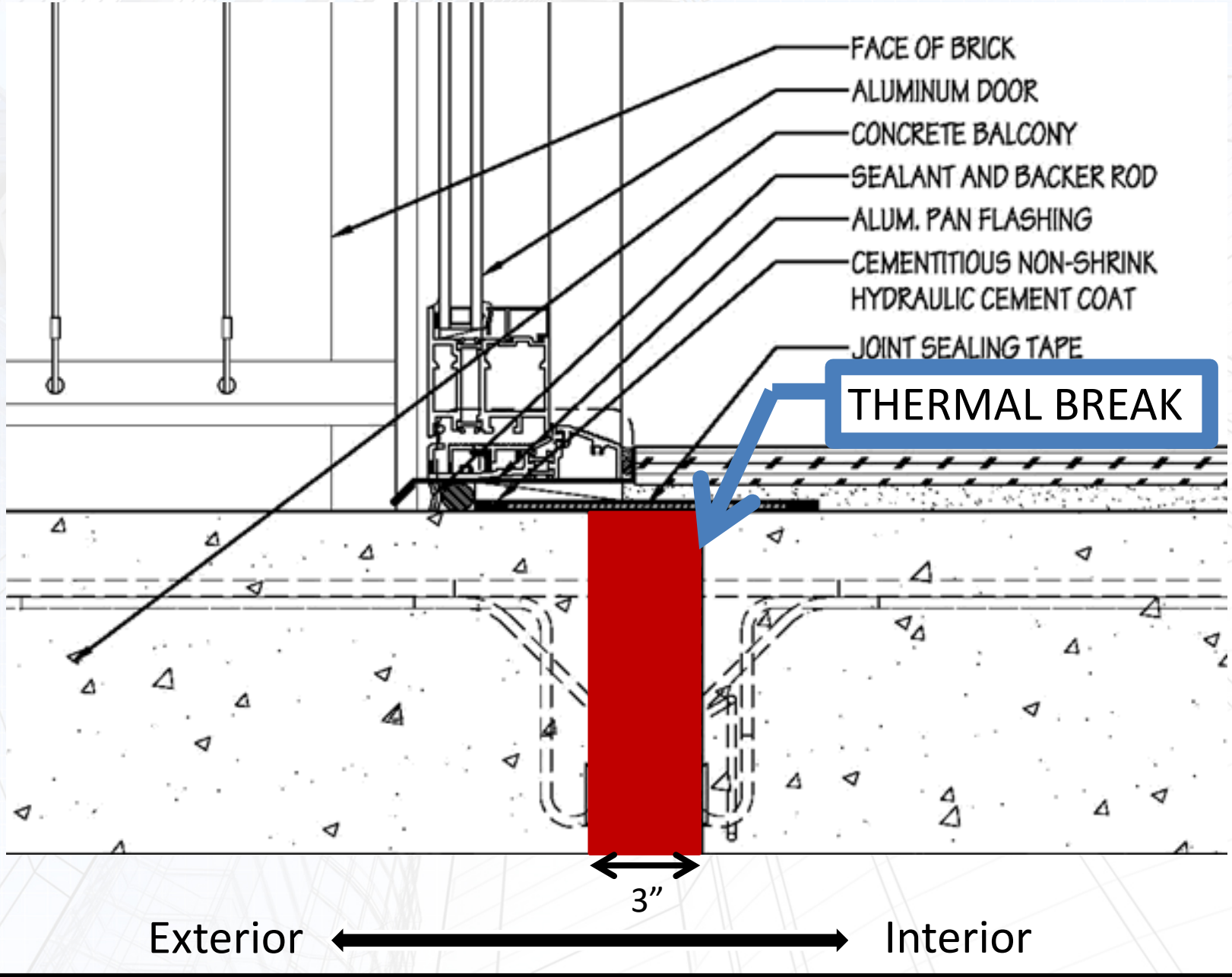
FACE OF BRICK
ALUMINUM DOOR
CONCRETE BALCONY
SEALANT AND BACKER ROD
ALUM. PAN FLASHING
CEMENTITIOUS NON-SHRINK
HYDRAULIC CEMENT COAT
JOINT SEALING TAPE
THERMAL BREAK
3”
Exterior
Interior

Delegated Design:

Transferring design responsibility of some portion of the project to a party other than the Designer-of-Record

"Delegated-design solutions require specific input from a professional engineer retained by the constructor, supplier, fabricator, or manufacturer.
--The Construction Specifier, November 2018
(Robinson, Franchuck, Murnane)

Benefits

- Design fees can be reduced
- Project schedule can be improved
- Specialty designs are prepared by specialists with unique knowledge of materials, systems, and construction
- Potential for reduced construction costs

Perils

- Blurred responsibility for interfaces between delegated and prime design elements
- Contractual responsibility can be murky
- Licensing boards and building departments are not consistent regarding prime vs. specialty/delegated design responsibility

Outcome

- More project control ceded to the Contractor

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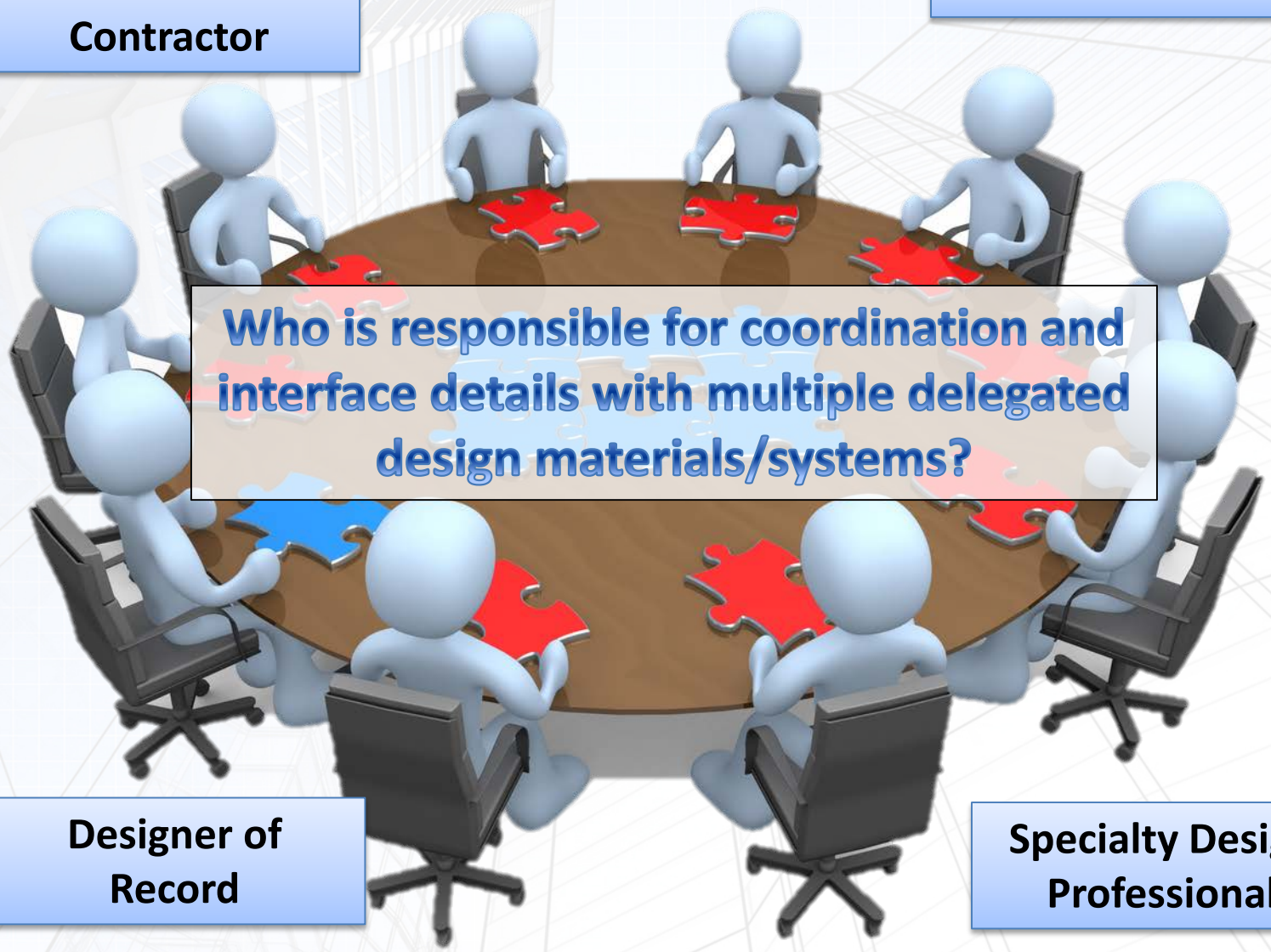
General Contractor

Subcontractor



Who is responsible for coordination and interface details with multiple delegated design materials/systems?

Designer of Record

Specialty Design Professional

Delegated Design:

Transferring design responsibility of some portion of the project to a party other than the Designer-of-Record

PART 2 - PRODUCTS

2.1 PERFORMANCE REQUIREMENTS

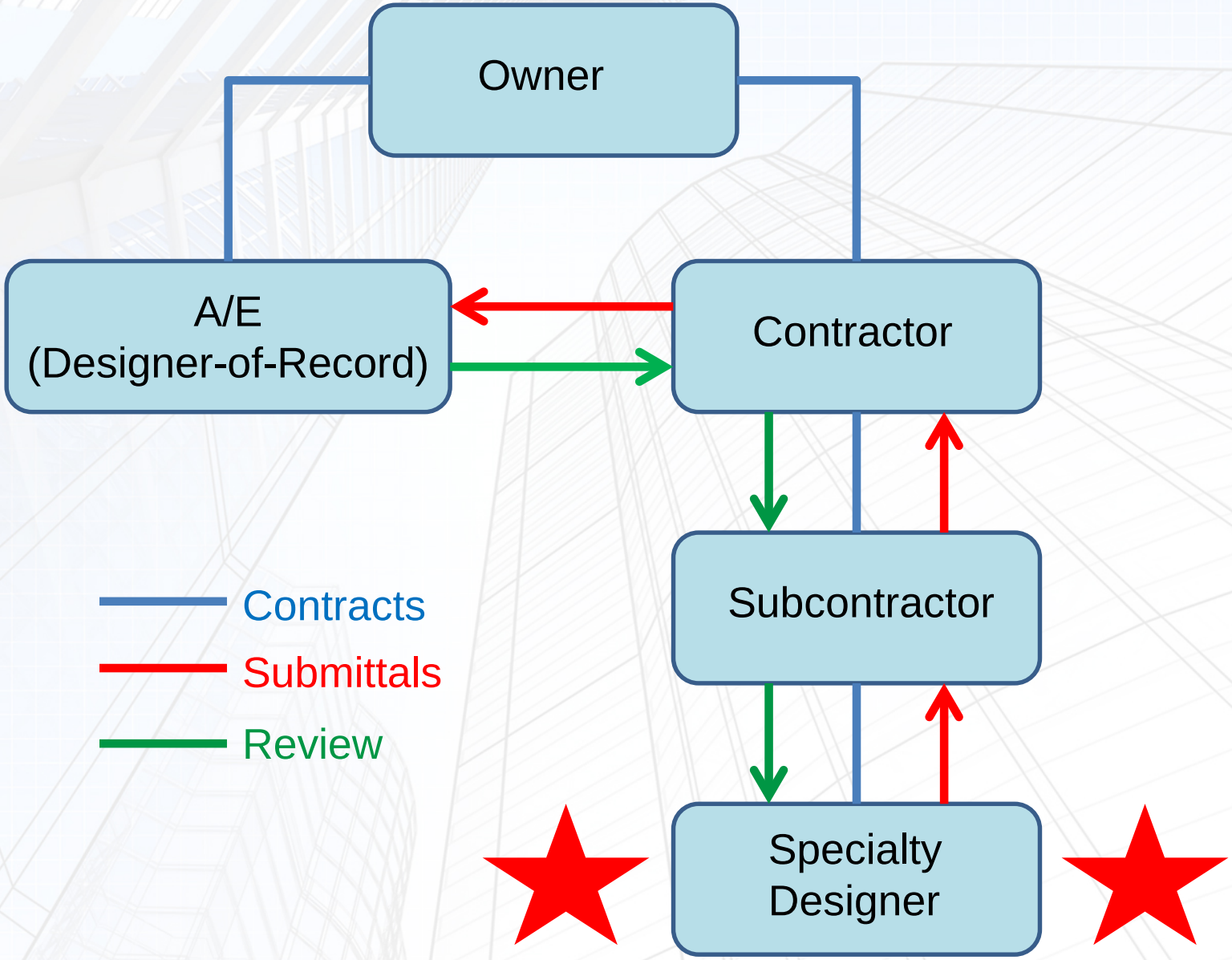
A. Delegated Design: Engage a qualified professional engineer, as defined in Section 014000 "Quality Requirements," to design Formed Metal Wall Panels.

B. Structural Performance: Provide metal panel systems capable of withstanding the effects of the following loads, based on testing according to ASTM E 1592:

1. Wind Speed 90 mph
2. Importance factor 1.15
3. Exposure B
4. Other Design Loads: As indicated on Drawings.
5. Deflection Limits: For wind loads, no greater than 1/180 of the span.

D. Roofing System Design: Tested by a qualified testing agency to resist the following uplift pressures:

1. Corner Uplift Pressure: As determined by Delegated Design Engineer.
2. Perimeter Uplift Pressure: As determined by Delegated Design Engineer.
3. Field Uplift Pressure: As determined by Delegated Design Engineer.
4. Basic Wind Speed: 90 mph.
5. Wind Exposure: Exposure B.
6. Wind Importance Factor 1.15.
7. Safety Factor: Twice the calculated load.


Owner
A/E
(Designer-of-Record)
Contractor
Subcontractor
Specialty
Designer
Contracts
Submittals
Review

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DRAFT AIA® Document A201™ – 2017

General Conditions of the Contract for Construction

for the following PROJECT:
(Name and location or address)

« »
« »

THE OWNER:
(Name, legal status and address)

« »« »
« »

THE ARCHITECT:
(Name, legal status and address)

« »« »
« »

TABLE OF ARTICLES

ADDITIONS AND DELETIONS: The author of this document has added information needed for its completion. The author may also have revised the text of the original AIA standard form. An *Additions and Deletions Report* that notes added information as well as revisions to the standard form text is available from the author and should be reviewed.

This document has important legal consequences. Consultation with an attorney is encouraged with

AIA

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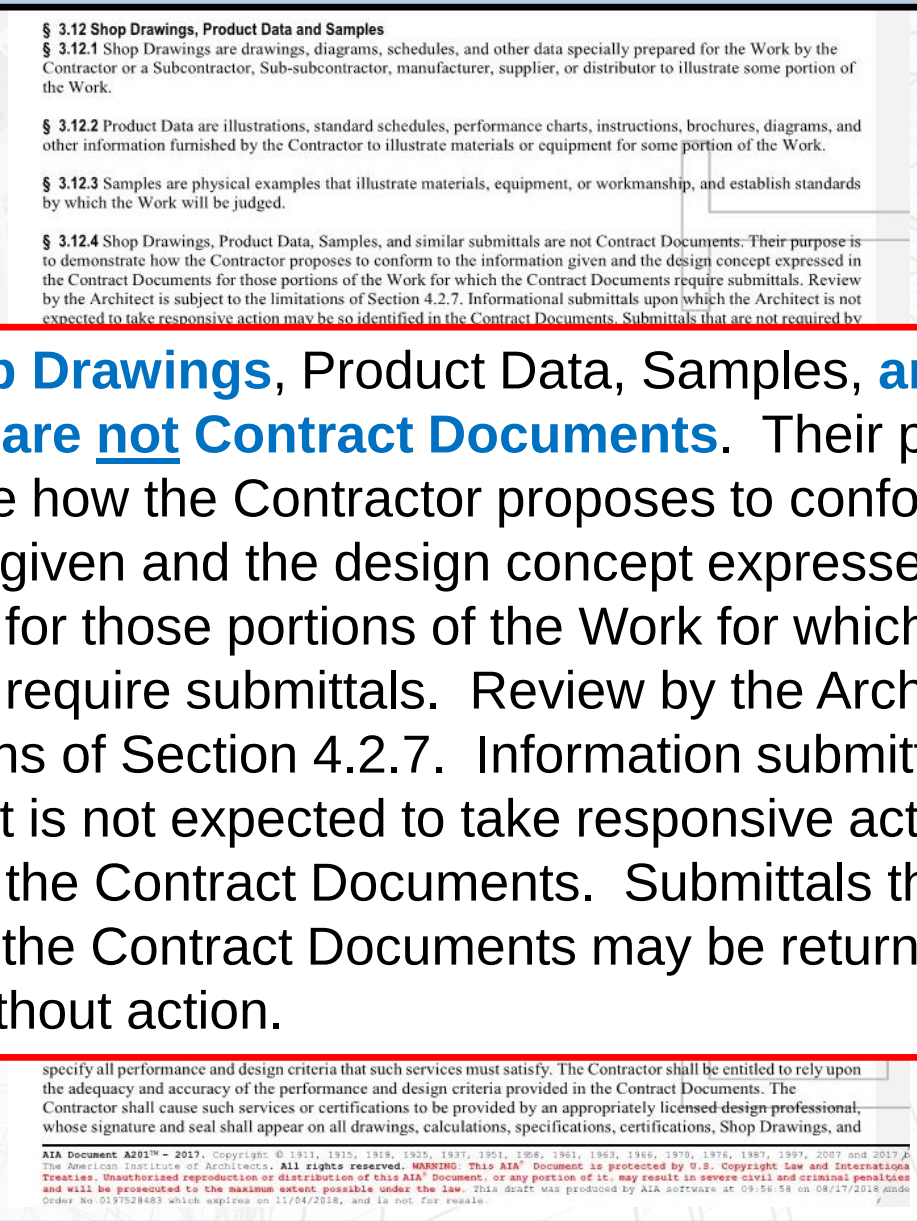
AIA A201-2017: 3.12 Shop Drawings, Product Data and Samples



§ 3.12 Shop Drawings, Product Data and Samples

§ 3.12.1 Shop Drawings are drawings, diagrams, schedules, and other data specially prepared for the Work by the Contractor or a Subcontractor, Sub-subcontractor, manufacturer, supplier, or distributor to illustrate some portion of the Work.

§ 3.12.2 Product Data are illustrations, standard schedules, performance charts, instructions, brochures, diagrams, and other information furnished by the Contractor to illustrate materials or equipment for some portion of the Work.

§ 3.12.3 Samples are physical examples that illustrate materials, equipment, or workmanship, and establish standards by which the Work will be judged.

§ 3.12.4 Shop Drawings, Product Data, Samples, and similar submittals are not Contract Documents. Their purpose is to demonstrate how the Contractor proposes to conform to the information given and the design concept expressed in the Contract Documents for those portions of the Work for which the Contract Documents require submittals. Review by the Architect is subject to the limitations of Section 4.2.7. Informational submittals upon which the Architect is not expected to take responsive action may be so identified in the Contract Documents. Submittals that are not required by

3.12.4 **Shop Drawings**, Product Data, Samples, **and similar submittals are not Contract Documents**. Their purpose is to demonstrate how the Contractor proposes to conform to the information given and the design concept expressed in the Contract Documents for those portions of the Work for which Contract Documents require submittals. Review by the Architect is subject to the limitations of Section 4.2.7. Information submittals upon which the Architect is not expected to take responsive action may be so identified in the Contract Documents. Submittals that are not required by the Contract Documents may be returned by the Architect without action.

specify all performance and design criteria that such services must satisfy. The Contractor shall be entitled to rely upon the adequacy and accuracy of the performance and design criteria provided in the Contract Documents. The Contractor shall cause such services or certifications to be provided by an appropriately licensed design professional, whose signature and seal shall appear on all drawings, calculations, specifications, certifications, Shop Drawings, and

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AIA A201-2017: 3.12 Shop Drawings, Product Data and Samples

3.12.10 The Contractor shall **not** be required to provide professional services that constitute the practice of **architecture or engineering** unless such services are **specifically required by the Contract Documents** for a portion of the Work…

3.12.10.1 If professional design services or certifications by design a professional are specifically required of the Contractor by the Contract Documents, the **Owner and the Architect will specify all performance and design criteria** that such services must satisfy…

…the Architect will review and approve or take appropriate action on submittals only for the limited purpose of **checking for conformance with information given and the design concepts expressed** in the Contract Documents.

3.12.10.2 If the Contract Documents require the **Contractor's design professional** to certify that the work has been performed in accordance with the design criteria, **the Contractor shall furnish such certifications** to the Architect…

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MasterFormat® Numbers & Titles

April 2016

01 35 00	**Special Procedures**
01 35 03	Conservation Treatment Procedures
01 35 13	Special Project Procedures
01 35 13.13	Special Project Procedures for Airport Facilities
01 35 13.16	Special Project Procedures for Detention Facilities
01 35 13.19	Special Project Procedures for Healthcare Facilities
01 35 13.26	Special Project Procedures for Clean Rooms
01 35 13.43	Special Project Procedures for Contaminated Sites
01 35 16	Alteration Project Procedures
01 35 23	Owner Safety Requirements
01 35 26	Governmental Safety Requirements
01 35 29	Health, Safety, and Emergency Response Procedures
01 35 29.13	Health, Safety, and Emergency Response Procedures for Contaminated Sites
01 35 33	Infection Control Procedures
01 35 43	Environmental Procedures
01 35 43.13	Environmental Procedures for Hazardous Materials
01 35 43.16	Environmental Procedures for Toxic Materials
01 35 46	Indoor Air Quality Procedures
01 35 53	Security Procedures
01 35 63	Sustainability Certification Project Requirements
01 35 66	Sustainability Certification Project Procedures
01 35 73	Delegated Design Procedures
01 35 91	Period Treatment Procedures

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SECTION 011300 - DELEGATED DESIGN REQUIREMENTS

PART 1 - GENERAL

1.1 SUMMARY

A. Section Includes: Administrative and procedural requirements for portions of the Work the design of which is delegated to the Contractor.

1.1.A. Section Includes: Administrative and procedural requirements for portions of the Work the **design of which is delegated to the Contractor**.

1. AHJ: Authority Having Jurisdiction.

B. Definitions:

1. Delegated: Means transferred by the Architect to the Contractor.
2. Design: Means the complete planning, arrangement, and coordination of a discrete

1.1.B.1 Delegated: Means **transferred by the Architect to the Contractor**.

3. Engineering Services: Means structural engineering services performed for the design, fabrication, and installation of systems, assemblies, and components similar in material, design, complexity and extent to that indicated for the delegated design portion of the Work.

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1.3 ADMINISTRATIVE REQUIREMENTS

A. Portions of the Contract Documents may delegate the design of discrete portions of the Work to the Contractor, or may otherwise specify "delegated design requirements" in individual specification Sections.

B. The Contractor is professionally liable for delegated design work, including design, engineering, and conformance to specified performance requirements.

1.3.B. **The Contractor is professionally liable** for delegated design work, **including design, engineering**, and conformance to specified performance requirements.

2. Relationships between adjacent components of the Work;
3. Location, identification, dimension and size of components, assemblies, accessories, and other components of the Work; and
4. Schematic joining and attachment details and diagrams of fasteners and connections.

D. Specifications for delegated design portions of the Work are performance based, and establish the minimum qualities and performance criteria for materials, fabrications, products, systems, assemblies, and methods of execution.

E. The Architect reviews and determines whether or not the Contractor's proposed delegated designed work:

1. Conform to the design intent of the delegated design portion of the Work being reviewed;
2. Conform to the specified graphic and specification requirements, including subsequent modifications; and
3. Is appropriately integrated into the adjacent components of the Work and, where applicable, the overall design of the project.

F. In the event of a dispute regarding the Contractor's proposed delegated design solutions and the design intent of the Contract Documents, the decision of the Architect is final.

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PART 3 - EXECUTION

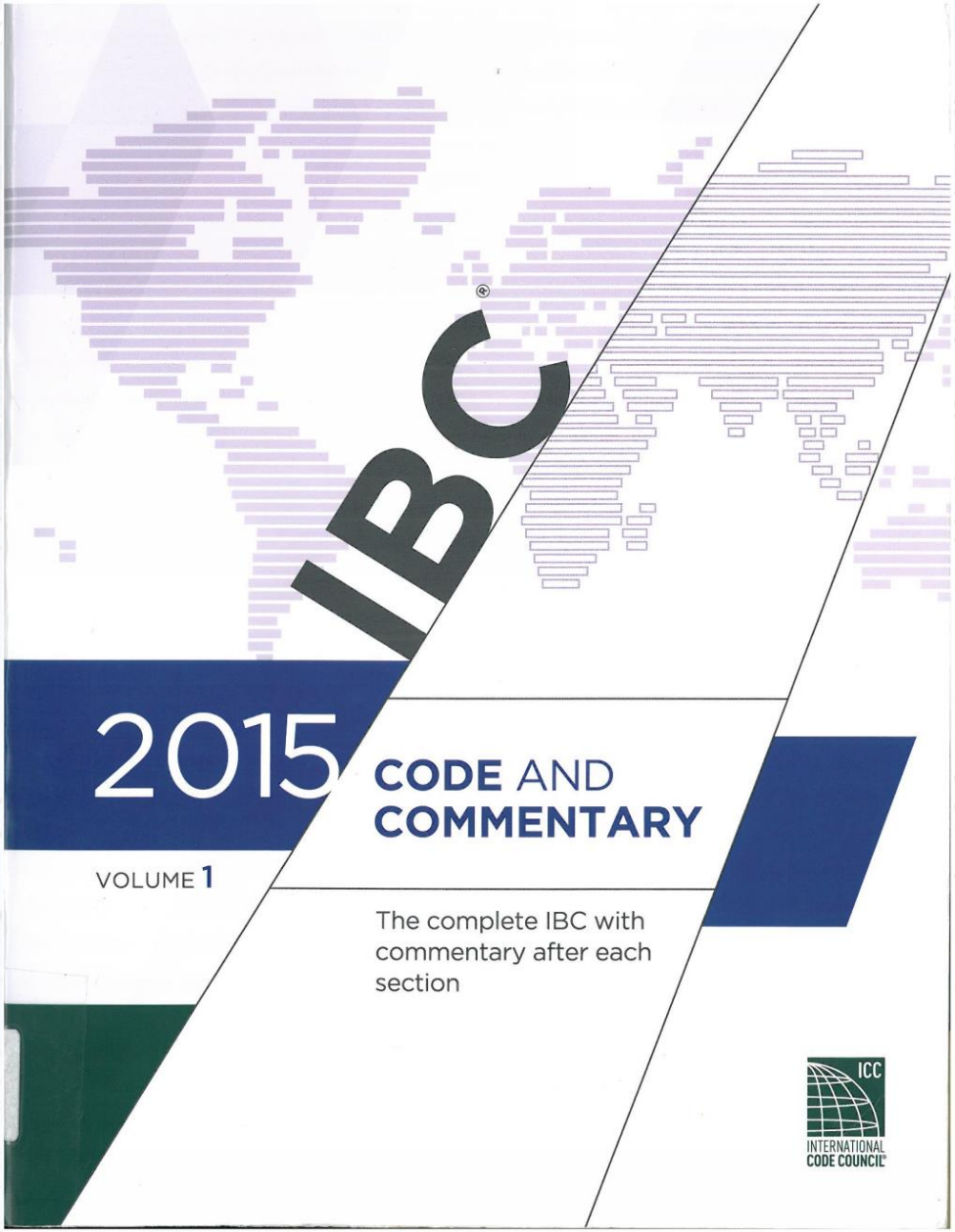
3.1 DESIGN

A. Unless otherwise indicated or specified, maintain the design intent and conform to the performance requirements indicated on the Drawings and in the Specifications, as determined by the Architect.

3.1.A. Unless otherwise indicated or specified, **maintain the design intent and conform to the performance requirements indicated on the Drawings and in the Specifications**, as determined by the Architect.

B. Engage a qualified professional structural engineer to design connection details and determine fastener types and sizes.

1. Fasteners or connections may neither conflict with nor require revision to the finish profiles indicated or the supporting work.
2. Connections may not impose eccentric loading, nor induce twisting or warping to the supporting structure.
3. Connections must be designed to accommodate potential and actual misalignment of adjacent work within tolerances specified in other Sections.


IBC
2015
CODE AND
COMMENTARY
VOLUME 1
The complete IBC with commentary after each section
ICC
INTERNATIONAL CODE COUNCIL

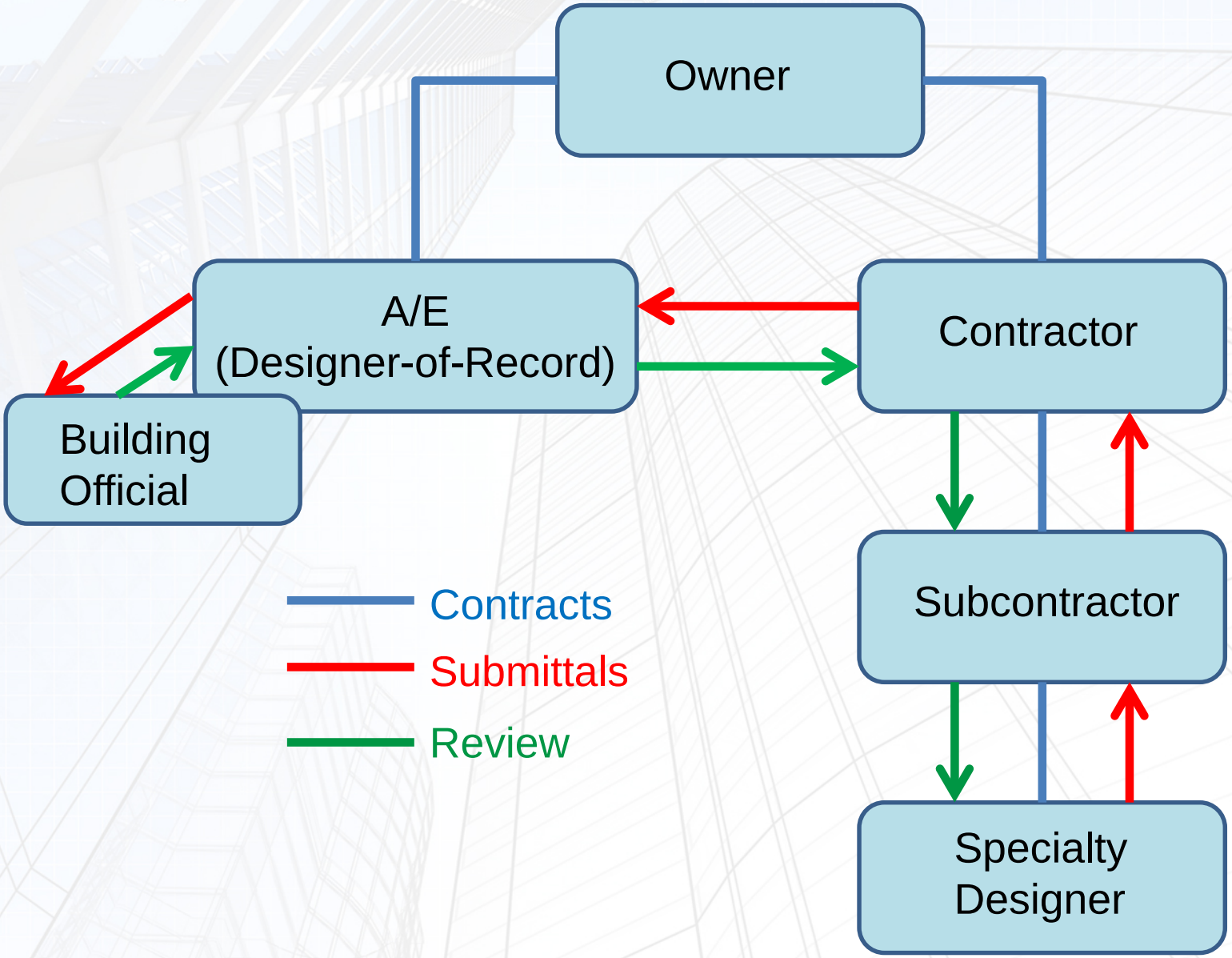
Section 107 - Submittal Documents

107.3.4.1 **Deferred submittals**

- Deferral of any submittal items shall have **prior approval of the building official**. The registered design professional in responsible charge shall **list the deferred submittals** on the construction documents for review by the building official.

- Documents for deferred submittal items shall be submitted to the **registered design professional in responsible charge who shall review them and forward them to the building official** with a notation indicating that the deferred submittal documents have been reviewed and found to be in general conformance to the design of the building.

- The deferred submittal items **shall not be installed** until the deferred submittal documents have been approved by the building official.


Owner
A/E
(Designer-of-Record)
Contractor
Building
Official
Subcontractor
Specialty
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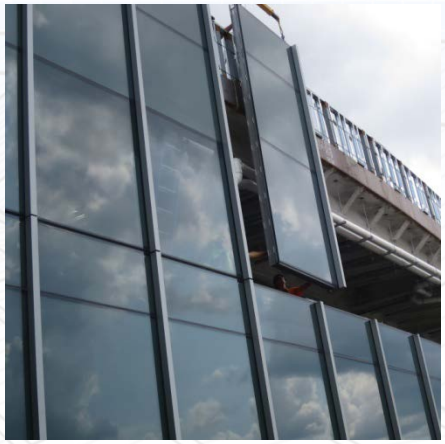
Contracts
Submittals
Review

Project Workflow for a Project with Integrated Project Delivery – Unitized Curtain Wall (Design Assist)



- Architect/Construction Manager selected
- Schematic Design
- Design Development
- Curtain wall subcontract bid/interviews
- Review proposed curtain wall systems/manufacturers
- Curtain wall subcontract awarded
- Design-assist meetings commence
- 100% Construction Documents (Issued for permit/construction)
- Design-assist meetings continue
- Bulletins issued by Architect
- Curtain wall shop drawings issued for preliminary review
- Fabrication commences (dye profiles, etc.)
- Review and comment on curtain wall shop drawings
- Revise curtain wall shop drawings
- Additional fabrication
- Performance mock-up
- Shop drawing calculations issued
- Installation commences
- Shop drawings approved by CM and DOR
- Installation continues and shop drawings revised throughout project

Time Lag?

Review?

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Factory Fabrication of Building Materials and Systems

Topic 3

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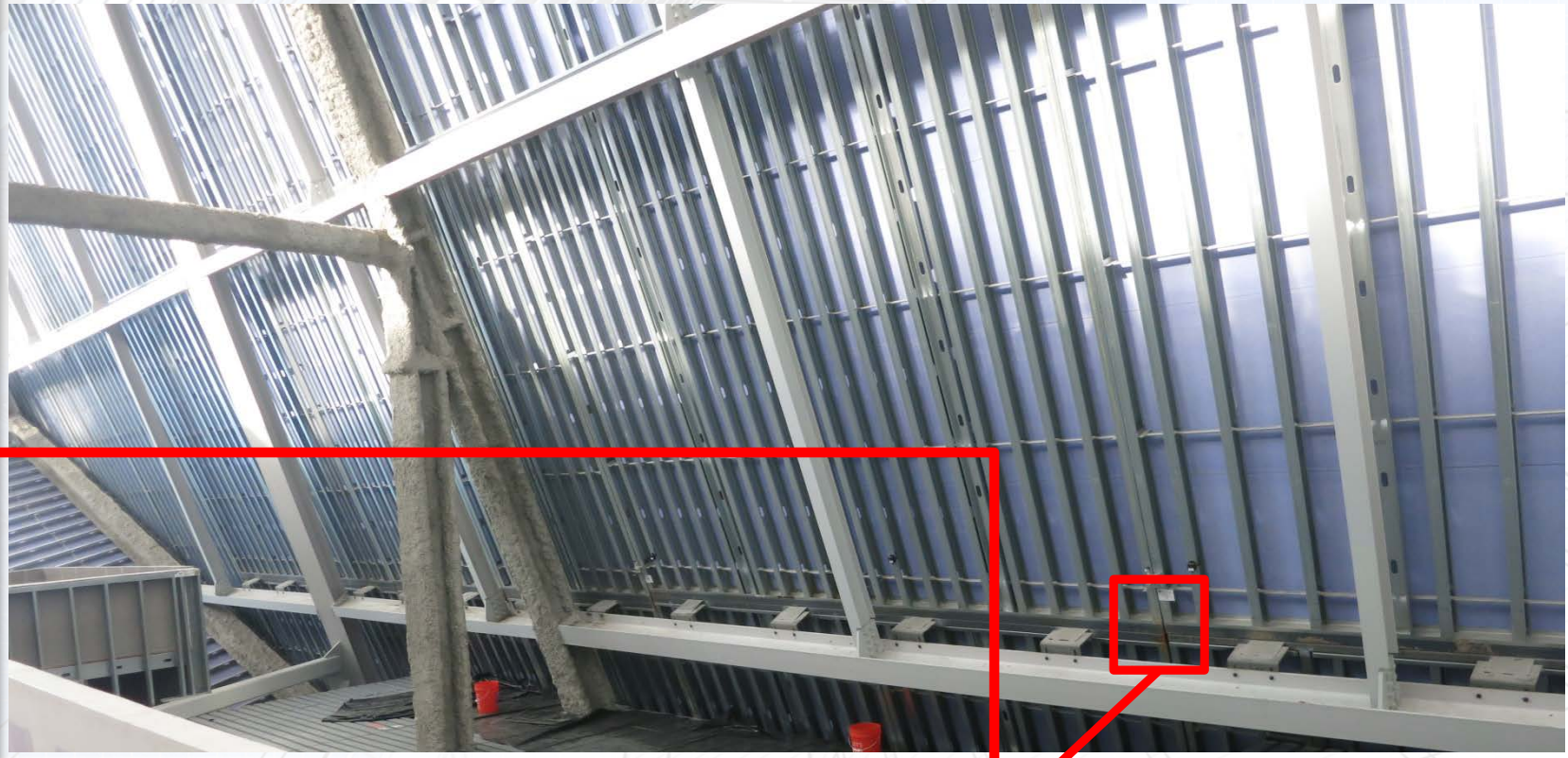

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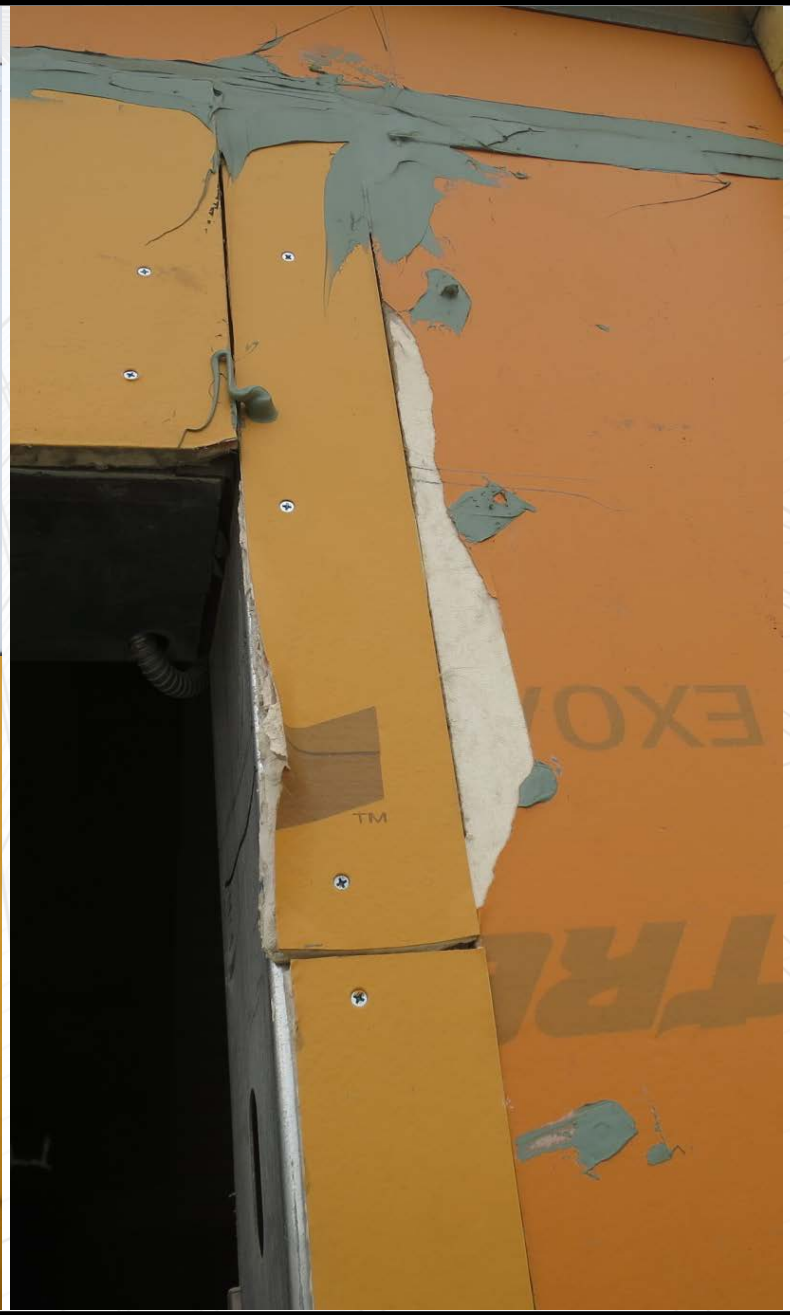

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ROOFING TRENDS

BY VINCE HILL

RCI Interface
March 2017

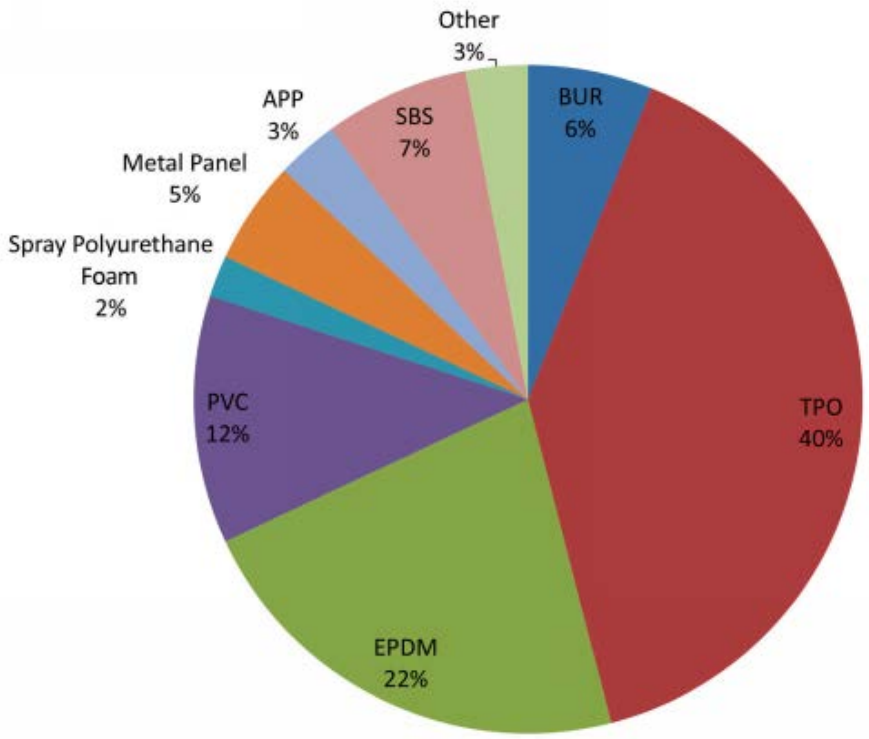

Figure 1 – Product mix of new low-slope construction sales by roof system of contractor members of the NRCA, 2016.

GROWTH OF SINGLE-PLIES

In 2000, built-up roofing (BUR) was the leader of the low-slope roofing market, with a 45.7% market share.[1] Now BUR accounts for only 6% of the new low-slope construction roofing market and 9% of the reroofing market of contractors who are members of the National Roofing Contractors Association (NRCA).[2]

2016: ~75% of roofs are single ply membranes

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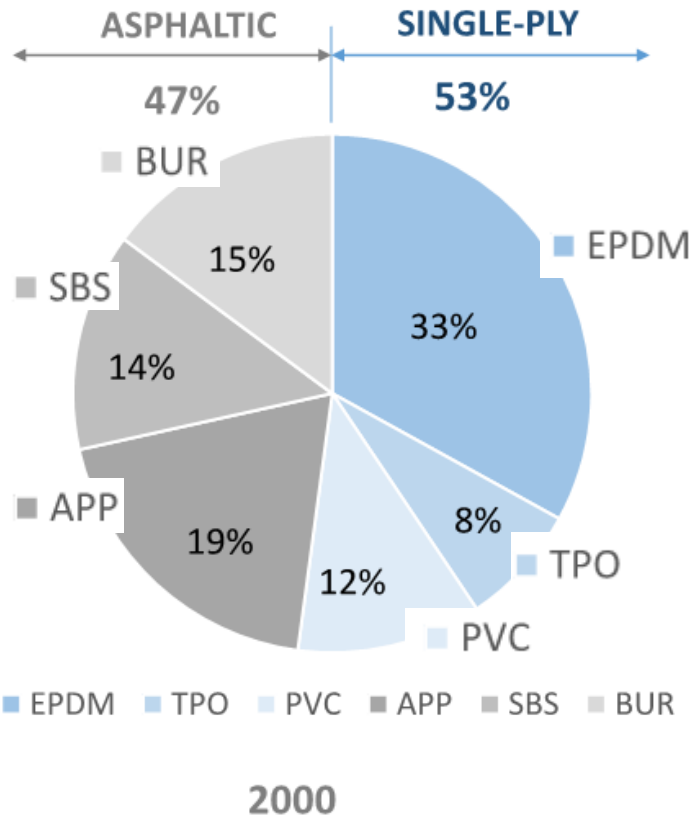
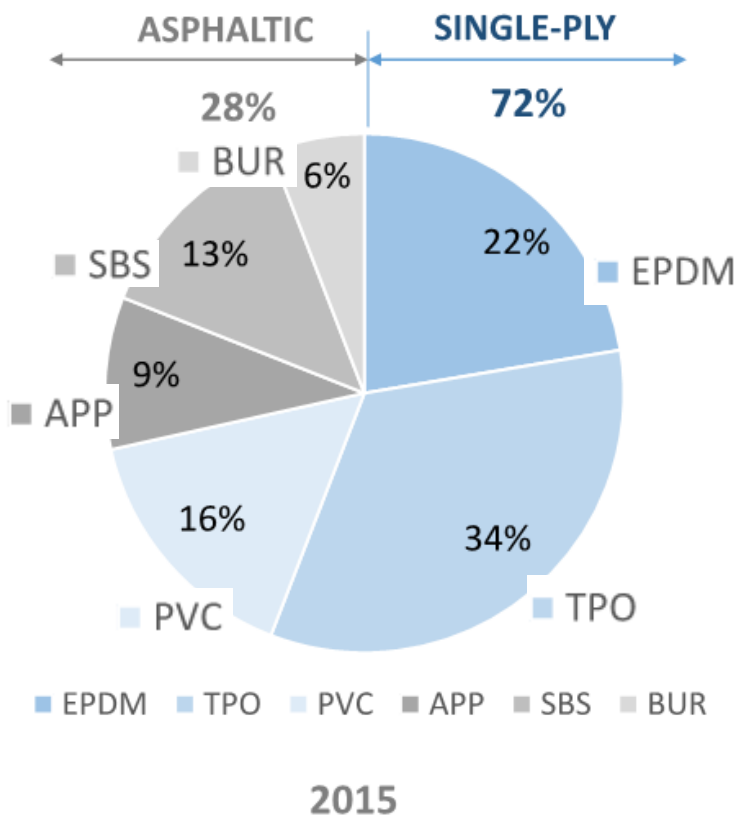
U. S. Low-Slope Commercial Roofing Market
2000 - 2015
(Percent Share)



2000



2015

July 1, 2017

TEGNOS Research, Inc.

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Where Has All the Asphalt Gone?

Colin Murphy, RRC, FRCI, LEED AP BD+C, PRA;

and

Darbi Krumpos, CDT, BECxP, CxA+BE

Trinity|ERD

Roofs were previously manufactured at the site. Now they are assembled at the site. –Rolf Snobeck

SECTION 075113
COLD-APPLIED BUILT-UP ASPHALT ROOF

PART 2 - PRODUCTS

2.1 MANUFACTURERS

A. Basis-of-Design Product: Subject to compliance with requirements, provide cold-applied, 3-ply [redacted] roofing system by [redacted] Equivalent products and systems manufactured by companies indicated below may also be accepted by the Architect, subject to compliance of the substituted product with the Contract requirements, providing all roof system material components meeting physical properties indicated below:

1. [redacted]
2. [redacted]

2.2 ROOFING MEMBRANE PLIES

A. Ply Sheet: ASTM D4601-98, Asphalt coated trilaminate reinforced high strength ply sheet.
   1. Tensile Strength: 133 pound-force per inch MD, 258 pound-force per inch XMD, ASTM D146.
   2. Tear Resistance per ASTM D 689:
      a. Machine Direction: 2610 grams.
      b. Cross Machine Direction: 3910 grams.
      c. Puncture Resistance per ASTM D 781: 42 inch-pounds.
   3. Materials per 100 sq ft (9.3 m2) of Roof Area
      a. Asphalt Primer (If required): 0.5 gallons.
   4. Interply: Manufacturer's BUR Adhesive or MBR Cold Application Adhesive:
      a. Incline per foot Adhesive Type Per 100 sq ft (9.3 m2) l/m2
      b. Up to 3" (250 mm/m) JM BUR Adhesive 61/2-71/2 gal 2.7-3.1
      c. or MBR Cold Application Adhesive
   5. Surfacing: Per 100 square feet:
      a. Gravel: 400 pounds.
      b. Slag: 300 pounds.
      c. Granules: 60 to 100 pounds.
   6. Adhesive Type: Manufacturer's BUR Adhesive or MBR Cold Application Adhesive at 3 to 4 gallons.

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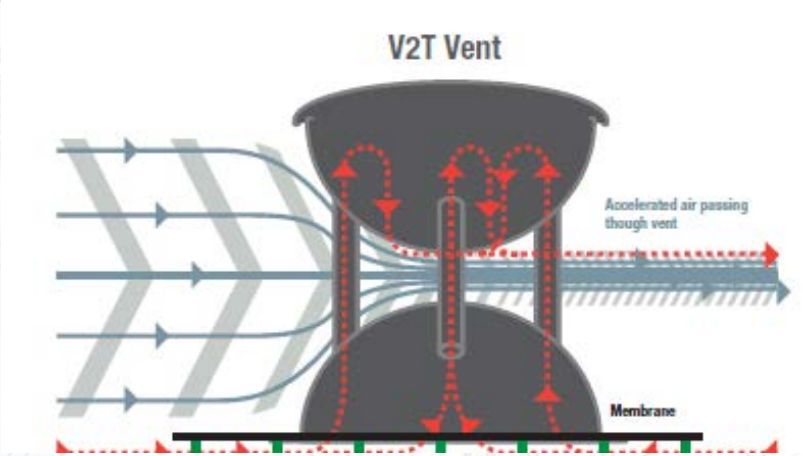
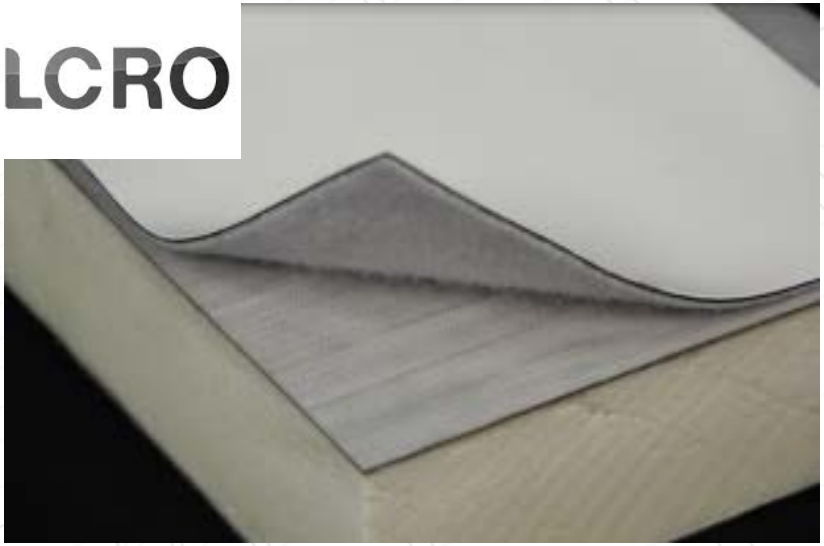
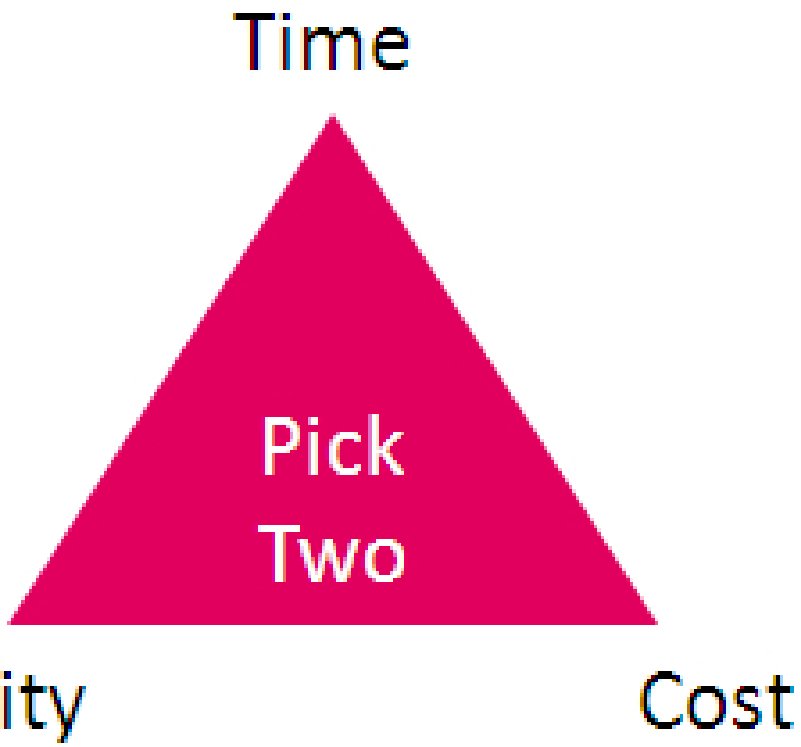
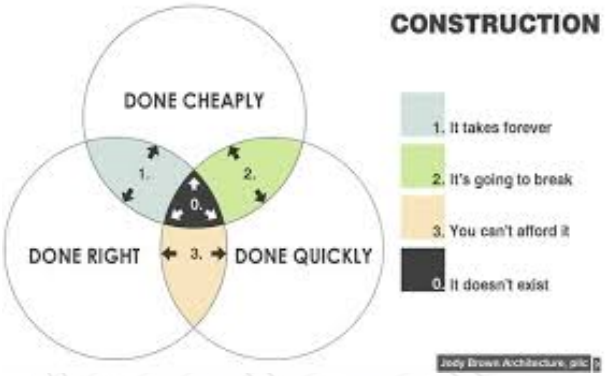
VACUSEAL™ VENT SECURED ROOF SYSTEM



VELCRO







You can have something:

- **FAST & CHEAP** but it won't be good quality
- **CHEAP & GOOD QUALITY** but it won't be quick or on time
- **ON TIME & GOOD QUALITY** but it won't be cheap

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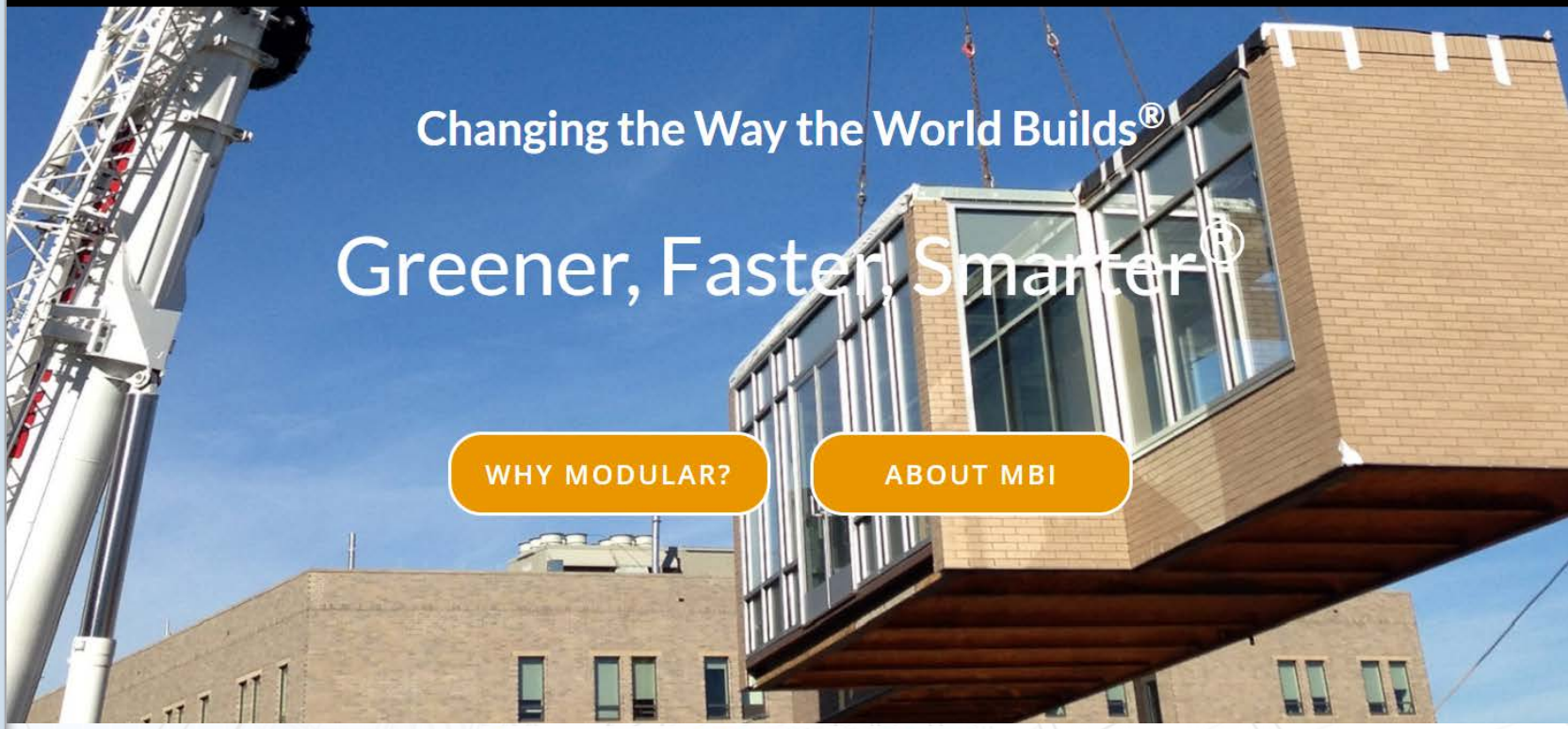

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MBI founded in 1983

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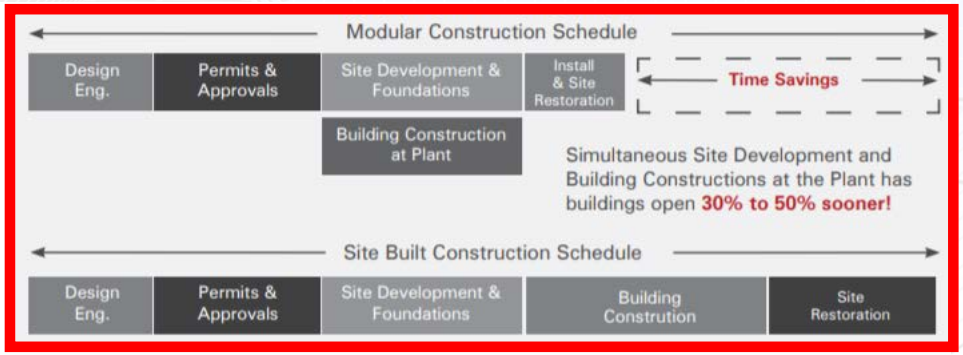

Improving Construction Efficiency & Productivity with **Modular Construction**

Prepared by

The Modular Building Institute
944 Glenwood Station Lane, Suite 204
Charlottesville, VA 22901 USA

with Excerpts from:

Recently, the National Institute of Standards and Technology (NIST) requested that the National Research Council (NRC) appoint an ad hoc committee of experts to provide advice for advancing the competitiveness and productivity of the U.S. construction industry. The committee's specific task was to conduct a workshop to identify and prioritize technologies, processes, and deployment activities that have the greatest potential to advance significantly the productivity and competitiveness of the capital facilities sector of the U.S. construction industry in the next 20 years. The committee identified five breakthroughs to improve the efficiency and productivity of the construction industry, including breakthrough number three: "Greater use of prefabrication, preassembly, modularization, and off-site fabrication techniques and processes."

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Off-Site Construction Council

Report of the Results of the 2014 Off-Site Construction Industry Survey

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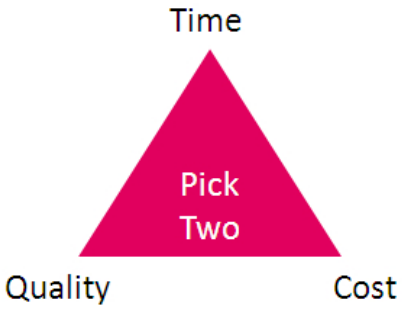
QUESTION 6

For this project, what were the actual benefits realized by using off-site construction?

Time

Quality

Cost



Schedule Advantage/Speed to Market

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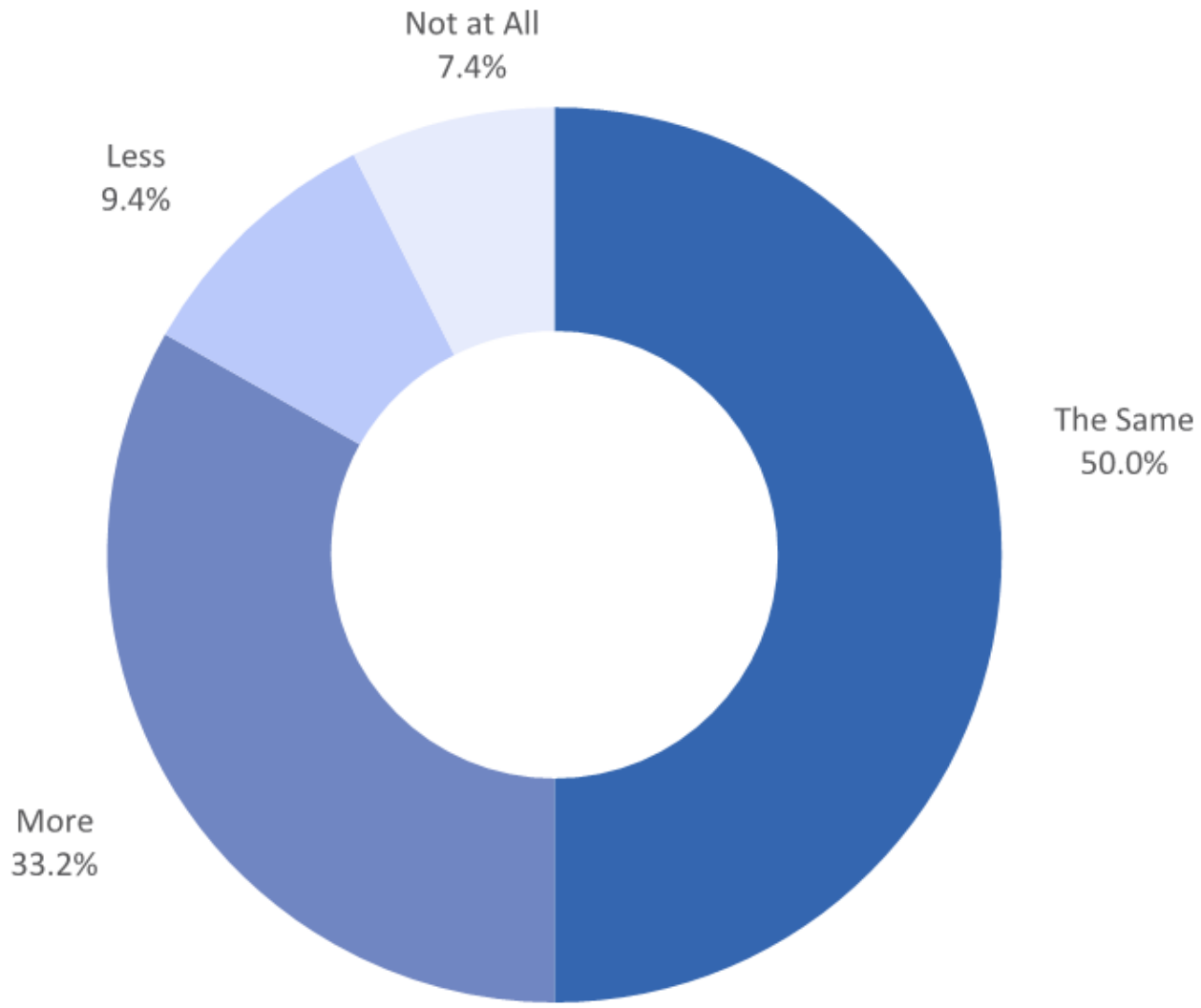
QUESTION 9

In the next 12 months, how often do you anticipate using off-site construction?



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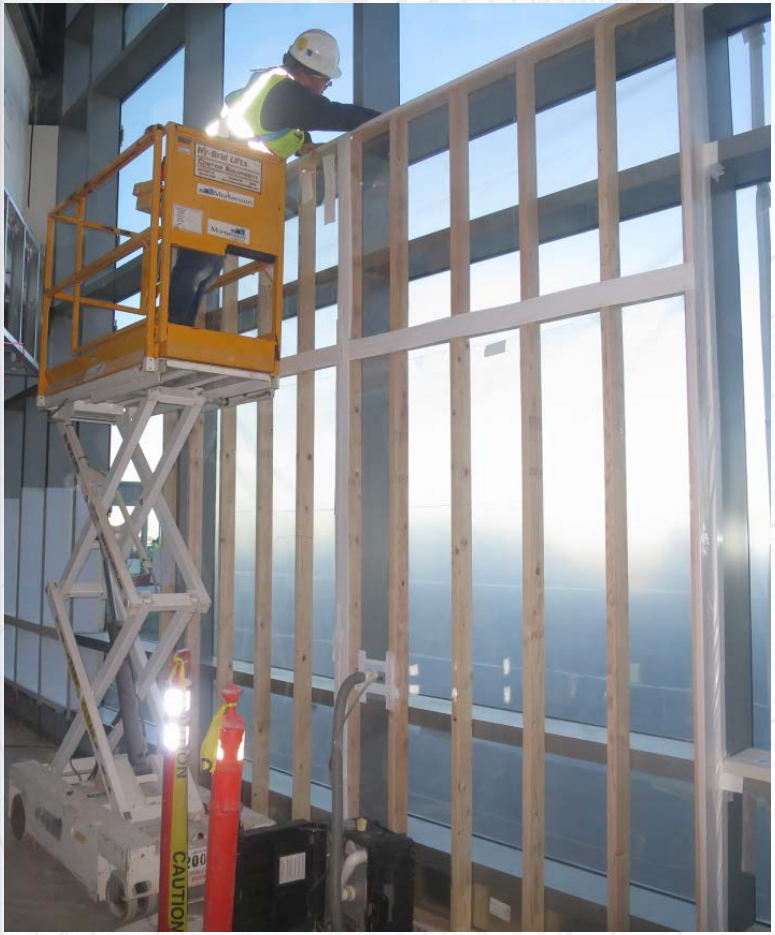
Field Quality Control Testing

Topic 4

Is the Quality of Building Enclosure finally being taken seriously?

- It depends…
- What is quality?
  - Quality refers to the project requirements established by the contract documents.
  - Quality does not have a universal definition.
  - Quality is always **project-specific**.
- Owner's expectations:
  - Developer of condominiums vs. healthcare, e.g.
  - Initial cost (testing) versus long-term risk trade-offs
  - Impact on schedule
- Contractor risk management:
  - Litigation and insurance company concerns
  - Water intrusion claims make up more than 70 percent of construction litigation


CAUTION

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Roofing/Waterproofing System Testing

075323 - EPDM Roofing

3.1. FIELD QUALITY CONTROL

A. Testing Agency: [**Owner will engage**] [**Engage**] a qualified testing agency to perform tests and inspections.

B. Perform the following tests:

1. Flood Testing: Flood test each roofing area for leaks, according to recommendations in ASTM D 5957, after completing roofing and flashing.
   a. Flood to an average depth of [**2-1/2 inches**] for [**48**] hours.
2. Infrared Thermography: Testing agency shall survey entire roof area using infrared color thermography according to ASTM C 1153.
   a. After infrared scan, locate specific areas of leaks by electrical capacitance/impedance testing or nuclear hydrogen detection tests.
   b. After testing, repair leaks, repeat tests, and make further repairs until roofing and flashing installations are watertight.
3. Electrical Capacitance/Impedance Testing: Testing agency shall survey entire roof area for entrapped water within roof assembly according to ASTM D 7954/D 7954M.
4. Nuclear Hydrogen Detection Testing: Testing agency shall survey entire roof area for entrapped water within roof assembly according to SPRI/RCI NT-1.
5. Low-Voltage Electrical Conductance Testing: Testing agency shall survey entire roof area and flashings to locate discontinuity in the roof membrane using [**an exposed metal electrical loop to create an electrical field tested with handheld probes**].

C. Prepare test and inspection reports.

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The "Who, What, Where, How, and When" of Field QC Testing Specifications

ITEM	WHO	WHAT	WHERE	HOW	WHEN
COMPONENT / SYSTEM TO BE TESTED		X			
QUANTITY / TIMING OF TESTS		X			X
LOCATIONS OF TESTS			X		
TEST STANDARD / DESCRIPTION OF TEST				X	
TEST METHOD / METHODOLOGY				X	
PASS/FAIL CRITERIA				X	
PARTY RESPONSIBLE FOR TESTING / REPORTING	X				
REPORTING REQUIREMENTS		X		X	
REQUIRED ADDITIONAL TESTING IN CASE OF FAILED TESTS	X	X	X	X	X
PARTY RESPONSIBLE FOR COSTS ASSOCIATED WITH FAILED TESTS	X				

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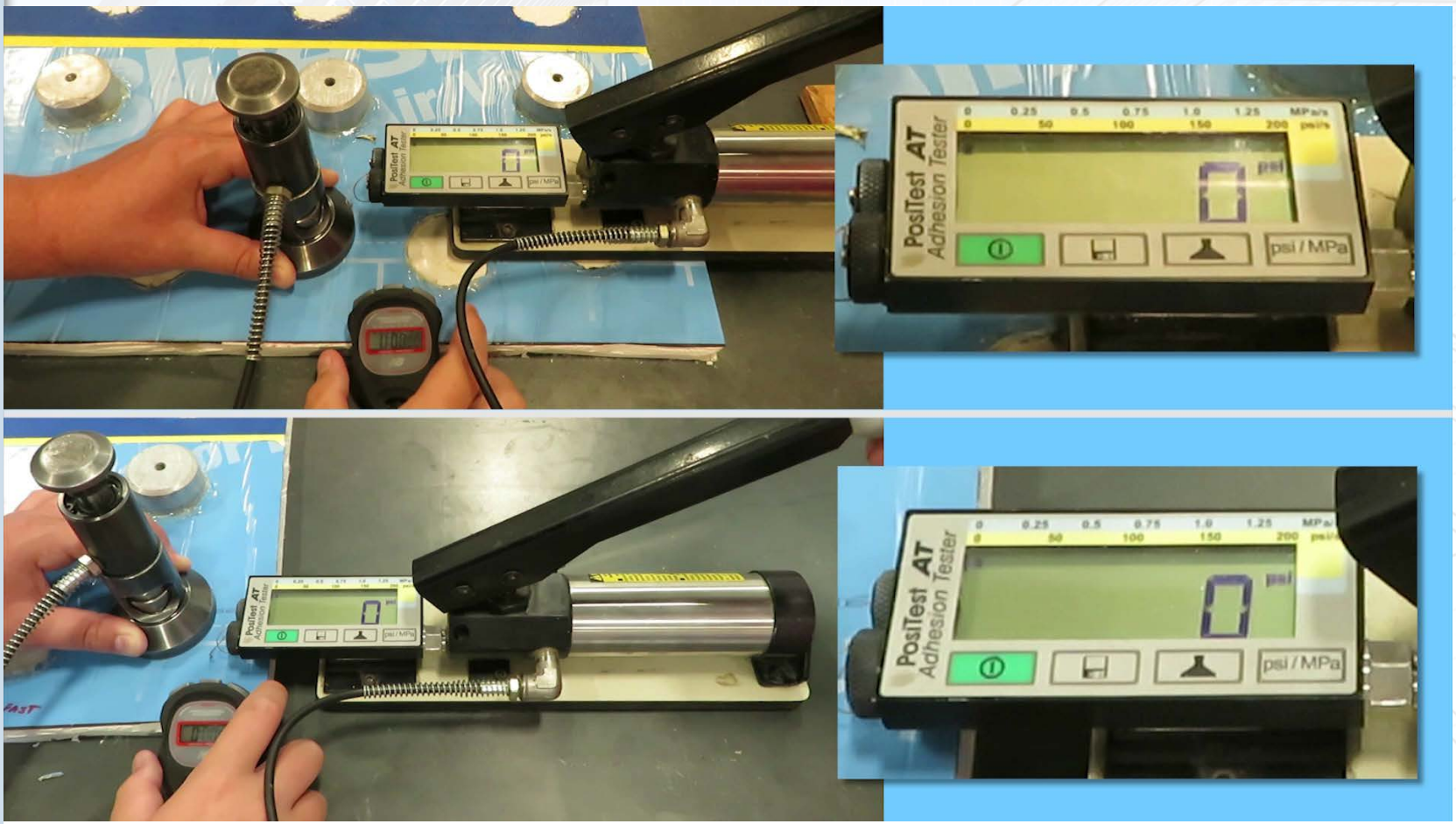
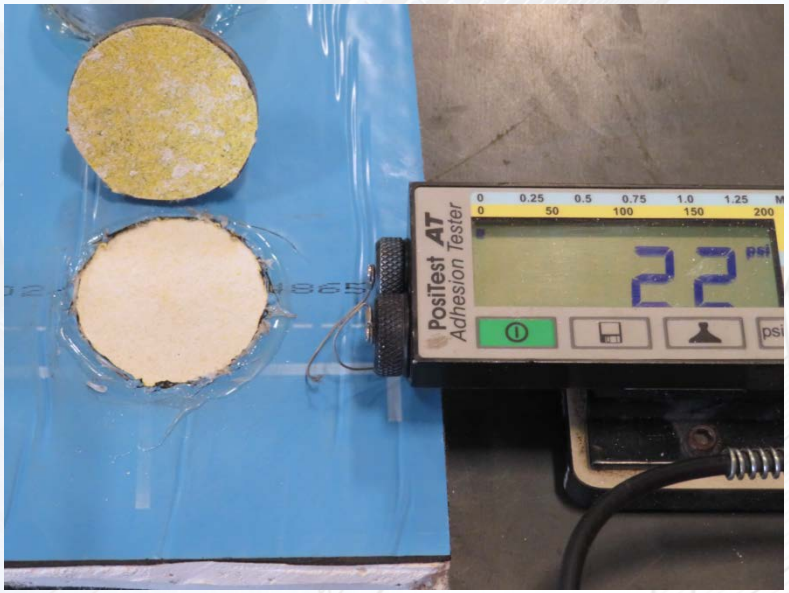
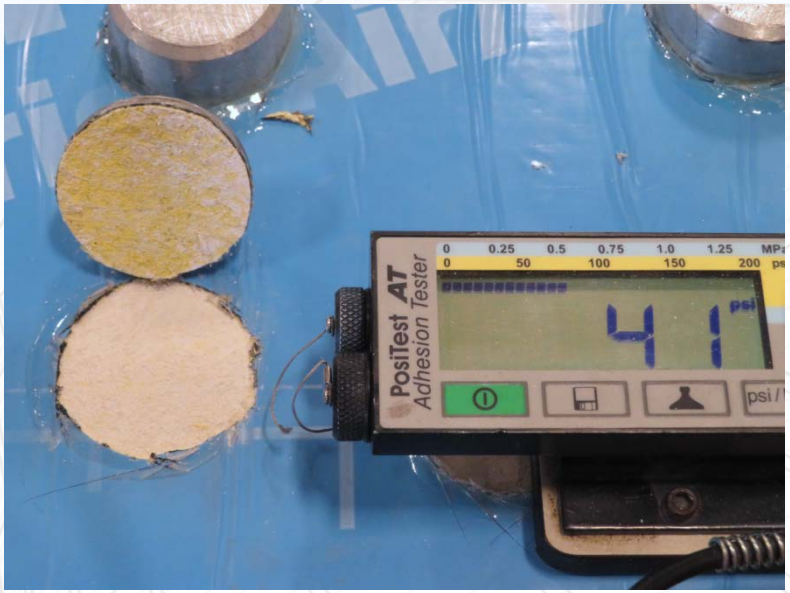
The Effect of Load Rate on Pull-Off Adhesion Strength



PRACTICE	ASTM D4541	ASTM D7234	ABAA 0002
Maximum Load Rate	150 psi/sec	30 psi/sec	0.97 psi/sec (58 psi/min) *or* 6 crank revolutions/min

The Effect of Load Rate on Pull-Off Adhesion Strength





~1 psi / second → 22 psi **~40 psi / second → 41 psi**

~86% increase

PRACTICE	ASTM D4541	ASTM D7234	ABAA 0002
Maximum Load Rate	150 psi/sec	30 psi/sec	0.97 psi/sec (58 psi/min) *or* 6 crank revolutions/min

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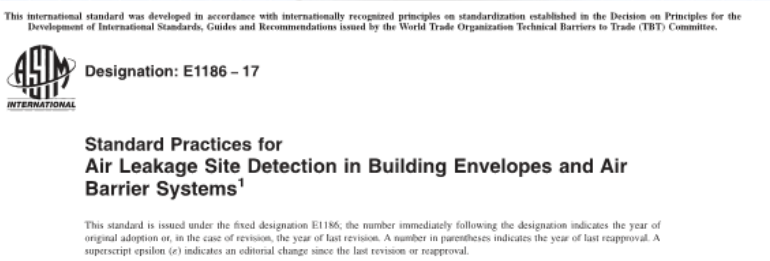
ASTM E 1186 – *Standard Practices for Air Leakage Site Detection in Building Envelopes and Air Barrier Systems*



This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.

Designation: E1186 – 17

Standard Practices for Air Leakage Site Detection in Building Envelopes and Air Barrier Systems[1]

This standard is issued under the fixed designation E1186; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

PRACTICE	PARAGRAPHS
Building Depressurization (or Pressurization) with Infrared Scanning Techniques	4.2.1 and 7.2 to 7.2.5
Smoke Tracer or Theatrical Fog in Conjunction with Building Pressurization or Depressurization	4.2.2 and 7.3 to 7.3.3
Building Depressurization (or Pressurization) in Conjunction with Airflow Measurement Devices, or Anemometers	4.2.3 and 7.4 to 7.4.4
Generated Sound in Conjunction with Sound Detection	4.2.4 and 7.5 to 7.5.5
Tracer Gas	4.2.5 and 7.6 to 7.6.4
Chamber Pressurization or Depressurization in Conjunction with Smoke Tracer or Theatrical Fog	4.2.6 and 7.7 to 7.7.5
Chamber Depressurization in Conjunction with Leak Detection Liquid	4.2.7 and 7.8 to 7.8.6

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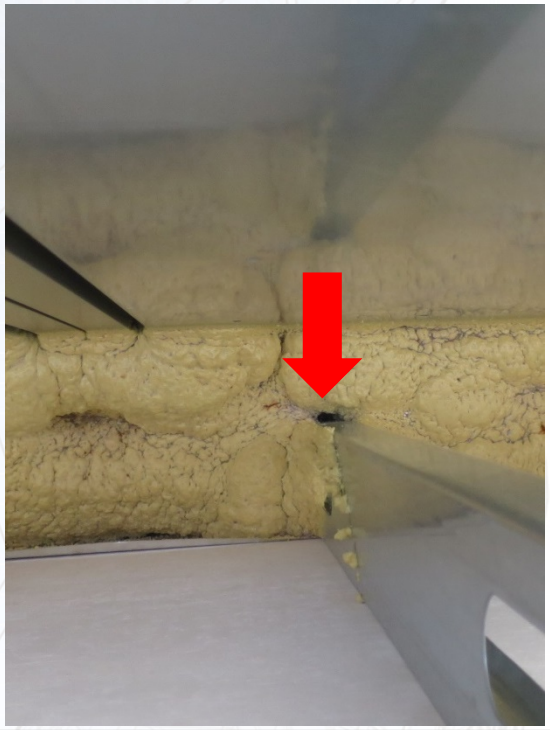
ASTM E 1186 – *Standard Practices for Air Leakage Site Detection in Building Envelopes and Air Barrier Systems*



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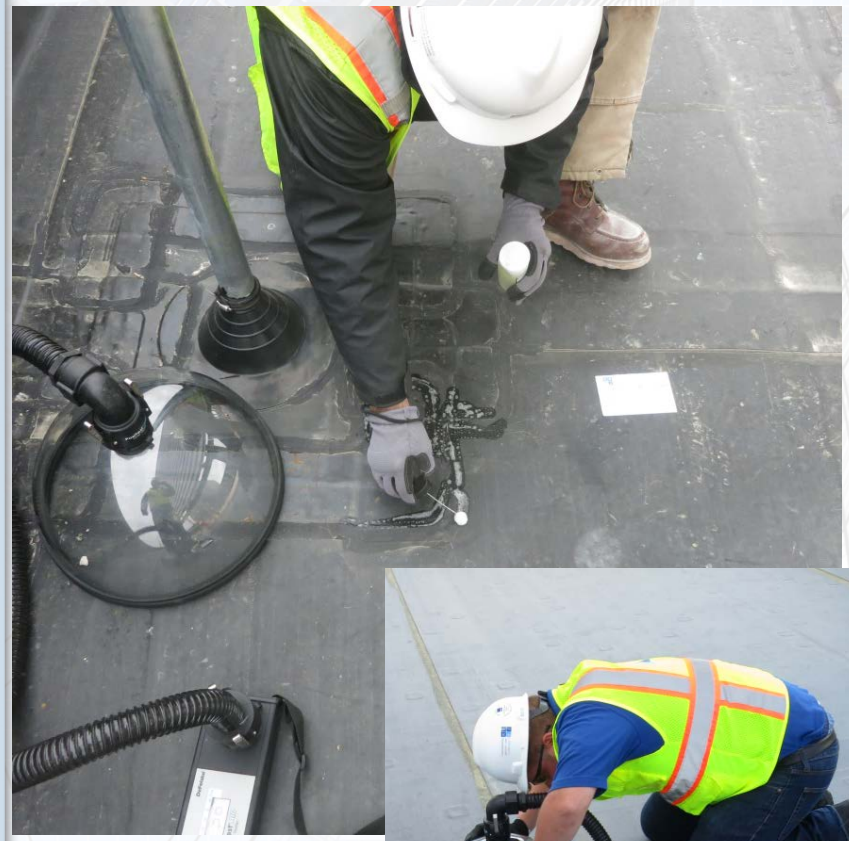
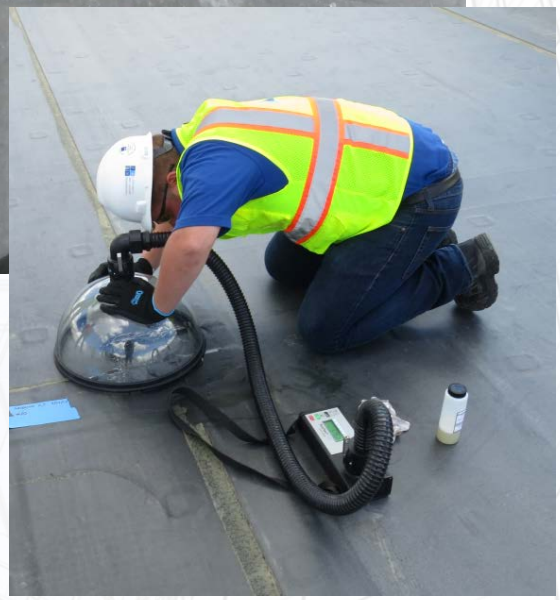
ASTM E 1186 – *Standard Practices for Air Leakage Site Detection in Building Envelopes and Air Barrier Systems*





ASTM E 779 – *Standard Test Method for Determining Air Leakage by Fan Pressurization*

Building enclosure is tested to quantify the air tightness.

The te sure under Requi

IECC 2021? 2024?

- State of Washington
- United States General Services Administration
- United States Army Corps of Engineers projects
- Performance-based option (IECC) that many designers are requiring.

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ASTM E 779 – *Standard Test Method for Determining Air Leakage by Fan Pressurization*

WASHINGTON STATE ENERGY CODE, COMMERCIAL PROVISIONS (2015)

C402.5.1.1 Air barrier construction. The continuous air barrier shall be constructed to comply with the following:

5. **Construction documents shall contain a diagram showing the building's pressure boundary in plan(s) and section(s)** and a calculation of the area of the pressure boundary to be considered in the test.

C402.5.1.2 Building test. The completed building shall be tested and the **air leakage rate of the building envelope shall not exceed 0.40 cfm/ft2** at a pressure differential of 0.3 inches water gauge (2.0 L/s x m 2 at 75 Pa) at the upper 95 percent confidence interval in accordance with **ASTM E 779** or an equivalent method approved by the code official. A report that includes the tested surface area, floor area, air by volume, stories above grade, and leakage rates shall be submitted to the building owner and the Code Official. **If the tested rate exceeds that defined here, a visual inspection of the air barrier shall be conducted and any leaks noted shall be sealed to the extent practicable.** An additional report identifying the corrective actions taken to seal air leaks shall be submitted to the building owner and the Code Official and any further requirement to meet the leakage air rate will be waived.

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Standard Guide for
Specifying and Testing Field-Constructed Exterior Building Wall System Mockups in New Construction[1]

draft of Work Item # WK25809

Proposed Scope of Guide

- Assist in the specification, design, and **performance testing** of field-constructed exterior wall assemblies
- Testing procedures for water penetration resistance, air leakage resistances, etc.
- Exterior wall mock-ups:
  - Curtain walls, windows, doors, masonry walls, precast concrete, cast-in-place concrete, EIFS, **roofing interfaces**, stucco, wood siding, metal panels, sealants, appurtenances, **penetrations**, louvers, etc.
  - **Intersections between wall systems**

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Building Enclosure Commissioning (BECx)

Topic 5

Building Enclosure Commissioning (BEC_x)

History of Process Development

2006

- **NIBS Guideline 3** - *BEC_x Process* (Edition 1)

2012

- **NIBS Guideline 3** - *BEC_x Process* (Edition 2)
- **ASTM E2813** - *Standard Practice for BEC_x* (Edition 1 – numerous subsequent revisions)

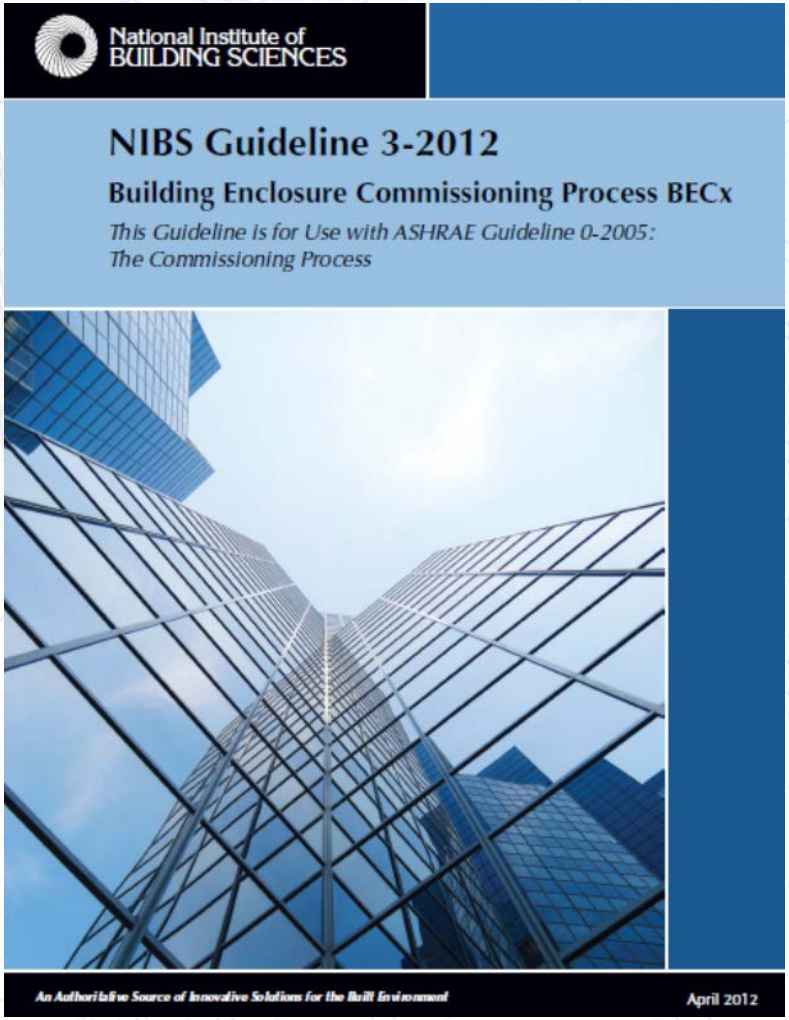
2014

- **ASTM E2947** - *Standard Guide for BEC_x* (Edition 1 – subsequent revisions in 2015 and 2016)

Building Enclosure Commissioning (BEC_x)

NIBS GL3

- "The purpose of this guideline is to describe the specific application of the BECx process described generically in ASHRAE Guideline 0."
- "…intended to be usable by all owners for all building types."
- Not a 'one-size-fits-all' approach. BECx objectives may vary by:
  - Type of Owner
  - Occupancy
  - Use
  - Size
  - Project Requirements
- Describes a process



Building Enclosure Commissioning (BEC_x)

ASTM E2813

Designation: E2813 – 12$^{\varepsilon 1}$

Standard Practice for

4.1 This practice establishes two levels of BECx: *Fundamental and Enhanced.*

ε¹ NOTE—Editorial changes were made throughout in April 2015.

INTRODUCTION

Building Enclosure Commissioning (BECx) is a process that begins with the establishment of the Owner's Project Requirements (OPR) and endeavors to ensure that the exterior enclosure and those

1.4 This practice includes mandatory BECx Performance Testing Requirements (Annex A2) approved for use with this

1. Scope

1.1 This practice is intended to serve as a concise, authoritative, and technically sound practice for Building Enclosure Commissioning (BECx) that establishes two levels of BECx: *Fundamental* and *Enhanced* (refer also to Section 4).

1.2 The BECx process as defined in this practice includes the following phases and sub-phases:

1.2.1 Pre-Construction,[2]

1.2.2 Design,

1.2.3 Construction,

1.2.4 Occupancy and Operations.

practice to evaluate the performance and durability of enclosure materials, components, systems, and assemblies.

1.5 This practice mandates independent, third-party design peer review during the Design Phase of both Fundamental and Enhanced BECx.

1.6 This practice recognizes that the OPR for exterior

1.5 This practice mandates independent, third-party design peer review during the Design Phase of both Fundamental and Enhanced BECx.

1.6.3 Safety,

1.6.4 Security,

1.6.5 Durability,

1.6.6 Sustainability, and

1.6.7 Operation.

1.3 This practice includes a mandatory OPR Development Guideline (Annex A1) and requires the development of an OPR for both Fundamental and Enhanced BECx that addresses, at a minimum, the performance attributes and metrics included in Annex A1 of this practice.

1.4 This practice includes mandatory BECx Performance Testing Requirements (Annex A2) approved for use with this

1.7 The terms "building enclosure" and "enclosure" as they appear in this practice refer collectively to all materials, components, systems, and assemblies intended to provide shelter and environmental separation between interior and exterior, or between two or more environmentally distinct interior spaces in a building or structure.

1.8 This practice establishes that the Building Enclosure Commissioning Provider (BECxP) refers specifically to the individual retained by the Owner to develop, manage, and be in responsible charge of the BECx process, including individual members and technical specialists that may comprise the BECx team (see 4.2).

[1] This practice is under the jurisdiction of ASTM Committee E06 on Performance of Buildings and is the direct responsibility of Subcommittee E06.55 on Performance of Building Enclosures.

Current edition approved Feb. 1, 2012. Published April 2015. Originally approved in 2012. Last previous edition approved in 2012 as E2813–12. DOI: 10.1520/E2813-12E01.

[2] See 5.1.3, Pre-Construction Phase, which includes BECx activities that occur prior to contract award and the start of construction, and is included in ASHRAE Standard 202 and Guide E2947 as a sub-phase under the "Construction Phase" of the BECx process.

Building Enclosure Commissioning (BEC_x)

ASTM E2813

Primary Differences	
Fundamental BECx	**Enhanced BECx**
BECx provider engaged during Design phase	BECx provider engaged during pre-design phase
Review of preliminary OPR	Assist with preliminary OPR development
Minimum of 1 design peer review at CD completion	Minimum of 3 design peer reviews at SD, DD, and CD phases
9 total mandatory field mock-up test types	11 total mandatory field mock-up test types
11 total mandatory field in-situ test types	15 total mandatory field in-situ test types

Building Enclosure Commissioning (BEC_x)

ASTM E2947

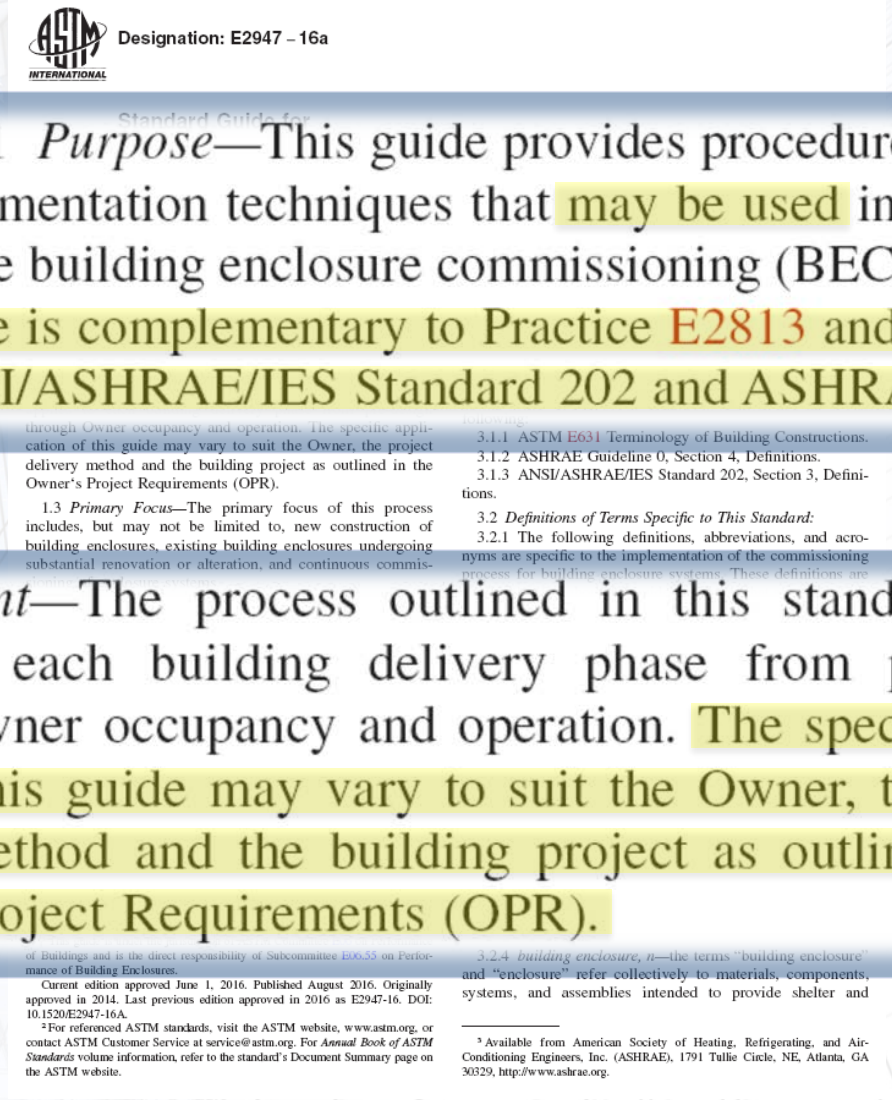
- Table A2.1 – BECx Performance Testing Requirements

TABLE A2.1 *Continued*

Property	Standard Designation	Title	Lab System Testing	Enhanced		Fundamental	
				Field Mockup Testing[A]	In-Situ Field Testing	Field Mockup Testing	In-Situ Field Testing
Water Penetration							
Water penetration	ASTM E331	Test Method for Water Penetration of Exterior Windows, Skylights, Doors, and Curtain Walls by Uniform Static Air Pressure Difference	L (M)	. . .	. . .	. . .	. . .
	ASTM E514	Test Method for Water Penetration and Leakage Through Masonry	OL	(OF)	(OF)	(OF)	(OF)
	ASTM C1601	Test Method for Field Determination of Water Penetration of Masonry Wall Surfaces	. . .	(OF)	(OF)	(OF)	(OF)
	ASTM D5957[F]	Guide for Flood Testing Horizontal Waterproofing Installations	. . .	(OF)	✓ (All horizontal surfaces)	(OF)	✓ (All horizontal surfaces)
Static water penetration	ASTM E1105	Test Method for Field Determination of Water Penetration of Installed Exterior Windows, Skylights, Doors, and Curtain Walls by Uniform or Cyclic Static Air Pressure Difference	. . .	✓ (1X)	✓ (2X)	✓ (1X)	✓ (1X)
Dynamic water penetration	AAMA 501.1	Standard Test Method for Water Penetration of Windows, Curtain Walls, and Doors Using Dynamic Pressure	OL (M)	(OF)	✓ (1X)	(OF)	(OF)
	ASTM E2268[G]	Standard Test Method for Water Penetration of Exterior Windows, Skylights, and Doors by Rapid Pulsed Air Pressure Difference	OL	(OF)	(OF)	(OF)	(OF)
	AAMA 501.2	Quality Assurance and Diagnostic Water Leakage Field Check of Installed Storefronts, Curtain Walls, and Sloped Glazing Systems	. . .	✓ (1X)	✓ (1X)	✓ (1X)	✓ (1X)

Building Enclosure Commissioning (BEC_x)

ASTM E2947



Designation: E2947 – 16a

Standard Guide for

1.1 *Purpose*—This guide provides procedures, methods and documentation techniques that may be used in the application of the building enclosure commissioning (BECx) process. This guide is complementary to Practice E2813 and is aligned with ANSI/ASHRAE/IES Standard 202 and ASHRAE Guideline 0.

through Owner occupancy and operation. The specific application of this guide may vary to suit the Owner, the project delivery method and the building project as outlined in the Owner's Project Requirements (OPR).

1.3 *Primary Focus*—The primary focus of this process includes, but may not be limited to, new construction of building enclosures, existing building enclosures undergoing substantial renovation or alteration, and continuous commis-

1.2 *Extent*—The process outlined in this standard guide applies to each building delivery phase from pre-design through Owner occupancy and operation. The specific application of this guide may vary to suit the Owner, the project delivery method and the building project as outlined in the Owner's Project Requirements (OPR).

following:

3.1.1 ASTM E631 Terminology of Building Constructions.

3.1.2 ASHRAE Guideline 0, Section 4, Definitions.

3.1.3 ANSI/ASHRAE/IES Standard 202, Section 3, Definitions.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 The following definitions, abbreviations, and acronyms are specific to the implementation of the commissioning process for building enclosure systems. These definitions are

of Buildings and is the direct responsibility of Subcommittee E06.55 on Performance of Building Enclosures.

Current edition approved June 1, 2016. Published August 2016. Originally approved in 2014. Last previous edition approved in 2016 as E2947-16. DOI: 10.1520/E2947-16A.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

3.2.4 *building enclosure, n*—the terms "building enclosure" and "enclosure" refer collectively to materials, components, systems, and assemblies intended to provide shelter and

[3] Available from American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc. (ASHRAE), 1791 Tullie Circle, NE, Atlanta, GA 30329, http://www.ashrae.org.

Building Enclosure Commissioning (BEC_x)

LEED

Version	Energy and Atmosphere (EA)	
	EA Prerequisite: Fundamental Commissioning	EA Credit: Enhanced Commissioning
V3 (2009) and earlier	No requirements related to building enclosure (BE)	
V4 (2016)	References NIBS GL3-2012	
	BE requirements to be included in OPR and BOD	2 points for BECx
	Review of the OPR and BOD relative to BE	Rev[illegible] of BE contractor submittals
	1 design peer review of BE	De[illegible]op on-going Cx plan
		Prepare an O&M Plan (including training in CDs)
		Verify operator and occupant training delivery and effectiveness
		Verify seasonal testing

Building Enclosure Commissioning (BEC_x)

2018 NIBS/ASTM/RCI JOINT STATEMENT

joint statement July 11 announcing their intent to avoid duplication of effort relating to their respective building enclosure commissioning (BECx) programs.

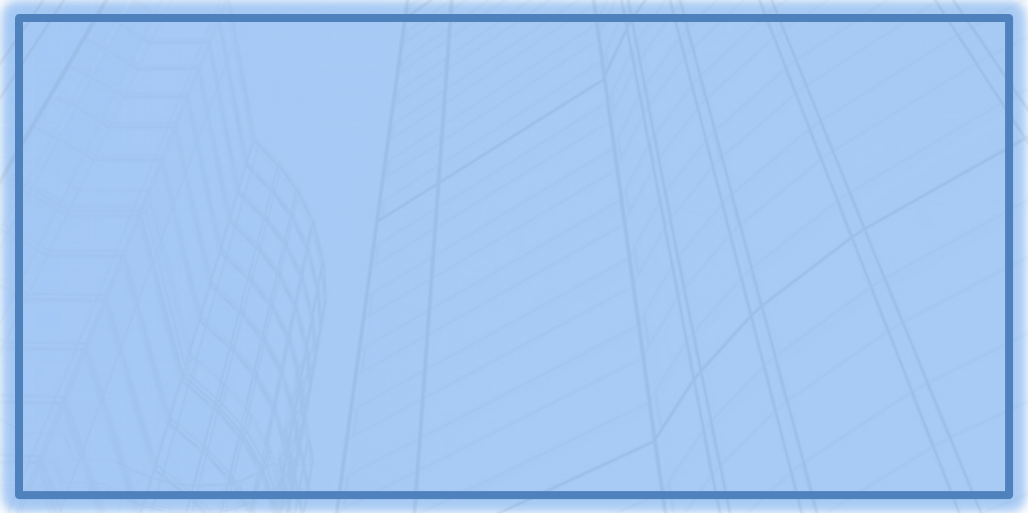
The Institute is rolling out a series of new BECx certificate modules as an education component of an agreement with ASTM to create a joint certificate in building enclosure commissioning. The first three

In addition, RCI Inc., in partnership with Professional Testing, Inc., a certification and examination development company, is developing certifications for the various BECx roles as defined by ASTM. RCI's goal is to develop full-scope certifications for each area to advance the level of quality and standards across the U.S. BECx industry. These certifications will be developed in accordance with accreditation

Building Enclosure Commissioning (BEC_x)

CONSULTANT'S ROLE AND FOCUS

- Primary BECx Tasks by Design Phase
  - **Pre-Design Phase:** Kick-off meeting, BECx plan, Owner's Project Requirements (OPR) development
  - **Design Phase:** Peer reviews at SD, DD, and CD
  - **Pre-Construction:** Shop drawing/submittal review, mock-up performance testing, and pre-con meetings
  - **Construction:** Field observation and performance testing
  - **Occupancy:** Post-occupancy walk-through, warranty review/report, and final BECx report



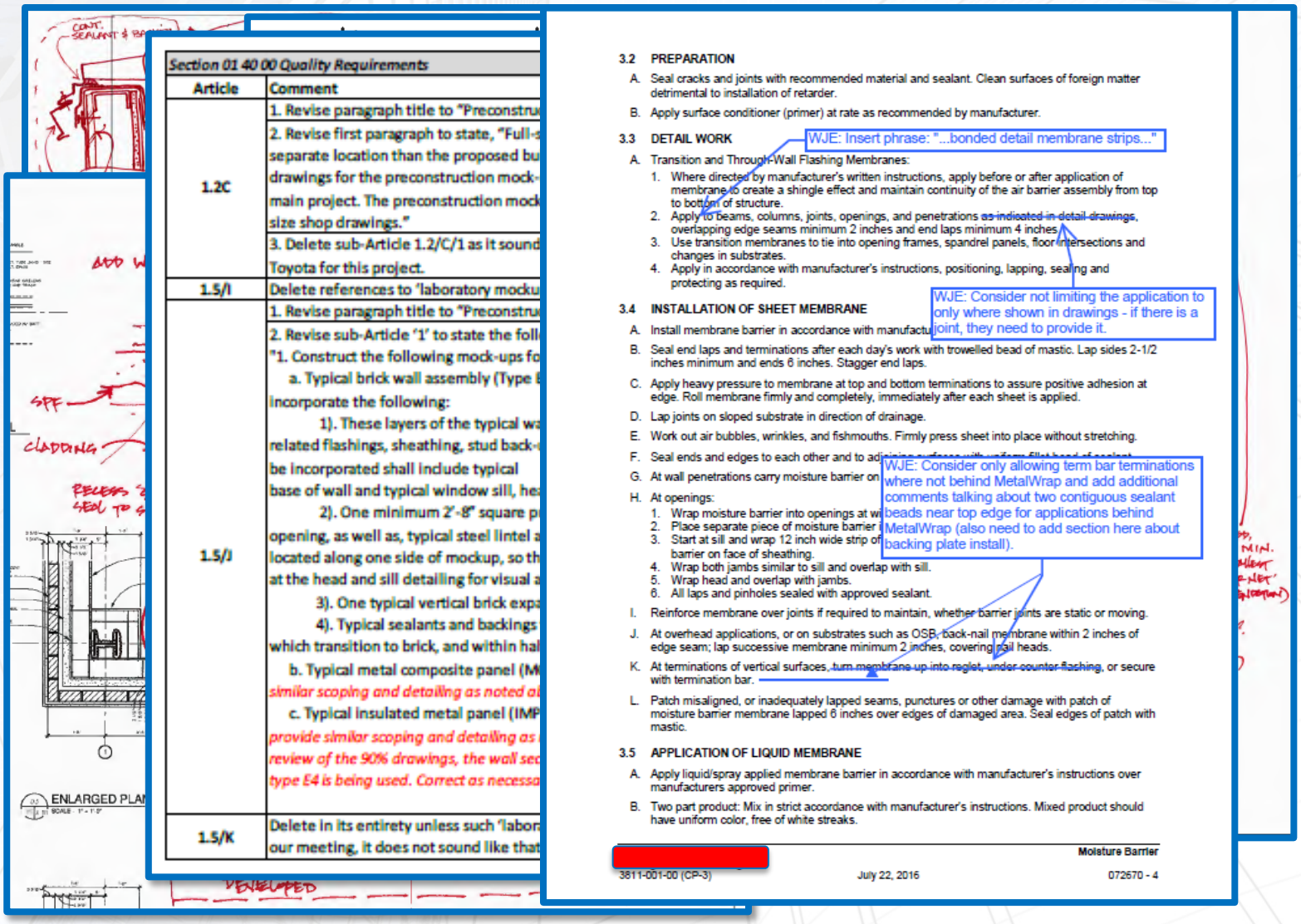
Building Enclosure Commissioning (BEC_x)

CONSULTANT'S ROLE AND FOCUS

- Major Focus: Transition detailing/tie-ins (water management, heat transfer, air seal/air barrier continuity)
  - Roof-to-exterior wall
  - Cladding system transitions
  - Window jamb/head/sill conditions

Building Enclosure Commissioning (BEC_x)

CONSULTANT'S ROLE AND FOCUS



Section 01 40 00 Quality Requirements

Article	Comment
1.2C	1. Revise paragraph title to "Preconstru 2. Revise first paragraph to state, "Full- separate location than the proposed bu drawings for the preconstruction mock- main project. The preconstruction mock size shop drawings." 3. Delete sub-Article 1.2/C/1 as it sound Toyota for this project.
1.5/I	Delete references to 'laboratory mocku
1.5/J	1. Revise paragraph title to "Preconstru 2. Revise sub-Article '1' to state the foll "1. Construct the following mock-ups fo a. Typical brick wall assembly (Type incorporate the following: 1). These layers of the typical wa related flashings, sheathing, stud back- be incorporated shall include typical base of wall and typical window sill, he 2). One minimum 2'-8" square p opening, as well as, typical steel lintel a located along one side of mockup, so th at the head and sill detailing for visual a 3). One typical vertical brick exp 4). Typical sealants and backings which transition to brick, and within hal b. Typical metal composite panel (M *similar scoping and detailing as noted a* c. Typical insulated metal panel (IMP *provide similar scoping and detailing as* *review of the 90% drawings, the wall sec* *type E4 is being used. Correct as necessa*
1.5/K	Delete in its entirety unless such 'labor our meeting, it does not sound like that

3.2 PREPARATION

A. Seal cracks and joints with recommended material and sealant. Clean surfaces of foreign matter detrimental to installation of retarder.

B. Apply surface conditioner (primer) at rate as recommended by manufacturer.

3.3 DETAIL WORK

WJE: Insert phrase: "...bonded detail membrane strips..."

A. Transition and Through-Wall Flashing Membranes:
1. Where directed by manufacturer's written instructions, apply before or after application of membrane to create a shingle effect and maintain continuity of the air barrier assembly from top to bottom of structure.
2. Apply to beams, columns, joints, openings, and penetrations ~~as indicated in detail drawings~~, overlapping edge seams minimum 2 inches and end laps minimum 4 inches.
3. Use transition membranes to tie into opening frames, spandrel panels, floor intersections and changes in substrates.
4. Apply in accordance with manufacturer's instructions, positioning, lapping, sealing and protecting as required.

3.4 INSTALLATION OF SHEET MEMBRANE

WJE: Consider not limiting the application to only where shown in drawings - if there is a joint, they need to provide it.

A. Install membrane barrier in accordance with manufactu
B. Seal end laps and terminations after each day's work with trowelled bead of mastic. Lap sides 2-1/2 inches minimum and ends 6 inches. Stagger end laps.
C. Apply heavy pressure to membrane at top and bottom terminations to assure positive adhesion at edge. Roll membrane firmly and completely, immediately after each sheet is applied.
D. Lap joints on sloped substrate in direction of drainage.
E. Work out air bubbles, wrinkles, and fishmouths. Firmly press sheet into place without stretching.
F. Seal ends and edges to each other and to adj
G. At wall penetrations carry moisture barrier on
H. At openings:
1. Wrap moisture barrier into openings at w
2. Place separate piece of moisture barrier
3. Start at sill and wrap 12 inch wide strip of barrier on face of sheathing.
4. Wrap both jambs similar to sill and overlap with sill.
5. Wrap head and overlap with jambs.
6. All laps and pinholes sealed with approved sealant.

WJE: Consider only allowing term bar terminations where not behind MetalWrap and add additional comments talking about two contiguous sealant beads near top edge for applications behind MetalWrap (also need to add section here about backing plate install).

I. Reinforce membrane over joints if required to maintain, whether barrier joints are static or moving.
J. At overhead applications, or on substrates such as OSB, back-nail membrane within 2 inches of edge seam; lap successive membrane minimum 2 inches, covering nail heads.
K. At terminations of vertical surfaces, ~~turn membrane up into reglet, under counter flashing~~, or secure with termination bar.
L. Patch misaligned, or inadequately lapped seams, punctures or other damage with patch of moisture barrier membrane lapped 6 inches over edges of damaged area. Seal edges of patch with mastic.

3.5 APPLICATION OF LIQUID MEMBRANE

A. Apply liquid/spray applied membrane barrier in accordance with manufacturer's instructions over manufacturers approved primer.
B. Two part product: Mix in strict accordance with manufacturer's instructions. Mixed product should have uniform color, free of white streaks.

[redacted] Moisture Barrier

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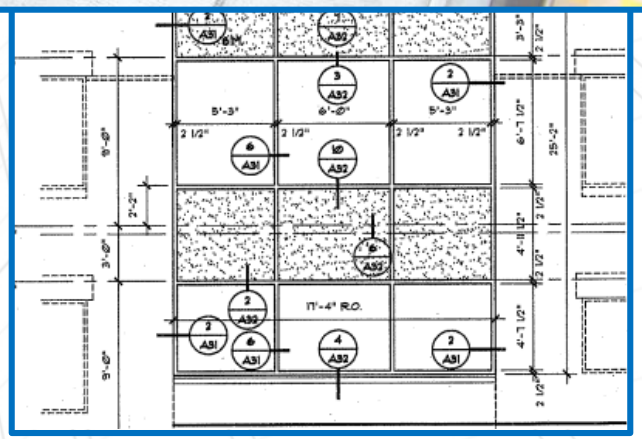
Building Enclosure Commissioning (BEC_x)

CONSULTANT'S ROLE AND FOCUS



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What Does the Future Hold?

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