Air Tightness Requirements of the Passive House Standard

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Scott Pusey

NESEA BuildingEnergy Boston Conference
March 2018

Steven Winter Associates, Inc.
Improving the Built Environment Since 1972

Overview of Presentation

- Brief Overview of Passive House
- PH Air Tightness Requirements
- Design Phase
- Construction Phase QA/QC
- Case Studies
  - The House at Cornell Tech
  - St. John Neumann
  - Beach Green North

What is Passive House (PH)?

- PH is a building standard
- The most rigorous energy efficiency certification available
- Performance based approach
- Attention to insulation continuity and reduction of thermal bridges
- Emphasis on balanced ventilation

What can be certified PH?

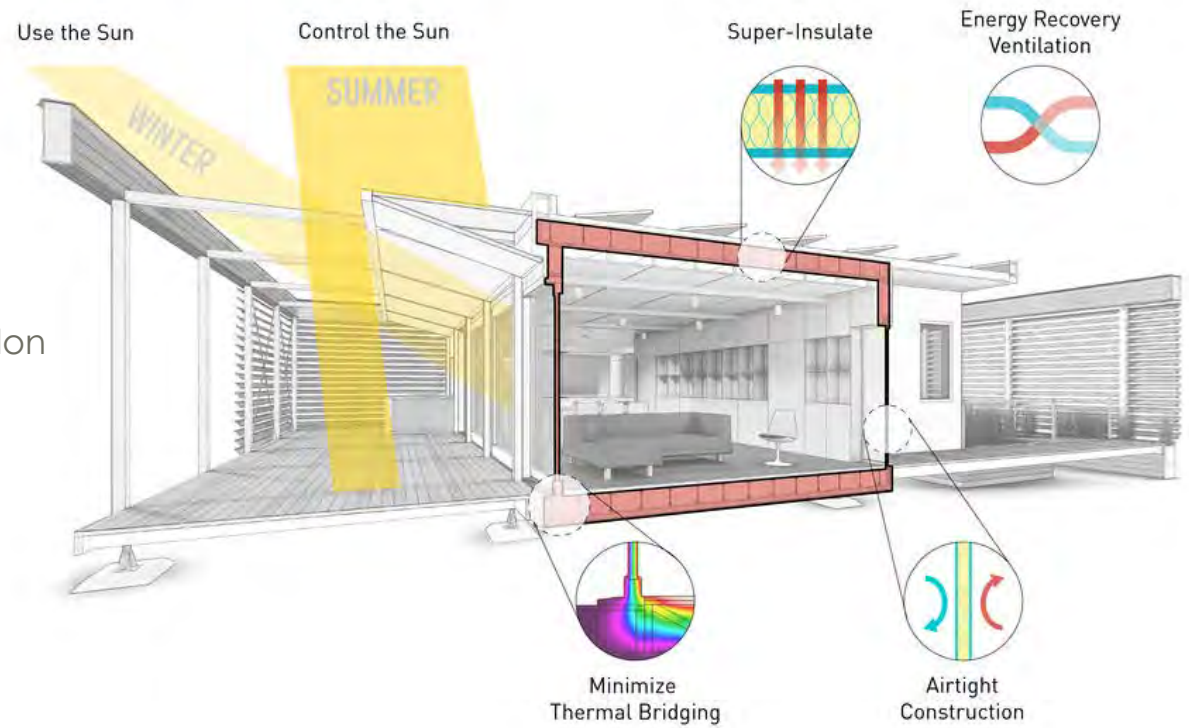
Passive House Criteria

Criteria	Threshold
Space heating/cooling demand	4.75 kBtu/ft^2 yr
Whole building energy demand*	38.0 kBtu/ft^2 yr
Air infiltration	**0.6 ACH@50****
Frequency of overheating***	<10%

* Source
** PHI Limit
*** Must not be exceeded if no mechanical cooling is present.

PH Design Principles

The SURE House
Winner of the 2015
D.O.E. Solar Decathlon
www.surehouse.org



- Continuous Insulation
- Minimize Thermal Bridging
- **Airtight Construction**
- Energy Recovery Ventilation
- Optimal Solar Orientation and Shading

PH AIR TIGHTNESS REQUIREMENTS

PHI vs PHIUS: Differences

Requirement	PHI	PHIUS	Notes
Comfort criteria	Mandatory	Recommended	Leads to triple pane windows in NYC for PHI
Whole building energy demand	/ft^2 of conditioned envelope	/person	
Heating demand	Same for all climates	Changes based on climate	
Cooling demand	Changes based on latent load from climate and occupant density & internal loads	Changes based on climate, sensible only	Temporary adjustment being allowed for cooling demand by PHIUS
Air Tightness	0.6 ACH50 required / 0.033 cfm/ft2 of façade recommended for large buildings	0.08 cfm/ft2 of façade for 6+ stories & non-combustible, 0.05 cfm/ft2 for all others	
Ventilation	Not a lot of approved ERVs in US	Approve a lot more ERVs	
Cooling & Heating Loads	Can certify based on demand or load	Must meet both demand and load thresholds	Can be difficult to meet both

Air Tightness

- Requirement: < 0.6 ACH@50
- What does this mean?
  - @50 refers to 50 pascals pressure difference between indoors and out during a blower door test, ≈ 20mph wind on all sides of house
  - 0.6 ACH50 = 5 times tighter than ENERGY STAR®
- Method A and Method B Testing
  - A: Configures building to operation during the heating and cooling seasons
  - B: Any intentional openings in the building envelope are sealed

Blower Door Testing

- Basic Components
  - Gauge (manometer)
  - Shroud
  - Frame
  - Fan

DESIGN PHASE

PH Design Phase Process

Schematic Design: 1-2 months

- Feasibility Analysis & Recommendations – several iterations

100 % DD: 3-6 months

- Pre-Construction Energy Calculations – 1st detailed model

50% CD: 2-3 months

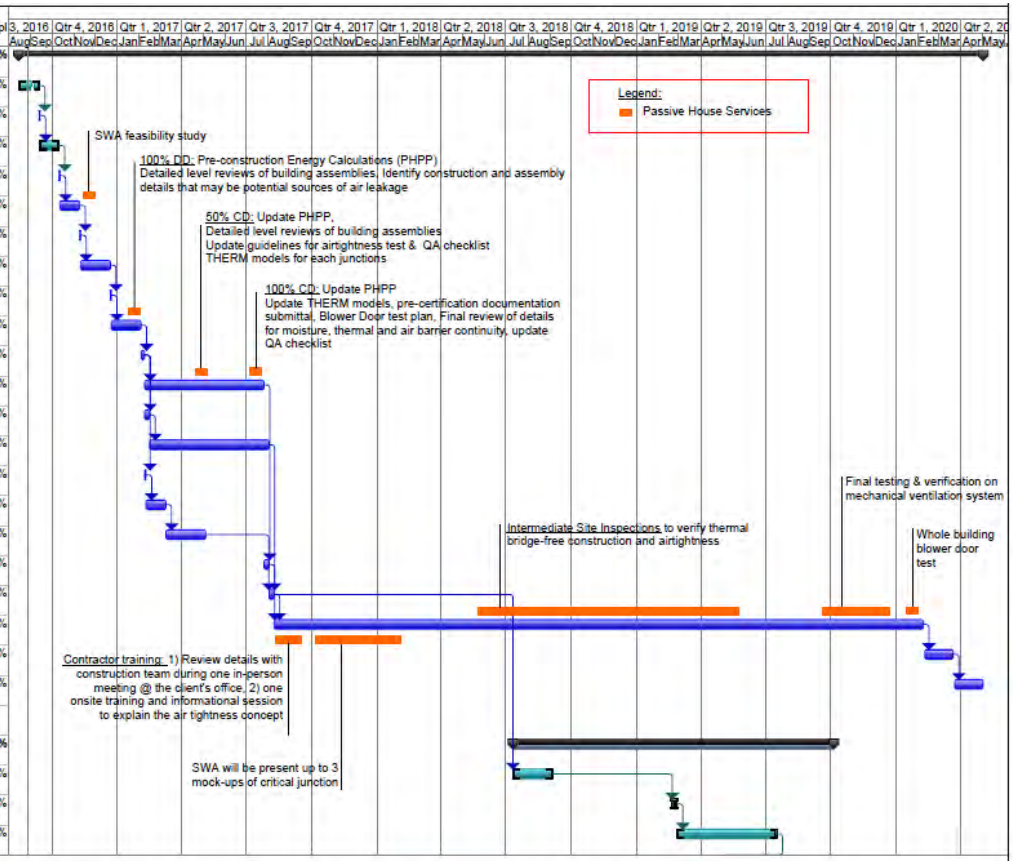
- Update Model & Start THERM Modeling
- Air Barrier Review, QA/QC Checklists & Blower Door Test Plan

100% CD:

- Pre-Construction Energy Calculations & THERM Modeling
- Update Air Barrier Review, QA/QC Checklists & Blower Door Test Plan
- Pre-Certification Submittal to Certifying Body

PH Design Phase

ID	Task Name	Duration	Start	Finish	Predeces	% Compl
1	**Design, Approvals, Construction**	**970 days**	**Mon 8/15/16**	**Fri 5/1/20**		0%
2	Concept Design	20 days	Mon 8/15/16	Mon 9/12/16		0%
3	Concept Design Review	1 day	Tue 9/13/16	Tue 9/13/16	2	0%
4	Preliminary Schematic Design	20 days	Tue 9/13/16	Mon 10/10/16	3	0%
5	Preliminary Schematic Design Review	1 day	Tue 10/11/16	Tue 10/11/16	4	0%
6	Final Schematic Design	20 days	Wed 10/12/16	Tue 11/8/16	5	0%
7	Final Schematic Design Review	1 day	Wed 11/9/16	Wed 11/9/16	6	0%
8	Preliminary Design Development	30 days	Thu 11/10/16	Wed 12/21/16	7	0%
9	Preliminary Design Development Review	1 day	Thu 12/22/16	Thu 12/22/16	8	0%
10	Final Design Development	30 days	Fri 12/23/16	Thu 2/2/17	9	0%
11	Owner Review and Approval of Final DD Drawings	3 days	Fri 2/3/17	Tue 2/7/17	10	0%
12	Final Construction Documentation Set	120 days	Wed 2/8/17	Tue 7/25/17	11	0%
13	Submit drawings to DOB for approval	5 days	Wed 2/8/17	Tue 2/14/17	11	0%
14	DOB Review & Approval	120 days	Wed 2/15/17	Tue 8/1/17	13	0%
15	Issue RFP for GC Bid	2 days	Wed 2/8/17	Thu 2/9/17	11	0%
16	GC Estimating & Bid Submission	20 days	Fri 2/10/17	Thu 3/9/17	15	0%
17	Bid Review & Negotiation	40 days	Fri 3/10/17	Thu 5/4/17	16	0%
18	Final CD's Review and Approval	5 days	Wed 7/26/17	Tue 8/1/17	12	0%
19	Award of CD's & Letter of Intent	5 days	Wed 8/2/17	Tue 8/8/17	18,17	0%
20	Construction	653 days	Wed 8/9/17	Fri 2/7/20	19,14	0%
21	Inspections, Punch List and Occupancy (TCO)	30 days	Mon 2/10/20	Fri 3/20/20	20	0%
22	Final Sign-Offs and Final Certificate of Occupancy	30 days	Mon 3/23/20	Fri 5/1/20	21	0%
23						
24	**Leasing and Marketing**	**323 days**	**Wed 7/11/18**	**Fri 10/4/19**		0%
25	Complete Model Apartment	40 days	Wed 7/11/18	Tue 9/4/18	19FS+24	0%
26	Stage / Prep Model Apartment	5 days	Wed 2/20/19	Tue 2/26/19	25FS+12	0%
27	Show Model Apartment	100 days	Wed 2/27/19	Tue 7/16/19	26	0%

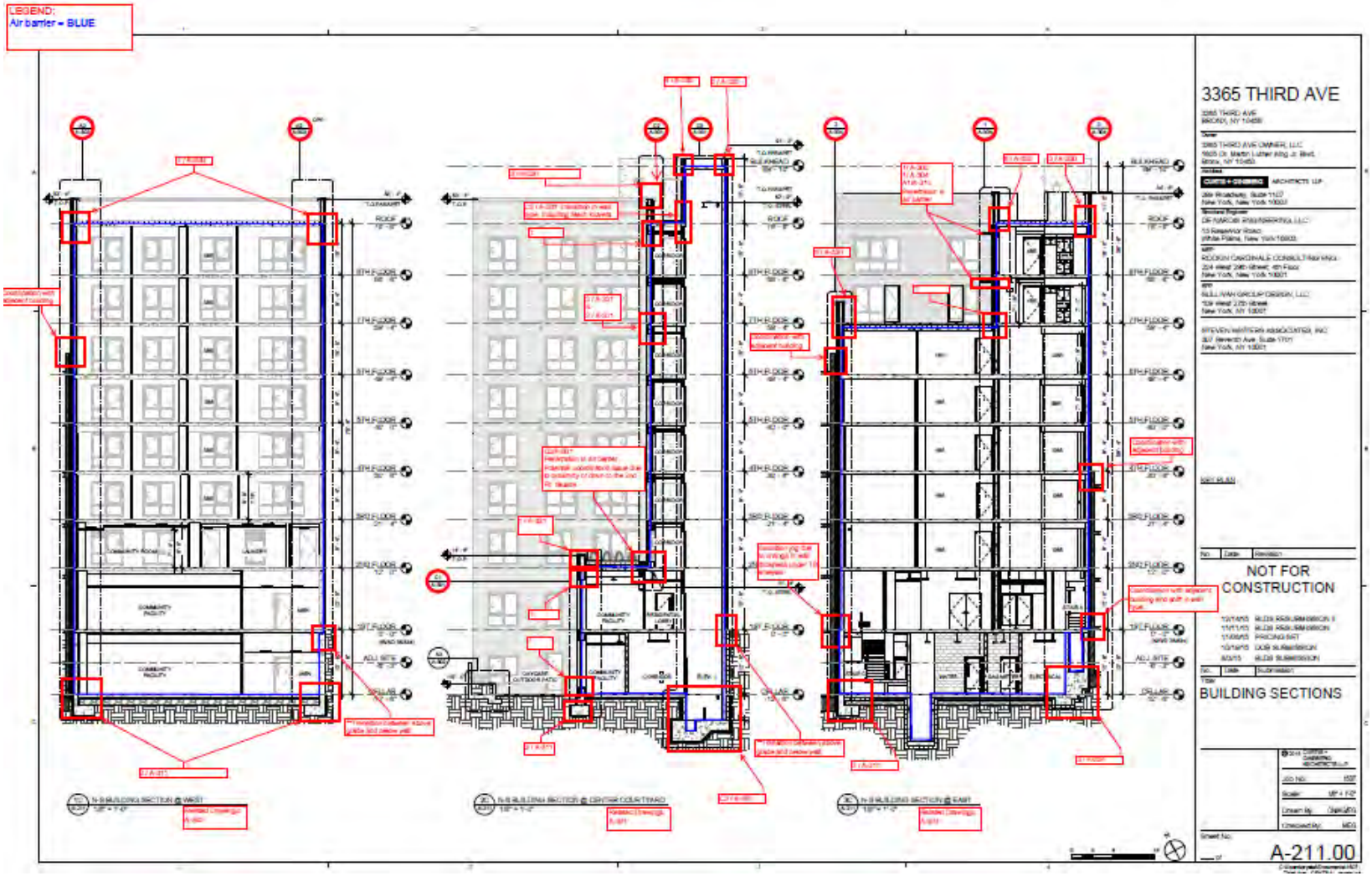


Project: 86th St - Schedule - 7.20.16
Date: Mon 8/29/16

Task	External Tasks	Manual Task	Finish-only
Split	External Milestone	Duration-only	Progress
Milestone	Inactive Task	Manual Summary Rollup	Deadline
Summary	Inactive Milestone	Manual Summary	
Project Summary	Inactive Summary	Start-only	

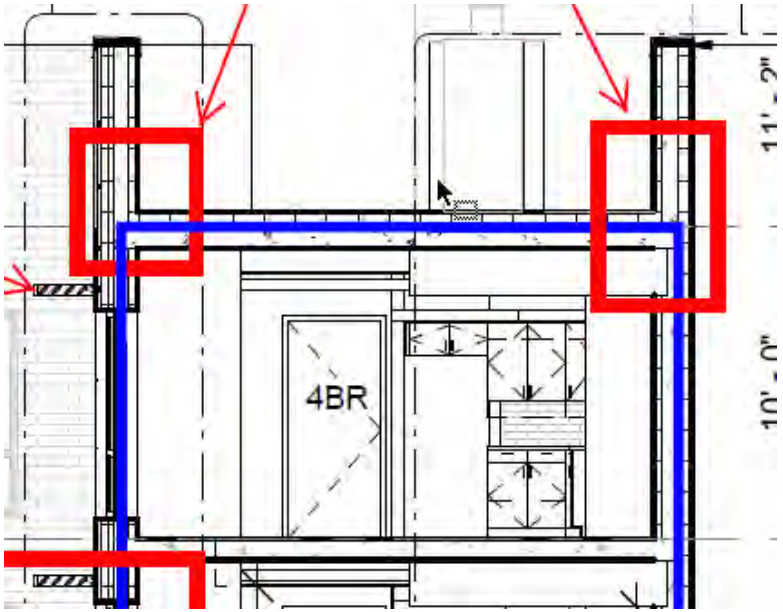
Page 1

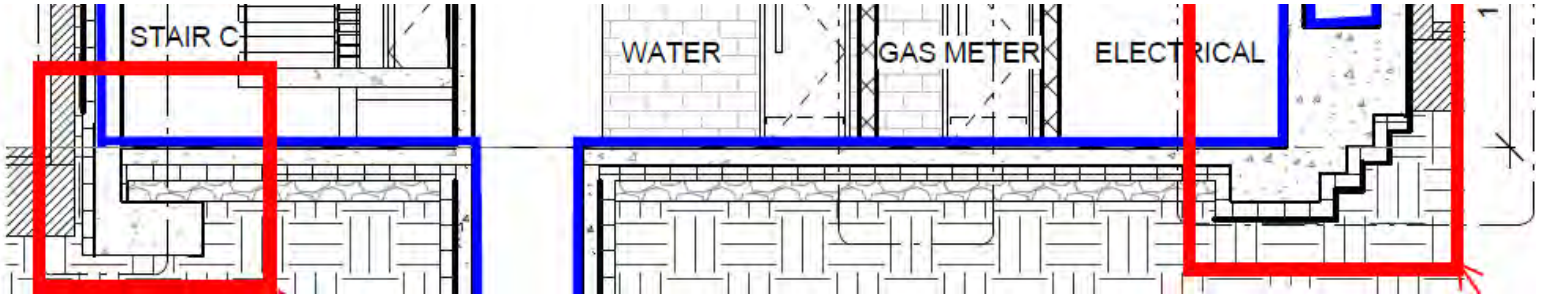
Continuous Insulation & Air Barrier



Continuous Insulation & Air Barrier

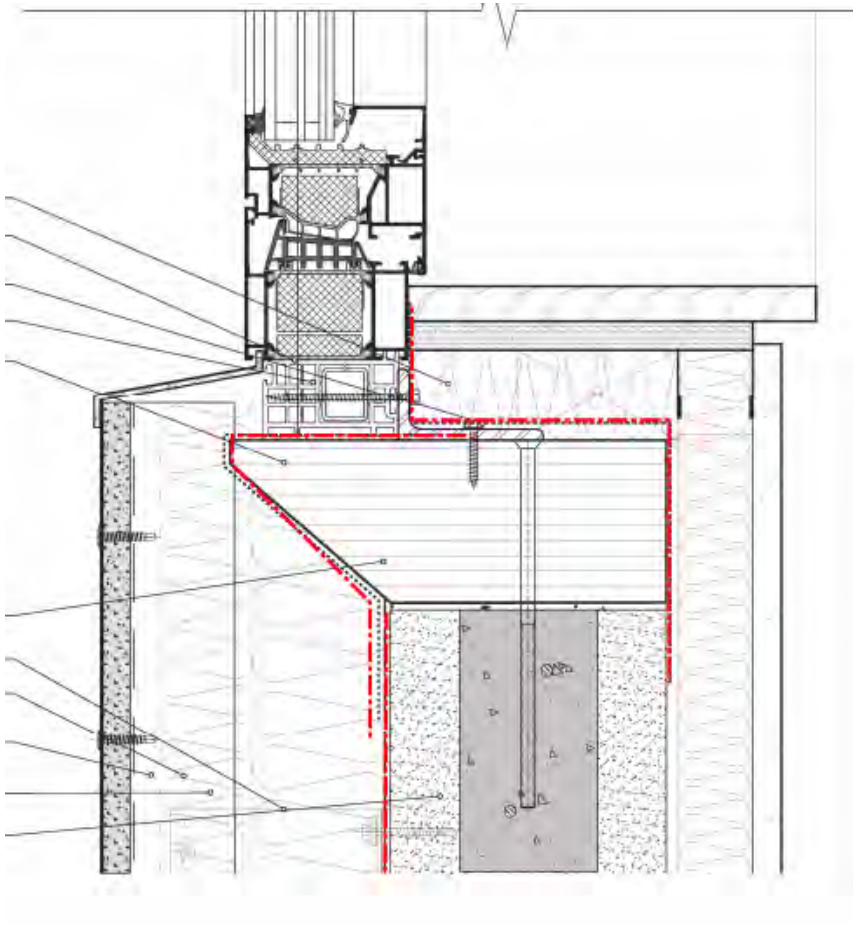
1. Roof slab
2. Interior Gyp on Exterior Walls
3. Foundation Slab



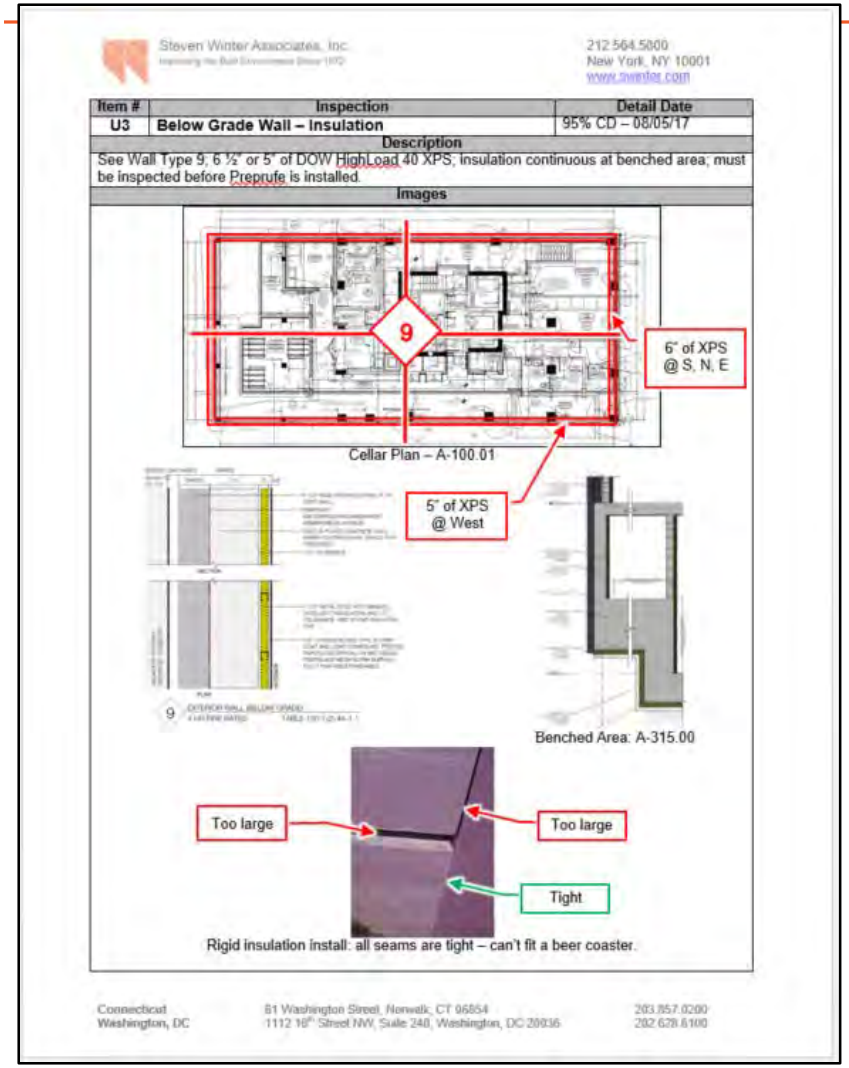


Air Barrier Details

- Air barrier continuity
  - High attention to the details
- Insulation continuity
  - Thermal bridge mitigation



QA/QC Checklists



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New York, NY 10001
www.swinter.com

Item #	Inspection	Detail Date
U3	Below Grade Wall – Insulation	95% CD – 08/05/17

Description

See Wall Type 9; 6 ½" or 5" of DOW HighLoad 40 XPS; insulation continuous at benched area; must be inspected before Preprufe is installed.

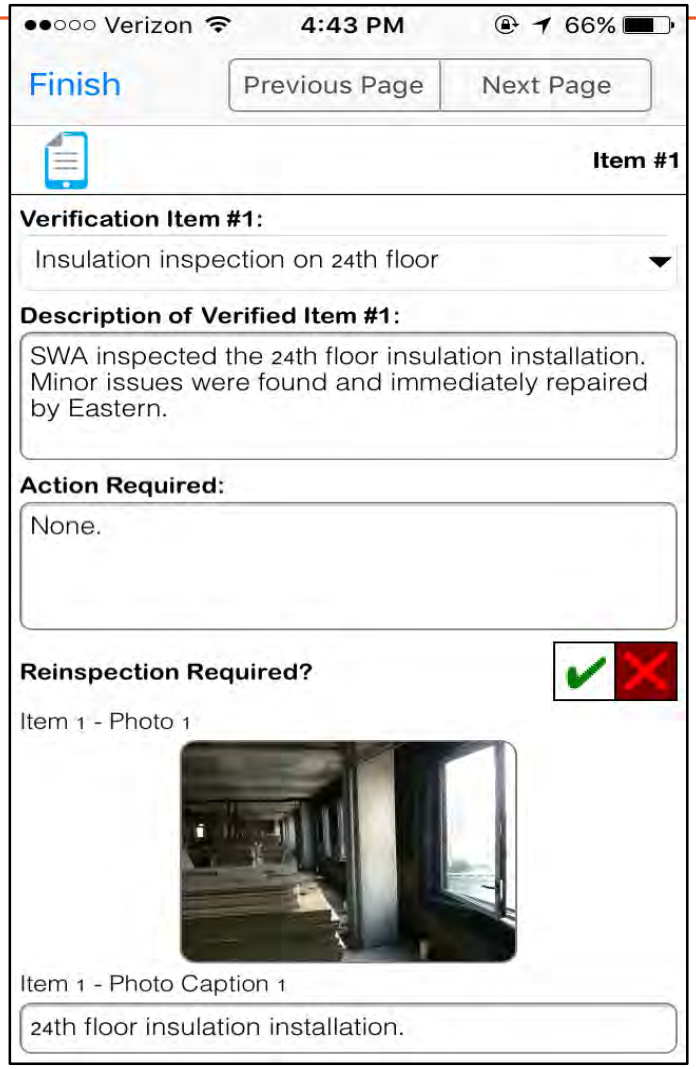
Images

Rigid insulation install: all seams are tight – can't fit a beer coaster.

Connecticut
Washington, DC

81 Washington Street, Norwalk, CT 06854
1112 16th Street NW, Suite 240, Washington, DC 20036

203.857.0200
202.628.6100



CONSTRUCTION PHASE QA/QC

PH Contractor Buy-In

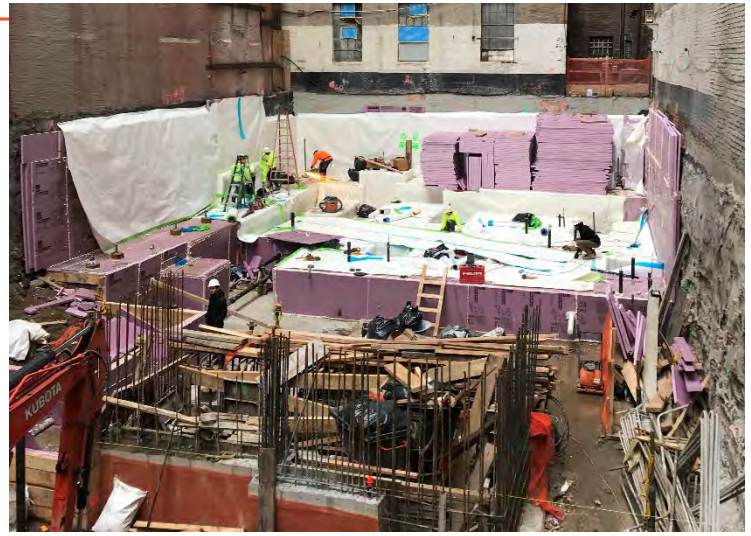
- General contractor and subcontractor buy-in is critical to project success
- All trades have an impact on project results and may require a mind shift on performance testing
- Passive House Tradesperson training mandatory for key personnel
- GC needs at least two people who will be dedicated to PH scope and coordination

PH Contractor Buy-In

- Ensure GC and trades fully understand what's included in respective work scopes
- Discuss expectations with whole project team during bidding phase

Verification for Large Projects

- Foundations
  - Abutting neighbor(s)
  - Staging of foundation
  - Under slab / stem walls
- Above Grade Walls
  - Wall construction type: CMU, wood framed, etc.
  - Sequencing for hoistways, upper vs. lower floors
- Roof
  - Thermal breaks and roof membrane penetrations
  - Bulkheads, louvers & dampers



Testing Tools and Protocols

- Window mockup testing
- Guarded blower door testing
- Envelope compartmentalization and window testing
- Unique component testing
- Whole building blower door test

CASE STUDIES

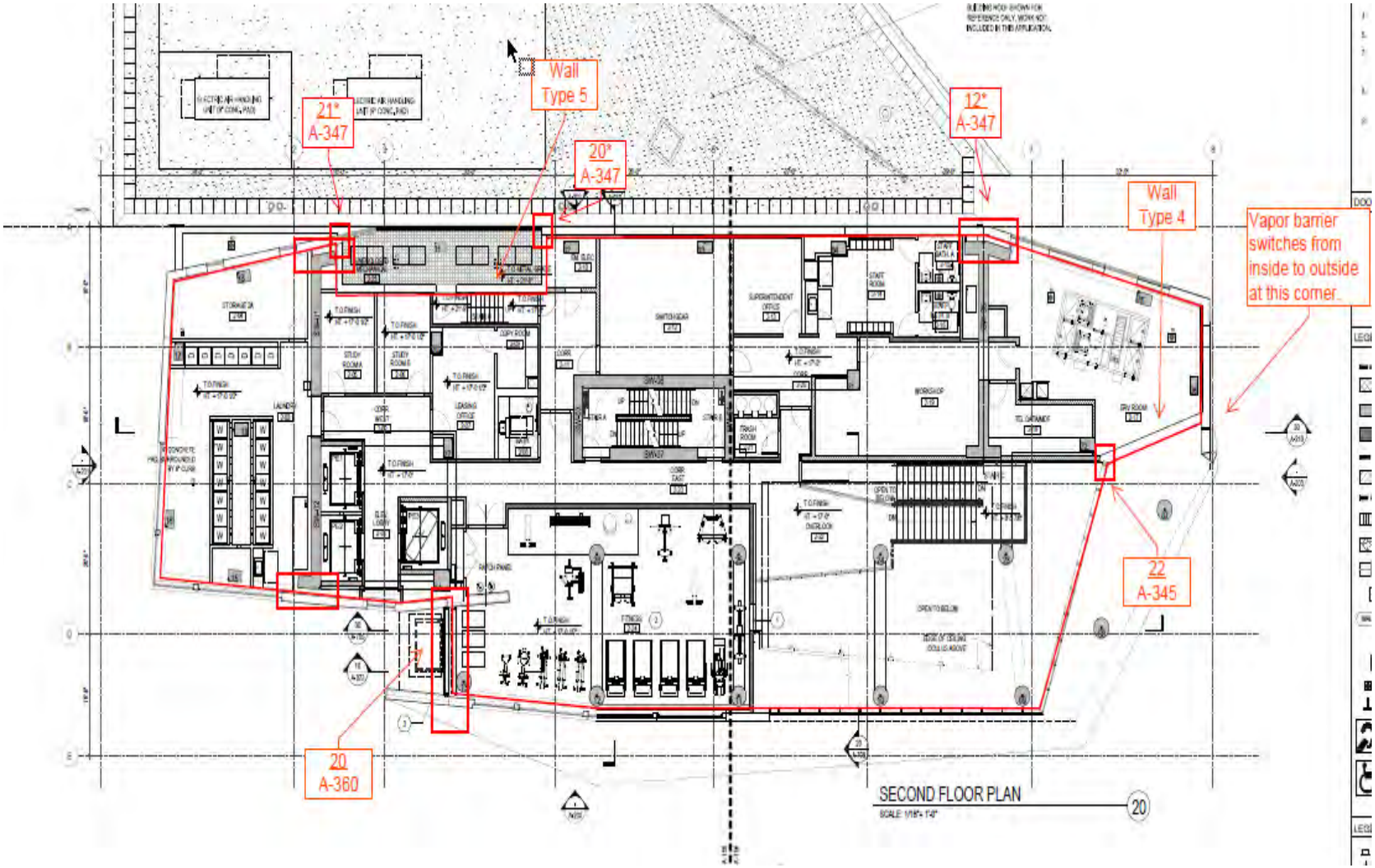
CORNELL TECH CAMPUS

Tallest Passive House Project in the World

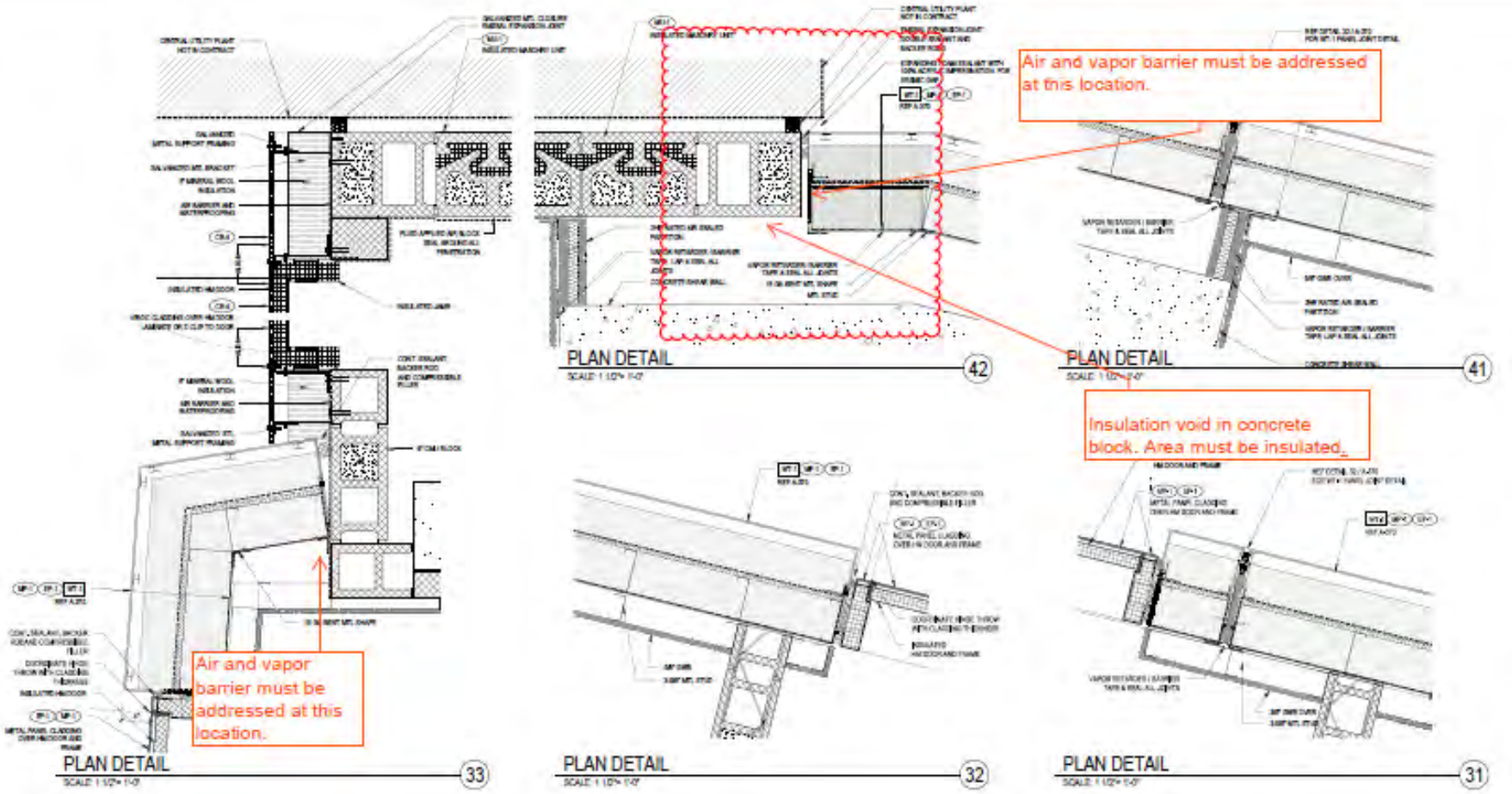
352 units

Roosevelt Island, NY

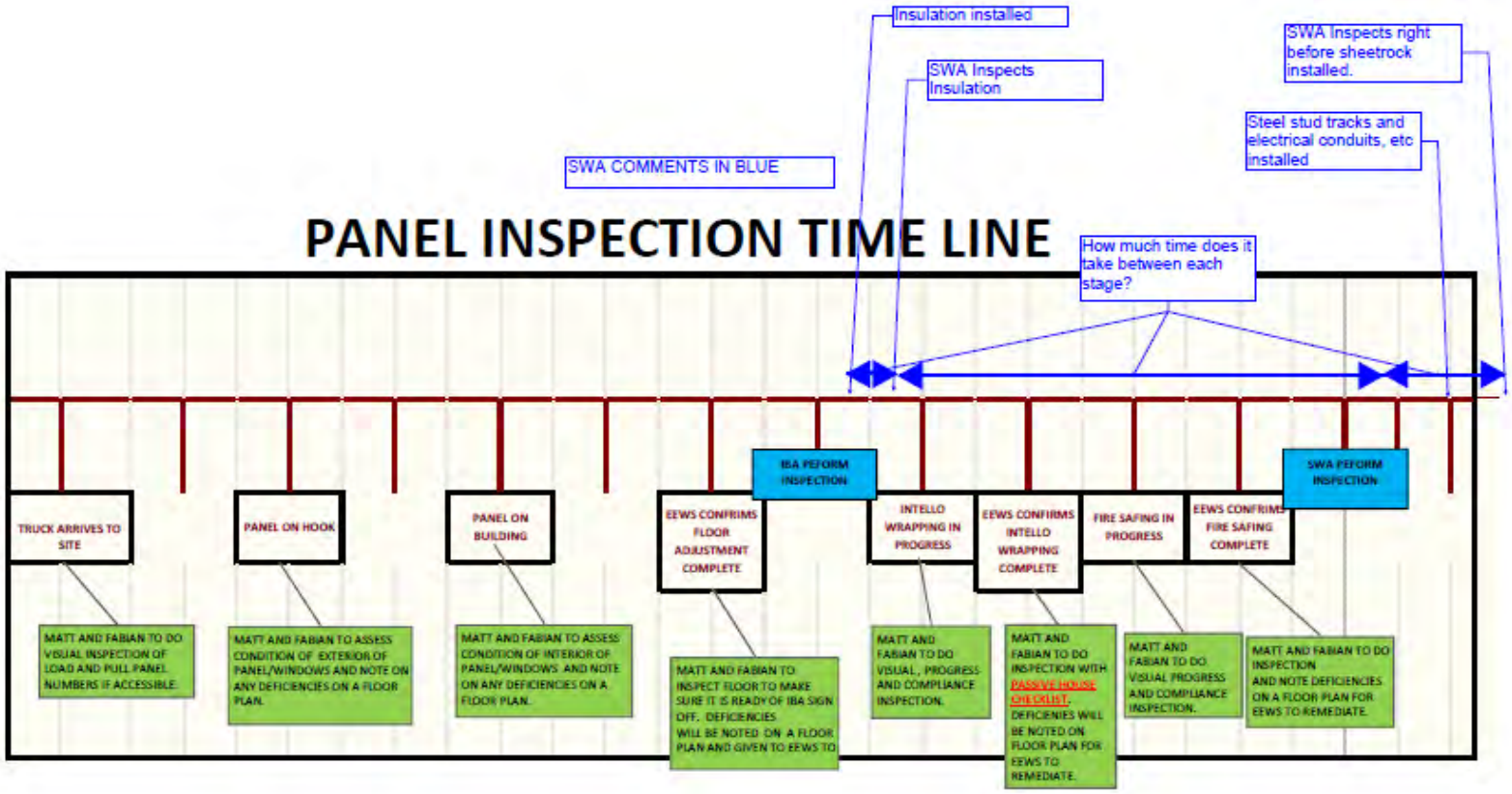
Redline Plan & Section



Drill Into Details



Identify Sequencing & Timing of Inspections



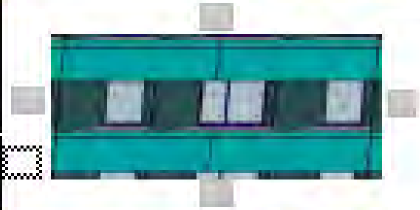
Develop Contractor Checklists

DATE: ___________ WEATHER: ___________
PANEL #___________ FLOOR: ___________

MONADNOCK

PASSIVE HOUSE PANEL WALL INSPECTION CHECKLIST

PANEL SUBSTRATE



A. PANEL

B. POURED CONCRETE

C. CMU

PANEL WALL INSPECTION

PANEL INSULATION

	YES
Wall panel insulation installed without gaps?	
Insulation installed at panel slab anchors?	
Panel insulation dry?	
Insulation installed at panel to panel transition?	

NOTES:

CONFIRMATION OF INTELLO SURFACE PREPARATION

	YES
Is surface dry per SIWS checklist ?	
Is surface even free of voids and sharp protrusions per SIWS checklist?	
Is surface free from dust, dirt or other foreign matter per SIWS checklist?	
If substrate is concrete has it been allowed to cure ?	

INTELLO INSTALLATION

	YES
Is printed side facing installer?	
Is membrane free of sags or creases?	
Is Intello to concrete surface adhered with Contega SL tape?	
Is Intello to metal stud surface adhered with Duplex doubled side tape?	
Is Intello to Intello seam adhered with Tescon Vana tape?	
Has Intello and Tescon Vana tape anchor patch been installed?	

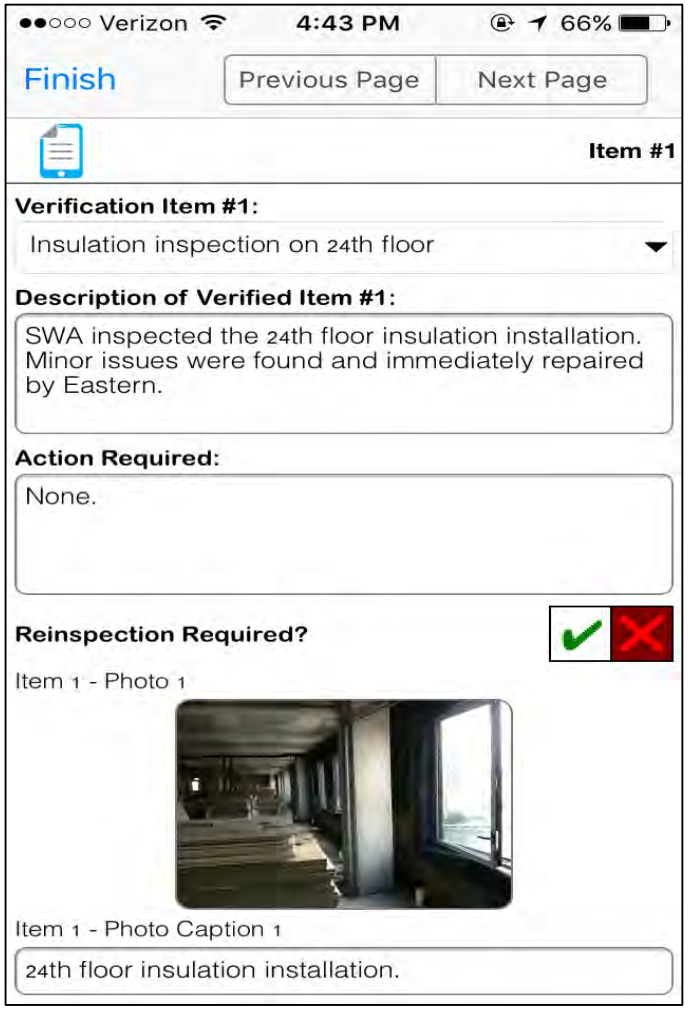
PANEL WALL WINDOW INSPECTION

Wall Panels

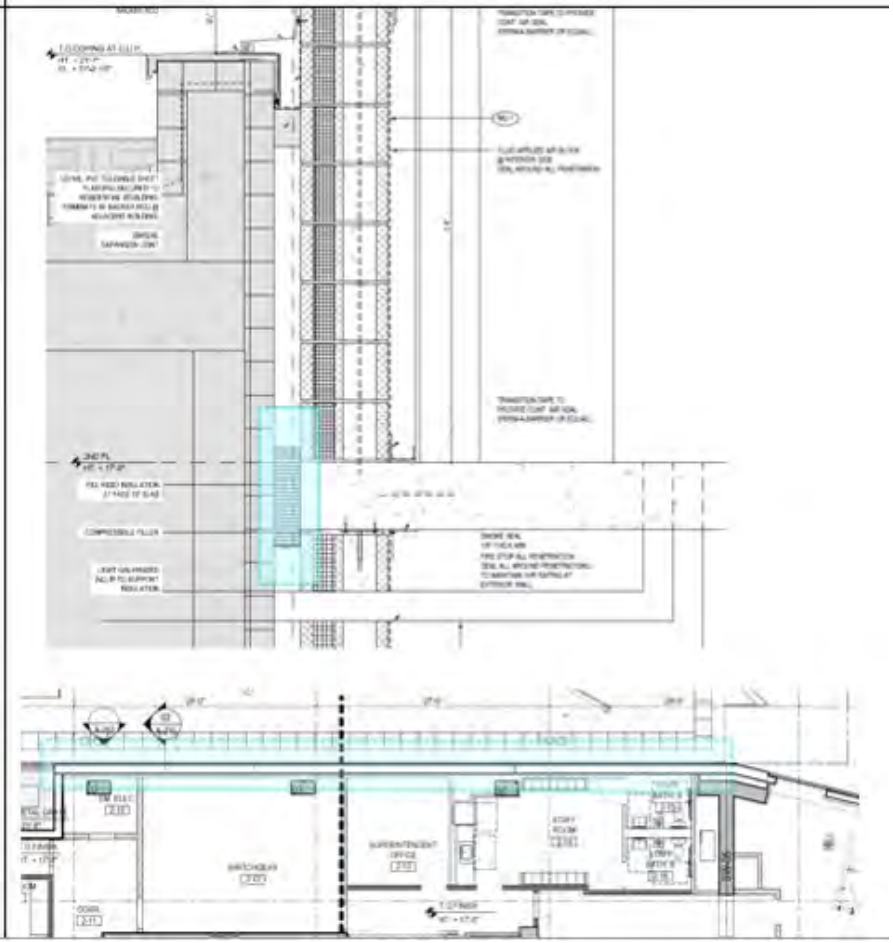
SWA Checklists

Automated Inspection Checklists

- Large projects w/ multiple dwellings
- Repetitive tasks – duct & unit by unit leakage testing
- Insulation inspections



Site Visit Reports

Item #	Description	Image
	2nd Floor Slab Edge Insulation: Refer to architectural details 20 A-356. Detail 20 shows 4" thick nsulation at the slab edge between the CUP and the Residential Tower extending 2" above and below the slab (highlighted area in detail at right). This conditions exits at the area highlighted on the plan to the right.	

Issues Log

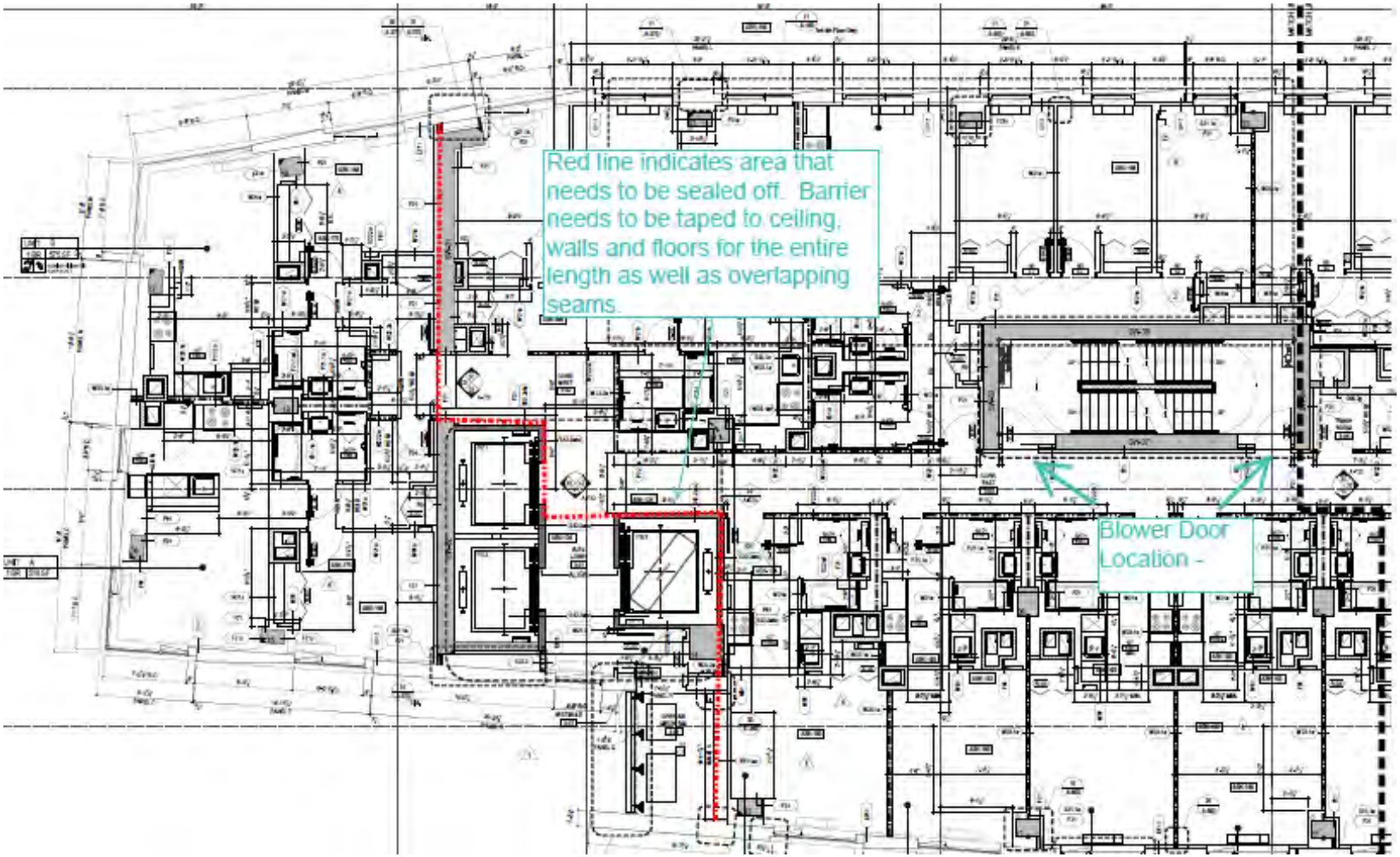
Issues Log - 1/25/2017

SVR #	SVR Item	Issue Type	Location	Issue	Found by	Date Found	Action Required	Responsible Party	Reinspection Required?	Actions Taken/Updates	Date Verified/ updated	Open/ Closed
7	1	ENV	7th Floor	**Panel Insulation at Joints:** Insulation at the panel joints was found to be around 6 inches deep. Shop drawings indicate 9" (EEWS Shop Drawings Sheet 501, Detail 1, second image right). SWA notified Monadnock of the issue. Monadnock followed up with a photo on 5/11/16 and informed SWA that EEWS will continue to install insulation at 9 inch depth. All panels below the six floor will need to be inspected for insufficient insulation and corrected if needed via exterior scaffolding when exterior caulk is applied.	SWA	5/10/16	Photo documentation using a measuring device will be required to verify PH compliance. SWA & EEWS to agree on frequency of photos and method of depth verification	Eastern	Y	On 9/22/16, Eastern issued photos of joint insulation being installed along two swing stage areas (Rig 3 Drop 2 and Rig 3 Drop 4). SWA will continue keeping track of Eastern's progress.		Ongoing
24	2	ENV	2nd Floor	Gap at the corner of storage room and condenser porch located behind the column is not air sealed at this time. Neither is the connection of Intesana to block. SWA to inspect when complete.	SWA	8/9/16	Monadnock to send photos of the area to SWA	Monadnock	N			Open
42	3	HVAC	All Floors	**Damaged Ductwork Covers:** SWA observed numerous instances of damaged ductwork opening covers damaged or loose throughout the first and second floors. SWA believes a significant amount of dust has likely accumulated in the ductwork. The project is now at risk of losing a LEED point needed for LEED Platinum certification.	SWA	11/21/16	Monadnock to make sure that all ductwork openings have been covered on floors 1, 2, 15-25. Monadnock to issue written confirmation to SWA once this work has been complete. SWA to spot check these areas in its next visit.	SWA	Y	On 11/30/16, SWA observed that much of previously noted loose and damaged ductwork opening covers were repaired. Issues still persist on the various floors. SWA performed spot checks on floors 1, 2, 15-25 and found issues in all floors. On 12/1/16, Monadnock emailed SWA notifying that floors 1,2, and 15-25 had been reinspected and damaged ductwork covers had been repaired. On 12/12/16, SWA observed issues on floors 1, 2, and 17.		Open
n/a	n/a	ENV	2nd Floor	**Insulation under 2nd floor condensor porch ballast** was covered before SWA could inspect. Images showing insulation depth and coverage must be provided.	SWA	5/24/16	Monadnock possesses photo documentation that shows depth and coverage. Provide images to SWA.	Monadnock	N	On 7/26/2016, Monadnock sent photos showing depth of insulation at condensor porch ballast.	7/26/2016	Closed
n/a	n/a	ENV	26th & 27th Floor	**Roof deck insulation inside AHU curb** was covered before SWA could inspect. Images showing insulation depth and coverage must be provided.	SWA	5/1/16	Monadnock possesses photo documentation that shows depth and coverage. Provide images to	Monadnock	N	On 10/1/2016, SWA received photos from Monadnock showing blurry tape measurements of insulation at the AHU curbs. On 10/24/2016, SWA	10/24/2016	Closed

Interim Testing

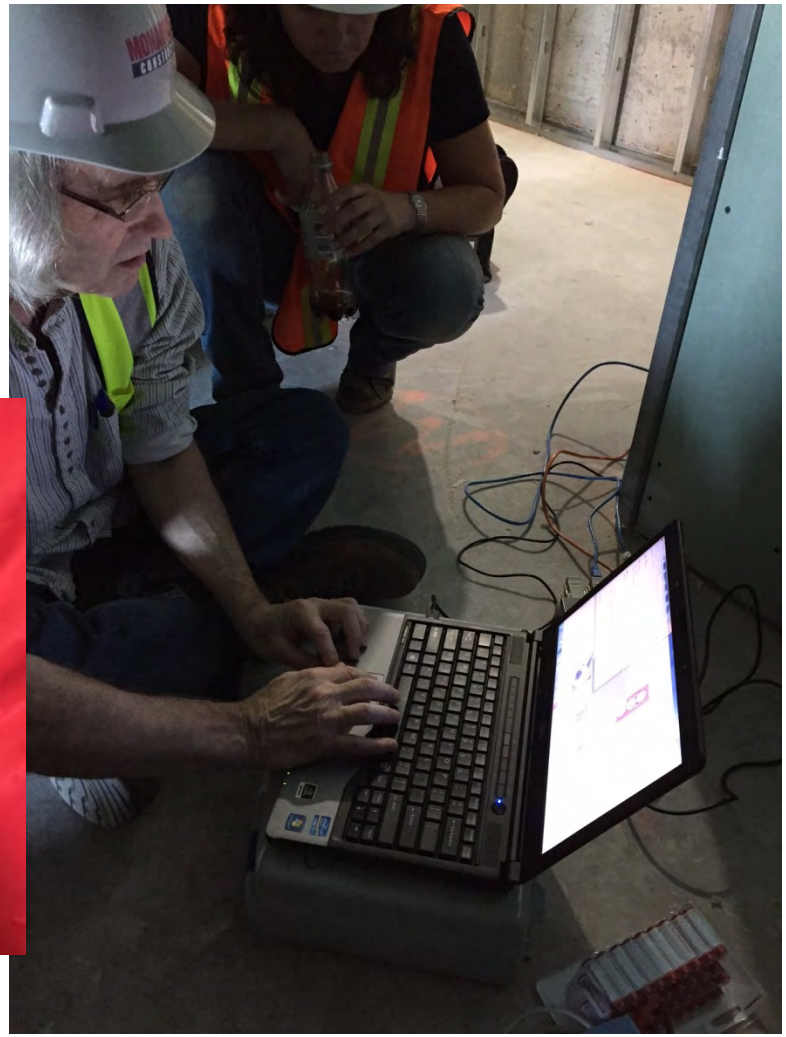
- Original plan – no whole floor testing
- Revised plan – guarded testing on 4th, 5th and 6th floors
- Window & Door Leakage
- Façade Leakage
- Compartmentalization

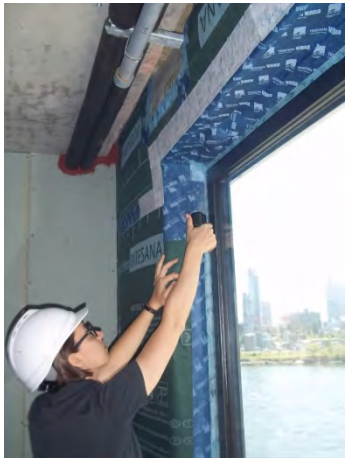
Guarded Testing



Temporary Air Barrier

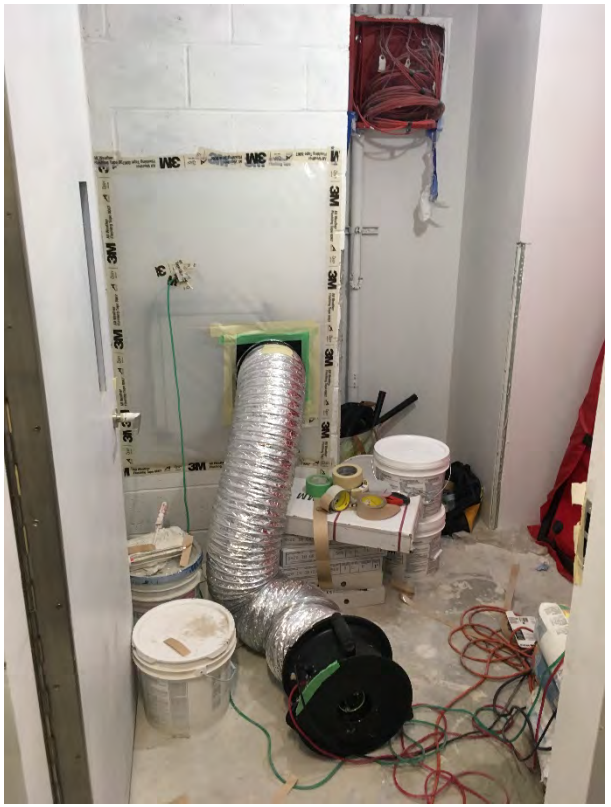
Blower Doors on 3 Floors





Other Tests

- Condenser porch doors
- Trash chute rooms / doors



Progress

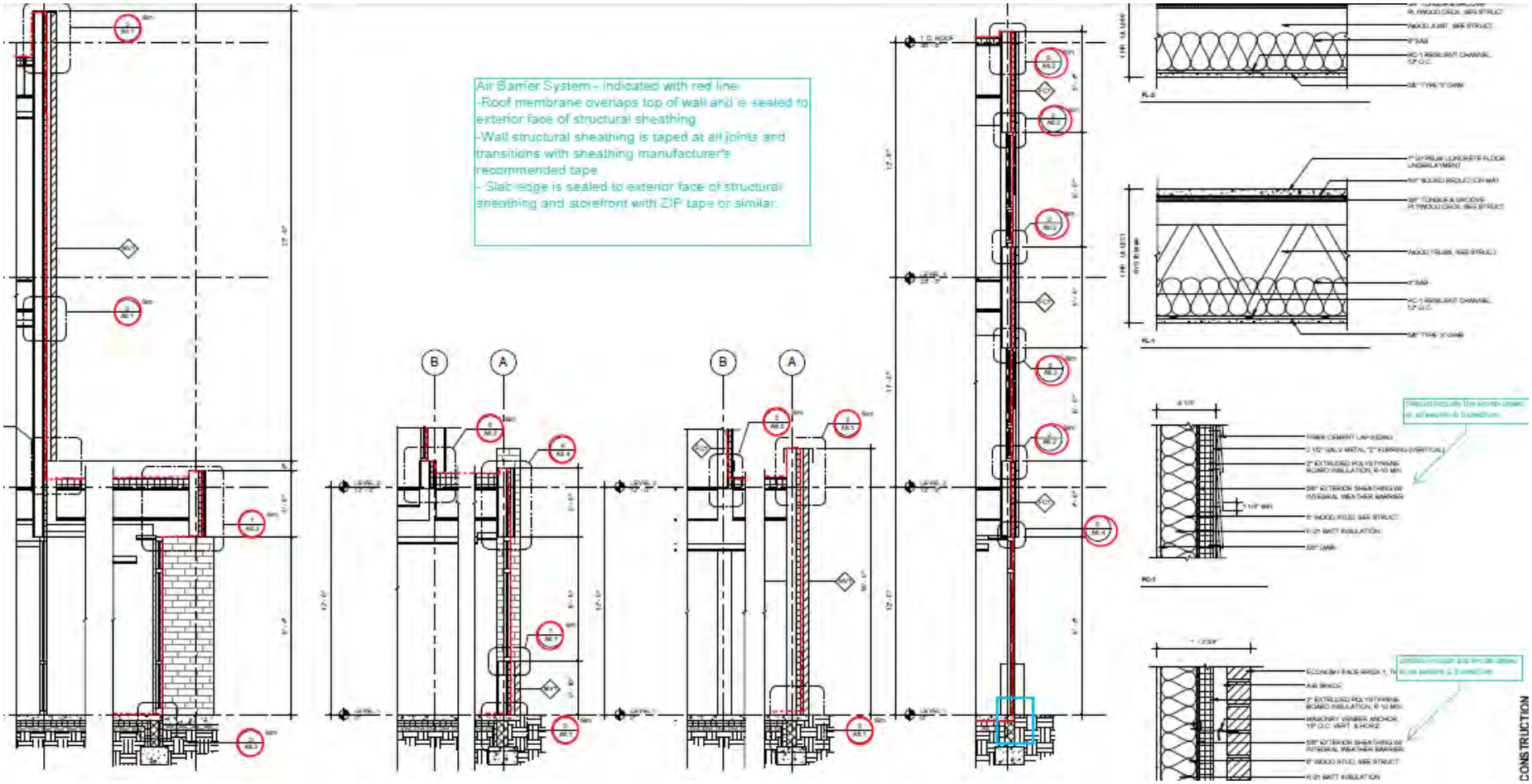
- Blower door test completed – 6/3/2017
- 0.13 ACH50 (more than 4x less than 0.6)
- ERVs commissioning completed
- Students moved in August 1, 2017
- ***PH Certification received on October 17, 2017!!!***

ST. JOHN NEUMANN PLACE

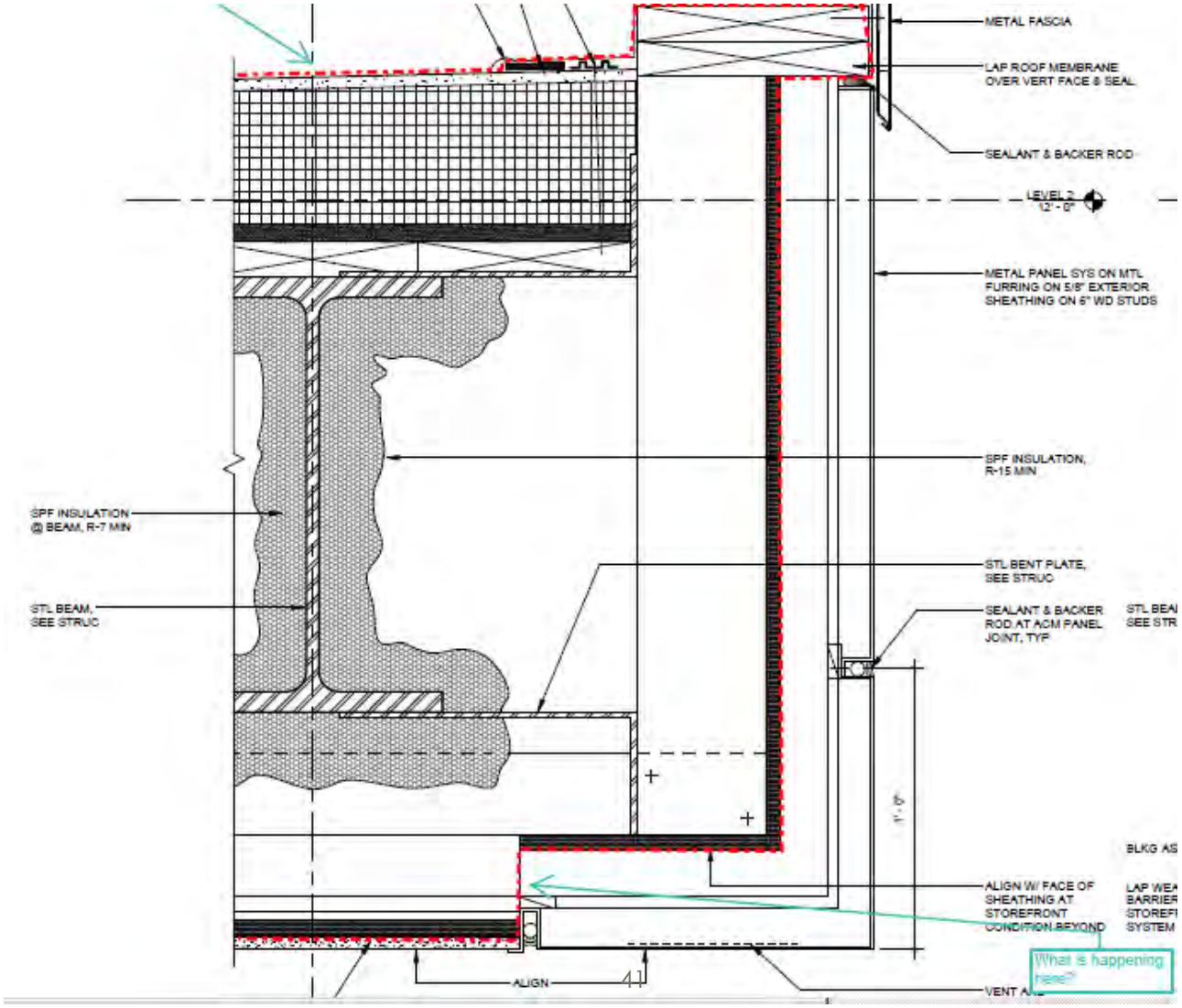
SENIOR HOUSING - 52 DWELLINGS

PHILADELPHIA, PA

Redline Plan & Section



Drill Into Details



Verify On Site

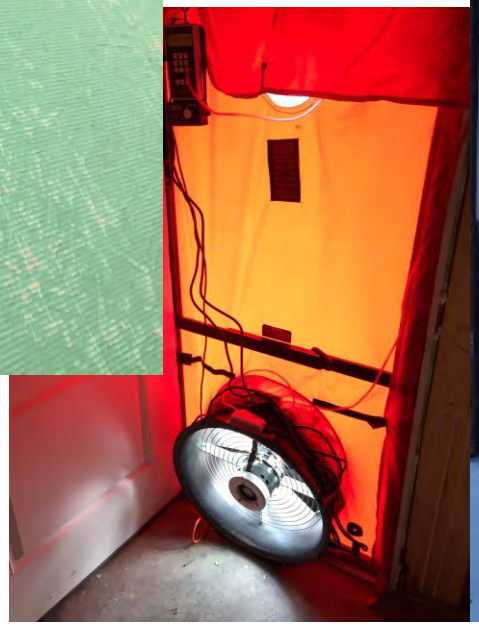
Site Visit Reports

Item #	Description and Action Required	Images
1	9" of OCSP needs to be sprayed on the ceiling of the canopy which is currently un-reachable due to the structural steel of the canopy. This may require temporary removal of the already installed exterior sheathing. After the sheathing is re-attached, OCSF needs to be applied to the interior of it. The condition needs to match Detail 1 on A6.3 shown below.	  

Interim Testing

- Insulation
- Original plan – whole building testing
- Revised plan – window/unitized testing
- Window Leakage
- Façade Leakage
- Heat / cool duct testing

Façade Leakage Measurements: Qualitative



Progress

- Blower door test did not passed – no interim whole building blower door or guarded test performed
- Two follow up visits to try and reduce infiltration - $$$
- ERVs balancing a challenge at low flows
- MEP installed exhaust only systems in some locations
- Did not receive certification

BEACH GREEN NORTH

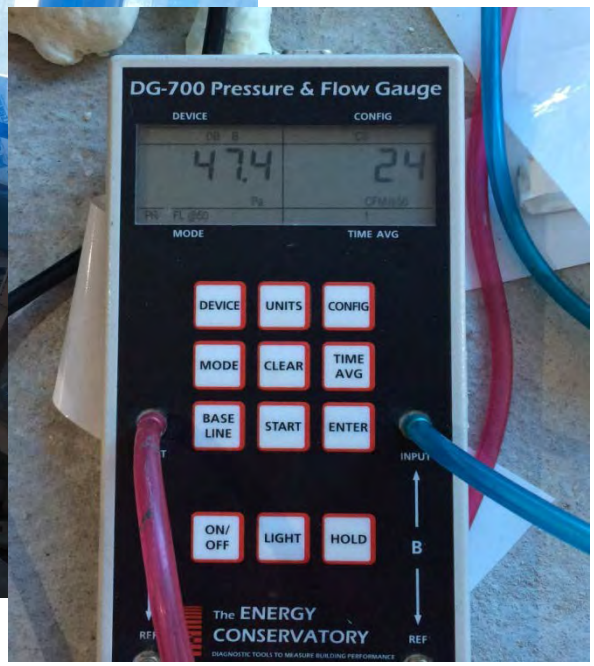
Affordable Housing – 101 units

QUEENS, NY

Wall Inspections

- ICF doesn't require as many inspections for insulation and air barrier

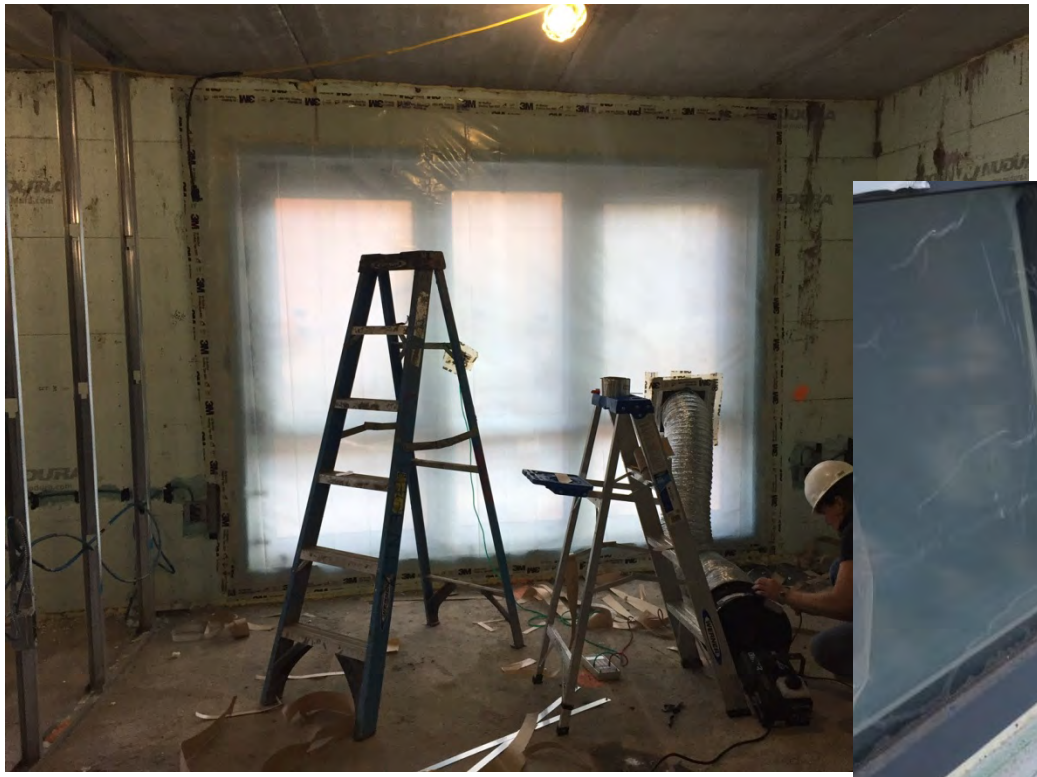
1st Window Mockup



2nd Window Mockup

Window Testing w/ Blower Door

1st Window Mockup – Different ICF Project



Further Window Mockups – Different ICF Project

Progress at Beach Green

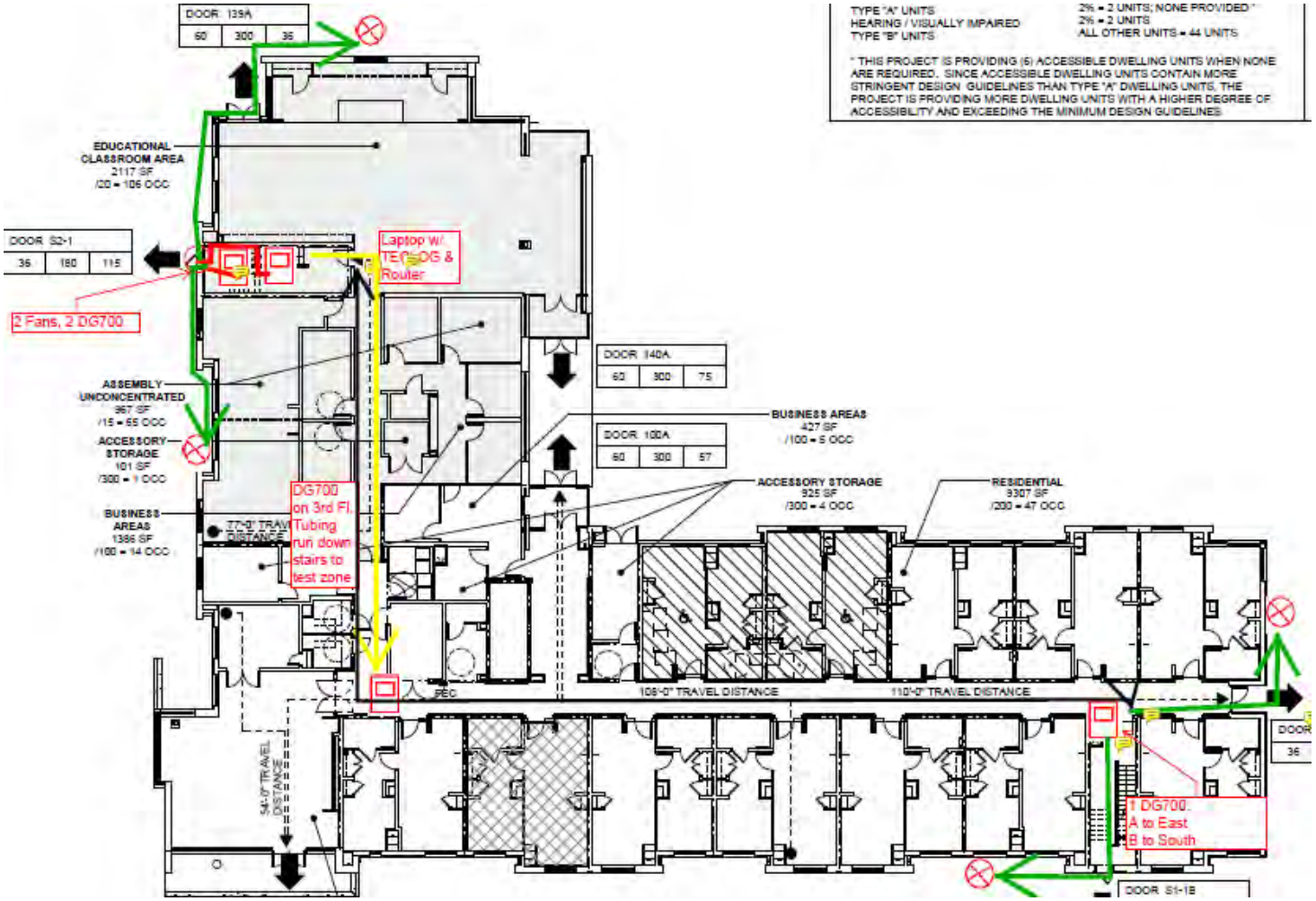
- AeroBarrier by Aeroseal was utilized
- Envelope leakage test performed 6/24/2017 – couldn't finish, Building Department shut down site for working on Saturday
- Infiltration test for model scheduled for 7/6/2017 – passed!!
- ERV testing & commissioning completed
- Documentation submitted to certifier and is in review

LOGISTICS

Whole Building Test Logistics

- Enough fans, cruise manometers, frames, shrouds, tubing, CAT5 cabling?
- Is building access limited to avoid people opening and closing doors, windows, etc.?
- Thorough walkthrough the day prior to test date to confirm prep has taken place?
- GC and appropriate subs on site to help with building prep and issues that come up on the test day?
- Saturday work permits pulled?

Blower Door Test Plan



Blower Door Test Conditions

Key: HVAC Contractor; Plumber; GC / Builder

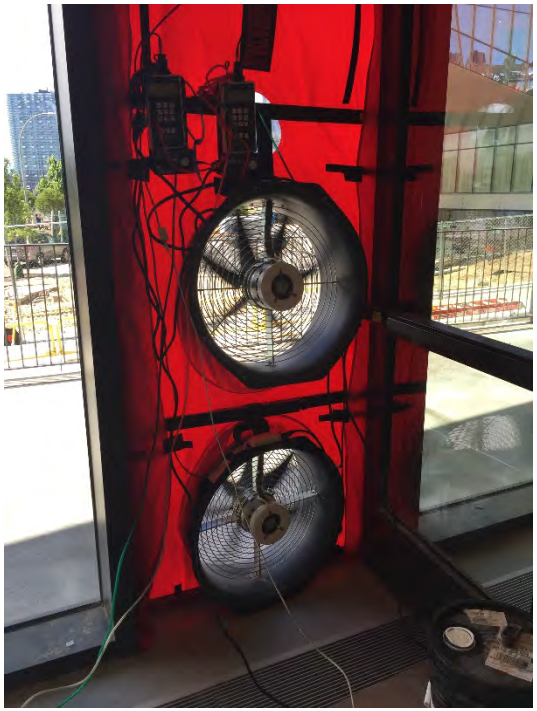
Intentional Opening	Test Setting	Notes
Windows, doors, skylights in the building enclosure	Closed and latched	
Doors and operable windows inside the test enclosure	Open	Use stairways to connect all zones of the building
Fire dampers	Remain as found	
Dryer doors	Closed and latched	
Gas meter room	Door to gas meter room closed and weather stripped	
Waste handling system	Trash chute termination at roof taped off. Door to trash rooms closed.	
ERVs (apartments)	Fan off, any dampers closed. Ducts to the outside sealed inside the ERV cabinet in each apartment.	Ventilation is continuous, so can remain taped off
Motorized dampers: ERV-4 (cellar)	Fan off, dampers closed. Taped off from the exterior	Ventilation is continuous, so dampers closed and sealed off
Motorized dampers: ERV-5 (1st floor)	Fan off, dampers closed. Taped off from the exterior	Ventilation is continuous, so dampers closed and sealed off
Motorized dampers: ERV-2A (1st floor)	Fan off, dampers closed. Taped off from the exterior	Ventilation is continuous, so dampers closed and sealed off
Motorized damper: Laundry Room (2nd floor)	Fan off, dampers closed. Taped off from the exterior	Untaped for Method A test
Motorized damper: ERV-2 (2nd floor)	Fan off, dampers closed. Taped off from the exterior	Ventilation is continuous, so dampers closed and sealed
Motorized dampers: EMR (1st floor), Stair A, Star B, Elevator, Boiler Room (roof)	Taped off from the exterior	Untaped for Method A test
ERV-3 (roof)	Fan off, dampers closed	Ventilation is continuous, so

ERVs & Blower Door

- Need to seal off ERVs for final test
- Can't seal off vents from outside for individual ERVs
- Tape off both outdoor connection ports inside every ERV
- Wrap rooftop ERVs

Whole Building Test Logistics

- A great resource is **Blower Door Applications Guide: Beyond Single Family Residential** PDF (Brennan, Clarkin, Nelson, Olson, Morin)



STAR GARMENTS

Clothing Manufacturing Plant: Retrofit

Sri Lanka

Logistics


EXPRESS WORLDWIDE
WPX
DHL
From : Steven Winter Associates, Inc
Dylan Martello
P.O Box 1 Ring Road 2 IPZ
c/o Star Garment Group
KATUNAYAKE
Sri Lanka
Contact: Ph : 2038570200
Origin:
CMB
To : Steven Winter Associates, Inc
Todd Esperance
61 Washington street,
2nd floor
06854 NORWALK
United States Of America
Contact:
Ph :2038570200
US-NWK-NWK
C-IMP
Ref:Bill Code TBD
Pce/Shpt Weight
9.0/69.0 kg
Piece
3 / 3
WAYBILL 25 4714 3535

RECOMMENDATIONS FOR SUCCESS

Do This

- Mockups
- Guarded testing
- Panelized construction if budget allows
- Insist on training for construction staff
- Make typical details readily available on site for all subs
- Use schedules in the plans to call out air barrier materials

Do NOT Do This

- Assume if the CM has done a PH project that the 2nd will automatically pass
- Keep going without passing the window mockup
- Depend on subs reading the specifications
- Allow the CM to exclude meeting PH requirements from the contract
- Ignore your PH Consultant!!!!!

Questions?

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THANK YOU!