THE WORLD'S LARGEST PASSIVE HOUSE BUILDING

Cornell Tech NYC Campus Residential Building

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Overview

High Rise vs. Low Rise

Cornell Overview

What’s Happening in the NE
PH DIFFERENCES: HIGH RISE VS. LOW RISE
High Rise vs. Low Rise

Likely cooling dominated

- Density of apartments & appliance loads
- Lack of external shading devices
- Additional loads such as fitness centers, elevators, DHW circulation pumps and line losses, retail space, etc.
High Rise vs. Low Rise

Envelope efficiency requirements of less concern than comfort criteria. Less insulation in slabs and roofs can help reduce cooling loads!
## High Rise vs. Single Family

<table>
<thead>
<tr>
<th></th>
<th>High Rise 200,000 ft²</th>
<th>Single Family Home 1600 ft²</th>
<th>PH Threshold</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>kBtu/ft² yr</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Space heating demand</td>
<td>2.5 (8)</td>
<td>7.73 (24.4)</td>
<td>4.75 (15)</td>
</tr>
<tr>
<td>Space cooling demand</td>
<td>4.75 (15)</td>
<td>3.95 (12.5)</td>
<td>5.39 (17)</td>
</tr>
<tr>
<td>Primary energy demand</td>
<td>37 (117)</td>
<td>58 (183)</td>
<td>38 (120)</td>
</tr>
<tr>
<td>PH</td>
<td>Yes</td>
<td>No</td>
<td>--</td>
</tr>
</tbody>
</table>
Curtain Wall

Pro’s
- Continuous insulation on the exterior of the building
- Panels constructed in factory, less variability of install quality

Con’s
- Attachments to building & other panels
- Final air sealing done from exterior
- Alignment of air, water, vapor barrier difficult
- Fire rated insulation needed
FAÇADE ISSUES

Roof
  » Parapets
  » Drain penetrations on flat roofs

Foundation
  » Loads can be 5000 psi: 1800 psi best compressive strength found to date

Windows
  » Limited selection of applicable windows
  » ISO values are required, no direct conversion from NFRC
  » Overhangs – not typical in high rise
  » More likely to use architectural elements
Comfort Criteria

» Interior surface temperatures should not deviate by more than 7.6 °F from the average operative temperature on the inside;
» the surface temperature must not be lower than 55.4 °F or greater than 132 °F at any point;
» the surface temperature of the floor must be between 66 °F and 81 °F.
## Potential Packages

<table>
<thead>
<tr>
<th>#</th>
<th>ft²</th>
<th># of Units</th>
<th>Roof R-value</th>
<th>Wall R-value</th>
<th>Windows U-value/SHGC</th>
<th>Foundation R-value</th>
<th>Heating Demand kBtu/ft²·yr</th>
<th>Cooling Demand kBtu/ft²·yr</th>
<th>Primary Energy kBtu/ft²·yr</th>
</tr>
</thead>
<tbody>
<tr>
<td>#1</td>
<td>1267</td>
<td>1</td>
<td>90</td>
<td>48</td>
<td>0.16/0.62</td>
<td>21/37</td>
<td>4.2</td>
<td>0.33</td>
<td>26.7</td>
</tr>
<tr>
<td>#2</td>
<td>8770</td>
<td>10</td>
<td>102</td>
<td>46</td>
<td>0.15/0.6</td>
<td>20/41</td>
<td>4.47</td>
<td>1.16</td>
<td>28.9</td>
</tr>
<tr>
<td>#3</td>
<td>34,927</td>
<td>30</td>
<td>40</td>
<td>33</td>
<td>0.21/0.32</td>
<td>33/10</td>
<td>4.23</td>
<td>4.84</td>
<td>34.3</td>
</tr>
<tr>
<td>#4</td>
<td>39,482</td>
<td>52</td>
<td>60</td>
<td>30</td>
<td>0.26/0.33</td>
<td>10/10</td>
<td>3.24</td>
<td>5.1</td>
<td>37.6</td>
</tr>
</tbody>
</table>
# Central vs. Local ERV’s

<table>
<thead>
<tr>
<th>Pros</th>
<th>Individual ERV</th>
<th>Central ERV</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Resident Meter</td>
<td>• Reduction in horizontal ducts</td>
<td></td>
</tr>
<tr>
<td>• No slab penetrations</td>
<td>• Continuous, boost flow achievable</td>
<td></td>
</tr>
<tr>
<td>• Continuous, boost flow easily achievable</td>
<td>• Significantly reduced maintenance</td>
<td></td>
</tr>
<tr>
<td>• PH certified units available</td>
<td>• No wall penetrations</td>
<td></td>
</tr>
<tr>
<td>• Precedent for unitized ERV</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Cons</th>
<th>Individual ERV</th>
<th>Central ERV</th>
</tr>
</thead>
<tbody>
<tr>
<td>• 2 penetrations/apartment</td>
<td>• Owner Meter</td>
<td></td>
</tr>
<tr>
<td>• Ceiling height issues</td>
<td>• No PH certified units available</td>
<td></td>
</tr>
<tr>
<td>• Exhaust/intake separation restrictions</td>
<td>• Floor space reduction</td>
<td></td>
</tr>
<tr>
<td>• In-unit maintenance, filter change 3x/yr</td>
<td>• Large slab penetrations</td>
<td></td>
</tr>
<tr>
<td>• Loss of floor space if ceiling space unavailable</td>
<td>• Fire rated shafts/dampers needed</td>
<td></td>
</tr>
<tr>
<td>• Exterior maintenance of grills</td>
<td>• Complexity of controls for variable flow rates</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• No precedent for central balanced system w/ HR in US</td>
<td></td>
</tr>
</tbody>
</table>
Central vs. Local ERV’s

120 Watts

220 Watts
Central vs. Local ERV’s

If central in multi-family,

» recommend constant volume to reduce complexity of controls
» Must balance code and PH requirements
» Special consideration from both parties may be necessary
» Efficient equipment not available yet
Delivery System Leakage

Implications of exhaust system leakage not as well understood by contractors

Leakage at sheetrock connections

Leakage at shaft/sheet metal connections
Comfort in Small Units

» 30 cfm is high for one small room
» Temperature of air very important - 80% efficient ERV will supply 56 F air to space if 0 F outside, 62 F if 30 F outside
» Preheat should be included for v. cold weather
» Pay attention to direction of throw from vent
» Need efficient preheat -90% or better
Other Considerations

» Increasing ventilation rate from 0.3 ACH to 0.45 ACH increases heat demand 17%
» ERV efficiency change from 0.85 to 0.75 increases heat demand by 23%
» Measurement is an issue under 10 cfm
» Duct tightness crucial to deliver proper flows
» # of occupants in certain types of buildings
Certification Programs

» LEED, ENERGY STAR, DOE ZERH, Enterprise Green Communities, Living Building Challenge – all reference ASHRAE 62.2 or IMC (25 cfm in kitchen vs. 5ACH)

» Passive House – own program requirements, much lower than 62.2
HVAC: Multifamily Options

Options for multi-family buildings
  » central boiler + window A/C
  » Individual apartment air handlers
  » Mini-splits
DHW Options

- High Efficiency Options for PH
- Condensing gas boilers
- HPWH
- Solar thermal
- Geothermal
DHW Options - Central Systems

Pros

» Fuel options – gas venting easy
» Space savings in apartment

Cons

» Pump power must be minimized, incorporate on-demand controls where possible
» Extensive piping for recirc loops
» Need to insulate the recirc lines
DHW Options - Individual Systems

Pros
» No recirc piping needed
» Tenants billed directly

Cons
» Gas is difficult because of venting,
» HPWH not recommended in small spaces,
» More difficult to incorporate solar
Auxiliary Spaces

- Common Area Lighting – pay attention to control strategies
- Fitness rooms – some equipment is very energy intensive
- Common Laundries – make up air for vented dryers
- Elevators – very little actual data, defaults
- Non-residential space ventilation – assume turn down when possible
MAIN CAMPUS ENTRY
ENTRY COURT/HIGHEST POINT
CAMPUS LAWN
RIVERFRONT WALK

NORTH/SOUTH AXIS BROAD SOUTHERN EXPOSURE. SHORT SIDES FACE EAST AND WEST
SITE
OUTDOOR CLASSROOM
RIVERFRONT WALK
CAMPUS PLAZA

NORTH LOOP ROAD
WEST LOOP ROAD
EAST LOOP ROAD

CENTRAL UTILITY PLANT (CUP)
EXECUTIVE EDUCATION CENTER (EEC)
FIRST ACADEMIC BUILDING (FAB)
CORPORATE CO-LOCATION (COLO)
ENCLOSURE: THERMAL WRAP

- Rainscreen Cladding System
- Angled Metal Spandrel
Shop assembled panelized wall system leads to exceptional quality control.

Windows installed in factory, not on site.

Typical panel size 10’x35’, allows for quick site installation.

Air seal at panel joints at interior face of exterior wall.

Prefabricated metal wall panel installation.
EXTERIOR WALL DETAIL

Section View

- High Performance Glazing
- Angled Metal Spandrel Beyond
- Rainscreen Cladding System
- R32 Wall
- Thermally Broken Support Clip

- ThermaBracket Assembly with Isolators

- Thermally broken construction
- Airtight envelope: 0.6 ACH@50pa
- Window-to-wall ratio calibrated to maximize performance

ThermaBracket Assembly with Isolators
BUILDING BALCONY - THERMALLY INSULATED DOOR

Insulation R value is 32 at 40°F.

Key Plan

INSTALLATION POINTS:
1. Bucks should be installed true, plumb and square and of sufficient size to accommodate door weight.
2. Wood bucks and back of door frame should be painted with a suitable preservative to protect against moisture penetration into wood.
3. Floor at door swing area should be smooth and level.
4. All bolts, lags and joints between buck and door frame should be vapor sealed with oil-suspended, nonhardening, waterproof caulking compound or similar material.
BUILDING CANOPY DETAIL - STEEL TO STEEL THERMAL SEPARATION

Key Plan

- Insulation
- Continuous Air/Water Barrier
- Continuous Vapor Barrier
- Steel Structure

Steel Embed

Rainscreen Cladding System

Exterior

Interior

Canopy Cladding

Structural Thermal Break
## WINDOW + FRAME

Standard metal frame and window is .45

<table>
<thead>
<tr>
<th>Window Type</th>
<th>Frame U-Value</th>
<th>Average Overall U-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Calculated Value (Average)</td>
<td>Target Value</td>
</tr>
<tr>
<td><strong>Window Type A</strong></td>
<td>0.28 Btu/h·ft²·F (1.59 W/m²K)</td>
<td>0.28 Btu/h·ft²·F (1.59 W/m²K)</td>
</tr>
<tr>
<td><strong>Window Type B</strong></td>
<td>0.27 Btu/h·ft²·F (1.51 W/m²K)</td>
<td>0.28 Btu/h·ft²·F (1.59 W/m²K)</td>
</tr>
<tr>
<td><strong>Window Type C</strong></td>
<td>0.26 Btu/h·ft²·F (1.50 W/m²K)</td>
<td>0.28 Btu/h·ft²·F (1.59 W/m²K)</td>
</tr>
</tbody>
</table>

**Condensation Risk (Te=0°F; Tᵢ=70°F; R.H.=30%)**

\[ T_{s, \min} = 50.2°F (10.1°C) \]
\[ T_{dp} = 37.0°F (2.8°C) \]

**Condensation Risk (Te=18°F; Tᵢ=68°F; R.H.=50%)**

\[ T_{s, \min} = 54.0°F (12.2°C) \]
\[ T_{dp} = 48.7°F (9.3°C) \]
Problem for Passive House blower door testing: caulking not complete until façade is completely installed. Therefore, there is no way to verify tightness during construction.

Interior vapor retarder will be used to determine compliance for air sealing during construction, therefore, continuity is critical.
AIR SEALING - AT INSIDE FACE OF EXTERIOR WALL

- Smart vapor retarder on interior installed in the shop
- Taped to interior face of window and studs
- Overlaps at panel joints - held back at factory and connected in field
- Panel joints taped in the field - bypassing slab edge
AIR SEALING - TYPICAL WINDOW

- Façade consultant and contractor – caulk is what was proven and usually done.
- Tape not accepted – too hard to work with and ensure quality
- Push from PH consultant and team to incorporate tape to ensure tight envelope over time
- Sequencing issues with manufacturer
- Invite a supplier to show examples and solutions to your particular issues.
AIR SEALING - ACCESS AT FACADE COLUMNS AND SHEAR WALLS

TYPICAL COLUMN DETAIL
17 PER FLOOR

SHEAR WALL CONDITION
AIR SEALING - AT FACADE ANCHORS

- 123 Anchors Per Floor
- Over 3,000 Anchors Total
AIR SEALING - AT FACADE ANCHORS

Exterior

Interior

Continuous insulation
Continuous air barrier
Facade anchor every 4’-0” +/-
MOCK-UP TESTS

Pressure Sensor

Blower Door Test Set-up
AIR SEALING - AIR LEAKAGE TESTING

• On-going
• Various components to be tested along the way
• Full blower door tests not possible
• Mock-up indicates very tight façade
• Components that should be spot checked throughout construction
  • Slab/wall connection
  • Windows & store front
  • Doors to rooms outside the air barrier
  • Roof/Wall connections
  • Penetrations through the facade
**Construction method challenges**
- Caulk: 20 years. Industry standard for keeping water out of buildings.
- Tape: 100 years. Not yet proven in industry.
- Site Monitoring, QA/QC.
Air Tightness Testing requirements for Passive House

- Large Building Test Procedures from RetroTec

- Ultimately need to create a plan for your particular building – can show Single family house vs. Cornell Resi images to make the point.

**Test Configuration of Intentional Openings**

<table>
<thead>
<tr>
<th>Intentional Openings</th>
<th>Test Status</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Windows, doors, skylights and hatches in the bounding enclosure</td>
<td>Closed and latched</td>
<td>Fan off, dampers closed, sealed</td>
</tr>
<tr>
<td>Doors, hatches and operable windows inside the test enclosure</td>
<td>Open</td>
<td>Ventilation units run continuously, so dampers closed and sealed.</td>
</tr>
<tr>
<td>Fire Dampers</td>
<td>Remain as found</td>
<td></td>
</tr>
<tr>
<td>Dryer Doors</td>
<td>Closed and latched</td>
<td></td>
</tr>
<tr>
<td>AHU-1 (ERV OA) Penthouse roof 26th Floor</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Trades Affected by PH Requirements

- Exterior Sealing
  - Exterior Panel Fabricator
  - Window Supplier
  - Carpenter
  - Mason
  - Caulker

- Interior Sealing
  - Mechanical
  - Electrical
  - Plumbing

- Heating / Ventilation / Airside Contractor

Control of Scope of Work

- Bid/Buy documents need to be sure to cover passive house requirements
- Not enough to say "follow spec"
- Contractors will exclude certain details/requirements
Exhaust Air
Exhaust air exits the building after passing through the ERV so heat energy can be captured.

Fresh Air
Tempered supply air provided to all units in separate supply risers.

Refrigerant
VENTILATION SYSTEMS

- As the building gets bigger ventilation has a bigger impact on energy
- As apartment size decreases ACH increases
- Central systems are easier to maintain, but less able to deal with variability
- This project:
  - Uses continuous ventilation
  - Average of 0.35 ACH
  - Kitchenettes = 10 CFM
  - Baths = 25 CFM
  - Supply = 10-20 CFM
  - Flow rates approved by EPA and LEED for Homes
  - ERVs connected to emergency generator
AIR SEALING - DUCT SEALING

**Benefits:**
- Improves comfort
- Improves indoor air quality
- Increases life span of HVAC units
- Save money
- Reduces noise
- Protect the environment

**Automatic Balancing Dampers:**
- Provide restriction in size of opening (increase static pressure)
- Dynamically self-adjust to changes in the system (automatic balancing)
CHANGE TO THE BUILDING CODE: MECHANICAL EXHAUST SYSTEM

- Permission by DOB to combine toilet and kitchen exhaust from multiple apartments in vertical shafts, which is not typically allowed by NYC code.
- Necessary for proper balancing and operation of ERV

Section of the Code:
501.5.1. Single or combined mechanical exhaust systems from bath, toilet, urinal, locker, service sink closets and similar rooms shall be independent of all other exhaust systems, except as permitted in Section 401.5.2.
PH GROWTH IN THE NE
SECTORS SEEING GROWTH

Affordable Multi-family Housing
» PHFA includes PH in Tax Credit Applications
» NYC Housing Agencies getting to follow
» NY State including PH in high rise multi-family incentive program

Market Rate Housing
» High end apartments in NYC
» High end homes in CT
WHERE WE NEED HELP

Products
» ERVs – small and large
» HVAC – small systems
» Windows – fire rated, aluminum frames
» Doors – accessible thresholds, fire rated, aluminum frames

Certifiers
» Need more capacity
» Need more uniformity in the certification process

Consultants
» More experience in large building testing and verification
» Further education in advanced topics
» Better resources to help us perform our analysis
ST. JOHN NEUMANN PLACE
SENIOR HOUSING - 52 DWELLINGS IN
CONSTRUCTION
PHILADELPHIA, PA
3365 3RD AVENUE
AFFORDABLE HOUSING - 30 UNITS
NEW YORK, NY
Questions?

Thank You.
Lois B. Arena, PE, CPHD