

Castle Square Mid-Rise Retrofit: Teaching an Old Building New Tricks

Passive House in New England: Residential and Beyond
Boston Architectural College
15 October, 2011



Castle Square Mid-Rise Retrofit

Who am I and why am I here?

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- Building America Research Partner
- Building science consulting
- Architecture
- Testing laboratory

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Who am I and why am I here?

- Building and apartment enclosure
- Ventilation

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Castle Square Mid-Rise Retrofit

Who am I and why am I here?

- Building and apartment Enclosure
- Ventilation

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Project Introduction – Castle Square



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Castle Square Mid-Rise Retrofit

Project Overview:

- Occupied rehabilitation
- 1960's era, brick and concrete public housing structure
- Majority owned by residents association



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Project Objective:

- Leverage tax incentive financing, grants, incentives, technical support, etc. to include Deep Energy Retrofit in rehabilitation scope
- Rehabilitation of otherwise limited scope



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Castle Square Mid-Rise Retrofit

Project Overview:

- Owner: Castle Square Tenants Organization, Winn Development
- Location: Boston, MA
- Buildings: 4 Buildings, 7 stories (6 Residential over Ground Floor Commercial)
- Units: 192 Units, 48 Units/Building, 600-900 sq. ft./Unit

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Circumstances of the Project

- 51% Tenant Owned
 - CSTO in charge
 - Interests of tenant group protected
 - Driving factors for the “energy” measures:
Comfort, IEQ concerns

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Circumstances of the Project

- Originally built as subsidized housing
 - Small, compact apartments
 - Economy of layout
 - Structure affords no opportunity to run services in interstitial spaces,
 - Structure and aesthetic expression poses challenge to thermal performance

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Circumstances of the Project

- 100% occupied renovation (!)
 - Severe constraints on scope within apartments
 - Completed over 2-3 days
 - Tenants return to functioning kitchen first day
 - Belongings in bedrooms, living room not moved

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Resident Surveys & Charrettes

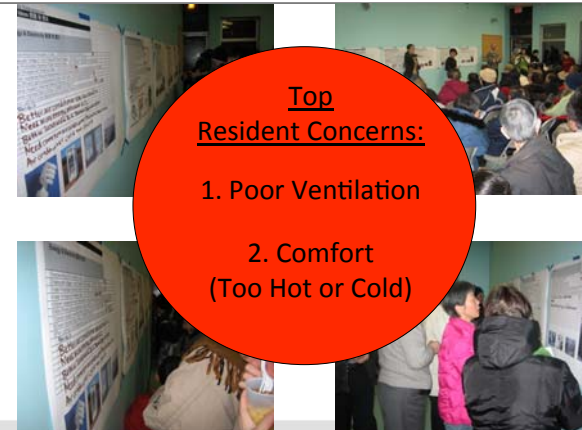


Image credit: Biome Studio

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Property Management Concerns:

- IAQ
- Comfort
- Energy costs
- Water leakage
- Façade maintenance and repair issues

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Project Overview:

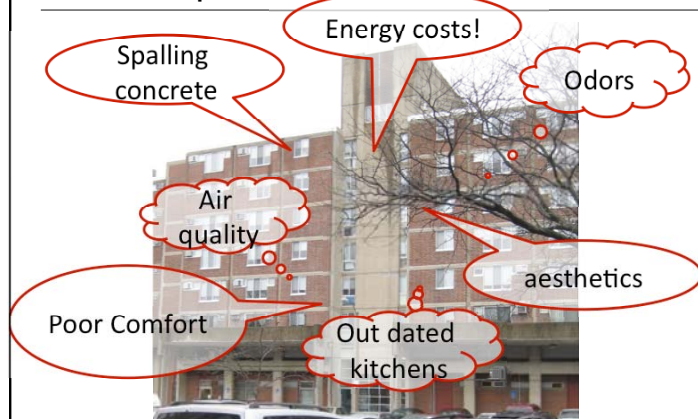
- Ambitious energy performance goals
 - Estimated Heating and Water Heating Energy Savings: >70%
 - Combined Gas & Elec. Savings: >50%
- Construction Start: October, 2010
- Construction Schedule: 18 Months

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What do we have to work with?

Understanding the building through:

- Testing/measurement
- Investigation of construction
- Simple analysis

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Castle Square Mid-Rise: Testing



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Castle Square Mid-Rise: Testing



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Castle Square Mid-Rise: Testing



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Castle Square Mid-Rise: Testing



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Castle Square Mid-Rise: Testing

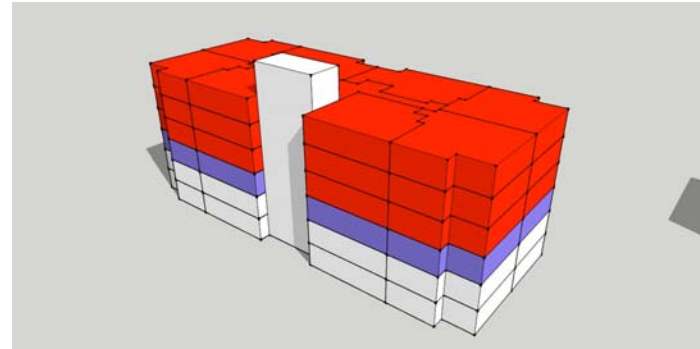


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Castle Square Mid-Rise: Testing

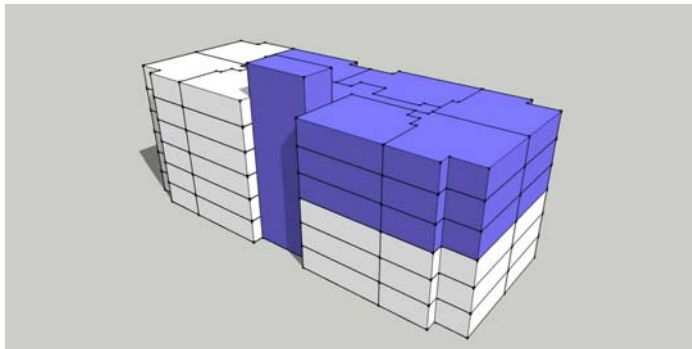


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Castle Square Mid-Rise: Testing

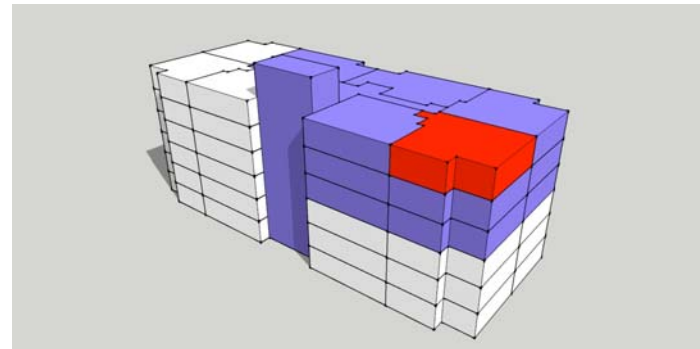


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Castle Square Mid-Rise: Testing

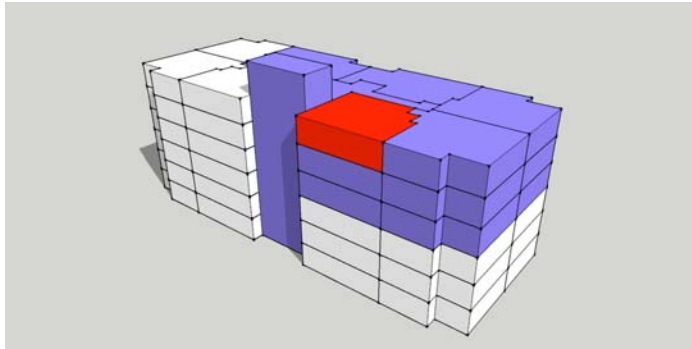


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Castle Square Mid-Rise: Testing

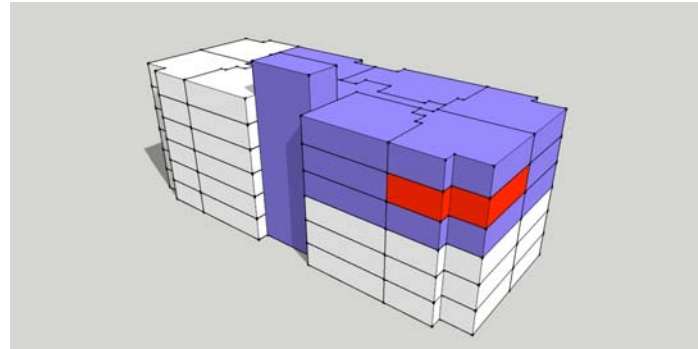


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Castle Square Mid-Rise: Testing

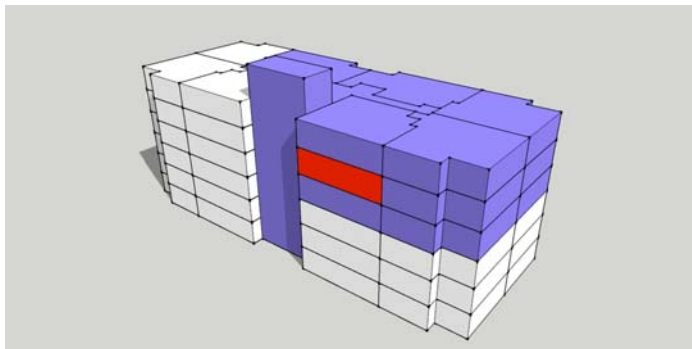


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Castle Square Mid-Rise: Testing



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Castle Square Mid-Rise: Testing

Testing and Measurement:

- Leakage to outside (guarded testing)
 - ~2.5 ACH50
 - ~0.7 cfm50 / sf exterior enclosure
- Total leakage for apartment units (unguarded)
 - ~10-17 ACH50
 - ~0.5-0.8 cfm50 / sf total enclosure

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Castle Square Mid-Rise: Investigation

- Looking at the building

Castle Square Mid-Rise: Investigation

Existing Enclosure:

- ~R-20 Roof Insulation
- Exposed concrete frame with **uninsulated** brick cavity wall infill
- Aluminum Frame Windows (assumed no thermal break in frame, no Low-E)

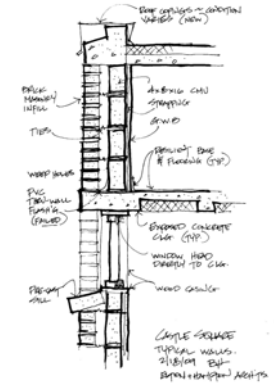
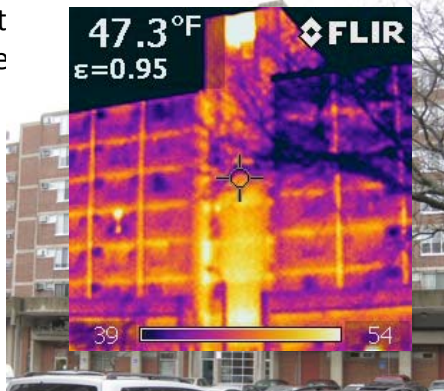


Image courtesy of Elton + Hampton Architects

Castle Square Mid-Rise: Investigation

- Struct challenge



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Castle Square Mid-Rise: Investigation



Castle Square Mid-Rise: Investigation



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Castle Square Mid-Rise: Investigation



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Castle Square Mid-Rise: Analysis

Simple Analysis

- UA analysis
- Estimates of ventilation, infiltration

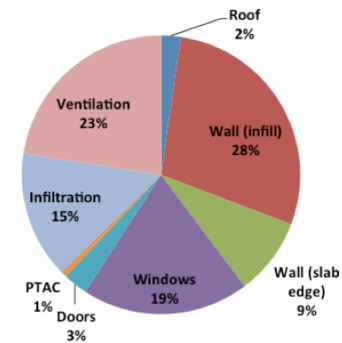
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Castle Square Mid-Rise: Analysis

Midrise Building Heating Load Components Percent of Heating Energy Use



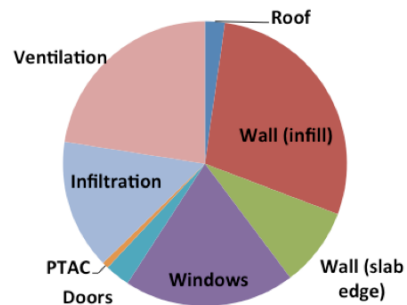
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Midrise Building Heating Load Components Percent of Heating Energy Use



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Castle Square Mid-Rise: Analysis

Scenarios

Table 1: Midrise Heating Loads

	Peak Heating Load (with ventilation)	% Reduction (with ventilation)
Baseline	868,205 Btu/hr	
Para #1	476,528 Btu/hr	45%
Para #2	249,619 Btu/hr	71%
Para #3	219,058 Btu/hr	75%

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Castle Square Mid-Rise

- Scenarios

Component	Existing Building	Proposed Systems
Infiltration	~100	~10
Doors	~20	~5
Windows	~100	~10
Wall (balcony slab)	~100	~10
Wall (concrete partition)	~200	~10
Wall (infill)	~100	~10
Roof	~10	~10
Total	~850	~150

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Testing, investigation, analysis:

- Building is moderately (but not abnormally) air leaky
- Apartment units are not well contained
- Any significant improvement to energy performance will require adding insulation to walls

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Testing, evaluation, analysis:

- High performance will require
 - adding insulation to walls,
 - controlling infiltration and ventilation,
 - improving windows

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Performance Targets:

- R-40 Walls
- R-5 Windows
- R-40 Roof
- Improve compartmenting as much as possible

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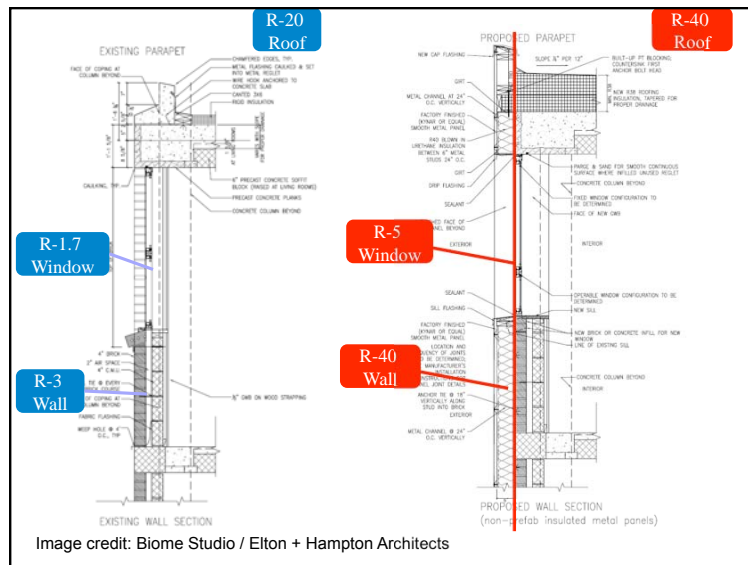


Image credit: Biome Studio / Elton + Hampton Architects

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1 super insulate

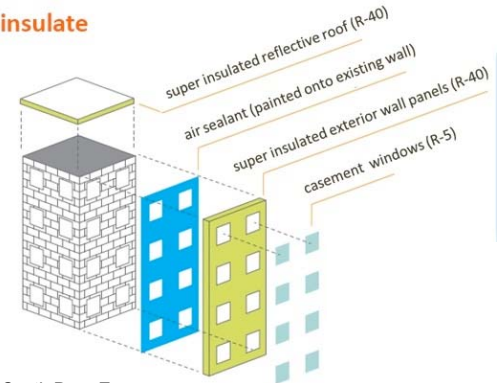


Image credit: www.CastleDeepEnergy.com

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2 air seal

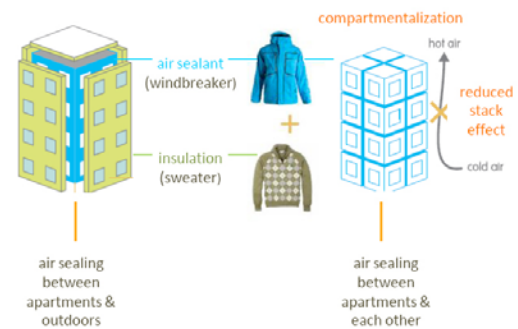


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Castle Square Airflow Control/Ventilation

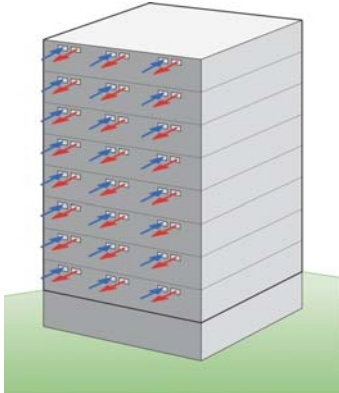
- Avoid cross-contamination
- Provide effective ventilation with minimal energy inputs
- Reduce drivers of infiltration
- *Compartmenting of apartments is critical to ventilation performance*

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Ventilation



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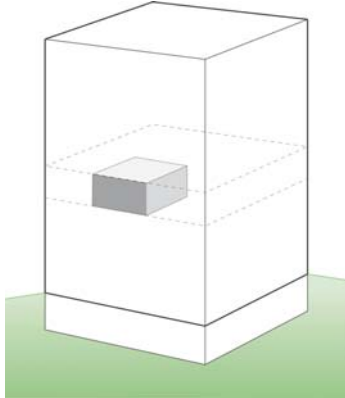
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Ventilation



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Ventilation

Context:

- Odor complaints a major motivation for residents
- Exhaust ventilation a part of existing infrastructure
- Project aspiring to LEED-NC recognition (ventilation distribution requirements)

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Ventilation

Challenges:




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Ventilation

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Ventilation

Options investigated:

- HRV per apartment
 - Ceiling too low for dropped soffit in circulation areas
 - Asbestos made penetration of partitions impractical
- Central supply and Hx
 - Would need to refit or reconfigure riser
 - Distribution within apartment

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Ventilation

Selected approach:

- Use existing ventilation shafts, exhaust
 - Controlled rate at unit – CAR
 - Seal exhaust riser from roof
 - Passive inlet vent (PIV)

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Ventilation

Whither the ventilation supply:

- Passive Inlet Vents (PIV)
 - Concern about effectiveness of passive vents
 - Act as intake only when apartment negative WRT exterior
 - Could exhaust ventilation act to depressurize enough – depends on how tight apartment is
 - Is source controlled?

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Ventilation

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Compartmenting

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Compartmenting

Context:

- Odor complaints a major motivation for residents
- Project aspiring to LEED-NC recognition (apartment air tightness requirement)

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Compartmenting

Challenges:

- Occupied renovation severely limits opportunities
 - 2 – 3 days total for interior work
 - Belongings not moved from living and bedrooms
- Interstitial interconnected
 - Openings into shafts
 - Hollow walls
- Limited disruption beyond kitchen and bath

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Compartmenting

How to identify effective and important measures?

- Have a look at building (may have to get destructive)
 - Understand/confirm construction
 - Assess significance of holes
 - Devise approaches to seal holes
 - Test implementation of measures.

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Compartmenting



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Compartmenting



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Compartmenting



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Compartmenting

Making it stick:

- Construction M&V
 - Performance target
 - guide contractor through first few
 - make sure measures are understood,
 - uncover implementation issues,
 - evaluate target
 - spot check (sample) to performance target

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Compartmenting

Making it stick: Performance specification

CASTLE SQUARE APARTMENTS
BOSTON, MA

May 24, 2010
SPECIFICATIONS

SECTION 01575

AIR TIGHTNESS AND TESTING REQUIREMENTS

PART 1 - GENERAL

1.01 SUMMARY

- A. Perform renovations of apartments, corridors, trash closets, elevator vestibules, and other rooms to achieve continuous enclosure air barriers that limit air leakage into (or out of) the space and verify air leakage control through testing. Assemblies modified or added as part of the renovation scope must be made to be air-, smoke-, and gas-tight. Apartments must achieve specific air leakage targets as indicated in this section.

The Owner's testing agency will be made available to provide technical assistance and testing for the first (6) garden apartments and the first (6) midrise apartments. Thereafter the Owner's testing agency will verify attainment of the air leakage target by sampling approximately 10% of

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Castle Square Wall Insulation Strategy

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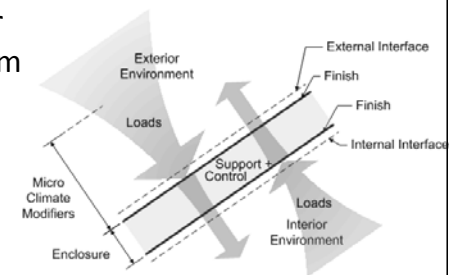
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Castle Square Wall Insulation Strategy

Environmental Separators

- Separate interior environment from exterior environment
- Separate two different interior environments



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Castle Square Wall Insulation Strategy

“The Perfect Wall”

- Structure
- Control Layers
 - Water
 - Air
 - Vapor
 - Thermal
- Cladding, finish

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Building Enclosure

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Castle Square Wall Insulation Strategy

Context

- Buildings are un-insulated
- Significant air leakage comfort complaints (papers blowing off of desks)
- Exterior rain infiltration issues
- Façade maintenance issues
- **R-40 performance goal**

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Castle Square Wall Insulation Strategy

Challenges:

- Occupied Retrofit
- Significant Thermal Bridging of Concrete Structure
- Existing Building Construction Tolerances

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Castle Square Wall Insulation Strategy

Options pursued:

- Exterior air barrier, insulation and cladding
- Exterior insulation and finish system (EIFS)
- Insulated metal panels (IMP)

Castle Square Wall Insulation Strategy

- Exterior air barrier, insulation, and cladding



Castle Square Wall Insulation Strategy

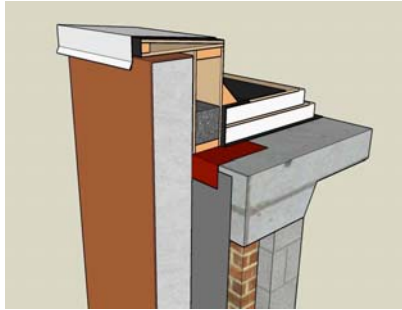
- Exterior air barrier, insulation, and cladding:
 - Large range of options
 - Insulation types
 - Air barrier materials
 - Cladding options

Castle Square Wall Insulation Strategy

- Exterior air barrier, insulation, and cladding:
 - Fire concerns
 - Lack of UL rated assemblies
 - Insulation thickness needed to achieve desired R-Value could be significant

Castle Square Wall Insulation Strategy

- Exterior insulation and finish system (EIFS)



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Castle Square Wall Insulation Strategy

- Exterior insulation and finish system (EIFS)
 - Lower cost option
 - No need for design of cladding attachment system

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Castle Square Wall Insulation Strategy

- Exterior insulation and finish system (EIFS)
 - Thick layers of insulation needed to achieve design goals
 - Insurance concerns (Fire, water, durability)

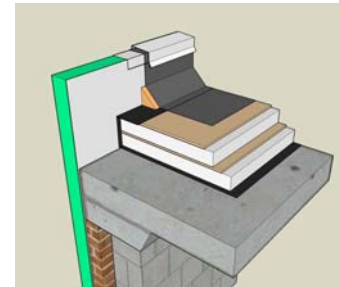
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Castle Square Wall Insulation Strategy

- Insulated metal panels (IMP)



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Castle Square Wall Insulation Strategy

- Insulated metal panels (IMP)
 - High R-Value – thinner overall thickness
 - Fire rated
 - Durable

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Castle Square Wall Insulation Strategy

- Insulated metal panels (IMP)
 - Attachment due to building variances
 - Water and Air control approach:
 - Use panels as the complete enclosure? (air barrier, insulation, water management)
 - Use the panels as an insulated cladding with another air barrier and water management layer behind?

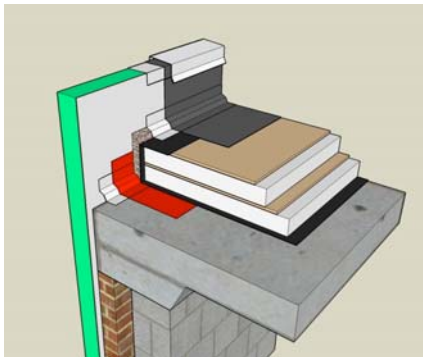
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Castle Square Wall Insulation Strategy

Insulated metal panels (IMP) as complete enclosure:



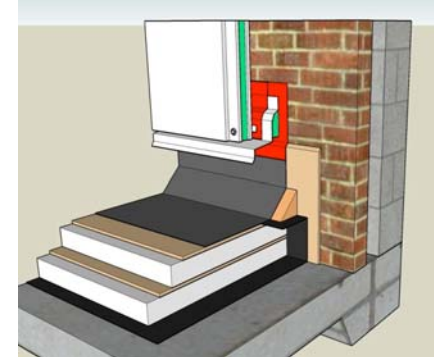
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Insulated metal panels (IMP) as complete enclosure:



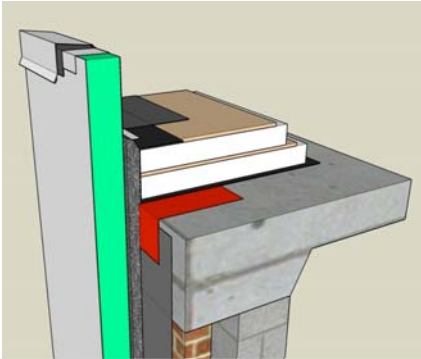
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Insulated metal panels (IMP) with separate water/air control:



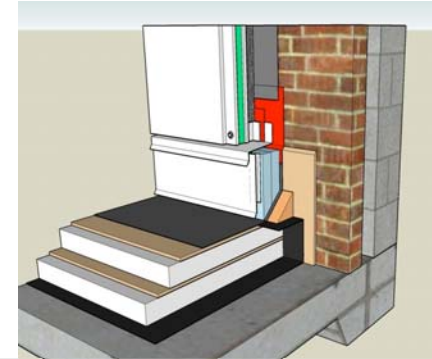
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Castle Square Wall Insulation Strategy

Insulated metal panels (IMP) with separate water/air control:



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Castle Square Mid-Rise Retrofit

- Wall System Approaches for Super Insulation (R40) Retrofit
 1. ~~Field-constructed system~~
separate components: applied air barrier and drainage plane, cladding attachment, exterior insulation, and cladding;
judged to costly and complicated
 2. ~~EIFS (Exterior Insulation and Finish System)~~
required thickness not approved by insurance
 3. Insulated metal panel system

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Castle Square Wall Insulation Strategy

- Insulated metal panels (IMP)
 - Compartmentalization of the living units

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Building Enclosure

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Building Enclosure

- Insulated metal panels (IMP)
 - Integration of windows and other enclosure elements made at the air barrier/water resistive barrier location

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Building Enclosure

- New roof membrane
- Extend blocking over top of insulated cladding panel
- Extend roof membrane over curb blocking and down over insulated cladding panel
- Continuous mineral wool air flow control and dimensional mitigation layer behind insulated cladding panel
- Membrane to wrap entire perimeter roof insulation and connect to air barrier of wall
- Insulated metal cladding panel
- Existing concrete structure
- Continuous air/water barrier membrane

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Building Enclosure

- Insulated metal cladding panel
- Membrane flap
- Panel cap
- Metal head flashing
- Backer rod and sealant
- Double-sided self-adhered membrane between metal head flashing and opening
- Foam sealant between window and membrane/flashing
- Membrane over inside edge of metal head flashing
- Continuous air/water barrier membrane turns in at opening

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Building Enclosure

- Foam sealant between window and membrane/flashing
- Plastic shims
- Backer rod and sealant
- Membrane sill flashing; extend over panel cap and turn up jambs
- Trim flashing
- Panel cap
- Line of existing brick sill to be removed
- Continuous air/water barrier/membrane turns in at opening
- Insulated metal cladding panel
- Continuous mineral wool air flow control and dimensional mitigation layer behind insulated cladding panel
- Existing brick and concrete wall assembly

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- Brick veneer/stone veneer
- Drained cavity
- Exterior rigid insulation — extruded polystyrene, expanded polystyrene, isocyanurate, rock wool, fiberglass
- Membrane or trowel-on or spray applied vapor barrier (Class I vapor retarder), air barrier and drainage plane (impermeable)
- Concrete block
- Metal channel or wood furring
- Gypsum board
- Latex paint or vapor semi-permeable textured wall finish

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Designed wall

The “perfect wall”

Vapor Profile

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Castle Square Mid-Rise Retrofit

- System Enhancements
 - New Heating Plant and Distribution (boilers, pumps, controls)
 - New Heating Distribution (new baseboard radiation and in-unit thermostatic control)
 - Controlled In-Unit Ventilation (CAR controlled exhaust with passive intake vents)
 - New DHW Plant and riser Insulation (insulate risers and improve recirculation)

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Castle Square Mid-Rise Retrofit



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Airflow Control Performance

Apartment Condition	ACH50 (air changes per hour at 50 Pascals)	cfm50 / sf (cfm at 50 Pascals relative to total enclosure area)	ELA/100 (ratio of effective leakage area per 100sf enclosure area)
Baseline	10 – 17	~0.5 – 0.8	2.5 – 4
1. Interior Scope Complete	6 – 7.5	0.25 – 0.3	1.3 – 1.6
2. New Windows, A/C sleeves	4.5 – 6	0.15 – 0.25	1– 1.4
3. Water/Air Control Membrane	< 5	< 0.2	< 1.25

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Castle Square Mid-Rise Retrofit


71 % decrease in natural gas for heating
78% decrease in natural gas for hot water
60% decrease in electric usage

10,791 MMBTU Savings Per Year
Avoids Emission of 1,506,120 lbs of CO2 Per Year

Data from Biome Studio

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Castle Square Mid-Rise Retrofit



Before

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Castle Square Mid-Rise Retrofit



After

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Castle Square Mid-Rise Retrofit

Thanks for your attention!

Questions?

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	MIDRISE Buildings (192 units) Deep Energy Retrofit		GARDEN Buildings (308 Units) Energy Efficiency Improvements		Total Property
	Therms	\$	Therms	\$	
TOTAL Baseline Gas Usage (2008)					
	126,744	\$193,918	270,056	\$413,186	\$607,104
Current Heating Energy Use Baseline					
	78,024	\$119,377	181,076	\$277,046	\$396,423
TOTAL Heating Savings					
	55,670	\$85,175	86,651	\$132,576	\$217,751
Current Hot Water Use Baseline					
	48,720	\$74,542	88,980	\$136,139	\$210,681
Total Hot Water Savings					
	38,061	\$58,233	12,997	\$19,885	\$78,119
Total Hot Water Savings as a Percentage of Baseline					
	78%	120%	15%		120%
TOTAL Gas Savings					
	93,731	\$143,408	99,648	\$152,461	\$295,870
Post Improvement Gas Usage (with Solar Thermal)					
	33,013	\$50,510	170,408	\$260,724	\$311,234
Gas Usage Per Unit					
		\$263		\$847	
Savings @7.18% & 1.1 debt ratio Additional Permanent Debt					
		\$1,747,851		\$1,858,188	\$3,606,039

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Note - KWH below excludes management office, CSTO offices, retail space, etc.)	MIDRISE Buildings (192 units) Deep Energy Retrofit		GARDEN Buildings (308 Units) Energy Efficiency Improvements		TOTAL
	KWH	\$	KWH	\$	
ELECTRIC					
Current Common Area Electric Usage Baseline	387,869	\$65,938	115,455	\$19,627	\$85,565
Savings from Lighting	53,342	\$9,068	46,887	\$7,971	\$17,039
Current Resident Electric Usage Baseline	309,924	\$52,687	1,026,882	\$174,570	\$227,257
Resident Savings from Lighting	68,512	\$11,647	20,709	\$3,520	\$15,168
Resident Savings from Refrigerators (assumes all but 40 refrigerators replaced)	87,488	\$14,873	122,119	\$20,760	\$35,633
Cooling Load from Enclosure and High Efficiency Air Conditioners	208,788	\$35,494	214,483	\$36,462	\$71,956
Average Savings Per Apartment	1,087	\$185	696	\$118	\$152
Total Electric Savings (Common Area + Resident)	418,130	\$71,082	404,197	\$68,714	\$139,796

Castle Square Apartments: Energy-Related Construction Budget		
Description	Unit Price	Value (includes General Contractor General Conditions and Overhead: 12%)
MIDRISE DEEP ENERGY RETROFIT IMPROVEMENTS		
Enclosure Improvements		
Roof replace - Midrise (R-40)	14.92	\$524,456
Roof replace - Midrise - Carpentry for raising equipment, curbs, etc (R-40)	2.00	\$70,302
Metal Panel - R41 using 5" Kingspan horizontal panel system (R-40)	28.85	\$2,329,824
Mid-rise Windows - Type 1 - fiberglass (R-5)	2,158	\$306,714
Mid-rise Windows - Type 2 - Fiberglass (R-5)	1,619	\$442,440
Mid-rise Windows - Type 3 - Fiberglass (R-5)	1,134	\$121,928
Replace sliding glass doors -Midrise (R-5)	1,800	\$64,512
Service door replacement - roof and retail units (R-12)	1,682	\$48,980
Common area Glazing and Door replacement -sqft estimate (R-5)	55.00	\$202,048
Storefront Glazing and Doors - sqft estimate	55	\$323,277
Mechanical Equipment		\$0
Air Conditioning Units - Energy Star	775	\$85,586
ALLOWANCE - Replace/repair baseboard heating elements at midrise units 50% allowance	600	\$193,536
Midrise Heating system upgrade - New high efficiency condensing boilers, indirect hot water tanks	223,000	\$999,040
Solar Thermal System to be located on each of the four mechanical bulkheads on roof	117,500	\$470,000
Air Sealing, Ventilation Rehab, Pipe Insulation		\$0
ALLOWANCE - In-Unit air sealing	500	\$107,520
Fire stop at kitchen wet walls	335	\$72,038
Drywall patch repair allowance at kitchen	200	\$43,008
Drywall patch repair allowance at bathrooms	100	\$21,504
Midrise Corridor ERV system - includes fire dampers, new return air ductwork	51,985	\$232,893
ALLOWANCE - Shaft closure, pipe insulation, and drywall repair for compartmentalization	785	\$168,806
Aeroseal work for 5days plus corridor grill preparation	17,340	\$77,683
Aeroseal work for Alternate ventilation plus grill preparation and passive air vents - wiring and exhaust fans	994	\$213,750
ALLOWANCE - Fire/smoke dampers for exhaust vents	250	\$94,080
Range hoods - 400cfm with fan delay	216	\$46,449

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Kitchen range hood installation with interlock wiring	172	\$36,987
Handicap unit remodels for 5% of unit types (MIDRISE) - Will include Extensive Air Sealing and Ventilation Rework	15,000	\$420,000
Other Improvements Required Due to Enclosure/Ventilation Improvements		
ALLOWANCE - Electrical rework for fixtures on skin	75,000	\$336,000
Asbestos allowance for glove bag and demolition work	150,000	\$168,000
Appliances		
Refrigerators E-star 18 cuft - Includes installation, old recycling	608	\$113,674
Handicap appliances - 1BR (MIDRISE) - Energy Star	1,770	\$19,826
Handicap appliances - 2BR (MIDRISE) - Energy Star	2,084	\$35,018
Lighting		
Handicap appliances - 1BR (MIDRISE) - Energy Star	1,770	\$19,826
Handicap appliances - 2BR (MIDRISE) - Energy Star	2,084	\$35,018
Lighting		
Lighting - Kitchen New - Energy Star	135	\$29,030
Lighting - Bathroom add light over medicine cabinet - Energy Star	130	\$27,955
Lighting - Hallway and Dining - Energy Star	275	\$59,136
Install new common area lighting - Energy Star	275	\$120,736
TOTAL MIDRISE ENERGY RELATED IMPROVEMENTS		\$8,706,736

Do Deep Energy Retrofits Make Economic Sense?

Total Baseline Gas Usage (Difference Shell No/No Shell)		
	29,412 therms	\$45,001
Additional Work Required if Super Insulated Shell is Eliminated	Additional Cost	
Central heating plant will be considerably larger, resulting in increased first cost. This plant would consist of three Buderus GB312/280 condensing boilers, larger pumps, piping, etc...). Wall-hung boilers (Buderus, Viessmann or other) would no longer be feasible. (\$50,000 increase per boiler room)	\$200,000	
Additional Masonry Work (Spawling, Parapet, etc. required)	\$300,000	
TOTAL	\$500,000	
Net Cost of Shell	No LIHTC	With LIHTC
Cost of Shell	\$2,080,000	\$1,456,000
Additional Work Required if Super Insulated Shell is Eliminated	\$500,000	\$350,000
Net Cost of Shell	\$1,580,000	\$1,106,000

	Net Cost of Work (With LIHTC)	Annual Savings	Payback Period (years)				
Straight Payback Period for Shell	\$1,106,000	\$45,001	25				
	Energy Savings from Shell (therms)						
Net Cost of Super Insulated Shell	\$1,106,000						
Therm Savings Due to Super Insulated Shell	29,412						
Discount Rate	8%						
NPV of Shell Savings	\$815,886		\$954,547	\$1,133,264	\$1,366,350	\$2,083,357	\$3,381,602
Annual Gas Escalator			3%	4%	5%	6%	8%
1	\$45,001	\$1.53	\$45,001	\$45,001	\$45,001	\$45,001	\$45,001
2	\$46,351	\$1.58	\$46,801	\$47,251	\$47,701	\$48,601	\$49,501
3	\$47,741	\$1.62	\$48,673	\$49,613	\$50,563	\$52,489	\$54,451
4	\$49,173	\$1.67	\$50,619	\$52,094	\$53,596	\$56,688	\$59,896
5	\$50,648	\$1.72	\$52,644	\$54,698	\$56,812	\$61,223	\$65,885
6	\$52,168	\$1.77	\$54,750	\$57,433	\$60,221	\$66,121	\$72,474
7	\$53,733	\$1.83	\$56,940	\$60,305	\$63,834	\$71,410	\$79,721

With Low Income Housing Tax Credits, shell is economically rational, if gas price rises at 5% per year.