Wilmcote House

A presentation for AECB Conference

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Wilmcote House

- Pre-retrofit situation and business case
- Aspiration
  - Measures proposed
  - Why EnerPHit?
- Form of contract
- EnerPHit specification
- Thermal modelling (PHPP)
- Ventilation and summer cooling strategies
- Air tightness and testing strategies
- EnerPHit compliance?
- Quality control
- Progress onsite

Project overview

Existing building

- Large Bison REEMA concrete panel construction
- Built 1968
- 11 storeys
- 100 x Three bedroom maisonettes
- 7 x One bedroom flats
- Average SAP 55
- Area Housing Office located on ground floor
- Previous major schemes & estate regeneration early 1990s

Pre-retrofit situation and business case

- Electric heating cost excessive for residents
  - > Fuel poverty
  - > Somerstown deprived area of city
- Maintenance costs significant
  - > Condensation reported by a third of residents
  - > Window repairs reported by 80% of residents over a 2 year period
  - > Water ingress issues to properties and communal stairwells
- Windows and roof at end of serviceable life
- Concrete repairs required to maintain life of structure
- Decorations to communal & external areas failing
- Security to communal areas ineffective
- Area Housing Office relocating to new community hub
- Factors against demolition

Aspiration

- Insulate external envelope with cladding EWI
- Replace roof and insulate
- Triple glazed window replacement
- New hot water cylinders & install electric showers
- Mechanical Ventilation Heat Recovery (MVHR) units
- Extend living areas and create sun room
- Enclose communal walkway, create additional entrance
- Introduce restrictive access doors
- Convert office into 4 additional flats
- Structural concrete repairs & decorations to external/ communal areas
- **Replace electric heating**

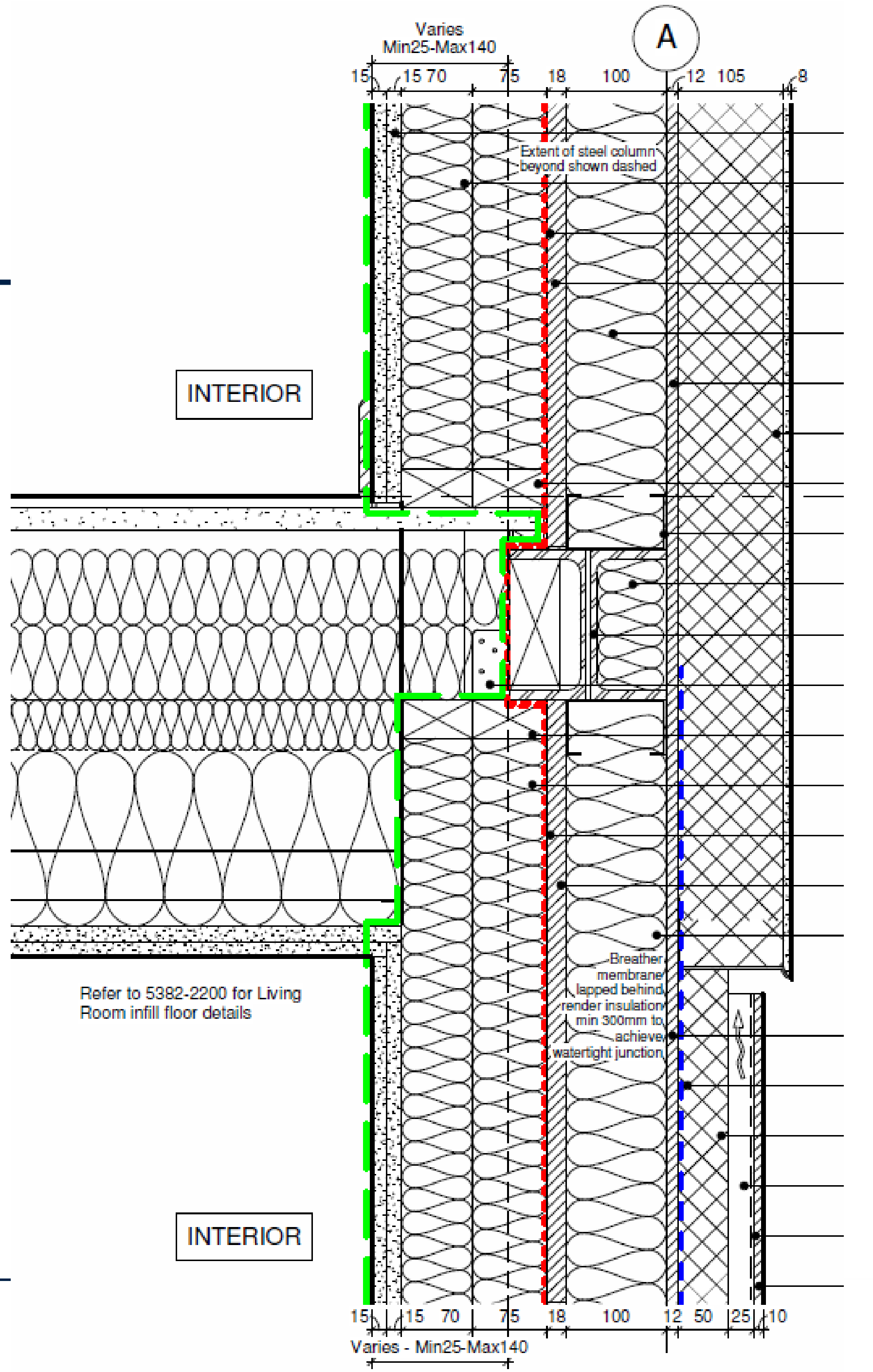
Aspiration – Why EnerPHit?

- Residents improved living environment
  - Fuel poverty & cost of heating
  - Health and social benefits
  - Effective management of property systems & controls
- Informing asset management strategy
  - Future proof against government energy standards for housing (U Values & SAP Ratings)
  - Future proof energy prices with strategy to insulate & reduce demand for energy
  - Reduce D2D maintenance demand in non-traditional stock
  - Learning from ‘actual’ complex large exemplar scheme informing strategy of all 17,000 PCC housing stock & not just Wilmcote House
- Priority is building performance versus certification

Form of contract

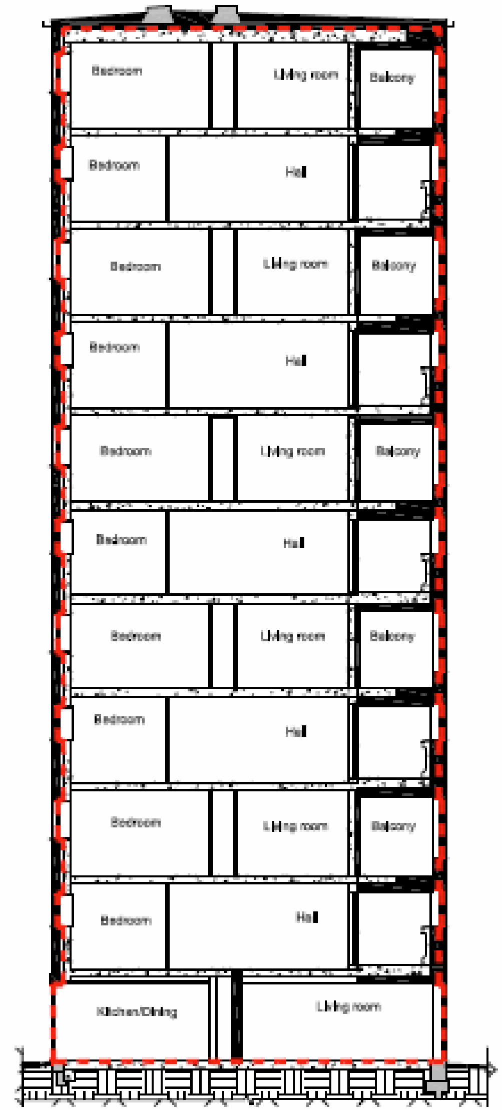
Design and build

- Contractor design portion
  - > Everything outside of the air barrier
  - > Air barrier implementation
  - > Air testing
  - > MVHR installation
  - > Building control compliance
- Non-contractor design portion
  - > Everything inside of the air barrier, apart from
    - MVHR installation
    - Air barrier implementation



EnerPHit specification

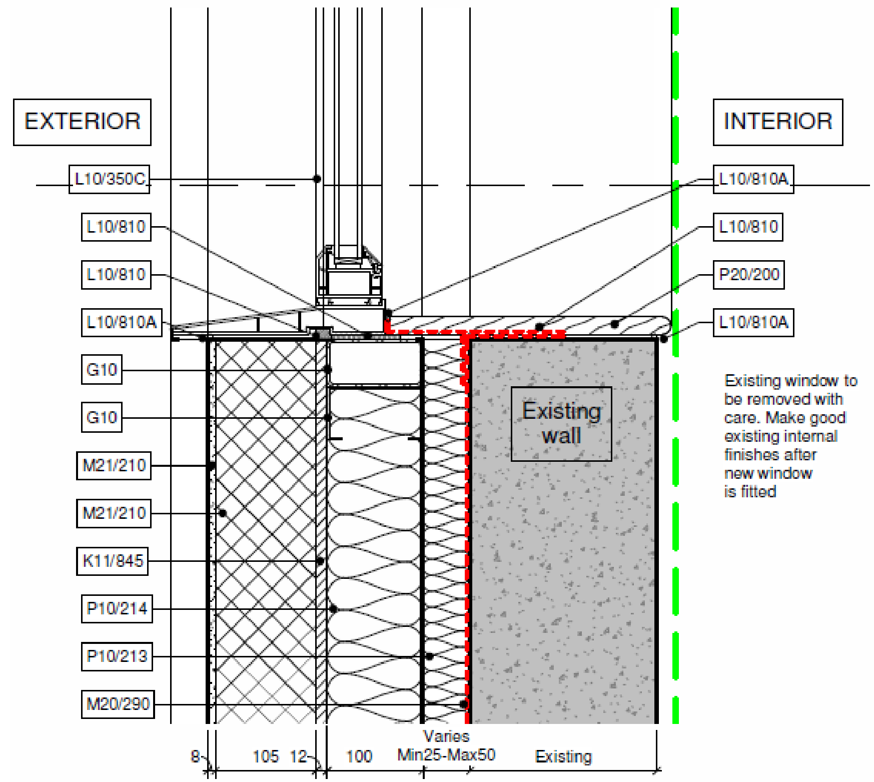
Building assembly overview	Average U-Value [W/(m²K)]
Windows (as installed)	0.928
Exterior walls	0.139
Roof	0.127
Floor slab	2.447
Sheltered End	0.337
Thermal bridges - Overview	Y-Value [W/(mK)]
Thermal bridges Ambient	0.029
Perimeter thermal bridges	-0.348
Average therm. envelope	0.555



1 Typical Block Cross Section - Air-tightness strategy
1 : 100

EnerPHit specification

- EWI system
  - > Rockwool quilt in variable layers
  - > Rockwool flexi in Metsec layer
  - > Rockshield/Brickshield/DuoBoard cladding systems
- Pro-Clima air barrier membranes and tapes
- Windows and doors
  - > Internorm KF410
  - > (Tender stage – Rehau Geneo)
- MVHR
  - > Zehnder ComfoAir 200
  - > (Tender stage - Paul Focus 200)



Thermal modelling & EnerPHit Compliance

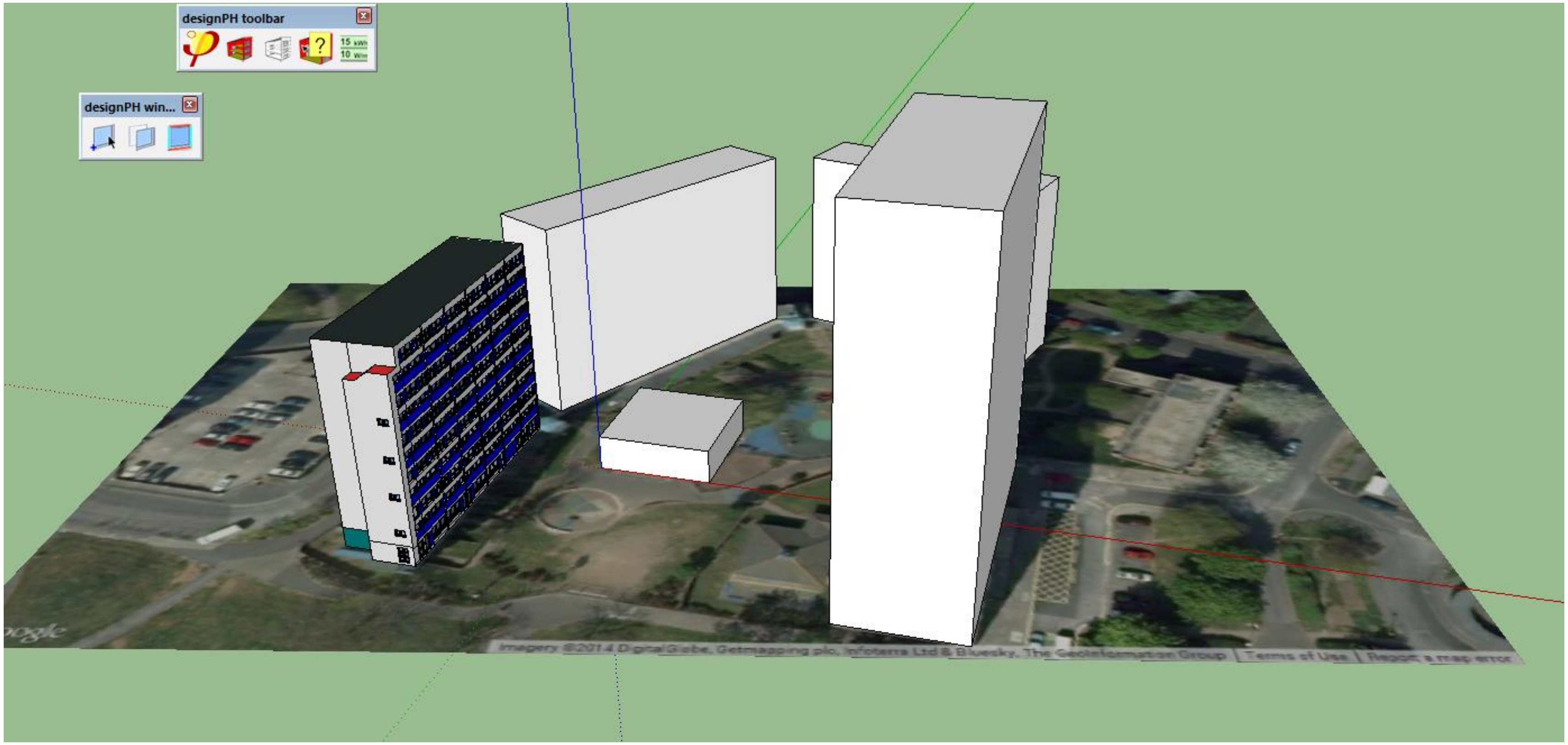
Ventilation & summer cooling strategies

Air tightness & air testing strategies

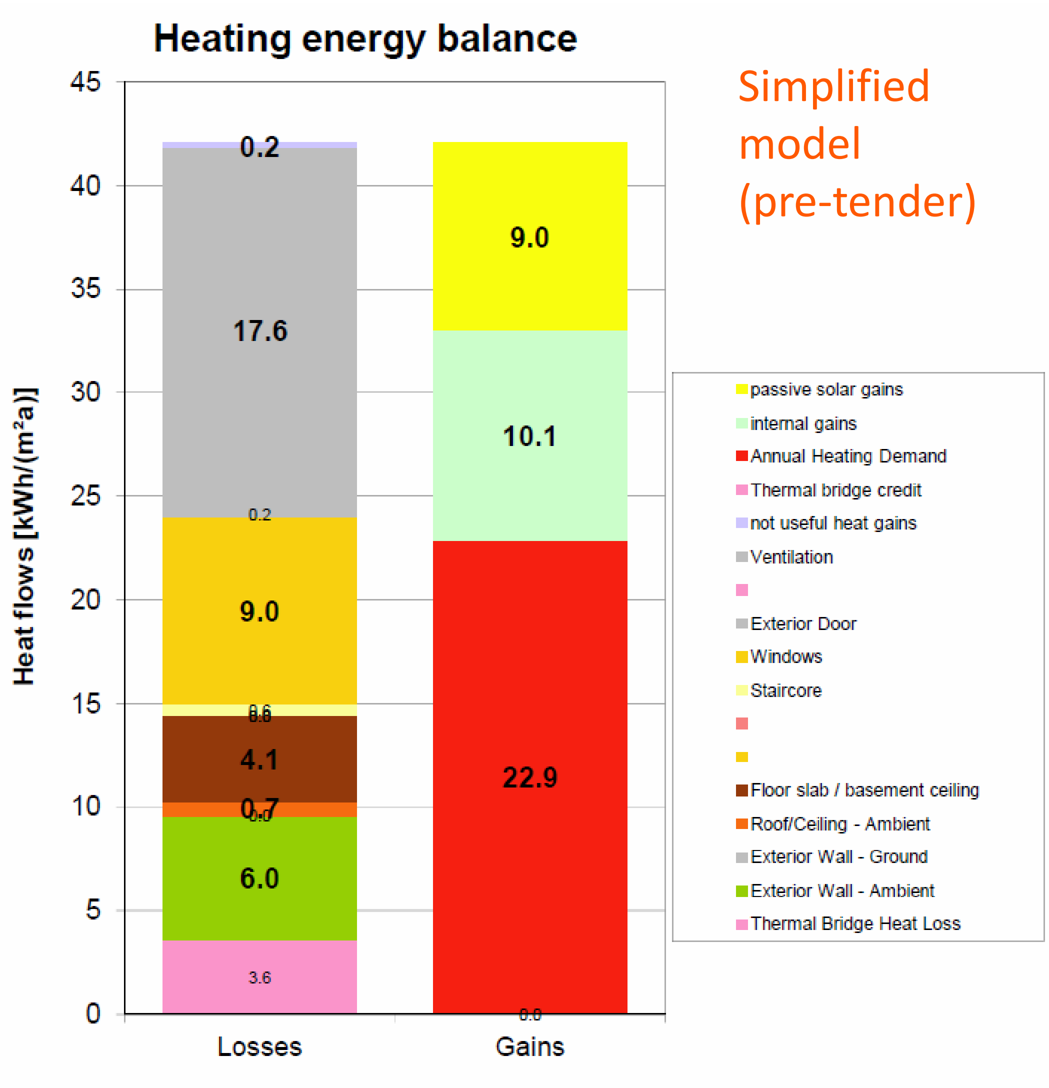
Quality control

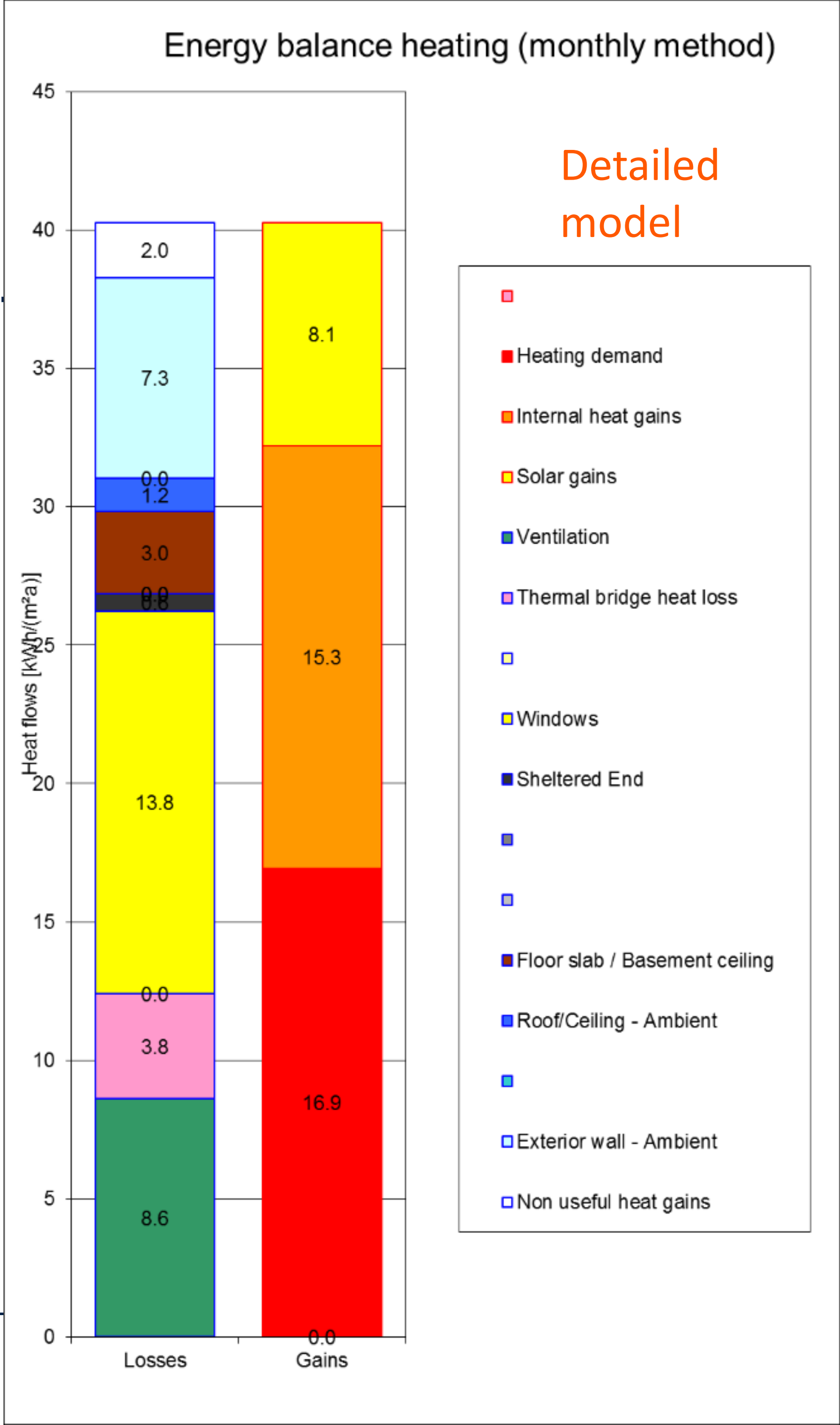
Thermal modelling

Thermal modelling in designPH and PHPP



Thermal modelling results





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Thermal modelling results

Simplified model (pre-tender)

Building element overview	Average U-Value [W/(m²K)]
North Windows	
East Windows	0.762
South Windows	
West Windows	0.808
Horizontal Windows	
Exterior Door	0.850
Exterior Wall - Ambient	0.144
Exterior Wall - Ground	
Roof/Ceiling - Ambient	0.090
Floor slab / basement ceiling	3.390
Staircore	0.374
Thermal Bridge Overview	Ψ [W/(mK)]
Thermal Bridges Ambient	0.300
Perimeter Thermal Bridges	0.300
Thermal Bridges Floor Slab	
Partition Wall to Neighbour	
Average Therm. Envelope	0.666

Detailed model

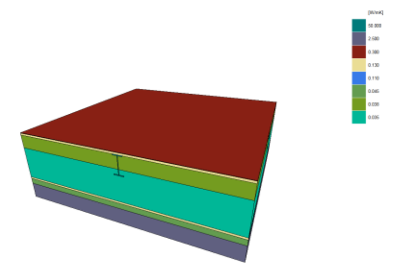
Building assembly overview	Average U-Value [W/(m²K)]
North windows	1.159
East windows	0.907
South windows	1.001
West windows	0.950
Horizontal windows	
Exterior door	
Exterior wall - Ambient	0.139
Exterior wall - Ground	
Roof/Ceiling - Ambient	0.127
Floor slab / Basement ceiling	2.447
Sheltered End	0.337
Thermal bridges - Overview	Ψ [W/(mK)]
Thermal bridges Ambient	0.029
Perimeter thermal bridges	-0.348
Thermal bridges FS/BC	
Partition wall to neighbour	
Average therm. envelope	0.555

Thermal bridge modelling

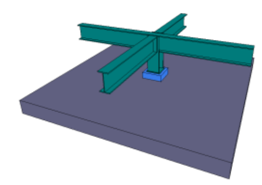
Type	Block	Façade/Floor/Roof	Plan/Sectio	Description	Nr.	Thermal bridge description		Group Nr.	Assigned to group	Quantity	User deter-mined length [m]	-	Subtrac-tion user-determin ed length [m]	)=	Length ℓ [m]	Input of thermal bridge heat loss coefficient W/(mK)	Ψ W/(mK)		Checked [	Relevant I
												-		) =						
Ground Floor	A and Stair Core A	Garden	S	Perimeter	1	G1	Psi	16		1	37.49						-0.009	Calculated	y	2003, 3301
Ground Floor	A and Stair Core A	Street and Gable	S	Perimeter	2	G2	Psi	16		1	43.68						-0.606	Calculated	y	2000, 2001
Ground Floor	A	Gable	S	Perimeter	3	G3	Psi	16		1	4.83						-0.648	Calculated	y	2001
Ground Floor	A	Sheltered	S	Perimeter	4	G4	Psi	16		0	10.81									1804, 1502
					5															
Wall	Stair Core A	Garden to Gable	P	Corner	6	EW1	Psi	15		0	26.40									2103
Wall	Stair Core A	Gable to Gable	P	Corner	7	EW2	Psi	15		1	26.40						-0.057	Calculated	y	2102
Wall	A	Gable to Street	P	Corner	8	EW3	Psi	15		0	28.98									2100
Wall	A	Street to Sheltered	P	Corner	9	EW4	Psi	15		0	28.98									2108
Wall	A	Sheltered to Garden	P	Corner	10	EW5	Psi	15		0	28.98									2118
Wall	A	Gable to Stair Core	P	Inverted Corner	11	EW6	Psi	15		1	25.15						0.426	Calculated	y	2101, 1501
Wall	A	Garden	P	Main vertical steel	12	EW7	Psi	15		1	168.54						0.044	Calculated		5, S.102, S.106, 2513
Wall	A	Garden	S	Main horizontal steel	13	EW8	Psi	15		1	368.92						0.037	Calculated		5, S.102, S.106, 2513
Wall	A	Street	P	Main vertical steel	14	EW9	Psi	15		1	310.49						0.021	Calculated		S.24, S.100, 2510
Wall	A	Street	S	Main horizontal steel	15	EW10	Psi	15		1	757.06						0.017	Calculated		S.24, S.100, 2510
Wall	A	Street	P	Secondary vertical steel	16	EW11	Psi	15		1	169.20						0.015	Calculated		S.100
Wall	A	Street	P	Vertical metsec at 600mm centres	17	EW12	Psi	15		0	30.15						0.008	Not Included		S.24, 1604*
Wall	A	Garden	P	Vertical metsec at 600mm centres	18	EW13	Psi	15		1	804.90						0.009	Calculated		S.24, 1604*
					19															
Partition	A	Street	P	Party wallto External Wall	20	P1	Psi	15		0	170.05									2531, 2537 no exact drawing
Partition	A	Floor	S	Party Wall to Floor	22	P2	Psi	15		0	60.00									
Partition	A	Garden	S	Intermediate Floor to External Wall Corridor Floor	23	P3	Psi	15		0	172.65									2535, 1802
Partition	A	Garden	S	Intermediate Floor to External Wall Living room Floor	24	P4	Psi	15		0	172.65									2200, 1802
Partition	A	Street	S	Intermediate Floor to External Wall	25	P5	Psi	15		0	357.20									2532, 2512
Partition	A	Gable	S	Intermediate Floor to External Wall	26	P6	Psi	15		0	48.30									
Partition	A		S	Intermediate Floor to External Wall	27	P7	Psi	15		0	10.92									
Partition	A	Sheltered	S	First Floor to External Wall	28	P8	Psi	15		1	10.81						0.297	Calculated	y	1804, 2409
Partition	A	Sheltered	S	Upper Intermediate Floors to External Wall	29	P9	Psi	15		0	97.29									1804, 2409
					30															
Roof	A	Garden	S	Eaves	31	R1	Psi	15		1	35.40						-0.083	Calculated	y	2810
Roof	A	Street	S	Eaves	32	R2	Psi	15		1	35.72						0.031	Calculated	y	2809
Roof	A	Gable	S	Gable	33	R3	Psi	15		0	10.81									2811, 2813
Roof	Stair Core A	Gable	S	Gable	34	R4	Psi	15		0	10.50									2815, 2803
Roof	A	Sheltered	S	Gable	35	R5	Psi	15		0	10.81									2814, 1804
Roof	A	Roof	S	N-S Main Steel	36	R6	Psi	15		1	135.06						0.031	Calculated	y	S.23, 2809
Roof	A	Roof	S	E-W Main Steel (On Party Wall)	37	R7	Psi	15		1	49.13						0.031	Calculated	y	2808,2807
Roof	A	Roof	S	E-W Main Steel (Off Party Wall)	38	R8	Psi	15		1	58.95						0.031	Calculated	y	2808,2807
Inverted Corner	A	Stair Core to Ext Wall	S	Roof of Stair Core to 11th Floor external wall gable end.	39	R9	Psi	15		0	6.34									2803, 2806, 2817
Roof	A	Roof	S	Metsec	40	R10	Psi	15		1	572.02						0.010	Calculated		S.25
Roof	A	Roof	S	Cold Water Pipes and Handrail including steels	41	R11	Psi	15		1	33.90						0.024	Calculated		2823, 2824, M501
					42															
					43															
Windows	A	Garden	S	General Cill to Render	44	W1	Psi	15									0.058	Calculated	y	2513
Windows	A	Garden	S/P	General Head/Jamb to Render	45	W2	Psi	15									0.038	Calculated	y	2515
Windows	A	Garden	S	General Cill to Rainscreen	46	W3	Psi	15									0.048	Calculated	y	2514
Windows	A	Garden	P	General Jamb to Rainscreen	47	W4	Psi	15									0.053	Calculated	y	2516
Windows	A	Street	S	Cill (steel rhs)	48	W5	Psi	15									0.066	Calculated	y	2510
Windows	A	Street	S	Head (steel rhs)	49	W6	Psi	15									0.033	Calculated	y	2512
Windows	A	Street	P	Jamb (steel channel)	50	W7	Psi	15									0.037	Calculated	y	2511
Windows	A	Street	P	Jamb (steel rhs)	51	W8		15									0.033	Calculated	y	2511
					52															
Misc	A	Garden	3d	Steel Penetration 1	53	M1	Chi	15		1	50.00						0.013	Calculated		2200's, 1814/5, 2052
Misc	A	Garden	3d	Steel Penetration 2	54	M2	Chi	15		1	10.00						0.006	Calculated		
Misc	A	Garden	3d	Steel Penetration 3	55	M3	Chi	15		1	10.00						0.006	Calculated		
Misc	A	Garden	3d	Steel Penetration 4	56	M4	Chi	15		1	5.00						0.020	Estimated		
Misc	A	Garden	3d	Steel Penetration 5	57	M5	Chi	15		1	2.00						0.010	Estimated		
					58	M6	Chi	15		0										
Misc	A	Street	3d	Steel Resin Anchors	59	M7	Chi	15		1	240.00						0.005	Estimated		S100 (detail A)
Misc	A	Garden	3d	Rockwool Duoslab Rainscreen Fixings	60	M8	Chi	15		1	1500.00						0.002	Estimated		Sub-contractor design
Misc	A	Street	3d	Brise-soleil fixings	61	M9	Chi	15		1	120.00						0.005	Estimated		tor Design 2624 2625
					62	M10	Chi	15		0										
Misc	A	Roof	3d	Steel penetrations over thermal break pads in roof at corner of bu	63	M11	Chi	15		1	2.00						0.030	Estimated		S23, 2800, 2807,
Misc	A	Roof	3d	Steel penetrations over thermal break pads in roof along edge of	64	M12	Chi	15		1	13.00						0.020	Estimated		S23, 2800, 2807,
Misc	A	Roof	3d	Steel penetrations over thermal break pads in roof	65	M13	Chi	15		1	20.00						0.010	Estimated		S23, 2800, 2807,
					66	M14	Chi	15		0										
					67	M15	Chi	15		0										
					68	M16	Chi	15		0										
Misc	A	Gable	P	Concrete Structural Fin	69	M17	Psi	15		1	115.92						0.335	Calculated	y	2101, 2100
Misc	A	Sheltered	P	Concrete Structural Fin internal ground floor)	70	M18	Psi	15		1	8.20						0.980	Calculated	y	1502, 2108
Misc	A	Sheltered	P	Concrete Structural Fin (external upper floors)	71	M19	Psi	15		1	115.92						0.335	Calculated	y	2409, 1804
					72															

Thermal bridge modelling – 3D

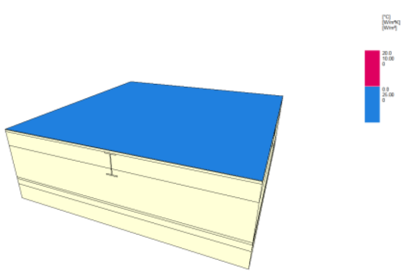
Detail Ref M13	Column thermal break roof support column	Modelled U_{roof}	ξ-value
		0.066 W/m^{2}K	0.056 W/K



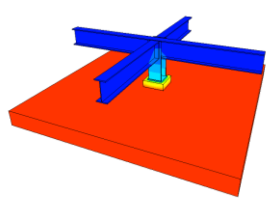
Full model showing all materials



Model showing only the thermal break, steel and co

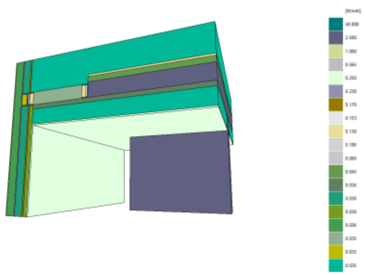


Full model showing boundary conditions

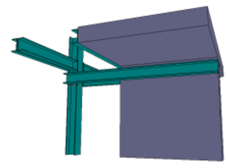


Model showing heat flow

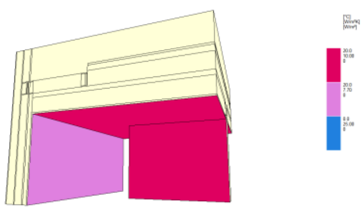
Detail Ref M4	Two tie back beams at eaves level – infill timber roof over balcony	Modelled U_{wall}	Modelled $U_{main\ roof}$	ξ-value
		0.138 W/m^{2}K	0.060 W/m^{2}K	0.092W/K fo



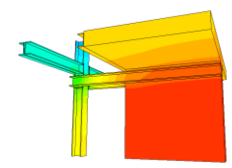
Full model showing all materials



Model showing only steel and concrete



Full model showing boundary conditions



Model showing heat flow

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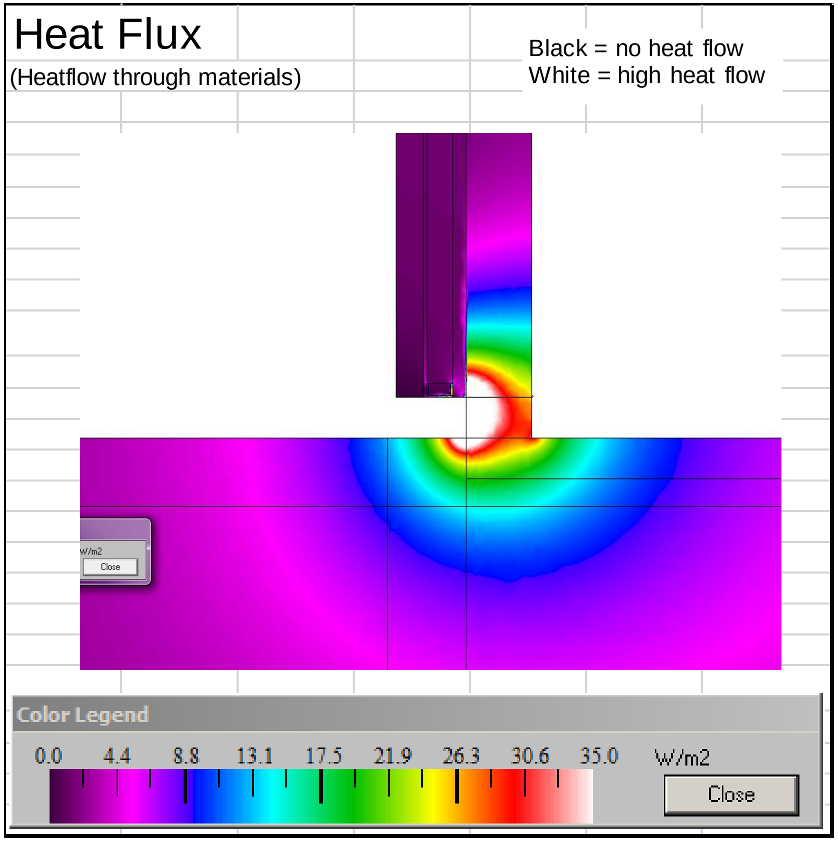
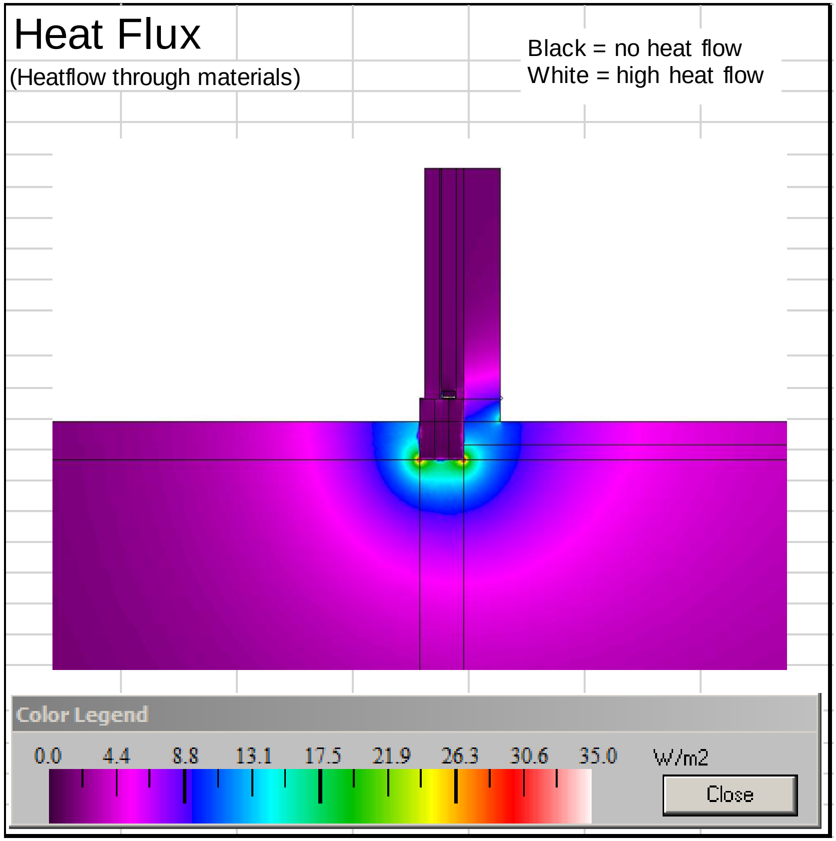
Thermal bridge modelling – 2D

Insulation stops above ground



psi External	0.70	W/mK

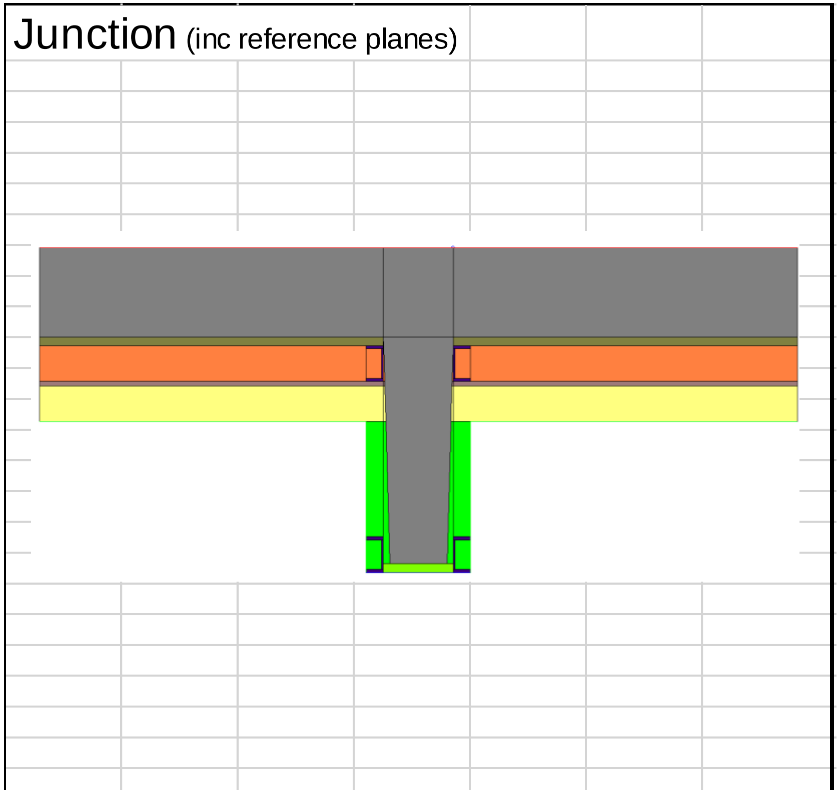
Insulation 250mm below ground



psi External	-0.57	W/mK

Thermal bridge modelling – 2D

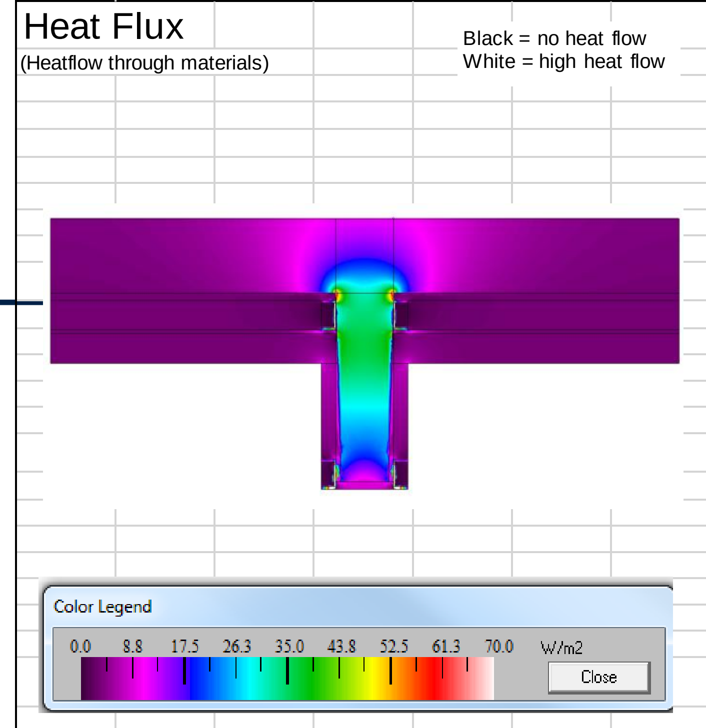
Concrete fin

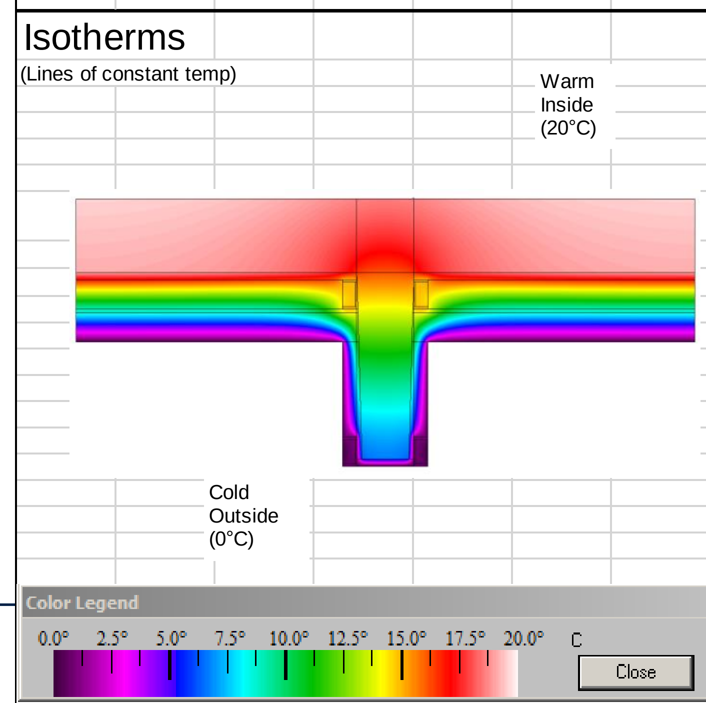


psi External	0.34	W/mK

Length = 232m

Heat loss = 2kWh/m^{2}a





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EnerPHit Compliance?

EnerPHit Compliance?

Areas of potential non-compliance

MVHR system efficiency

Criteria for certification:

- System efficiency ≥ 75%
- Cold duct runs (intake/exhaust) inside the thermal envelope should be kept as short as possible and well insulated
- Length in this case = 14m therefore Spiralite insulated duct is required

Ventilation of communal areas

Criteria for certification:

- All areas inside the thermal envelope should be mechanically ventilated
- Ventilation requirement is low due to low occupancy (communal areas are not habitable spaces)
- Demonstrate how the ventilation requirement can be met by door opening as occupants enter and exit the building

Kitchen extract ventilation

Criteria for certification:

- Not explicitly disallowed
- Should not compromise integrity of air barrier
- Include electricity consumption in PHPP
- Heat lost is assumed to be only the non-useful gains and therefore not included in PHPP

EnerPHit Compliance?

Specific building demands with reference to the treated floor area

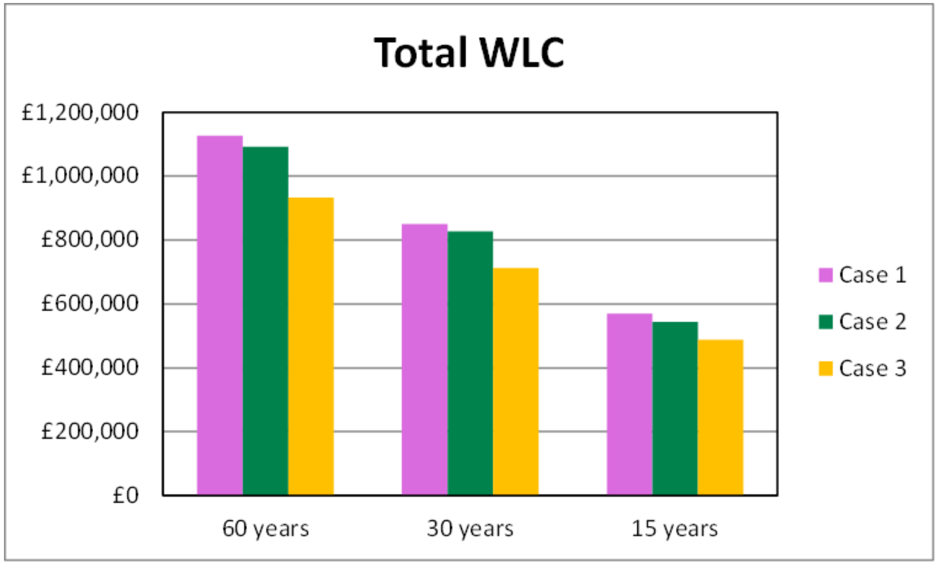
		Value	Unit	Requirements	Fulfilled?*
	Treated floor area	3119.6	m^2		
Space heating	Heating demand	**17**	**$kWh/(m^2a)$**	25kWh/(m²a)	**yes**
	Heating load	**10**	**W/m^2**	-	**-**
Space cooling	Overall specif. space cooling demand		**$kWh/(m^2a)$**	-	**-**
	Cooling load		**W/m^2**	-	**-**
	Frequency of overheating (> 25 °C)	0.7	%	-	**-**
Primary energy	Heating, cooling, dehumidification, DHW, auxiliary electricity, lighting, electrical appliances	**172**	**$kWh/(m^2a)$**	122kWh/(m²a)	**no**
	DHW, space heating and auxiliary electricity	119	$kWh/(m^2a)$	-	**-**
	Specific primary energy reduction through solar electricity		$kWh/(m^2a)$	-	**-**
Airtightness	Pressurization test result n_{50}	**1.0**	**1/h**	11/h	**yes**

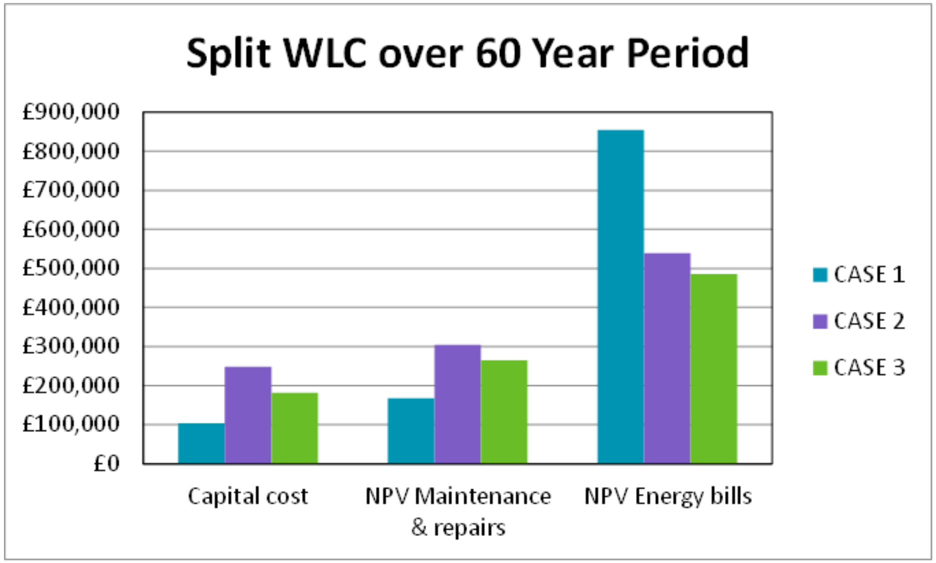
* empty field: data missing; '-': no requirement

EnerPHit Compliance?

Case 1 – Existing storage heaters
Case 2 – Air source heat pumps
Case 3 – Communal gas boilers

"In individual cases where a very high primary energy demand is necessary, this limit value can be exceeded after agreement with the Passive House Institute. For this, evidence of efficient use of electrical energy is necessary, with the exception of existing electricity uses for which an improvement of the electrical efficiency by means of upgrading or renewal would prove uneconomical over the lifecycle."





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Ventilation strategies

Heat Recovery Legend

The system is designed to operate continuously to provide ventilation rates in line with the requirements of Part F: 2010 - System 4 Continuous Supply and Extract Ventilation with Heat Recovery.

The unit specific Installation Instructions and Homeowner Guide are supplied with each unit and this product must be installed inline with the manufacturers guidance and Domestic Ventilation Compliance Guide (2010). The Homeowner Guide must be left with the unit.

Ducting
The specified unit must be ducted using one of the duct configurations below and in accordance with your ventilation design.

If joist layouts/sections are not supplied we assume the ceiling void is suitable to accommodate the specified duct. Clear paths through the ceiling/floor void for the duct to be installed are also assumed.

1. 204mm x 60mm duct - Minimum ceiling void depth required 85mm.
2. 125mmØ rigid plastic duct - Minimum ceiling void depth required 150mm.
3. Semi-rigid Combitube - Minimum ceiling void depth required 85mm.
   Combitube Grilles - Minimum ceiling void depth required 135mm.
4. Semi-rigid Flat 51 - Minimum ceiling void depth required 85mm.
   Flat 51Grilles - Minimum ceiling void depth required 105mm.

Ducting should be insulated where it passes through unheated areas and voids (e.g. loft spaces) with the equivalent of at least 25mm of a material having a thermal conductivity of ≤0.04 W/(m.K) to reduce the possibility of condensation forming. Where a duct extends above roof level the section above the roof should be insulated or a condensate trap should be fitted just below roof level.

The MVHR unit should incorporate a condensate drain, which should be connected to the nearest waste water network. Where units are sited in a position that makes the connection of piping to allow a fall impractical, a condensate pump may be incorporated as part of the installation.

Vertical ducting will require a condensate trap in order to prevent back flow of any moisture into the product (These items are to be purchased through others).

The performance of the ventilation system relies on efficient air distribution and it is vital that duct installation is not left until the last moment when the only means of overcoming obstructions is to install flexible duct where rigid had been specified.

For continuously running ventilation systems we recommend a recirculating cooker hood complete with carbon filter is installed to degrease the air at the source of pollution, preventing a build up of grease from forming within the ducting.

If terminating to a tile vent consideration should be paid to the effective equivalent area of the terminal to ensure that this does not adversely affect the fan performance. Please refer to the product installation instructions for further details.

Background ventilation
No background ventilators are required.

FS Fire
Fire stopping materials have not been quoted for. For advice on appropriate fire stopping products a fire officer should be consulted and the Building Regulations 2000: Approved Document B (Fire Safety) - Volume 1: Dwelling houses (2006) prior to any order being placed.
Extract valves should not be installed directly above a heat source. We suggest a minimum distance of 600mm from the nearest edge.

Wiring
WARNING: Class II appliances must be earthed. All wiring must conform with BS7671: IEE Wiring Regulations.
The installation must be carried out by a qualified electrician in accordance with prevailing regulations.

Please refer to the product Installation Instruction for further guidance.

Room name	Area	Clear height	Room vol.	Volume flow per room			Air chng. rate per room n
	A	h	A x h	V_{SUP}	V_{ETA}	V_{TRANS}	
	m²	m	m³	m³/h	m³/h	m³/h	1/h
Kitchen	13	2.50	33		47		1.42
Hall/Stairs 1	9	2.50	23			31	1.38
WC	1	2.50	3		22		7.30
Bed 3	6	2.50	15	18			1.23
Bed 2	11	2.50	28	20			0.72
Hall/Stairs 2	6	2.50	14			28	1.99
Bed 1	14	2.50	35	30			0.86
Living	25	2.50	63	30			0.47
Balcony	4	2.50	9			3	0.32
Bathroom	5	2.50	12		29		2.50

THESE DRAWINGS ARE FOR INDICATIVE PURPOSES ONLY

Our quotation is specifically based on the indicative design layout provided. For installations where deviations occur, additional materials may be required.

Greenwood Air Management cannot accept liability for the cost of extra parts required to complete an installation unless in the unlikely event, an error during the quotation process has occurred. Additionally, where changes to our indicative design proposals occur they must be validated to check whether they pose a major risk to performance with the original system designer.

To return items, we require as fitted drawings and a brief explanation to support the request for a credit.

Greenwood Air Management cannot accept returns unless in the unlikely event, an error during the quotation process has occurred where design layout differs from materials list.

Wilmcote House

Keepmoat

QUOTE	5798	SCALE	1:50
DRAWN	RK	DWG No	001e
PAPER SIZE	A1L	DATE	04.11.2014

GREENWOOD AIR MANAGEMENT Ltd, BROOKSIDE INDUSTRIAL ESTATE, RUSTINGTON, WEST SUSSEX. BN16 3LF. TELEPHONE : (01903) 771021. FAX : (01903) 782398

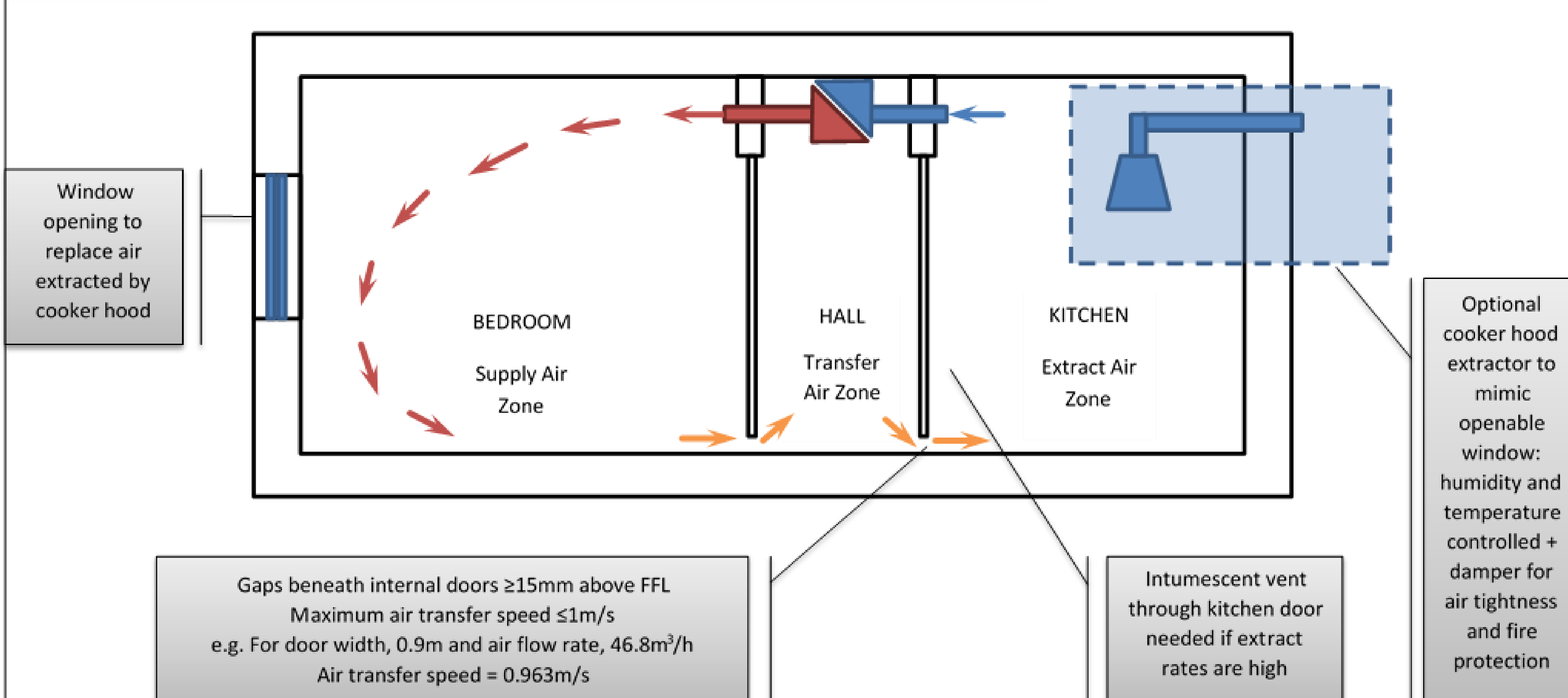
Ventilation strategy

<u>Ventilation Requirements from Part F:</u> Internal rooms with no openable window should be provided with the minimum extract rates, either by intermittent or continuous extract. It will take longer to purge when using the continuous extract option.

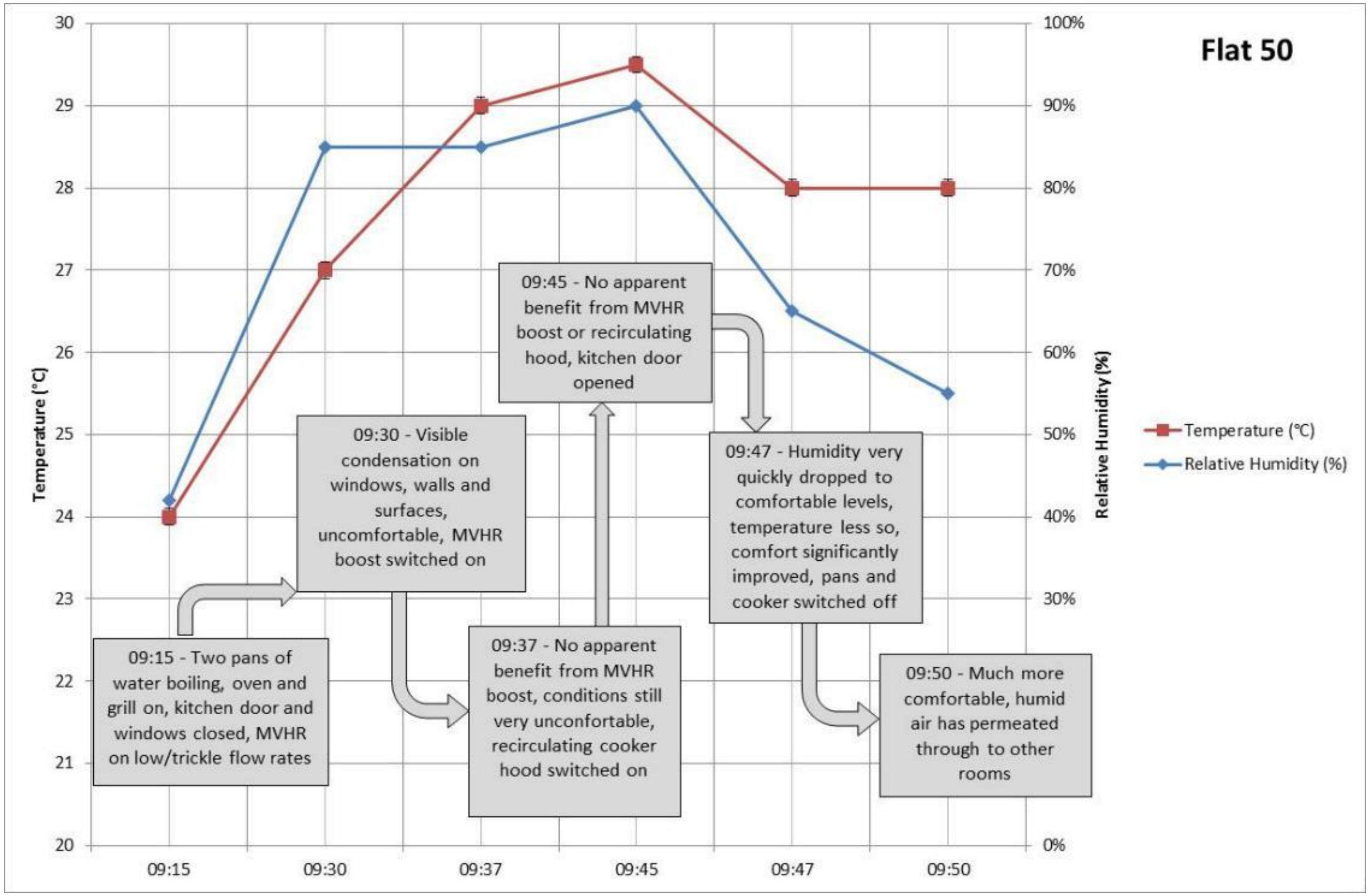
	Intermittent	Continuous
Kitchen	60l/s = 216m^3/h	13l/s = 46.8m^3/h
WC	6l/s = 21.6m^3/h	

<u>Ventilation Guidelines in PHPP:</u> Target continuous extract rates are the high rates i.e. to be delivered on the "boost" setting. Normal ventilation rates to be ~30% lower such that the average whole building ventilation rate works out to be around 0.3ach. There is a risk of dry air if the ventilation rates are too high.

	Continuous (High)
Kitchen	60m^3/h
Bathroom	40m^3/h
WC/Utility	20m^3/h



Ventilation strategy



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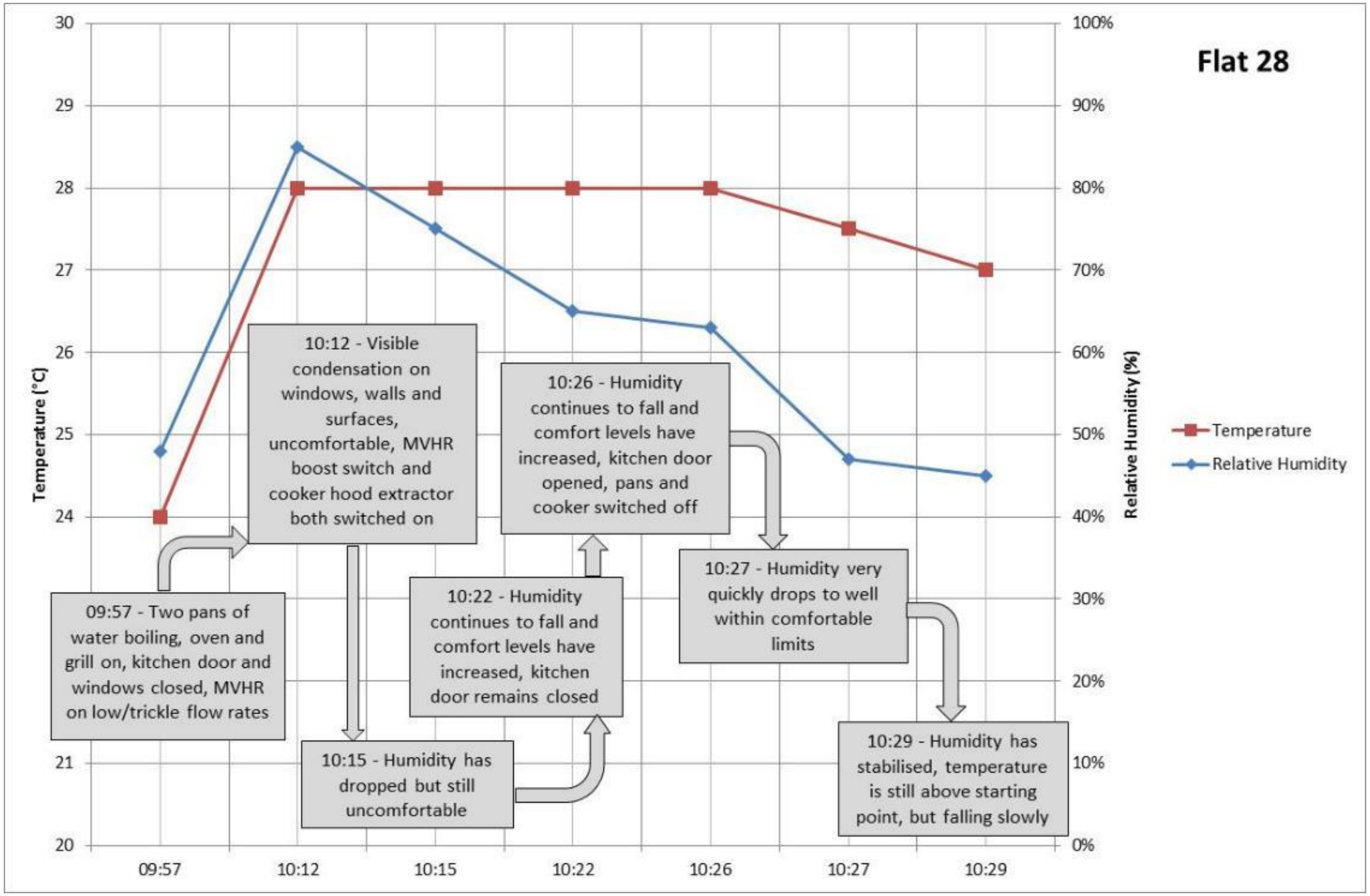
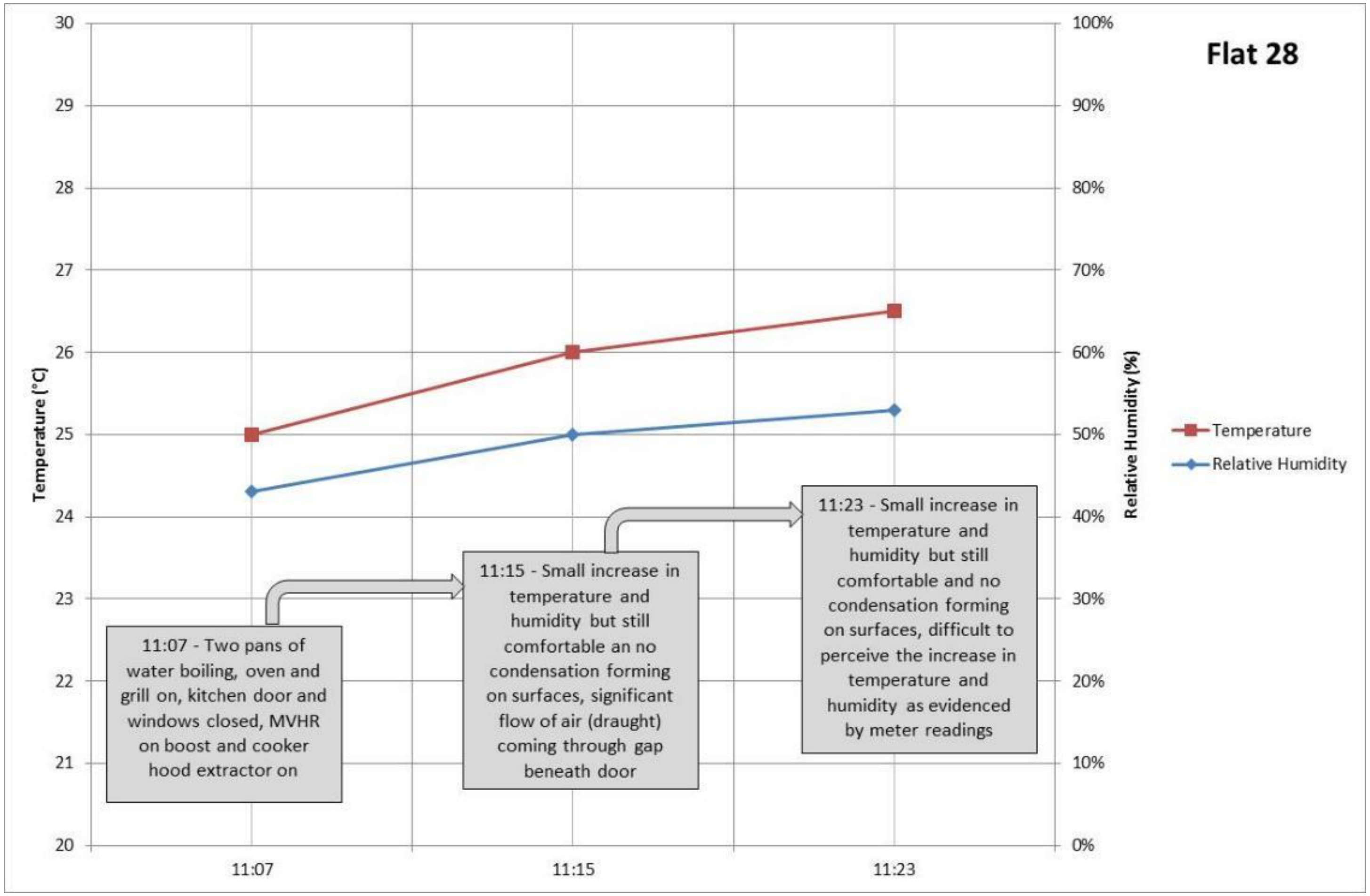
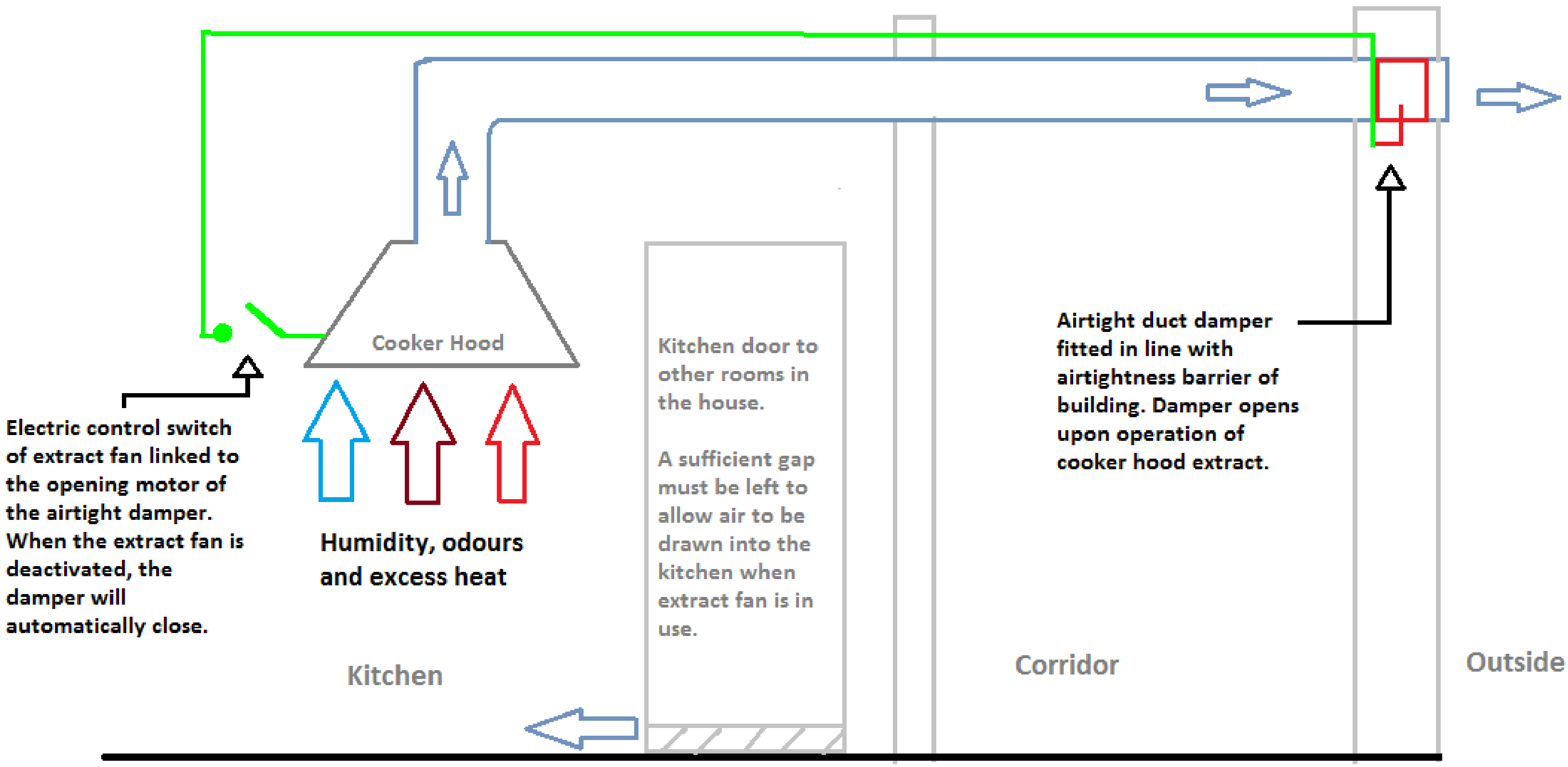
Ventilation strategy



Ventilation strategy



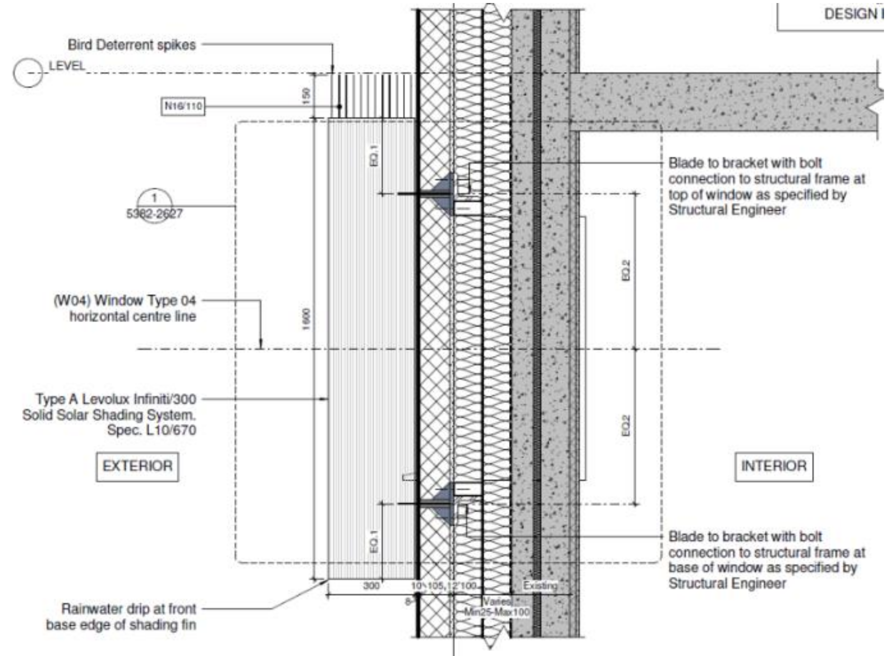
Ventilation strategy

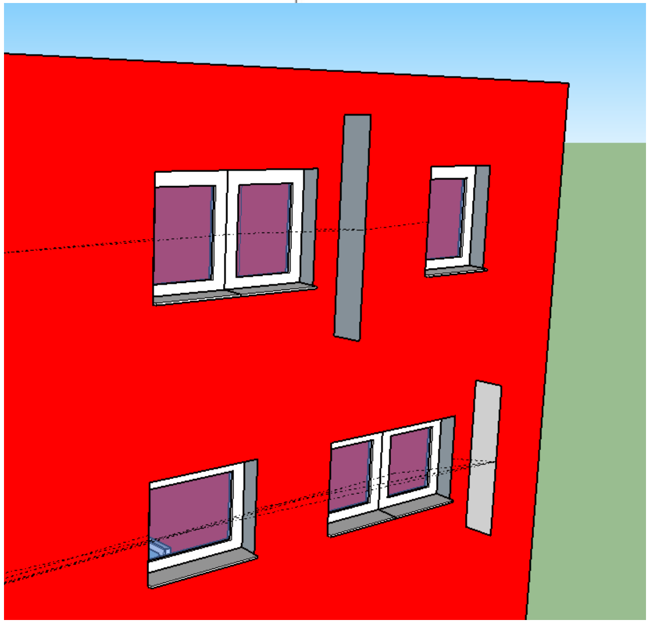


Summer comfort strategies

Brise Soleil

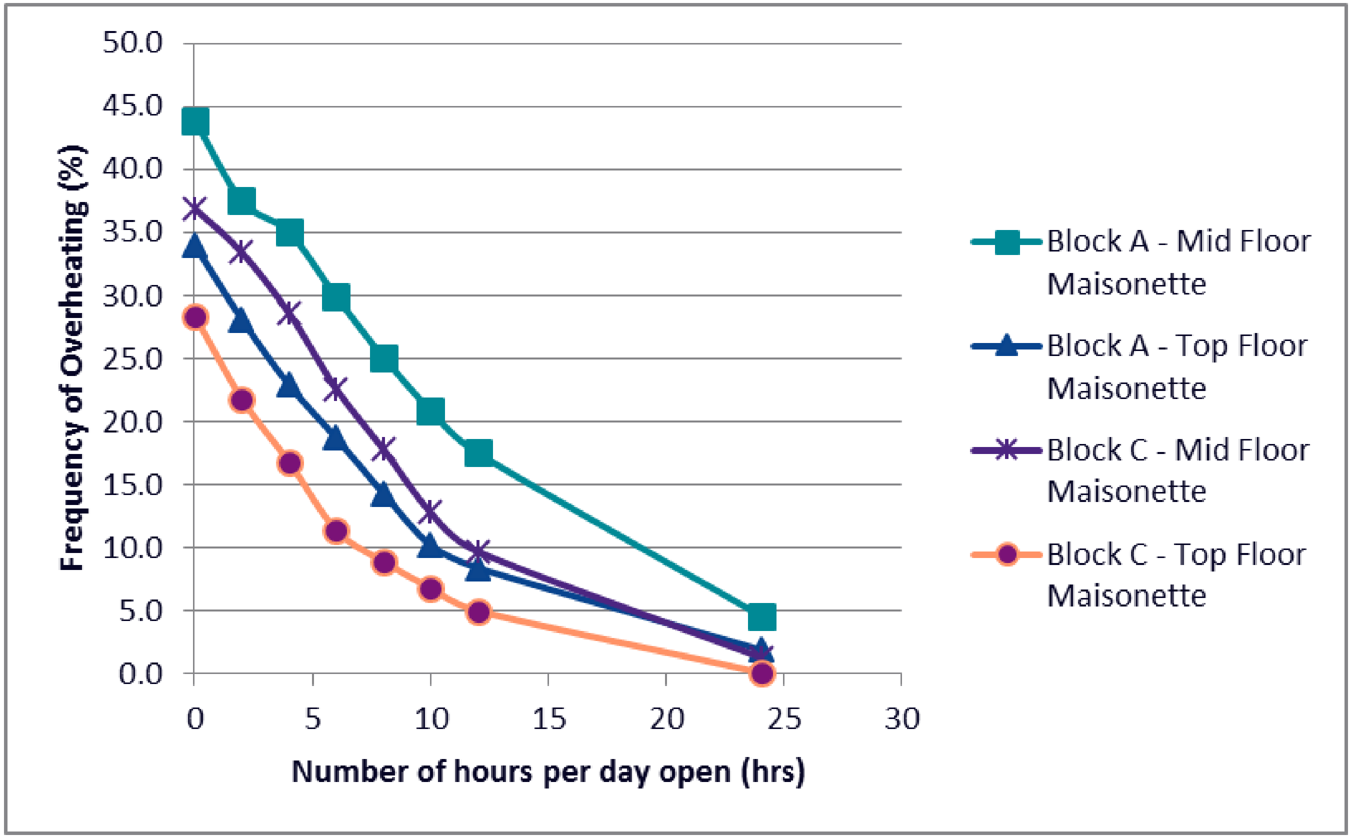
- Vertical brise soleil
- On half of the windows on the road side (west facing)
- 300mm depth
- 1600 – 2000mm length
- Frequency of overheating with and without the brise soleil was unchanged at 8.5% in both cases
- In this instance the brise soleil has no affect on the summer comfort and is only there for aesthetic reasons





Summer comfort strategy

4 (out of 10) of the openable windows in each maisonette open on a tilt



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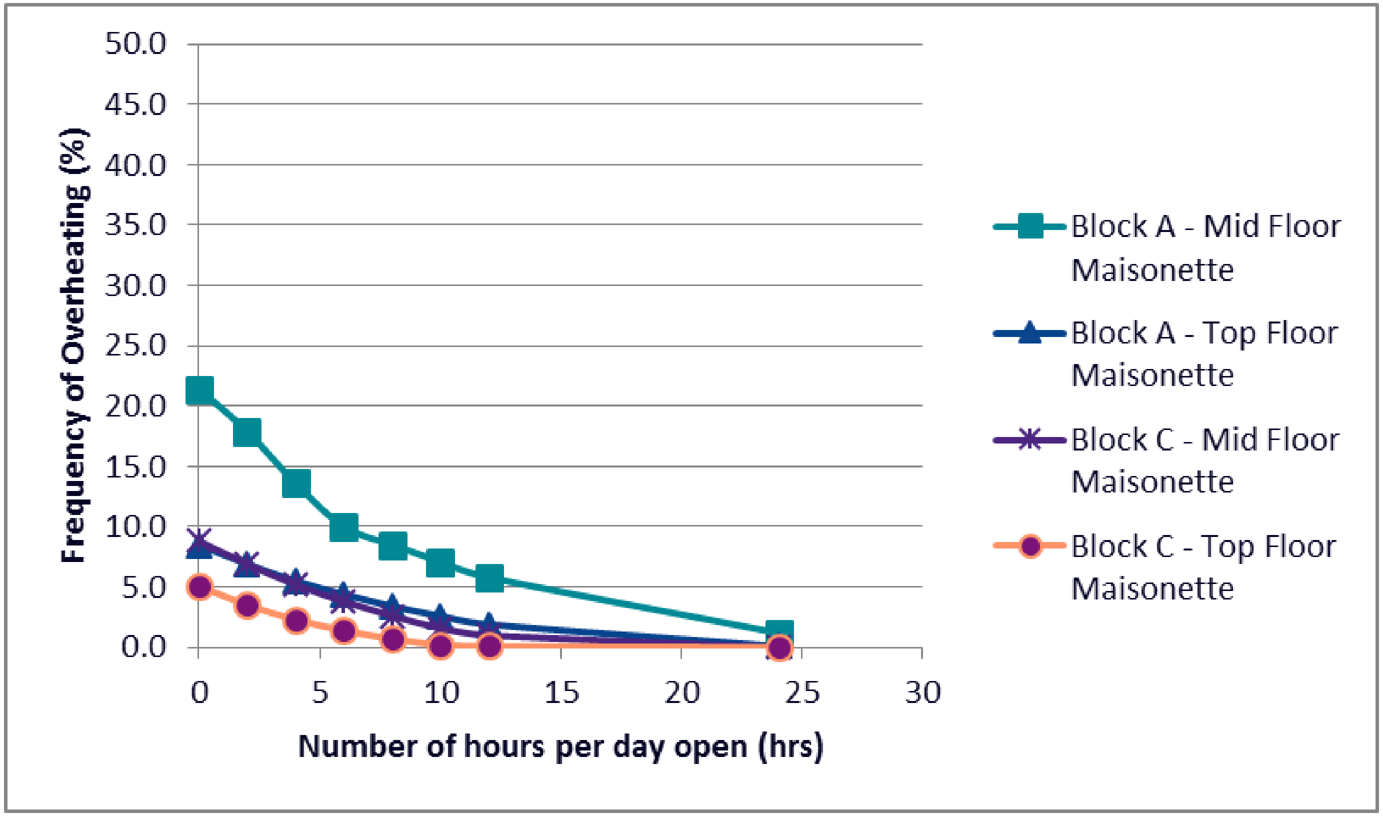
Summer comfort strategy

4 (out of 10) of the openable windows in each maisonette open on a tilt
2 *additional* windows fully opened on each façade allowing for purge cross ventilation for one hour per day



Summer comfort strategy

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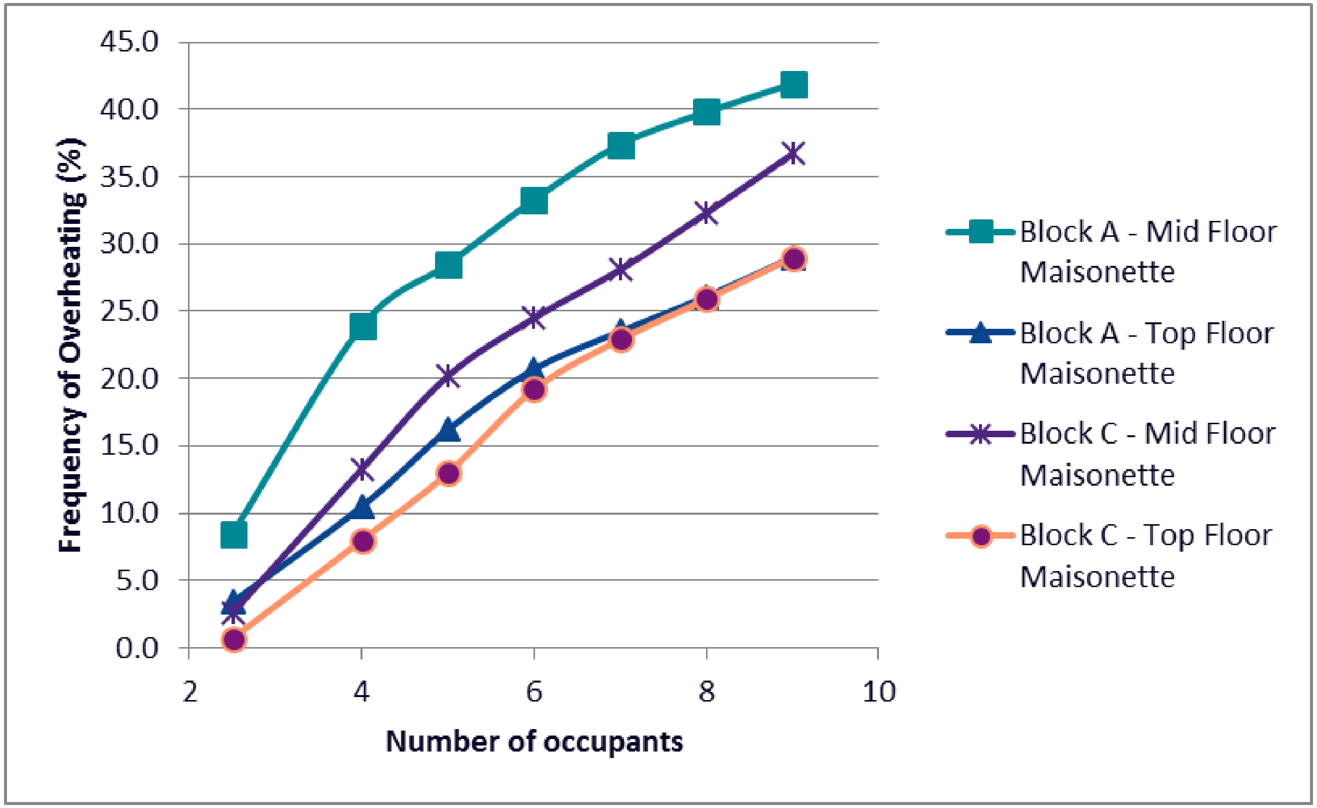

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Summer comfort strategy – extreme case

Block A, Mid floor flat, occupancy of 9 people

Two possible window opening strategies could be:

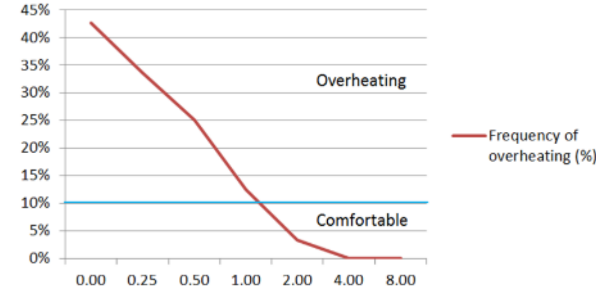
- All 10 openable windows open on a tilt for 24 hrs/day
  - Frequency of overheating = **8.1%**

OR

- All 10 openable windows open on a tilt for 8 hrs/day *and* 2 of these windows fully open (allowing for cross ventilation) for an additional 1 hr/day *and* 5 of these windows also open on a tilt throughout the night.
  - Frequency of overheating = **9.1%**

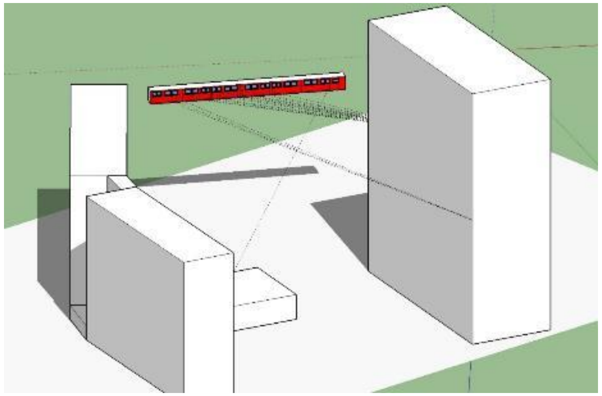
Access corridors

Overheating vs. Duration of window opening in hours

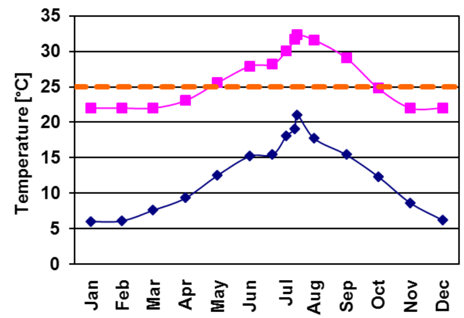


Ventilation strategy

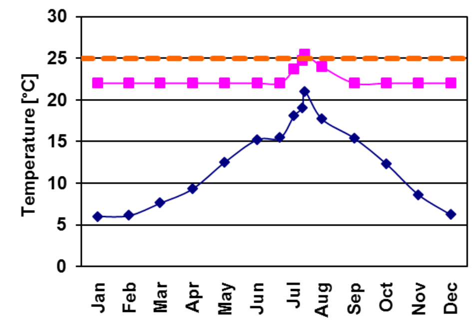
- Required air change rate, based on anticipated occupancy for given area = 0.009 ach
- Modelled air changes from anticipated door opening as occupants enter and exit their homes = 0.026ach



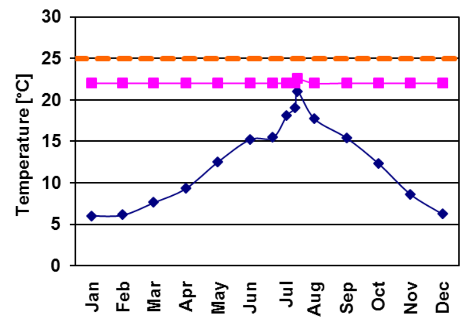
Summer comfort strategy



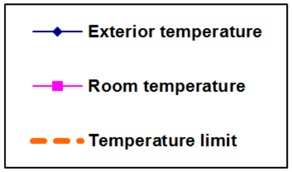
No window opening



2 hours per day window opening



8 hours per day window opening



Legend

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Air barrier and air testing strategies

Pre-Improvement Air Leakage Testing

- **Stage 1: for ECD Architects in July 2012**
  - **3 Dwellings, Nos 65, 88 & 96**
  - **In No 65, effect of replacement windows simulated by temporary sealing**
- **Stage 2: for Encraft in July 2014**
  - **6 Dwellings, Nos 98, 1 (a flat), 112, 65 (after improvement works), 104 & 92**
  - **Included co-pressure testing of 104/98/92**

Results – Individual Tests

Unit	Date Tested	Result – AC/hr @ 50 Pa	Notes
65	31/07/2012	3.4	As found
	31/07/2012	2.8	With windows temporarily sealed to simulate replacement
	16/07/2014	3.4	After demonstration MVHR installed
88	31/07/2012	3.1	As found
96	31/07/2012	2.8	As found
98	16/07/2014	3.2	As found
1	16/07/2014	3.2	As found
112	16/07/2014	3.9	As found
104	30/07/2014	5.1	As found; riser access hatches particularly leaky
92	30/07/2014	4.6	As found

What is Co-Pressure Testing?

- **It uses multiple sets of door fan equipment - 2, 3 or even 6 sets**
- **To apply pressure to more than one test volume at the same time**
- **By balancing pressure, flows between volumes are eliminated**
- **By subtraction, leakage between volumes can be established**

Why Co-Pressure?

Co-Pressure Testing is used:

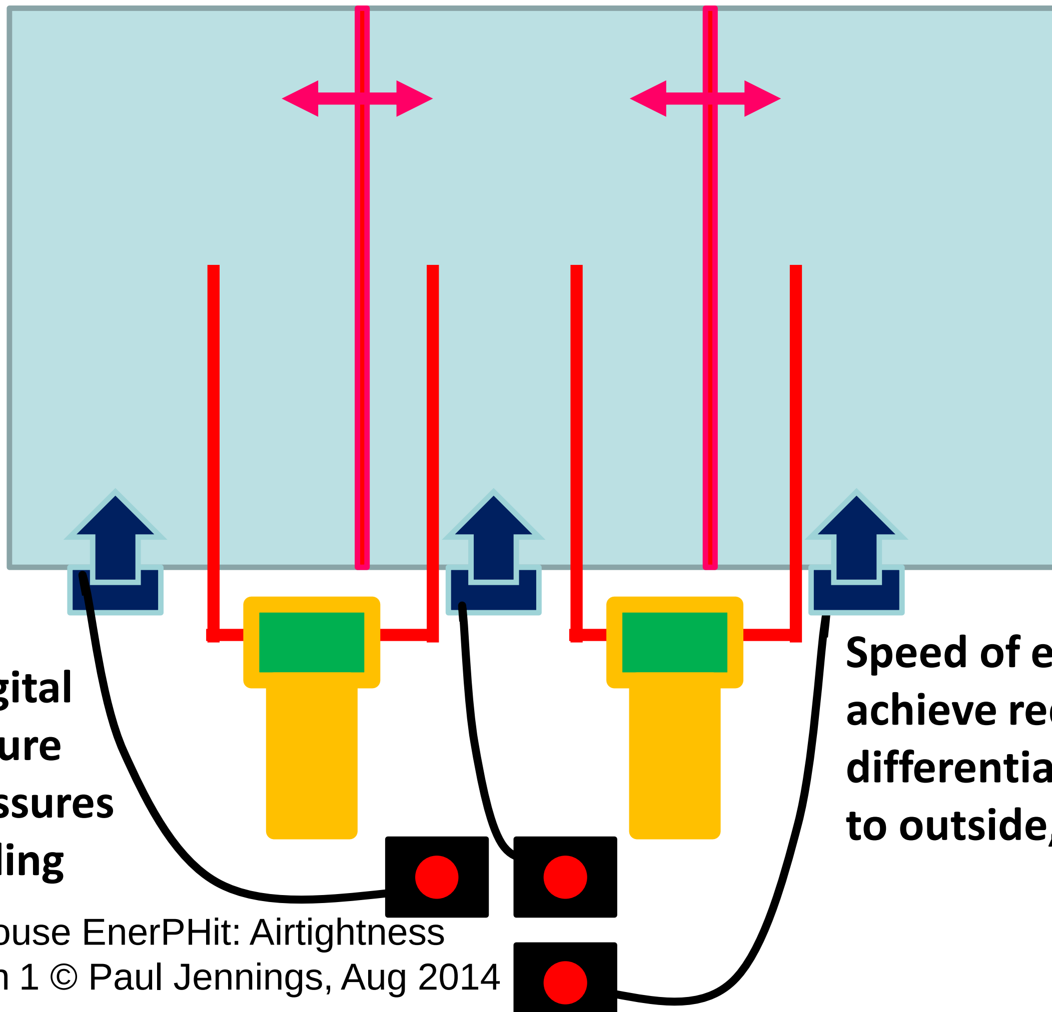
- **As a research tool, when more detailed evaluation of buildings is required**
- **To check critical leakage between adjacent volumes – e.g. fire separation between floors**
- **To identify party wall or similar leakage when developing refurbishment projects**
- **To accept multi-dwelling Passivhaus or EnerPHit projects modelled on a block basis**

Co-Pressure Illustration

Illustration of a 3-dwelling Co-Pressure:

Plan view of a terrace of three units

A door fan is mounted in the open front door of each unit

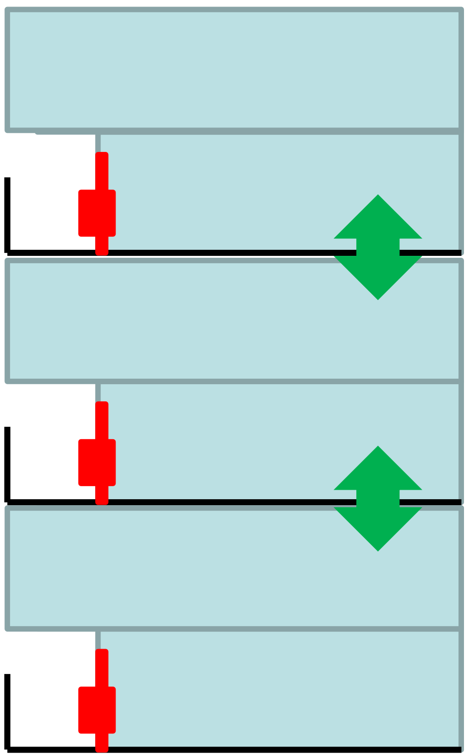


By balancing the pressures, there is negligible Party Wall leakage – the airflow shown by the arrows is minimal. This gives the best possible air leakage result for the middle dwelling

2-channel digital gauges measure imposed pressures in each dwelling

Speed of each fan adjusted to achieve required pressure differentials - +50 Pa from each unit to outside, ≈ 0 Pa between units

Wilmcote Co-Pressure Results



- Nos 104 (9th), 98 (7th) & 92 (5th) – vertical line
- Depressurisation test on No 98
- Leakage through risers to 104 & 92 'balanced out'
- With windows sealed, 98 down to 1.0 AC/hr @ 50 Pa

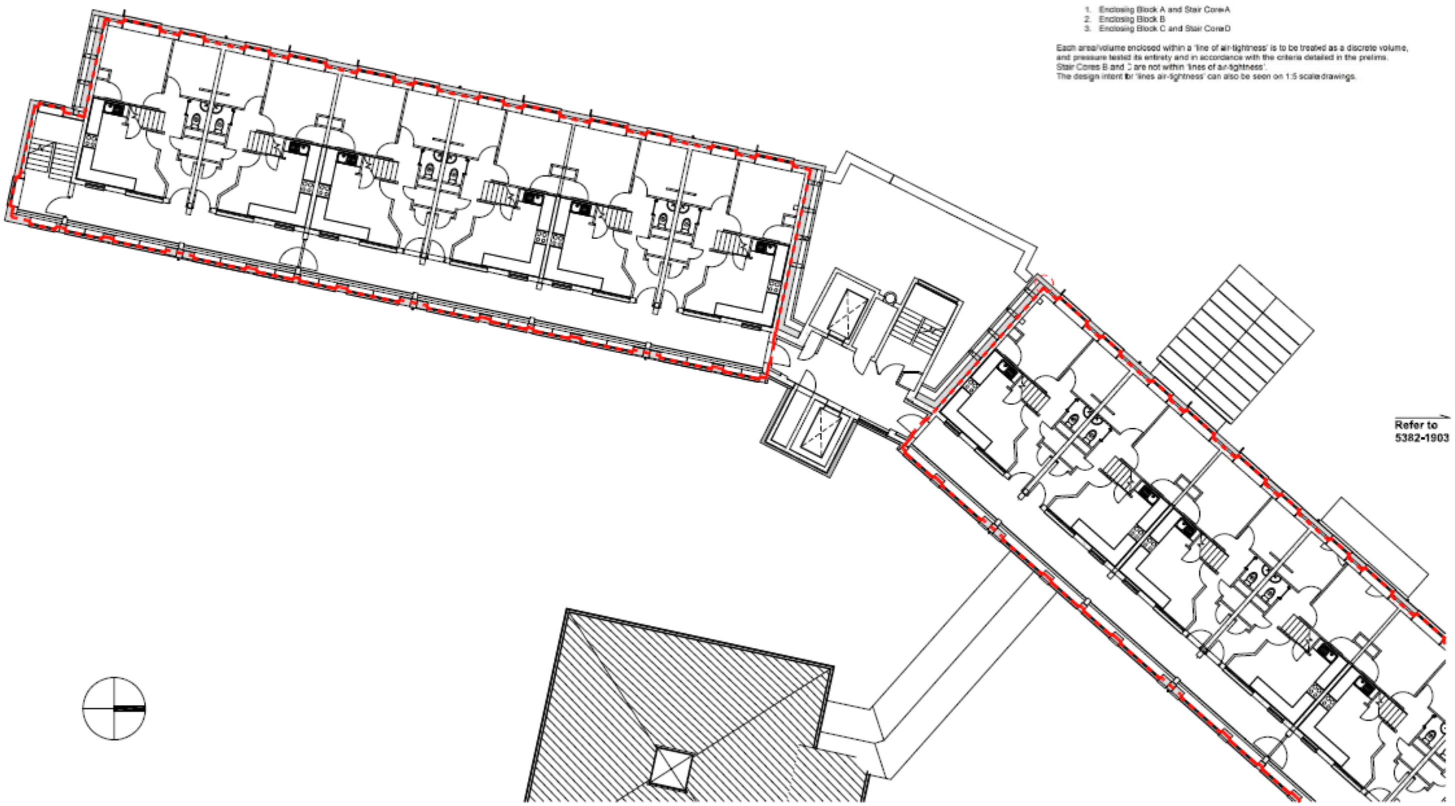
Air barrier strategy

Note

Red dotted lines represent the design intent 'or 'lines of air-tightness', which are as set out as follows;

1. Enclosing Block A and Stair Core A
2. Enclosing Block B
3. Enclosing Block C and Stair Core D

Each area/volume enclosed within a 'line of air-tightness' is to be treated as a discrete volume, and pressure tested its entirety and in accordance with the criteria detailed in the prelims.
Stair Cores B and C are not within 'lines of air-tightness'.
The design intent for 'lines air-tightness' can also be seen on 1:5 scale drawings.



1 **Typical Maisonnette Lower Plan 1/2 - Air-tightness strategy**
1 : 100

- - - - - - - - - Line of Air-tightness

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Air barrier strategy

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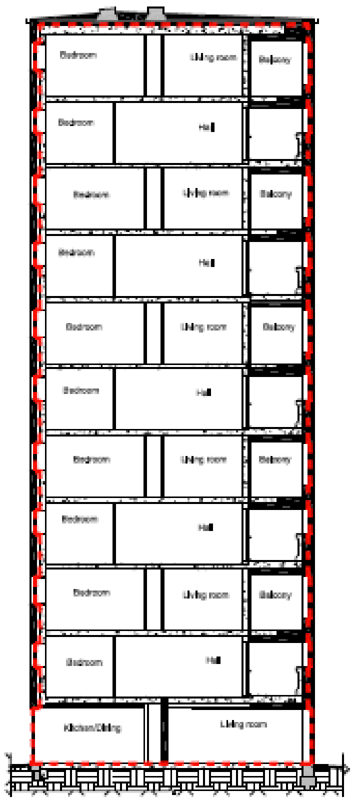
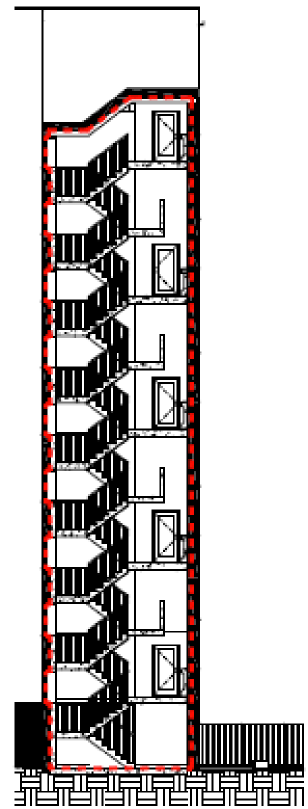
Air barrier strategy



1 Typical Block Cross Section - Air-tightness strategy
1 : 100



2 Typical End-Stair Core Section - Air-tightness strategy
1 : 100

- - - - - - - - - Line of Air-tightness

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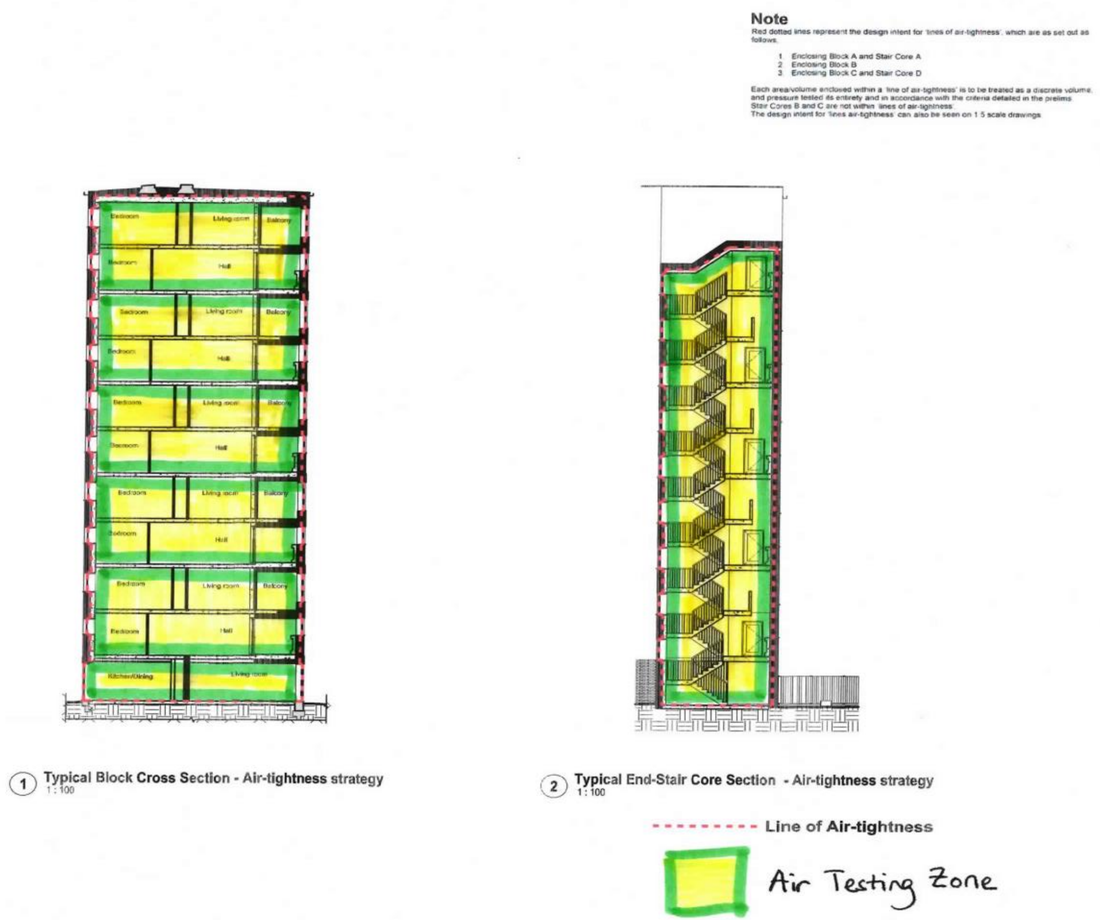
Air testing strategy

Air testing strategy

Air testing strategy

Air testing strategy



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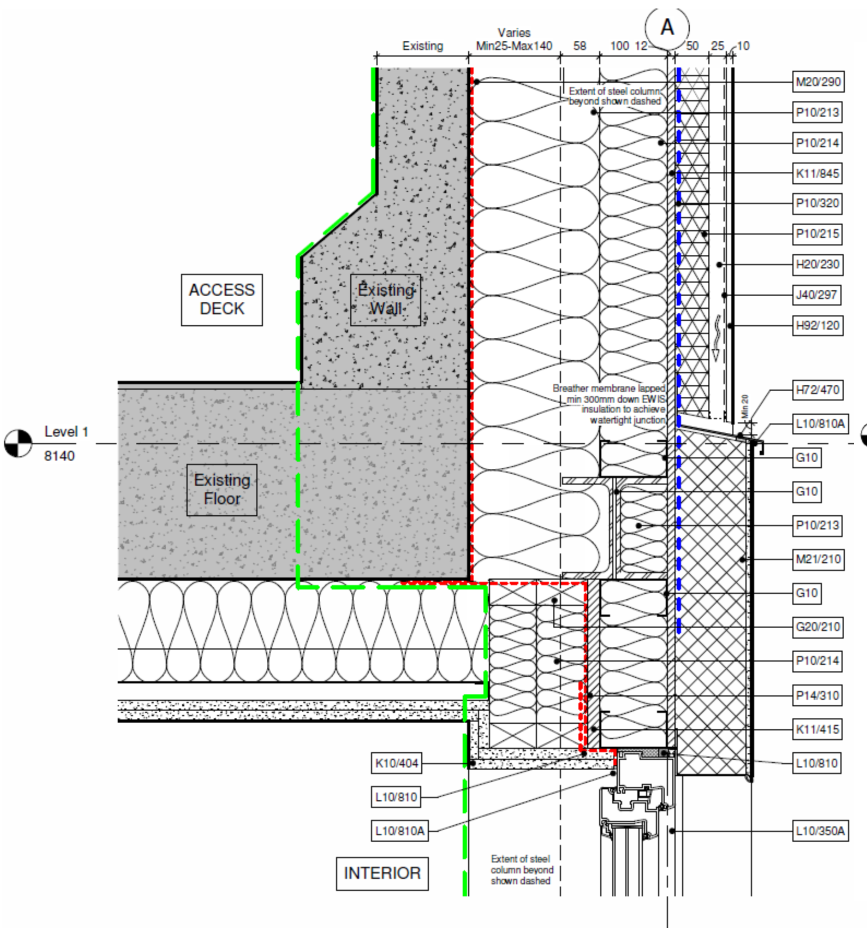
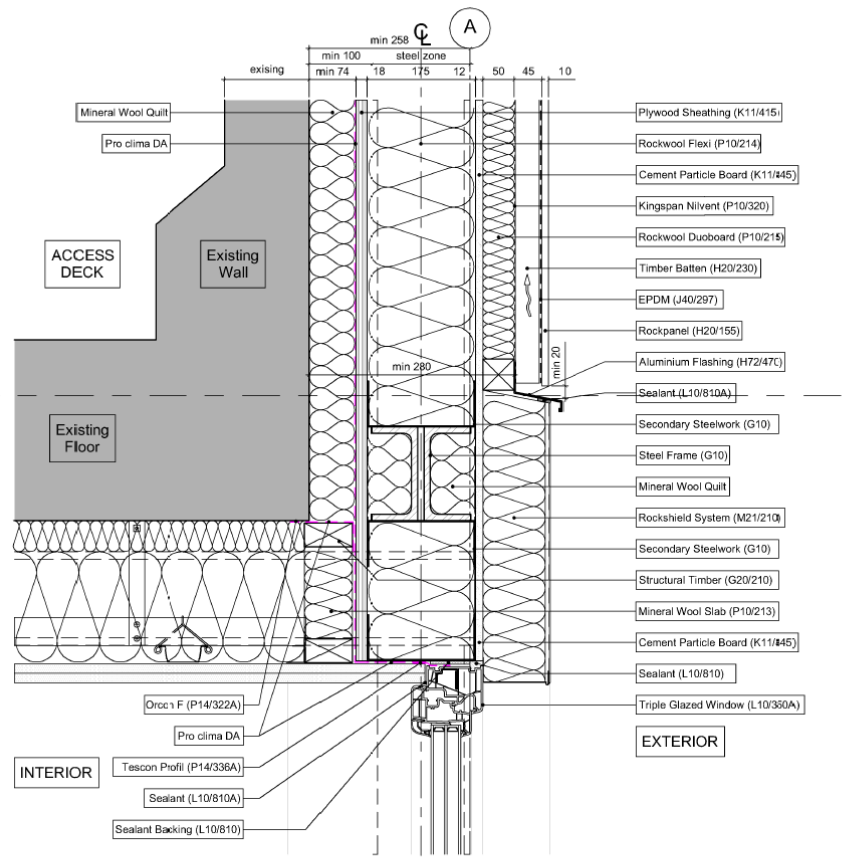
Pre-tender to Pre-construction





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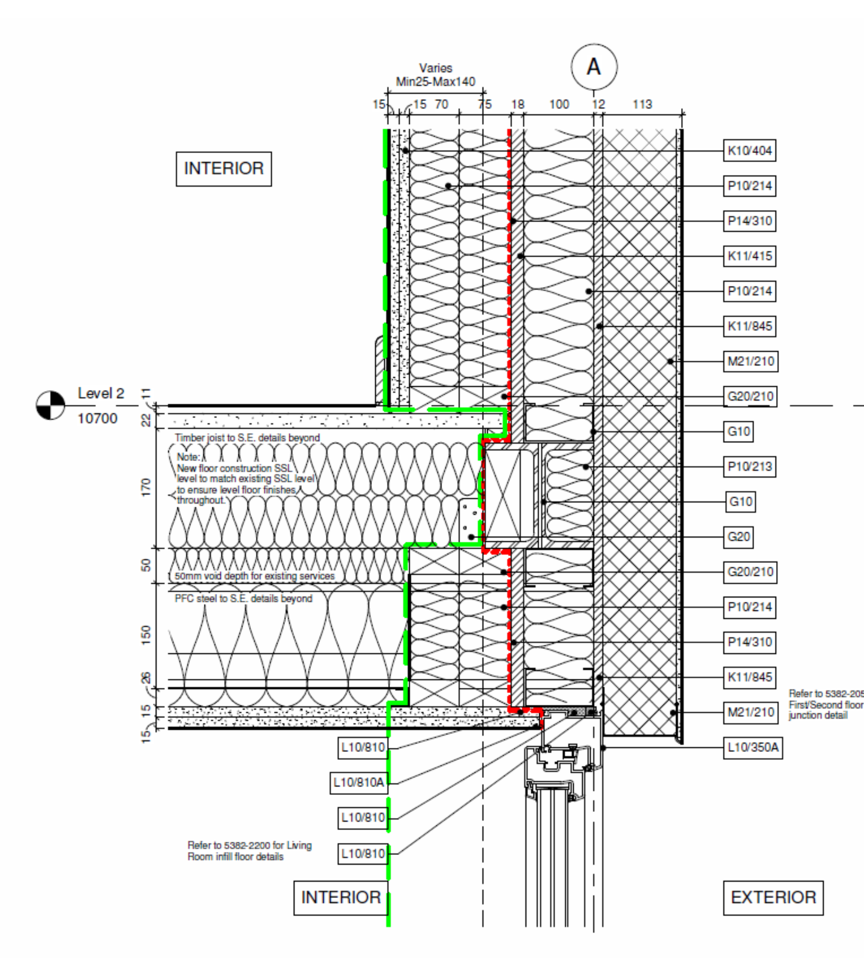
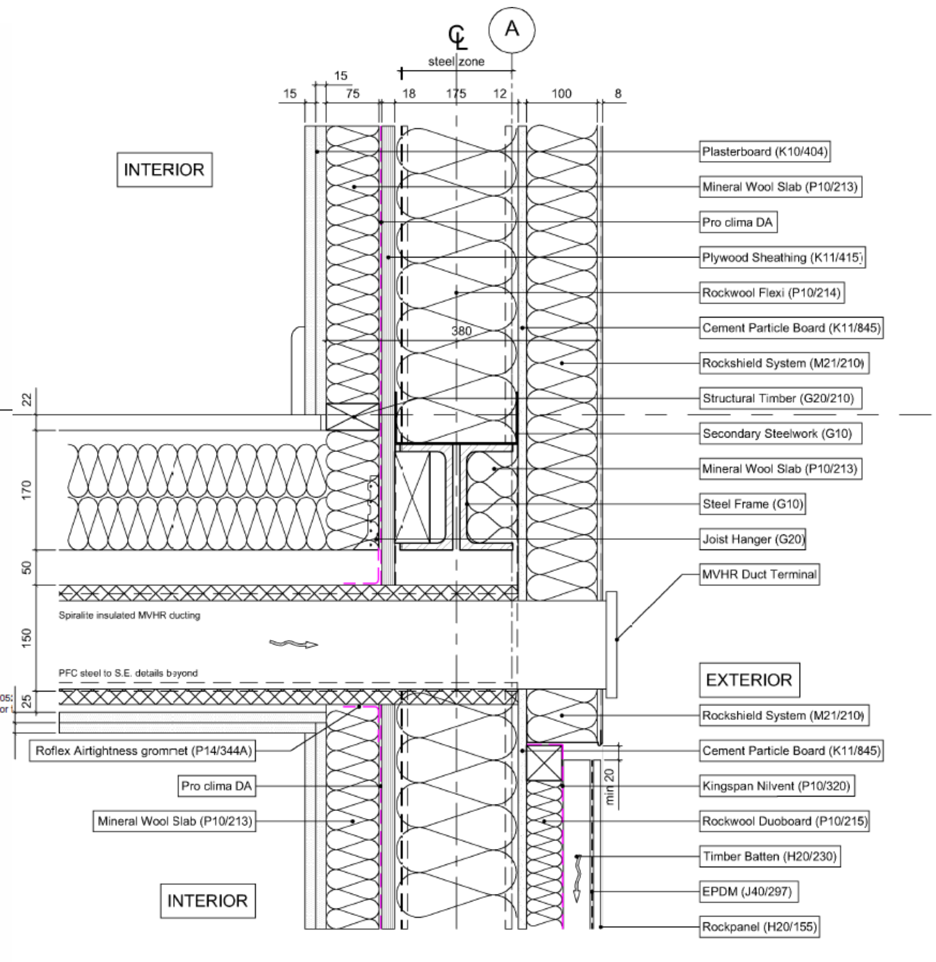
Pre-tender to Pre-construction





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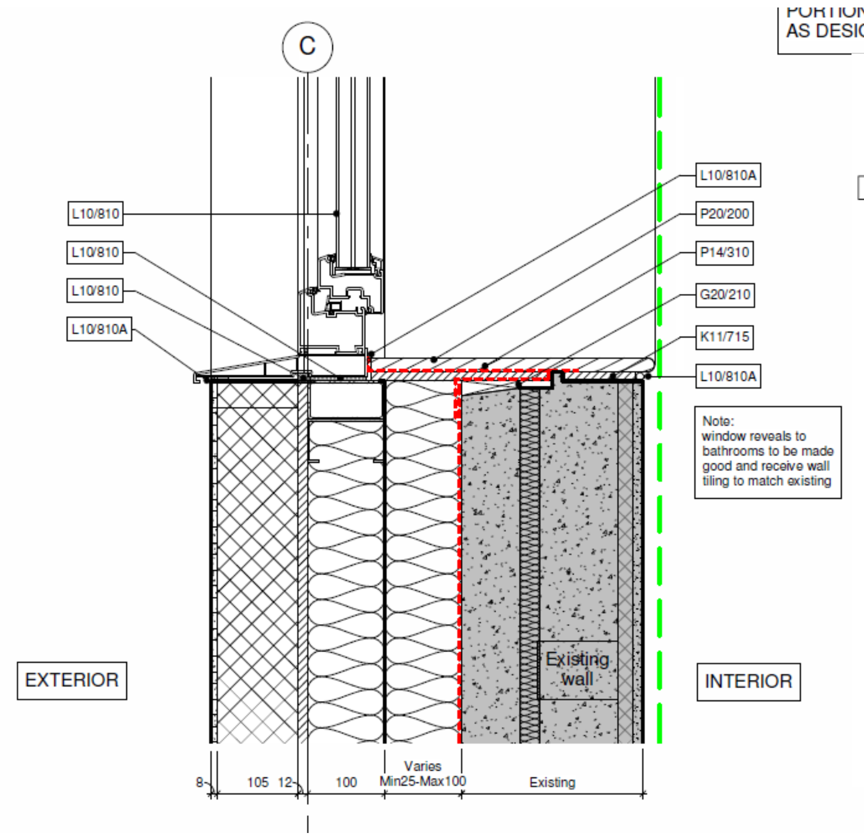
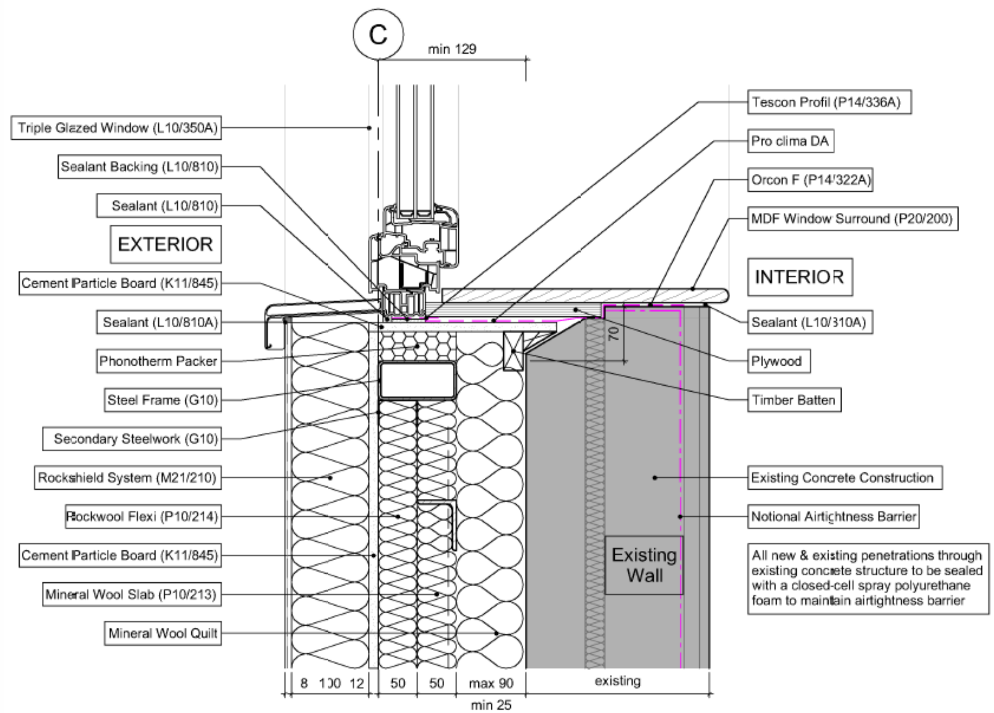
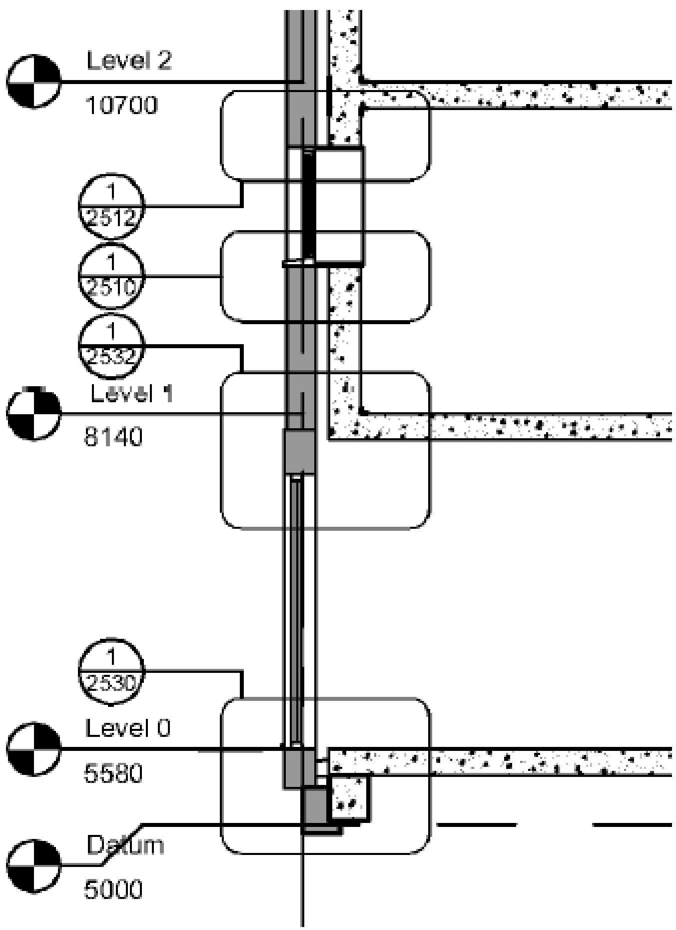
Pre-tender to Pre-construction





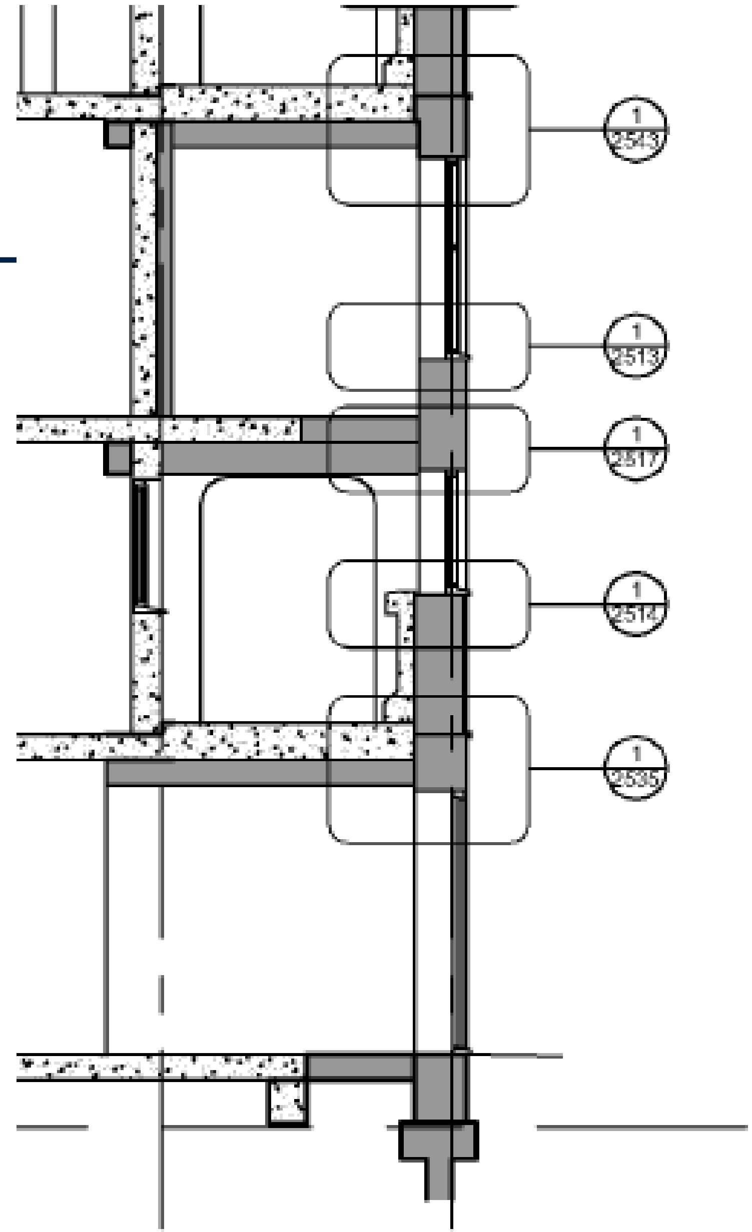
Air barrier detail



Road side

- Existing concrete walls
- Pro-Clima DA Membrane in new construction on the ground floor
- Ecohaus Internorm Windows and doors
- Risk of air escaping through concrete panel joints (convoluted path)
- Fill holes on the external face with closed-cell expanding foam
- Key detail to get right is the windows

Air barrier detail



Garden side

- Pro-Clima DA Membrane in entirely new construction
- Ecohaus Internorm Windows and doors
- Embedded in the insulation layer, on the warm side of the metsec
- Situation is complex around the steel bracing
- Encapsulate air test zone at the maisonette level

Air barrier detail

Roof

- Existing concrete roof
- The key detail to get right is sealing around the service penetrations through the roof

Ground floor

- Existing concrete floor slab
- DPM in new floor construction

Service risers

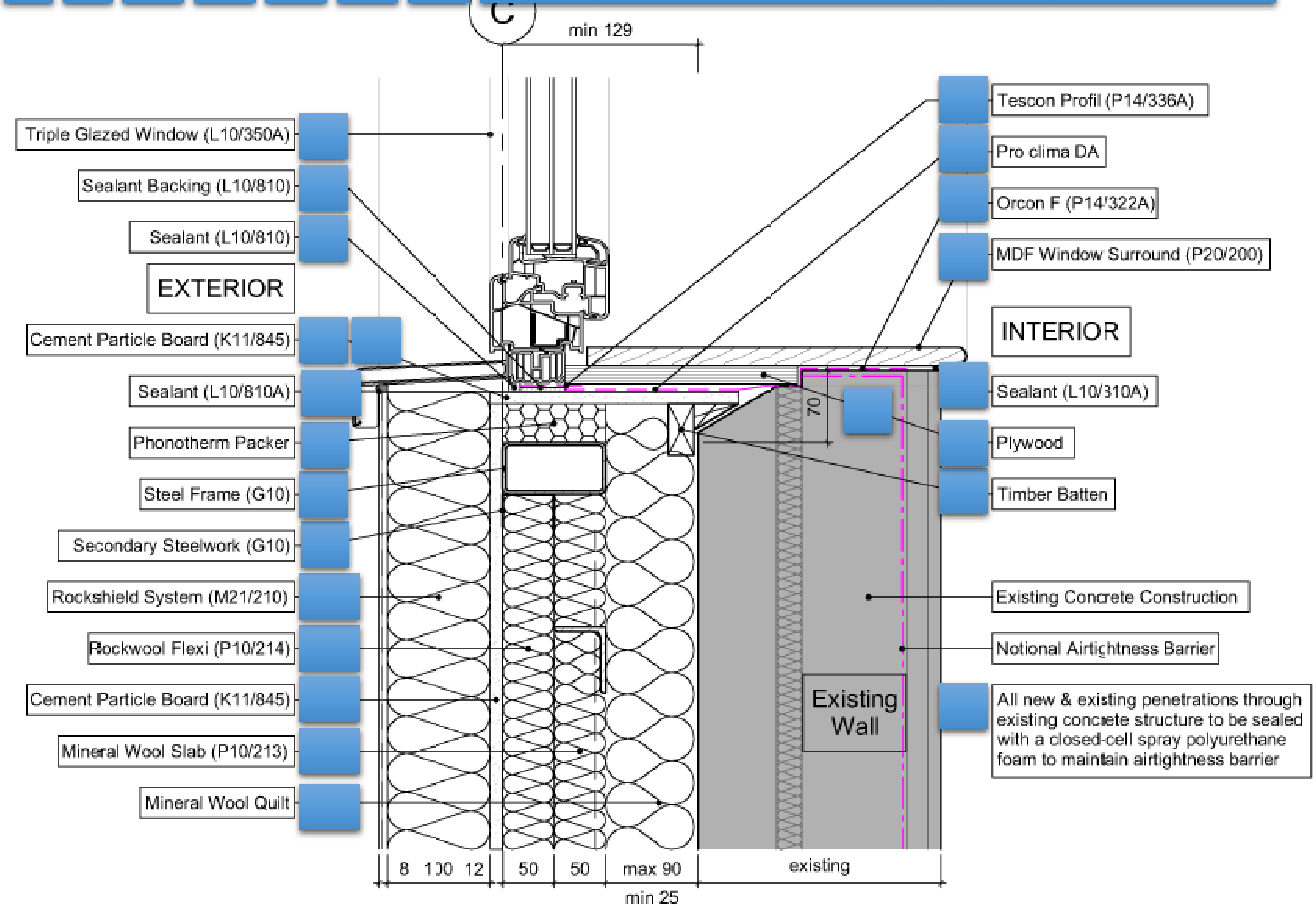
- Two per flat/maisonette
- Sealed at each dwelling level
- Key detail for achieving the air tightness target within the proposed testing regime
- Solution combined with fire stopping measures

Party walls and floors

- Existing concrete party walls and floors assumed to be fundamentally air tight

Interactive Sequencing Fun!

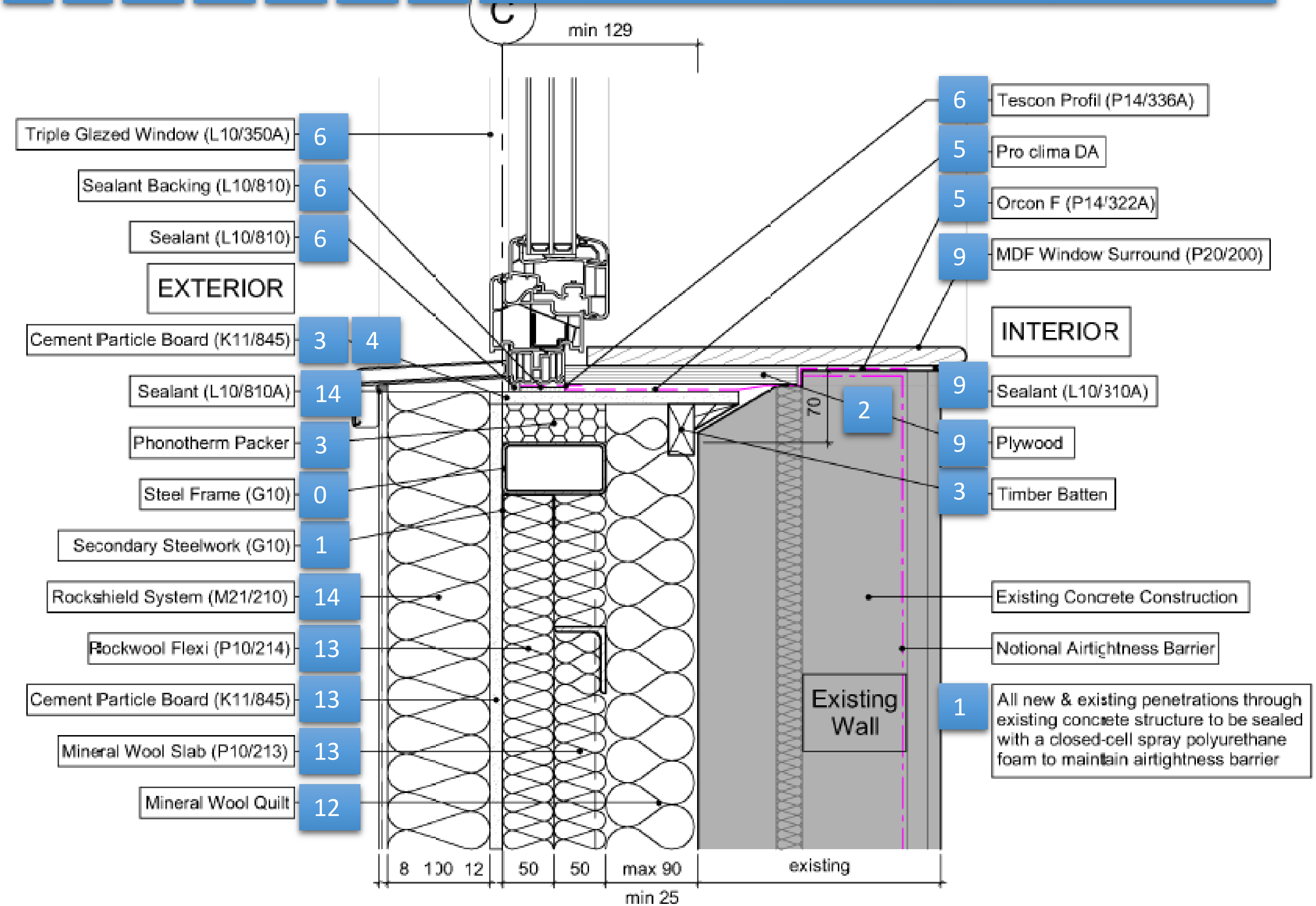
Air leakage audits and air tightness testing or sealing leaks after a test



Seal any leaks that are found	Remove existing window	Install rigid insulation between steel work and cement particle board sheething, ensuring there are no gaps in the insulation layer
Fill all holes in existing wall (e.g. around steel frame fixings) with closed cell expanding foam and install Metsec	Create new window opening including timber batten below existing window cill, insulated packer as required, followed by the cement particle board in the surround	After the air & wind barriers for an entire level are complete on all sides, carry out intermediate air test
Carry out air leakage check	Seal any leaks that are found (may require removal of window surround to expose leaks)	Fit ply-wood to bridge gap between new windows and existing opening, finish internally with new window surround, taking care not to damage the air barrier
Wrap the window opening in the air barrier membrane, stick membrane down with double sided tape, ensuring conditions are clean and dry	Install quilted insulation in varying thickness, tight up against the existing wall, ensuring there are no gaps in the insulation layer	Seal any leaks that are found
Prime surface of cement particle board in the window surround	Ensure steel work and concrete repairs are complete	After mast climber fixings have been removed, finish externally with external wall insulation system, ensuring there are no gaps in the insulation layer
Carry out air leakage check	Install new windows with tape pre-applied to frame and seal tape between the window frame and the membrane in the opening, ensuring conditions are clean and dry	Carry out final air test if required

7 | 8 | 10 | 11 | 15 | 16 | 17

Air leakage audits and air tightness testing or sealing leaks after a test



#	Description of works	Key Quality Indicator	Package Lead	Signed by Package Lead	Date/Time	Signed by Keepmoat	Date/Time
0	Ensure steel work and concrete repairs are complete	-	Keepmoat				
1	Fill all holes in existing wall (e.g. around steel frame fixings) with closed cell expanding foam and install Metsec	Ensure holes are fully filled	United Insulations				
2	Remove existing window	-	Ecohaus				
3	Create new window opening including timber batten below existing window cill, insulated packer as required, followed by the cement particle board in the surround	Phonotherm Packer λ = 0.076 W/mK	United Insulations				
4	Prime surface of cement particle board in the window surround	Pro Clima Tescon Primer	Ecohaus				
5	Wrap the window opening in the air barrier membrane, stick membrane down with double sided tape and flexible adhesive ensuring conditions are clean and dry	Pro Clima DA membrane, Duplex tape & Orcon F	Ecohaus				
6	Install new windows with tape pre-applied to frame and seal tape between the window frame and the membrane in the opening, ensuring conditions are clean and dry	Pro Clima Tescon Profil	Ecohaus				
7	Carry out air leakage check	Air leakage audit	Keepmoat				

#	Description of works	Key Quality Indicator	Package Lead	Signed by Package Lead	Date/Time	Signed by Keepmoat	Date/Time
8	Seal any leaks that are found	Pro Clima Tescon No.1	Ecohaus				
9	Fit ply-wood to bridge gap between new windows and existing opening, finish internally with new window surround, taking care not to damage the air barrier	-	Ecohaus				
10	Carry out air leakage check	Air leakage audit	Keepmoat				
11	Seal any leaks that are found (may require removal of window surround to expose leaks)	Pro Clima Tescon No.1	Ecohaus				
12	Install quilted insulation in varying thickness, tight up against the existing wall, ensuring there are no gaps in the insulation layer	Rockwool Roll λ = 0.044 W/mK	United Insulations				
13	Install rigid insulation between steel work and cement particle board sheething, ensuring there are no gaps in the insulation layer	Rockwool Flexi λ = 0.038 W/mK	United Insulations				
14	After mast climber fixings have been removed, finish externally with external wall insulation system, ensuring there are no gaps in the insulation layer	Rockshield System λ = 0.036 W/mK	United Insulations				
15	After the air & wind barriers for an entire level are complete on all sides, carry out intermediate air test	Air leakage audit	Aldas				

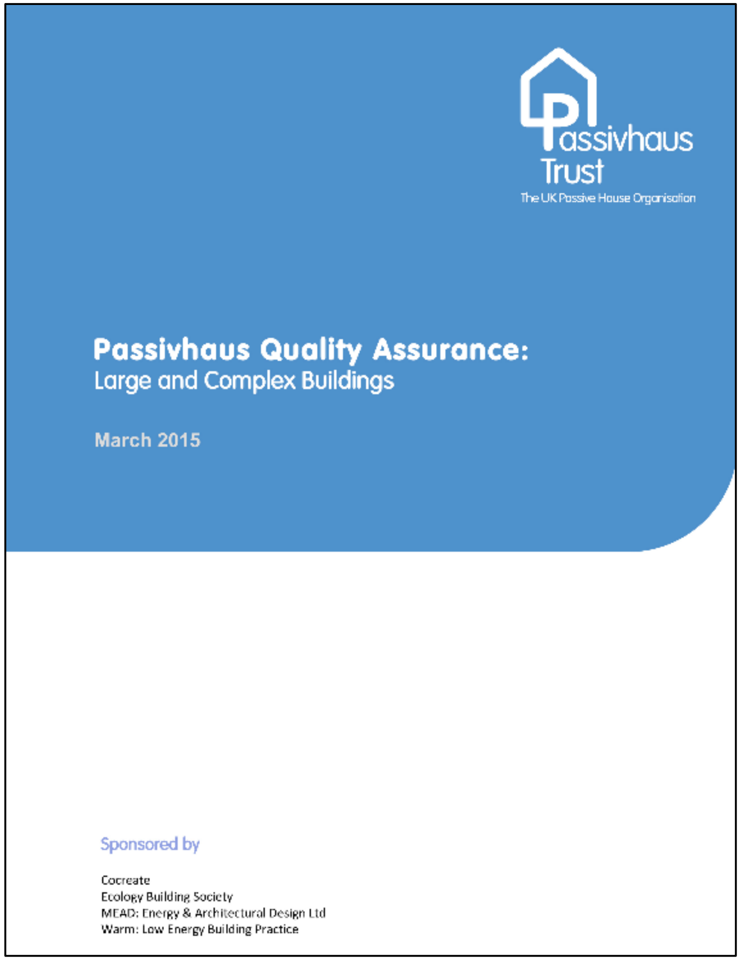
Quality control

Guidance from the Passivhaus Trust

Purpose of the guide

- To illustrate the need for formalised quality assurance tools and methods
- To demonstrate examples of tools and techniques
- To confirm and clarify the requirements of the Passivhaus standard with regard to workmanship and liability as they relate to site teams and managers

This paper was written by Mark Siddall, LEAP on behalf of the Passivhaus Trust, with input from the Passivhaus Trust Technical Panel.


Passivhaus Trust
The UK Passive House Organisation

Passivhaus Quality Assurance:
Large and Complex Buildings

March 2015

Sponsored by

Cocreate
Ecology Building Society
MEAD: Energy & Architectural Design Ltd
Warm: Low Energy Building Practice

Common risks

Risks at key stages: Procurement, Design, Construction, Commissioning

Client risks

- Design team selection
- Recognise learning will be at client's expense
- Inexperience will impact on cost of delivery
- Communication of requirements to design team

Design team risks

- Complex building forms will increase costs
- Buildability
- Availability and specification of materials
- Strategic decisions (e.g. air tightness strategy) will impact on cost
- Extra time must be invested in learning
- Communication of requirements to contractors

Contractor risks

- Standards of workmanship (skills gap)
- Sequencing of work is critical (especially with regard to air tightness)
- Substituting materials and products or other deviations from contract documents can impact on thermal performance
- Commissioning of building services
- Testing for air tightness

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Certified Passivhaus Consultants

Ask your consultant to provide

- Risk register
- Design stage assessment
- Project management checklists
- Desktop buildability reviews
- Buildability workshops
- Quality assurance champion training
- Tool box talks to provide basic training for site trades
- Change management sign off
- Intermittent site inspections and site inspection reports
- Contractors declaration proforma

Risk Register

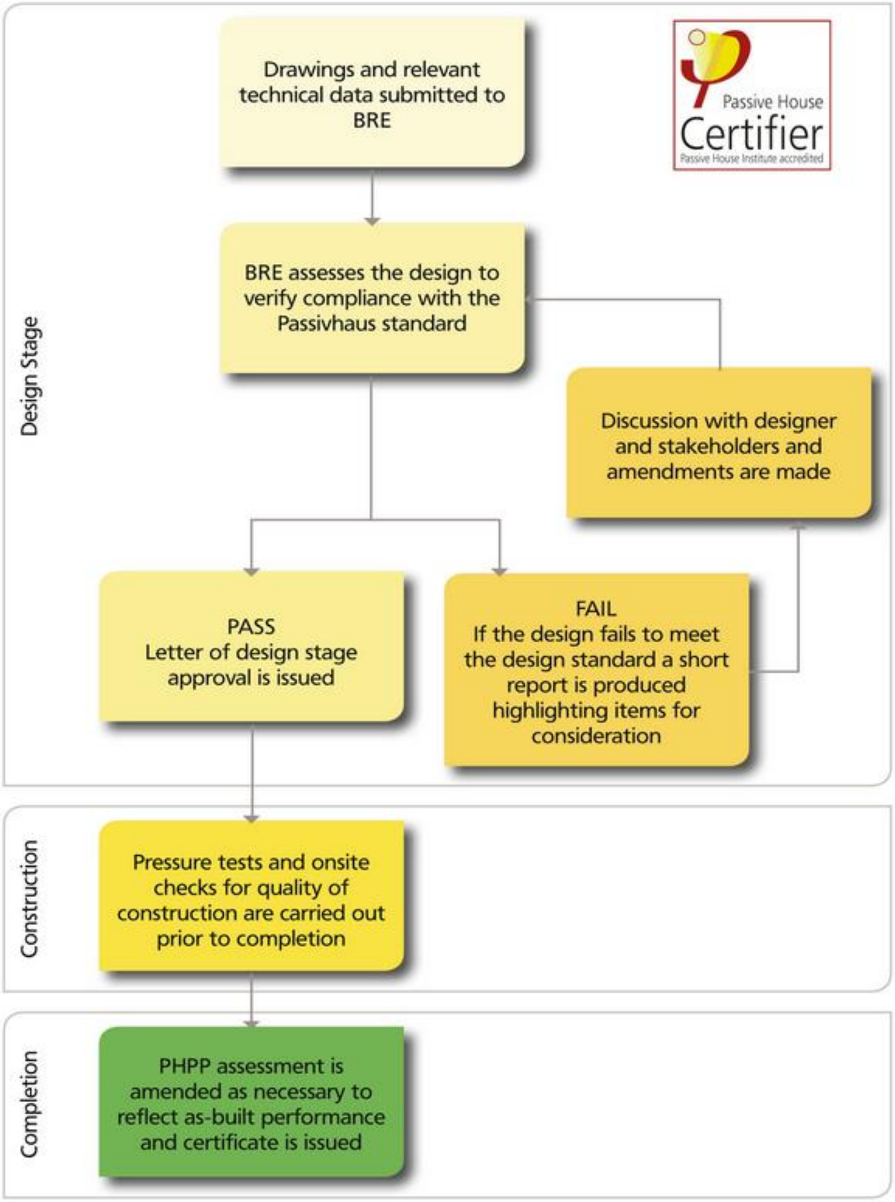
Wilmcote House

- Large scale EnerPHit
- 34 risks identified
- Focus on
  - Compliance
  - Thermal performance
- Monitor and take action

		Compliance with Enerphit Requirements						
E/N 1	18/06/2014	Space heating demand target	1	5	5	All	Review in PHPP and consider certification on the basis of the requirements for individual building components.	Modelling of Block A in designPH is in progress. Current score of 19 is well under the required 25 target.
E/N 2	09/02/2015	Primary energy demand target	5	5	25	All	Conduct white goods survey. Review in PHPP.	White goods survey to start on 19/06/2014. Update expected from KM by end of September. Aim to close mid-October with designated certifier. Passivhaus Institute to be consulted further on EnerPHit compliance fabric-first approach.
E/N 3	09/02/2015	Ventilation system efficiency target	closed	closed	closed	All	Find a way to install the MVHR unit as close to an external wall as possible to keep cold duct lengths short. Alternatively use Spiralite insulated duct.	Redesign in progress. Testing practicalities of installation in pilot Flat 50, due to complete 25/06/2014. Spiralite ducting confirmed
E/N 4	09/02/2015	Air tightness target	3	5	15	Con	A number of actions are detailed below in E/N 11, 14 and 25-30	Ongoing training, Airtightness & Quality champions. Detail design development from subcontractor workshops has simplified air-tightness barrier design, better understanding throughout contractor team
E/N 5	18/06/2014	Protection against moisture	closed	closed	closed	All	Complete thermal bridge calculations to identify cold spots at risk. BRE to assist.	Modelling in progress.
E/N 6	18/06/2014	Evidence base	1	3	3	Con	Prepare tracker for evidence base	HB preparing information
E/N 7	18/06/2014	PH certifiers	1	1	1	Con	Appoint certifier during pre-commencement stage. Present certifier with solutions not problems.	Kym Mead certifier appointed 20/06/2014.
E/N 8	18/06/2014	Conflict with other regulatory	3	2	6	All	Prepare tracker for building control requirements.	
E/N 9	18/06/2014	Performance of materials	1	3	3	Con	Ensure performance specification is clearly defined. Implement change management and approvals process.	Tradesperson training undertaken. Monitor delivery on site.
E/N 10	18/06/2014	Thermal bypass	2	4	8	Con	Implement quality control process to ensure insulation is continuous. Ensure operatives collect photographic evidence.	Ongoing training, Airtightness & Quality champions.
E/N 11	09/02/2015	Air barrier implementation	2	5	10	Con	Develop micro-sequencing notes for critical construction details, ensuring buildability and in collaboration with subcontract operatives. Experiment with void properties.	Ongoing training, Airtightness & Quality champions. Detail design development from subcontractor workshops has simplified air-tightness barrier design, better understanding throughout contractor team
E/N 12	18/06/2014	Thermal bridges	2	3	6	Con	Prepare a schedule of all thermal bridges. Calculate all bad thermal bridges. If necessary also calculate good thermal bridges. BRE to assist.	Schedule and modelling in progress.
E/N 13	09/02/2015	Steel fraction not fully accounted for in ECD pre-tender u-value calculations	closed	closed	closed	All	Calculate u-values accurately in PHPP. If the steel fraction is too high to be included in the u-value calculation it will need to be modelled as a thermal bridge. BRE to advise.	steel fraction allowed for in latest PHPP model
E/N 14A	09/02/2015	BT/Sky/Cable penetrations through air barrier during construction	closed	closed	closed	All	Client to advise of requirements for cabling. Contractor to ensure all penetrations are fully detailed for air tightness.	Grouped cable penetrations to maisonettes, vertically through core area then horizontally along corridor soffit. Ground floor units still TBC
E/N 14B	09/02/2015	Future resident penetrations through air barrier post construction	3	4	12	All	Handover pack and resident awareness.	Agree specific handover process. Residents can only use installed TV/data system
E/N 15	18/06/2014	Below ground wall perimeter insulation not being achieved.	closed	closed	closed	All	Confirm depth of insulation (constrained by depth of steel frame, constrained by level of existing drains) and review in PHPP.	HB doing U value calcs.
E/N 16	18/06/2014	MVHR system performance	1	1	1	Con	Prepare performance specification for design, installation and commissioning.	Specification issued 17/04/2014. Ensure CPs and subsequent work onsite meets the requirements.
E/N 17	18/06/2014	Ventilation to communal corridors and stair cores	1	3	3	All	Prepare method statement for ventilating communal areas naturally with window opening.	Overheating risk has been evaluated in PHPP. Letter of support to be provided by PCC (Adam to arrange).
E/N 18	09/02/2015	Kitchen extract ventilation (cooker hood + tumble dryer)	2	4	8	All	Ensure extract rates in kitchen are sufficient to keep temperature and humidity within comfort limits, even though there is no openable window. Explore idea of intermittent extract fans.	Testing installation of cooker hood extractor in Flat 28 pilot on 25/06/2014. Extractor duct to incorporate motorised air tight damper, controlled by operation of the extractor fan. Agree extract fan as Encraft spec
E/N 19	18/06/2014	Hot water cylinders + pipe insulation cause overheating in the prop	closed	closed	closed	All	Evaluate overheating risk in PHPP and decide if provision of insulation is necessary	
E/N 20	18/06/2014	Storage heaters inappropriate for newly refurbished building	3	1	3	All	Experiment with control of storage heaters once cladding work is complete to ensure that they do not overheat.	
E/N 21	18/06/2014	Code of conduct for site operatives not being adhered to.	1	4	4	Con	Ensure conduct of operatives onsite does not compromise integrity of air barrier and thermal envelope	Code of conduct and site rules issued 08/05/2014. This should be given to all subcontractors when they are invited to quote. Reinforce at toolbox talks for all site operatives.
E/N 22	18/06/2014	Rotating site teams	closed	closed	closed	Con	Ensure all site operatives who are new to site receive adequate training.	
E/N 23	09/02/2015	Skills gap	1	4	4	Con	Ensure EuroPHit and Encraft training for site operatives is delivered to the most appropriate people.	EnerPHit training on-going
E/N 24	09/02/2015	Air testing regime not complying with budgeted allocations	2	5	10	Con	Appoint air tester as soon as possible so they can help develop and take ownership of the testing regime. Carry out preliminary air testing on voids to investigate air leakage paths in existing dwellings, especially between	Appointment due to be confirmed during w/c 16/06/2014. Preliminary air tests to be carried out during July. Air-testing regime confirmed
E/N 25	09/02/2015	Timing of tests	1	3	3	Con	Impossible to test when air barrier is exposed (because the air barrier is sandwiched between layers). Obtain leak detection kit so spot testing can be carried out in situ by site operatives to check quality of their own work.	Quotation provided by air tester for preferred leak checker kit. Contractor purchased kit as advised
E/N 26	18/06/2014	Testing multiple dwellings as a block resulting in H & S risk	1	2	2	Con	Investigate potential fire risk issues. Consider evacuating dwellings during test.	
E/N 27	09/02/2015	Air volume calculation	closed	closed	closed	Con	Ensure accuracy by liaising with air tester.	air-tester on board, calcs TBC
E/N 28	18/06/2014	Residents compromise air barrier	closed	closed	closed	Con	Provide education to residents and RLOs	
E/N 29	18/06/2014	Residents compromise the air test	closed	closed	closed	Con	Consider evacuating dwellings during test.	
E/N 30	09/02/2015	Residents in multiple occupancy	3	3	9	Client	Review in PHPP to establish effect of high occupancy rates on the energy balance (internal heat gains, heating demand, overheating risk all affected). Model an individual dwelling at varying occupancy levels to check sensitivity.	Encraft model indentified window opening requirement to reduce risk
E/N 31	09/02/2015	Residents use of appliances	3	2	6	Client	Use of appliances could be more frequent than average (internal heat gains and overheating risk affected). Measurement/monitoring out of scope. Review in PHPP by modelling variable use in an individual dwelling to check sensitivity.	Residents use of tumble dryers is to be investigated during white goods survey. Survey complete
E/N 32	09/02/2015	Residents use of MVHR being interfered with	4	4	16	All	Provide simple controls, design system to minimise noise, provide user guide and education for residents and RLOs.	currently reviewing designs to minimise this, simple controls provided, noise mitigation designed, MVHR operation TBC
E/N 33	18/06/2014	Residents change in lifestyle in the use of heating	4	2	8	All	Provide education to residents and RLOs on how they must use storage heaters differently after refurbishment. Reference E/N 20.	
E/N 34	09/02/2015	Inadequate ventilation of kitchen and insufficient air changes	1	5	5	All	Pilot flats (x2) to test configuration of ventilation options	Testing installation of cooker hood extractor in Flat 28 pilot on 25/06/2014. Extractor duct to incorporate motorised air tight damper, controlled by operation of the extractor fan. Agree extract fan as Encraft spec

Design stage assessment

- Ideally completed before the build contract is finalised
- Detailed design needed
- Put as much detail into the PHPP as possible
- Post construction stage assessment can focus on test results, change management and onsite quality control



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Project Management Checklist

Core Components

Training/toolbox talks

Pre-start

- Site storage
- Workmanship
- Activities to be undertaken
- Sequencing of activities
- Building physics first principles
- Air testing protocol
- Practical hands on experience
- Site culture

Insulation installation

Materials & workmanship

- Walls, floor, roof, windows
- Junctions
- Services

Wind & air tightness

Materials & workmanship

- Primary wind barrier system
- Primary air barrier system
- Window installation
- Service penetrations

Services

Materials & workmanship

- MVHR unit installation
- MVHR duct work and silencers
- Builder's work (door undercuts)
- DHW
- Pipes and plumbing
- Heat sources
- Controls

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Role of the quality assurance champion

- Understand & communicate the air barrier strategy. Ensure it's adoption by all
- Know where the air barrier is & what forms it. Supervise or check all relevant works
- Ensure site inductions emphasise principle of building physics, heat loss, thermal bypass, air testing & the necessity to avoid leaks
- Manage relevant variations using a formalised change management process
- Operate an inspection checklist for key elements, interfaces and penetrations
- Ensure all materials which form part of the thermal envelope (including the air barrier) are correctly used
- Liaise with the Passivhaus consultant and air testers to organise visits for audits & tests, ensuring all necessary preparations are complete
- Verify that weather conditions are satisfactory for air testing
- Ensure that recommendations from site inspections and audits are acted upon
- Determine schedule of testing, which areas need to be tested & when
- Understand the correct air testing protocol and ensure the envelope area & volume for each dwelling type is traceably calculated
- Use a leakage check kit to check the effectiveness of sealing works

Change management

Changes that should be tracked include:

- Designs
- Products & materials
- Sequencing
- Staff/personnel changes

Site Inspections

Typical considerations will address:

- Below-ground and above-ground fabric
- Installation of insulation - including thermal bypass etc.
- Poor application of insulation at junctions
- Airtightness of service penetrations
- Poor application of air & wind barriers at junctions
- MVHR & ductwork installation
- MVHR commissioning
- Site storage

The Certified Passivhaus Consultant should be present at:

- Air tightness test
- MVHR commissioning
- Commissioning of other services
- Operator/occupant training

Contractor’s declaration

The Passivhaus standard requires that the construction supervisor makes a declaration of conformance

“Execution according to the reviewed PHPP project planning must be documented and confirmed with the construction manager's declaration. Any variation in construction should be mentioned; if any of the products used deviate from those included in the project planning, evidence of compliance with criteria must be provided.”

Example Contractors Declaration

Site Address:
Property:
Date:

I hereby confirm that the above property at the above site has been constructed in accordance with the construction drawings and specifications and that all observed defects in workmanship have been remediated in accordance with the site inspection reports.

Conducted Heat Loss

All insulation is continuous i.e. there are no gaps greater than 3mm in front, behind or between the insulation or any adjacent materials.
The conductivity of all materials conform to the specifications.
All workmanship conforms to the specified manufacturer’s installation requirements.
Each door and window was inspected upon delivery to ensure conformance with the specification.
All observed defects have been remediated.

Airtightness / Wind tightness

All surfaces were clean, dust free, and dry prior to air/wind barrier tapes being applied.)
During the air test no additional tapes or membranes were place over air leakage points.
Air leakage was measured in accordance with all required standards.

Ventilation

All MVHR intake and exhaust ductwork within the thermal has been insulated in order to mitigate all condensation risks.
All ductwork was protected from dust and debris during construction and that, where appropriate, remediation has been undertake by cleaning the ductwork prior to hand over.
All ductwork was installed in accordance with the MVHR designer’s drawings and specifications.
Other than when being commissioned I confirm that the MVHR unit was not left switched on prior to hand over.
The MVHR was commissioned in accordance with all required standards.

DHW

In confirm that all main branches of DHW pipework were insulated.
I confirm that all DHW insulation is continuous i.e. there are no gaps greater than 3mm in front, behind or between the insulation or any adjacent materials.

Name: Position:

Signature:

Company:

Company Address:

Progress onsite

Progress onsite

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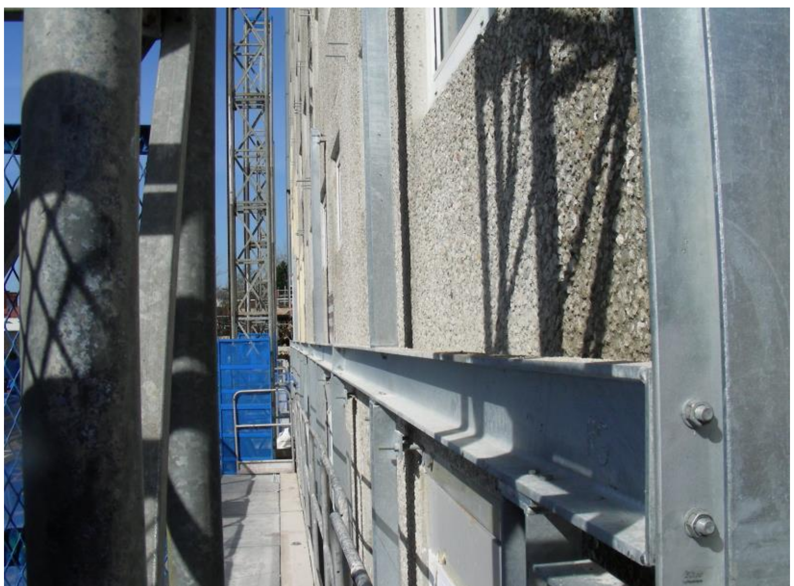

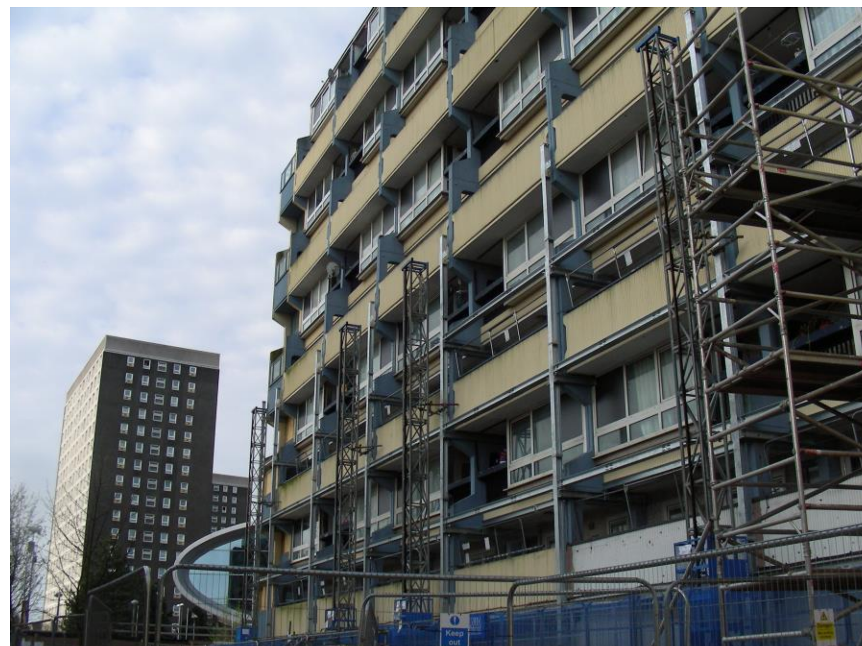
Keep out

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