The Old Quadrangle

Retrofitting a significant heritage building to Passive House EnerPHit standard

University of Melbourne, Parkville VIC

Presented by MILICA TUMBAS, Principal - Architecture

October 2019

Prepared for

Passivhaus Institut

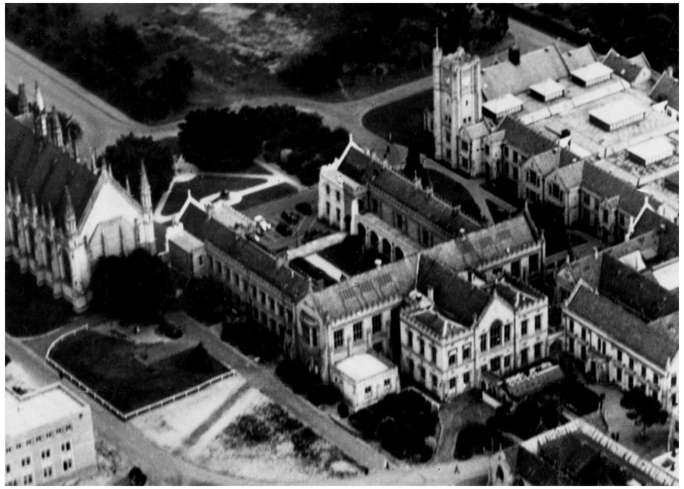
Prepared by

LOVELL CHEN

LEVEL 5, 176 WELLINGTON PARADE
EAST MELBOURNE 3002

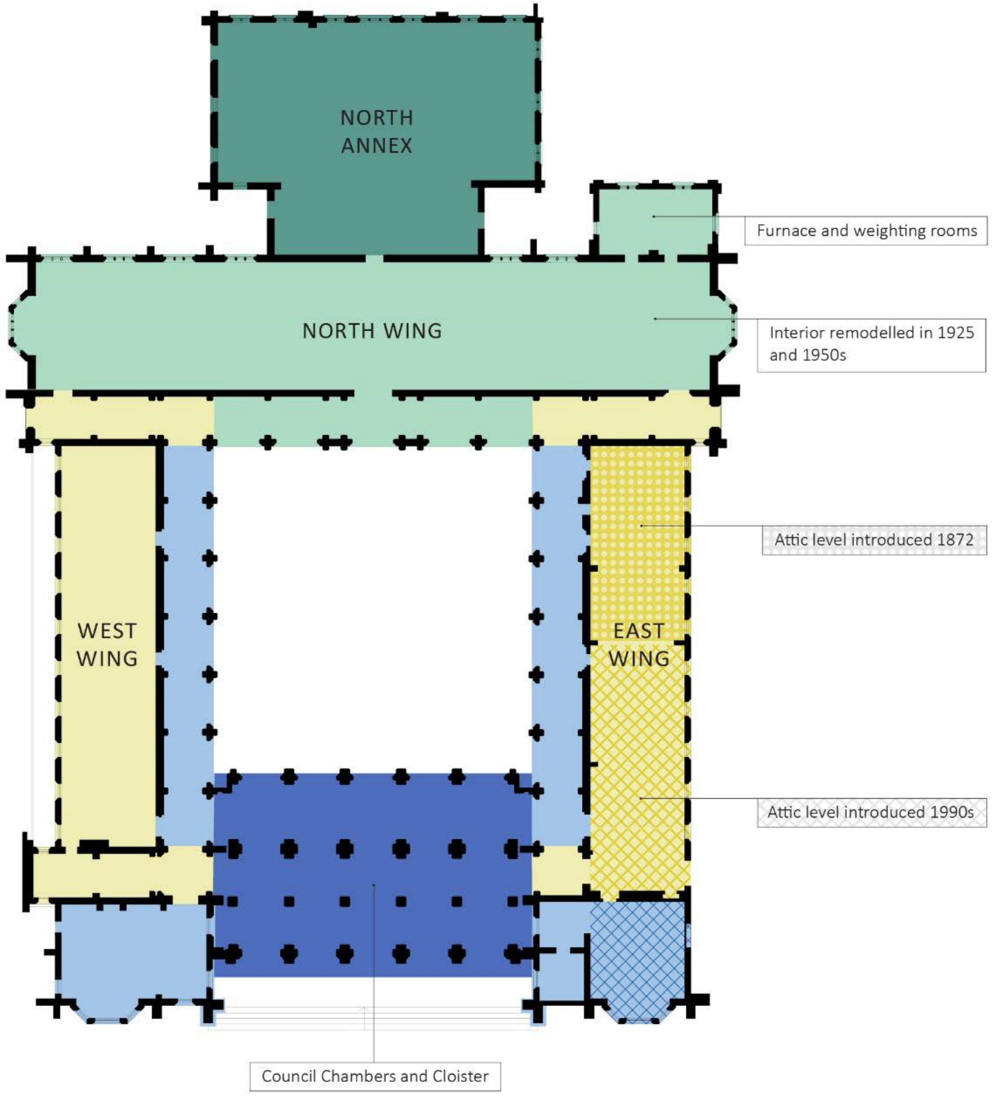
THE OLD QUADRANGLE

The University of Melbourne's Old Quad building is located at the heart of the University of Melbourne campus. It was the first university building in Australia. Construction commenced in 1854 and evolved in five stages, reaching completion with the vaulted cloister at the south end of the Quad in 1981. The Old Quad is **architecturally significant** for being the **oldest non-ecclesiastical Gothic revival structure in Victoria** and the most important work of **architect F M White**. The Old Quad is **socially significant** for the inclusion in the **original design of professorial accommodation to foster social experience** as well as **intellectual interaction** with the students and for the association with the University's Faculty of Law.



LOVELL CHEN

BUILDING EVOLUTION



1854-55

1856-57

1874-75

1930

1969-70 (Council Chambers) + 1981 (Cloister)

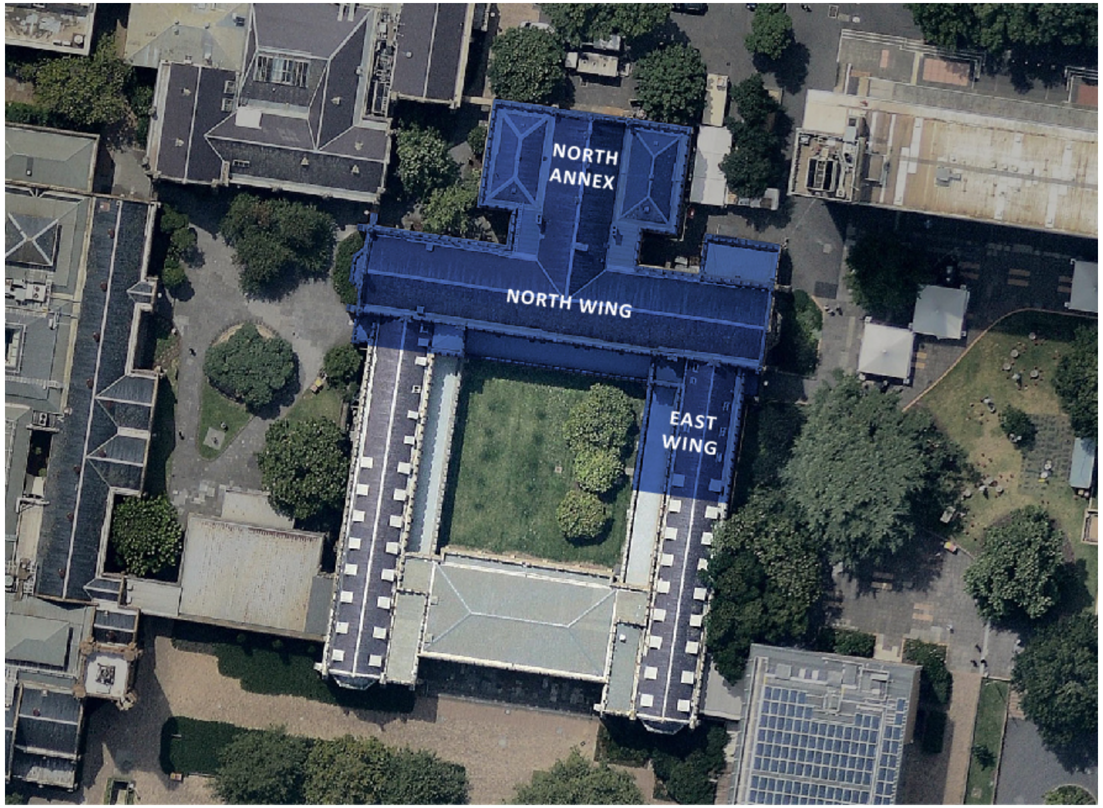
PROJECT SCOPE

Project objectives:

- adapt and refurbish the north and east wings and north annex; and
- re-establish the Old Quad as the ceremonial and engagement heart of the campus.

The works package includes:

- conservation of original fabric, details and features;
- reinstatement of the original planning, where possible;
- seismic strengthening;
- fire separation
- services upgrades including sprinkler protection; and
- EnerPHit standard to the affected areas.
- Green Star Pathway



LOVELL CHEN

The building interior, particularly in the north wing and annex, has been subject to significant alteration at various stages. The east wing retains much of the original 1850s fabric. This resulted in various degrees of fabric integrity and different conservation approaches to the three wings. The north wing has been adapted as a multi-use exhibition space and reception area, with a new University Hall on the first floor. The north annex will serve as the entry to the north wing.

BUILDING CODE REQUIREMENTS

- Strengthening for earthquake protection
  - Challenges: North Wing requires concealed and thermally separated steel structural members with multiple rigid structural connections
- Fire separation
  - Challenges: Separation where the wings abut each other
    Separation of structures
    Fire rated doors including hardware
- Wet fire protection of the building including fire hydrant and sprinkler system.
  - Challenges: Limited space for concealment
    Dealing with penetrations
- Services upgrade
  - Challenges: Limited space for mechanical services installation
    Achieving a comfortable temperature all year round and reducing the use of energy
- Energy efficiency - client required an innovative approach to design with a sustainable outcome
  - Typically, heritage buildings in Australia do not achieve significant energy savings when conventional approaches are pursued so it was determined this project would implement EnerPHit principles.

LOVELL CHEN

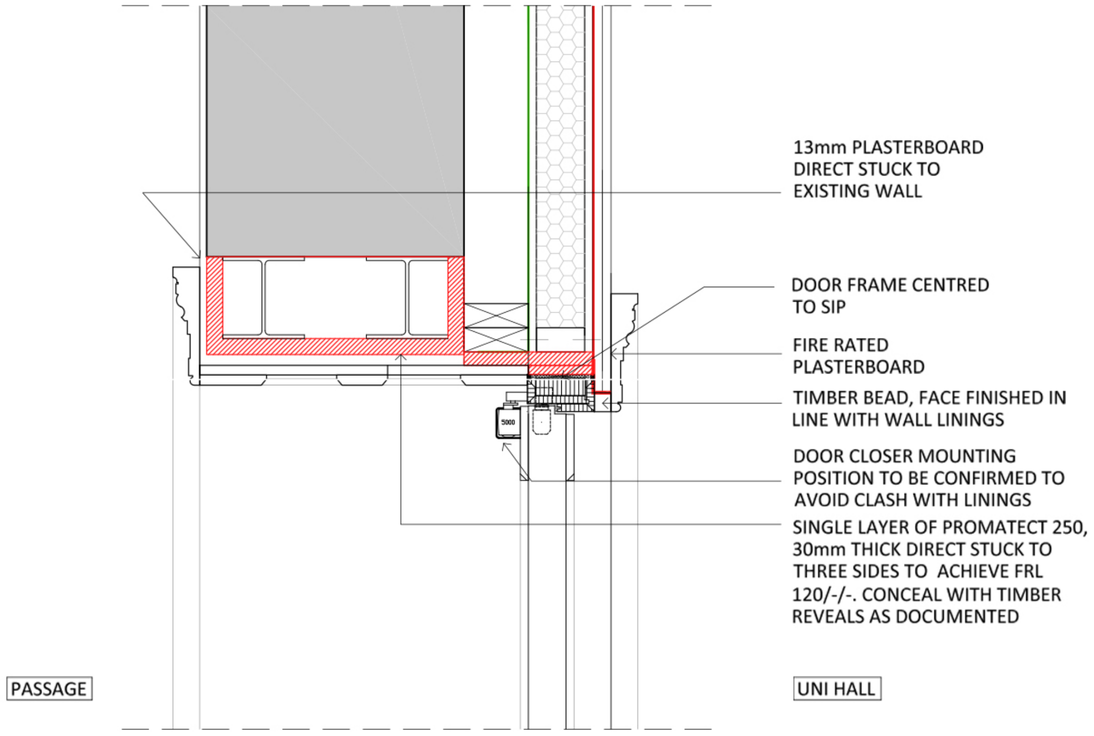
STRENGTHENING EXISTING BUILDINGS FOR EARTHQUAKE

Strengthening the Old Quad for earthquake protection was triggered due to the size and nature of the project. This was challenging to detail in the north wing as it required substantial steel structural members that needed to be concealed, thermally separated to minimise energy loss through the steel, and rigid structural connections throughout the airtightness envelope.

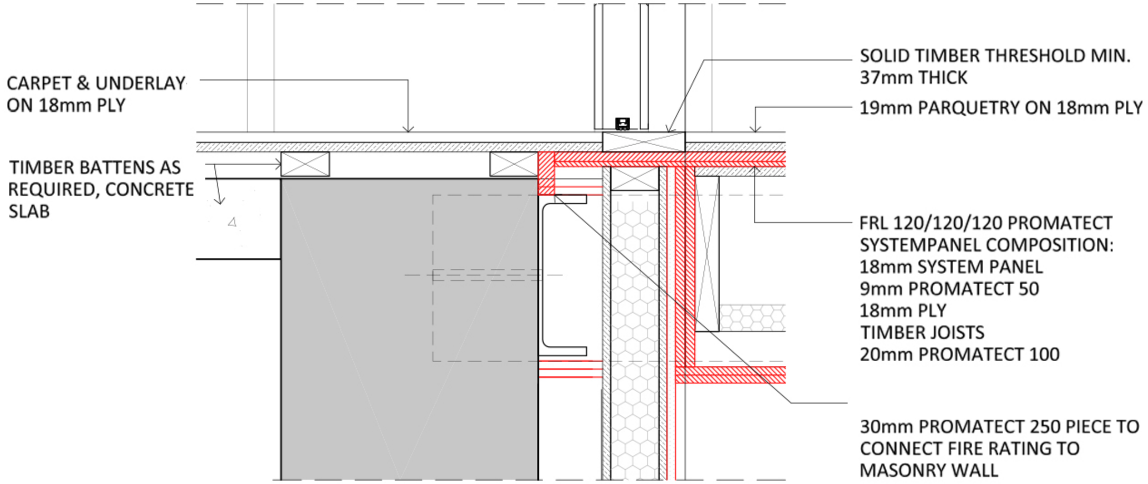
LOVELL CHEN

FIRE SEPARATION

The building is divided into several fire compartments which require separation where the wings abut each other. Careful detailing was necessary to achieve the fire separation and ensure thermal bridges have been eliminated in the critical fire rating details.

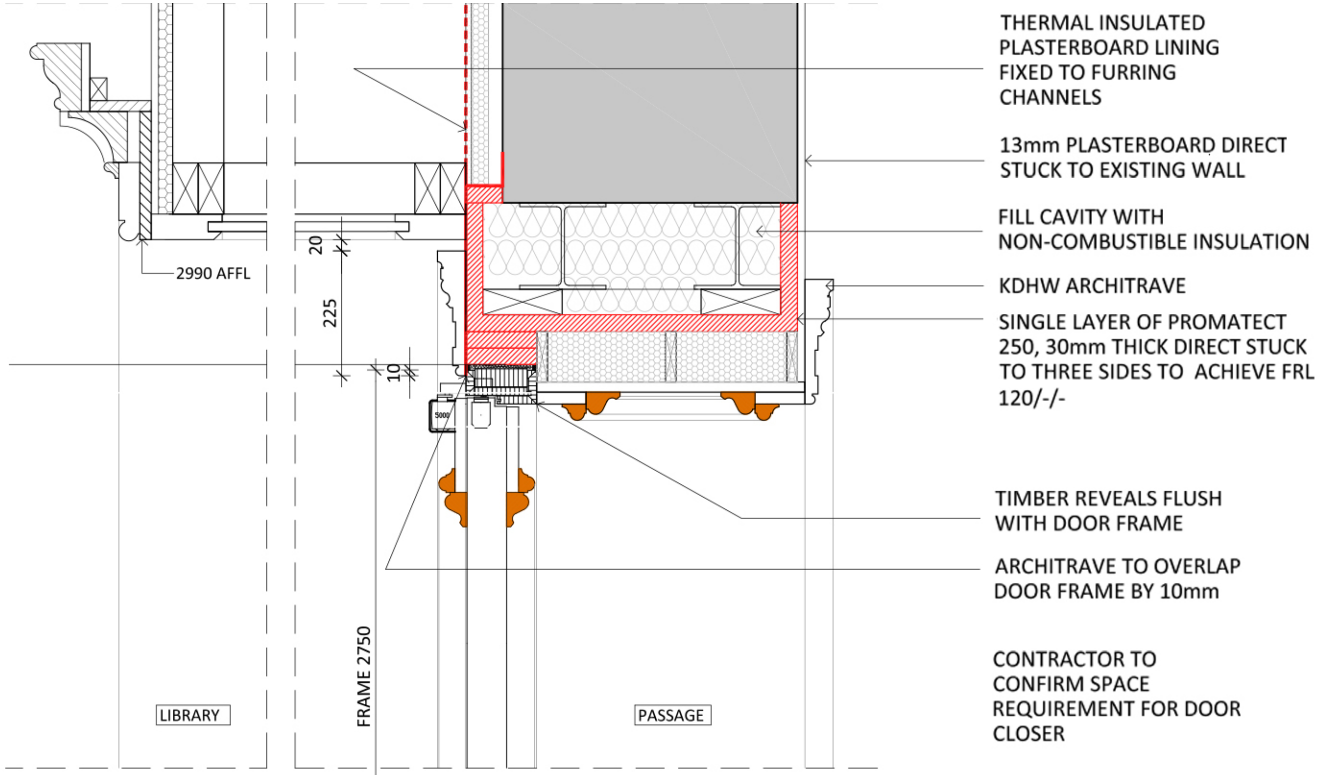


NND131, NND133 - HEAD

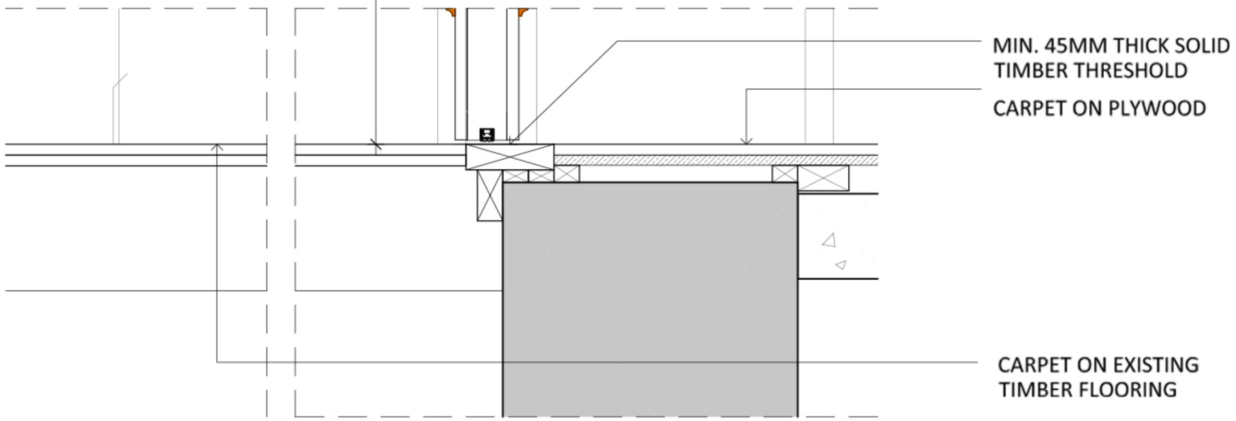


NND131, NND133 - THRESHOLD

LOVELL CHEN



NND122 HEAD



NND122, NND132 THRESHOLD

LOVELL CHEN

HYDRANT AND SPRINKLER PROTECTION

Sprinkler protection of the building was challenging due to the limited space for concealment which is usually shared by the necessary components required to achieve thermal insulation and airtightness.

LOVELL CHEN

EnerPHit – THE PASSIVE HOUSE STANDARD FOR RETROFITS

- First time the EnerPHit model has been applied to a building of heritage significance in Australia.
- The challenge of delivering EnerPHit standards in heritage buildings is to achieve an acceptable balance between **retaining the heritage qualities** and characteristics of the building and **achieving outcomes that improve thermal comfort** and economic efficiency.
- Umow Lai used the Passive House Planning Package Component Method to verify compliance with EnerPHit criteria
- The **Passive House EnerPHit design standard** has provided an evidence-based method for achieving a comfortable temperature all year round and to **reduce the use of energy up to 90%.**

Specific building characteristics with reference to the treated floor area

		Unit	Value		Criteria	Alternative criteria	Fullfilled?[2]
	Treated floor area	m²	1259.2				
Space heating	Heating demand	kWh/(m²a)	17	≤	-	-	-
	Heating load	W/m²	15	≤	-	-	
Space cooling	Cooling & dehum. demand	kWh/(m²a)	13	≤	-	-	-
	Cooling load	W/m²	13	≤	-	-	
	Frequency of overheating (> 25 °C)	%	-	≤	-		-
	Frequency excessively high humidity (> 12 g/kg)	%	0	≤	10		yes
Airtightness	Pressurization test result n_{50}	1/h	0.9	≤	1.0		yes
Minimum thermal protection	fulfilled?	yes/no			yes		yes
	Smallest temperature factor $f_{Rsi=0.25 m^2K/W}$	-	-	≥	0.55		-
	highest U-value	W/(m²K)	1.55	≤	-		-
	highest U-value	W/(m²K)	0.17	≤	1.30		yes
	highest U-value	W/(m²K)	0.55	≤	1.40		yes
	highest U-value	W/(m²K)	1.20	≤	-		-
Non-renewable Primary Energy (PE)	PE demand	kWh/(m²a)	65	≤	135.88602		yes
Primary Energy Renewable (PER)	PER demand	kWh/(m²a)	40	≤	-	-	-
	Generation of renewable energy	kWh/(m²a)		≥	-	-	

EnerPHit (refurbishment): Component characteristics

	Unit	Value		Criteria	Fullfilled?
Building envelope to exterior air[1] (U-value)	W/(m²K)	0.24	≤	0.5	yes
Building envelope to ground[1] (U-value)	W/(m²K)	0.57	≤	0.95	yes
Wall w/int. insulation in contact w/exterior air (U-value)	W/(m²K)	0.37	≤	0.75	yes
Wall w/interior insulation in contact w/ground (U-value)	W/(m²K)	-	≤	1.79	-
Flat roof (SRI)	-	36	≥	-	-
Inclined and vertical external surface (SRI)	-	32	≥	-	-
Windows/Entrance doors ($U_{W/D,installed}$)	W/(m²K)	1.33	≤	1.35	yes
Windows ($U_{W,installed}$)	W/(m²K)	-	≤	1.40	-
Windows ($U_{W,installed}$)	W/(m²K)	-	≤	1.50	-
Glazing (g-value)	-	0.40	≥	-	-
Glazing/sun protection (max. solar load)	kWh/(m²a)	178	≤	-	-
Ventilation (effective heat recovery efficiency)	%		≥	-	-
Ventilation (humidity recovery efficiency)	%		≥	-	-

[1] Without windows, doors and external walls with interior insulation

[2] Empty field: Data missing; '-': No requirement

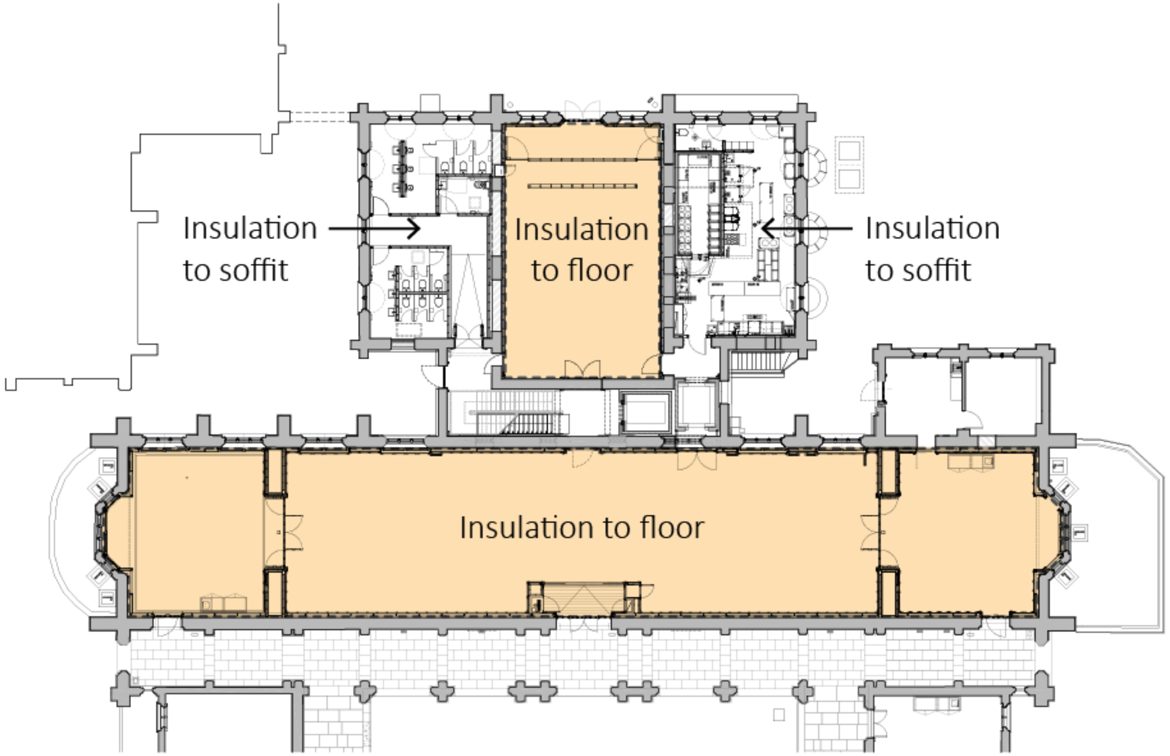
I confirm that the values given herein have been determined following the PHPP methodology and based on the characteristic values of the building. The PHPP calculations are attached to this verification.

EnerPHit Classic? yes

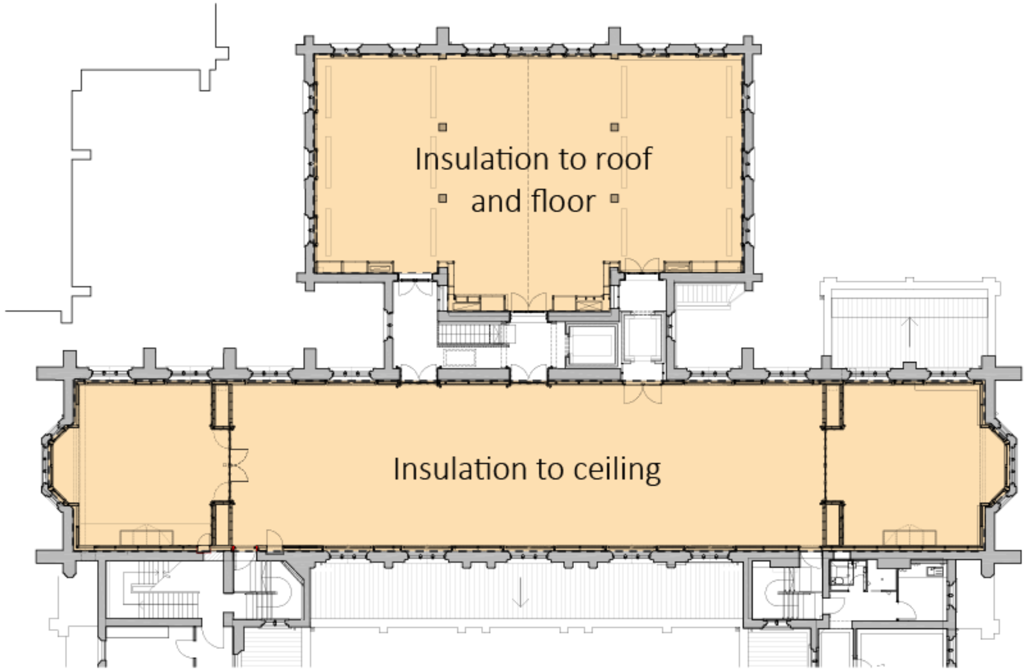
LOVELL CHEN

EnerPHit MODEL

Internal 'compartmental' approach



GROUND FLOOR PLAN

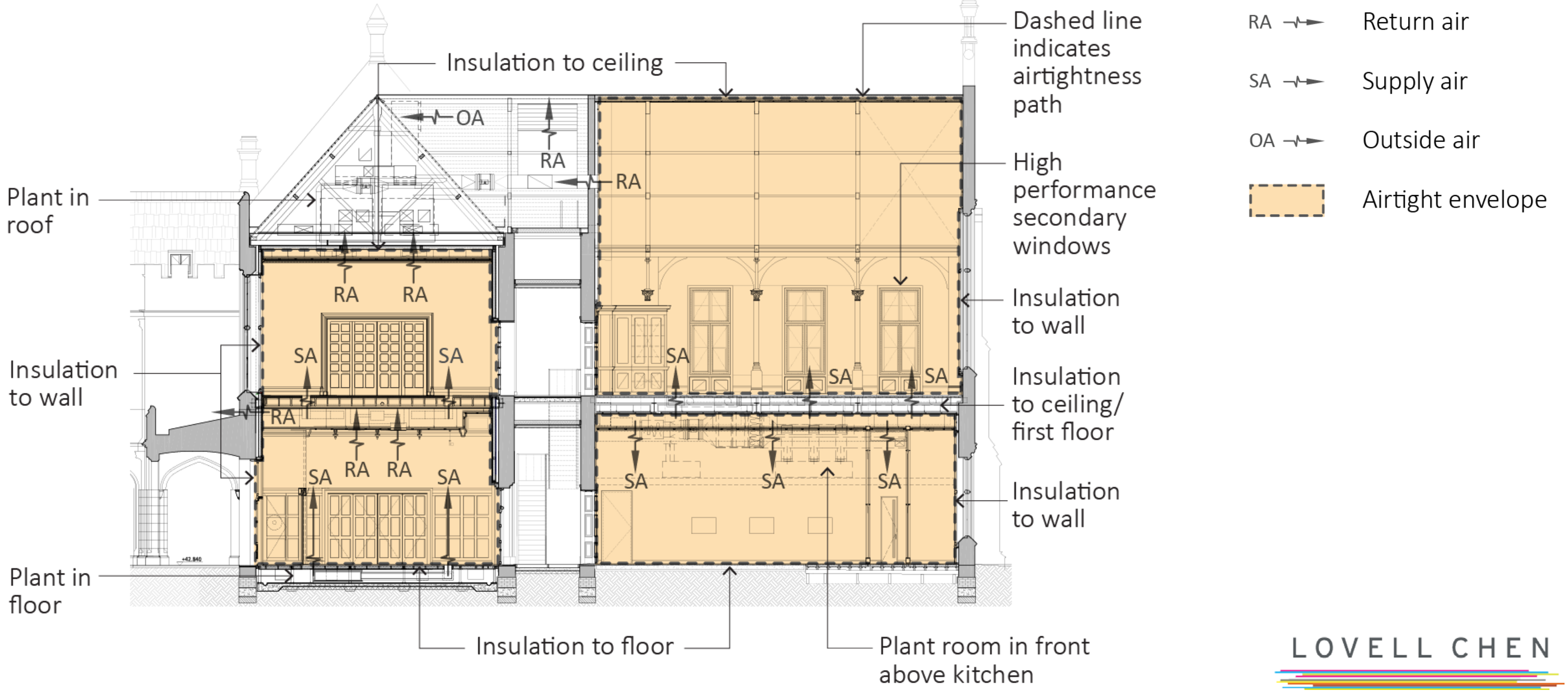


FIRST FLOOR PLAN

LOVELL CHEN

EnerPHit MODEL

Internal ‘compartmental’ approach was taken to identify the internal thermal envelope and airtightness barrier to the north wing and annex separately. Unconditioned and transient spaces are excluded from the EnerPHit thermal envelope.



LOVELL CHEN

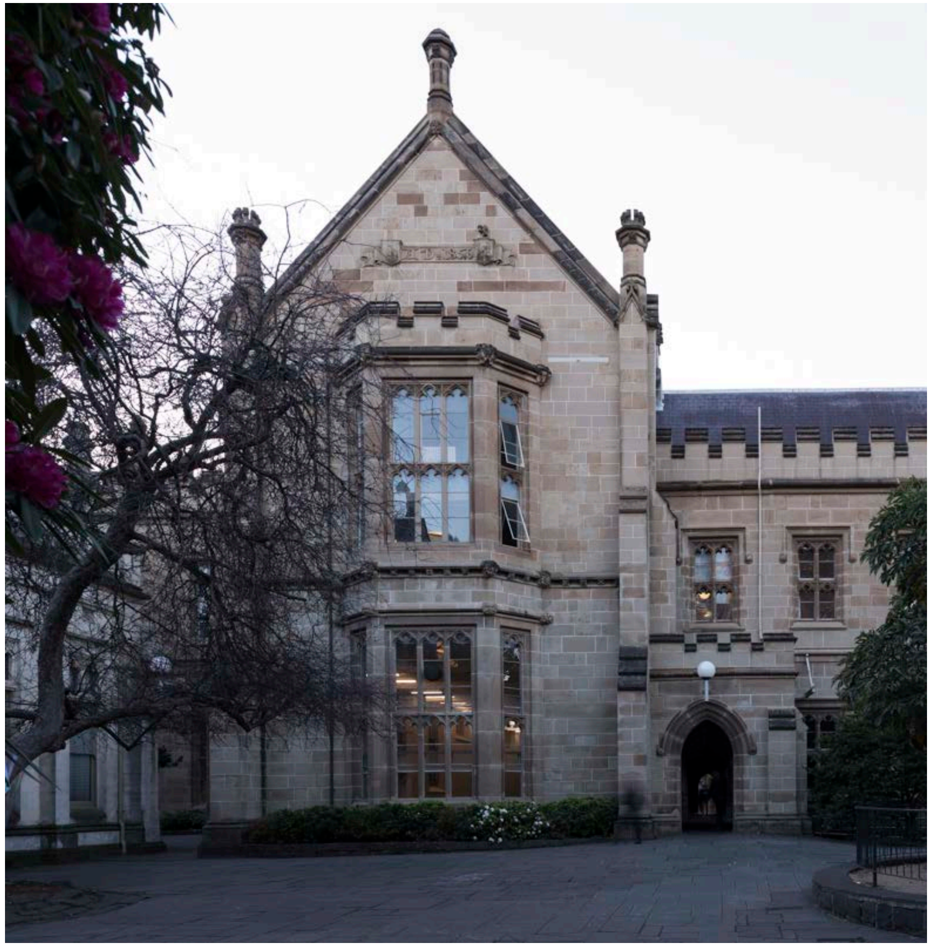
BUILDING FABRIC

In order to retain the architectural and heritage values of the building the introduction of sustainable interventions to the exterior of the building was not an option. Internal thermal envelopes and airtightness barriers are created through the installation of internal insulated structures and linings.

Internal fabric requiring intervention:

- Walls
- Floors
- Ceilings
- Windows
- Doors

Source: Hin Lim (photographer)



LOVELL CHEN

ROOFS

The roof structures are formed by transverse King post trusses in the north wing and King post arch-braced in the north annex. All trusses are connected with metal connectors, supporting under purlins, rafters, battens and slates. North wing and north annex roofs were not insulated. East wing roof was partially and insufficiently insulated.

EXISTING WALLS

The east, west and north wings of the Old Quad and the north annex exhibit conventional mid-nineteenth century techniques. The load bearing external walls are comprised of rough coursed rubble faced with Kangaroo Point sandstone sourced from Bellerive, near Hobart, Tasmania, with no cavities and in the order of 400-600mm thick. All internal walls are hard plastered masonry. The basement areas of the east and west wings are brick, faced with coursed squared bluestone blocks, with details in stone and brick.

The high conductivity of the rubble and brick construction as well as original connection details where external walls meet internal walls presents significant areas of thermal bridging, with the continuation of the same construction for internal perpendicular walls in many locations.

WALLS - INTERVENTION

The removal of non original floors in the north wing has enabled the installation of an internal EnerPHit envelope.

The walls in the north annex and the east wing were lined with insulated plasterboard.

FLOORS

Perimeter thermal bridges were significant given the junction of floors with stone walls with no insulation. Original floor construction and connection details as well as external paving adjoining occupied conditioned spaces created numerous thermal bridges. The original floors are of timber joist construction with herringbone braces and tongue and groove softwood boards. The east wing first floor was constructed as separate floor and ceiling structures for acoustic separation, doubling up the thermal bridging through the floors and ceilings.

INSULATED FLOORS

North wing cassette system pre-fitted with vapour permeable membrane and filled with insulation.

Floors during construction

EXISTING WINDOWS

LOVELL CHEN

WINDOWS

- Existing glazing - 3-4mm clear float glass, mounted within a range of framing systems including stone, steel and timber (very poor thermal and solar performance)
- According to Umov Lai analysis the total system U-values are likely to be ≥ 7.0 W/m^{2}K, with high solar heat gain coefficients (0.75–0.88) resulting in substantial heat loss through the single glazed steel and timber windows
- Several options were considered including:
  - fitting new single, double and triple glazed units into the existing frames; or
  - installing new frames in the existing stone tracery to the north wing and annex.

LOVELL CHEN

HIGH PERFORMANCE SECONDARY WINDOWS

Refurbishing and retaining the existing windows and adding a secondary layer of windows to the inner skin walls was the adopted strategy, with openable windows to allow for maintenance and cleaning of internal surfaces.

Secondary layer of openable windows
Source: Eve Wilson (photographer)

LOVELL CHEN

WINDOW PERFORMANCE

Performance of the windows is presented in the below table:

Window area orientation	Global radiation (main orientations)	Shading	Dirt	Non-vertical radiation incidence	Glazing fraction	g-Value	Solar irradiation reduction	Window area	Window U-Value	Glazing area	Average global radiation
Standard values →	[kWh/(m²a)]	0.75	0.95	0.85				m²	W/(m²K)	m²	kWh/(m²a)
North	97	0.59	0.95	0.85	0.65	0.40	0.31	60.57	1.30	39.50	100
East	186	0.28	0.95	0.85	0.72	0.40	0.16	27.08	1.33	19.57	183
South	353	0.38	0.95	0.85	0.64	0.40	0.20	133.41	1.34	85.19	349
West	199	0.36	0.95	0.85	0.71	0.40	0.21	35.75	1.32	25.36	210
Horizontal	307	1.00	0.95	0.85	0.00	0.00	0.00	0.00	0.00	0.00	307
Total or average value of all windows						0.40	0.22	256.81	1.33	169.61	

Total or average value for windows, from EnerPHit PHPP V9.3a [Umow Lai 2017].

NEW HIGH PERFORMANCE DOORS

Remaining original door details were used for the design of the new doors.

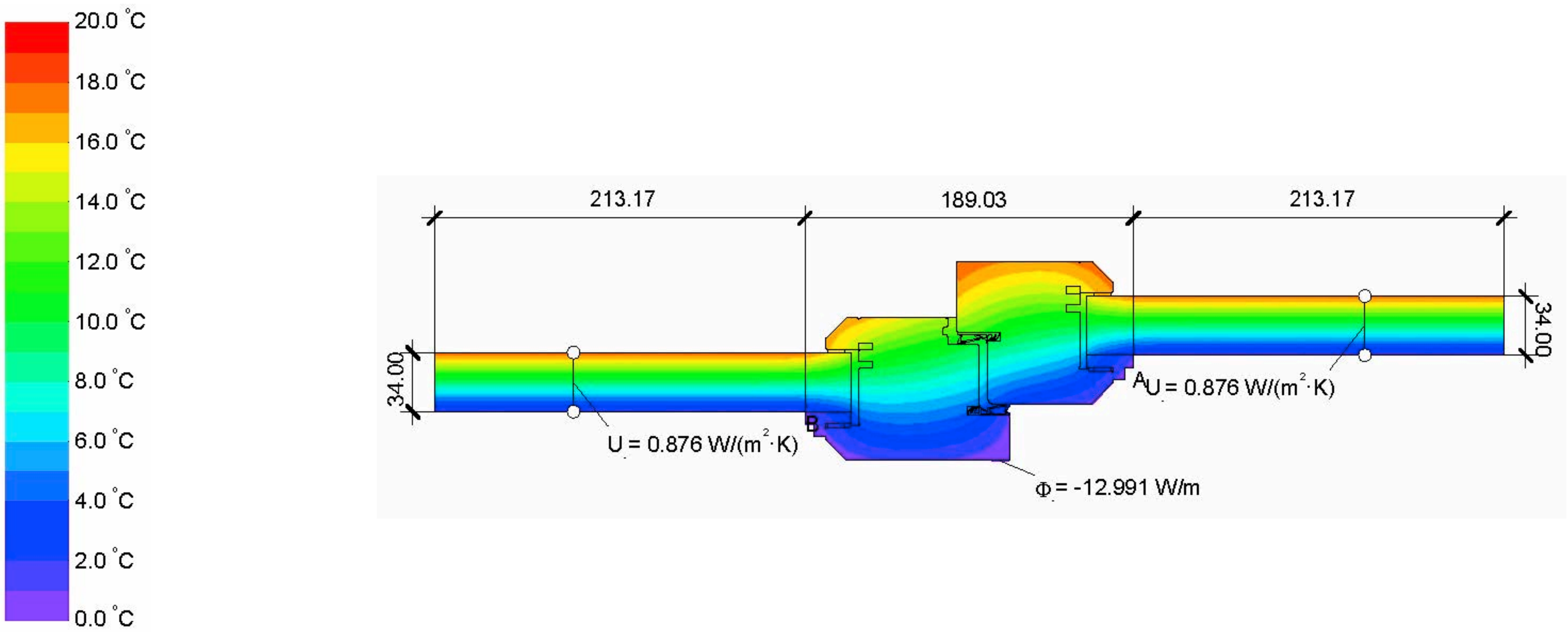
Original door

New high performance doors prior to installation

LOVELL CHEN

DOOR PERFORMANCE

Performance of the windows and doors was verified by the suppliers



Door NNDG18 – Silber Premium Windows and Doors – Source: Laros Technologies

LOVELL CHEN

MECHANICAL SYSTEM

Mechanical system is a multi-unit variable air flow air-conditioning system with pre-cooled outside air using indirect evaporative cooling units with high efficiency heat exchange cores to facilitate heat exchange between the wet area and dry area passages. The EnerPHit compartments are provided with independent heating and cooling with separate controls allowing each space to have demand-controlled ventilation.

Venti-lation unit no	Quan-tity	Description of ventilation units	Selection of type of ventilation unit	Design vol. flow	Application range for volume flow rate		Electrical efficienc
					from	to	
	[-]			m³/h	m³/h	m³/h	Pa
1	1	AHU 1: GL West	01ud-Old Ouad AHU Type 1	810	540	1000	0.75
2	1	AHU 2: GL Central	02ud-Old Ouad AHU Type 2	5508	2520	5500	0.75
3	1	AHU 3: GL East	01ud-Old Ouad AHU Type 1	810	540	1000	0.75
4	1	AHU 4: L1 West	01ud-Old Ouad AHU Type 1	810	540	1000	0.75
5	1	AHU 5: L1 Central	02ud-Old Ouad AHU Type 2	5508	2520	5500	0.75
6	1	AHU 6: L1 East	01ud-Old Ouad AHU Type 1	540	540	1000	0.75
7							
8	1	AHU: Annex L1	02ud-Old Ouad AHU Type 2	4860	2570	5500	0.75
9	1	AHU: Annex GL	01ud-Old Ouad AHU Type 1	1620	540	100	0.75

Ventilation system with multiple ventilation units, from EnerPHit PHPP V9.3a

MECHANICAL SYSTEM

The mechanical plant is concealed predominantly in the gable roof to the north wing with some units and ductwork installed in the floors and ceilings of the north wing and annex. Critically for the Old Quad project, a conventional mechanical system would require significantly larger plant including a chiller and associated infrastructure works to be installed in an adjacent building. This was eliminated by using EnerPHit.

Ventilation system, during installation in the north wing roof

LOVELL CHEN

MECHANICAL SYSTEM – PRIMARY ENERGY DEMAND

Annual heating demand is calculated but is not used for verification using the Component method. All building services are treated within the scope of EnerPHit for the purposes of Primary Energy demand calculation.

PE demand requirement in case of verification through PE (non-renewable) [kWh/(m^2a)]	**135.8860236**	Current building reaches following class for aspect	**65**	Reqirement met?	**yes**

Primary energy demand requirement, verification through PE, from EnerPHit PHPP V9.3a

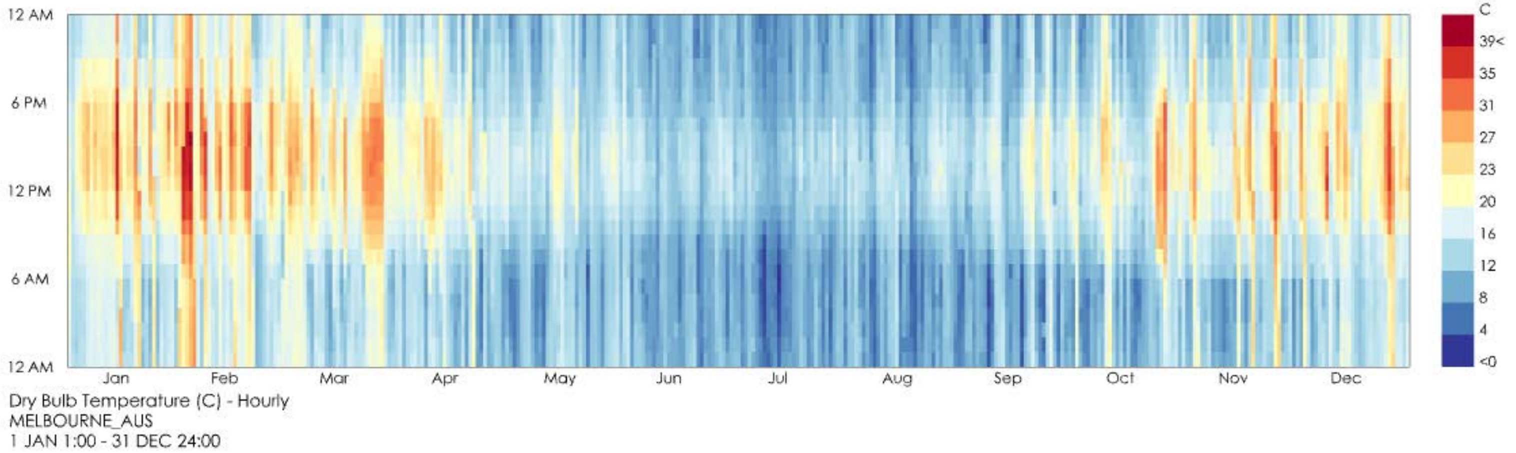
MOISTURE TRANSFER

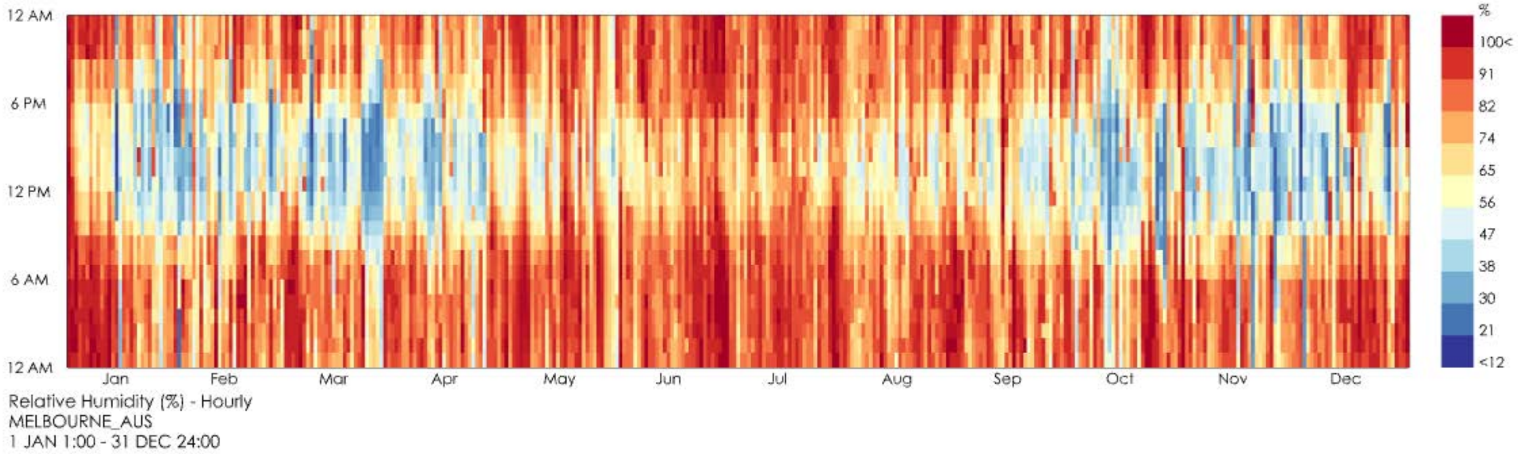
From the very beginning there were concerns that improvement of the external wall thermal performance by adding internal insulation would change the transfer of vapour through the walls and create moisture and condensation problems. When the building is insulated internally the 'breathing' of the building changes and the risk can be the creation of cold bridges leading to condensation and mould growth.

To mitigate this risk the documentation underwent a surface condensation analysis, hygrothermal assessment and thermal bridging assessment carried out by Inhabit using THERM 7.4. and WUFI Pro 6.1. The analysis highlighted that surface condensation is predicted to form on the internal surface of the existing single glazing and framing when the external temperature drops below 12ºC.

LOVELL CHEN

SURFACE CONDENSATION ASSESSMENT

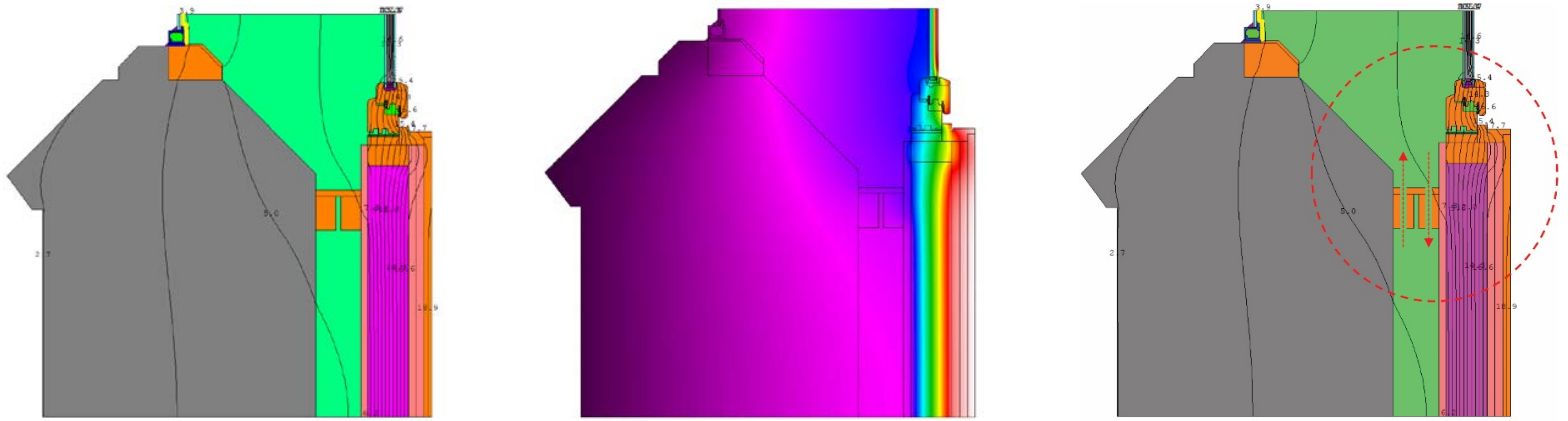




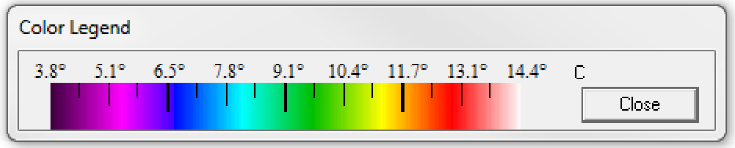
Annual External Dry Bulb Temperature (ºC) and Relative Humidity (RH), Melbourne – Inhabit.

ANALYSIS

The risk associated with the build-up of condensation in the airgap was resolved by providing vertical circulation of the air through the perimeter cavity of affected walls



a b c



a) THERM Isotherm Result;

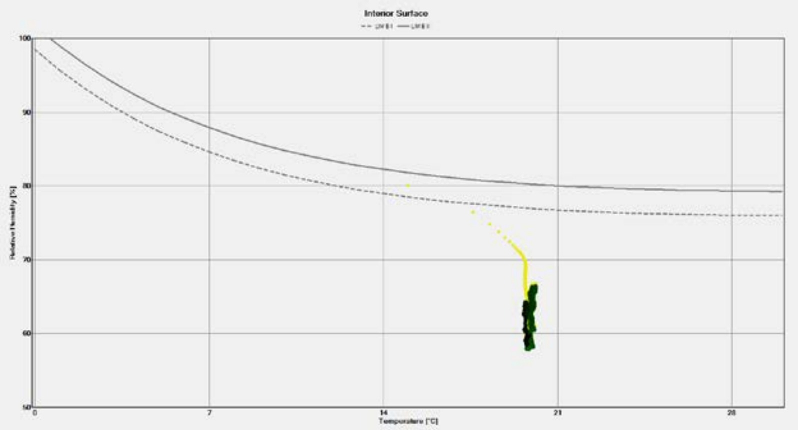
b) b) Colour Infrared Result;

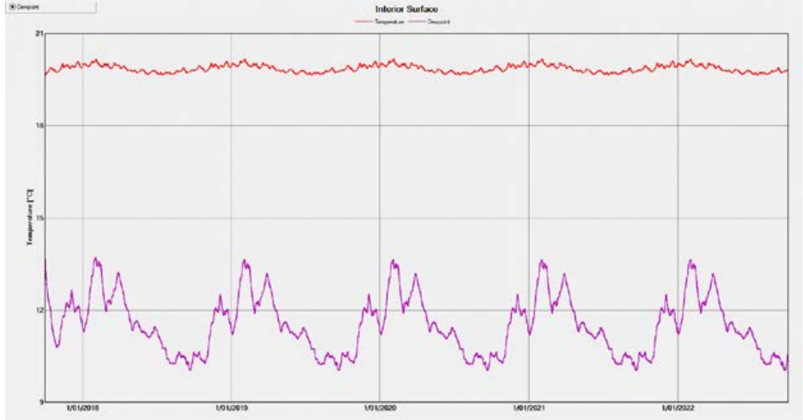
c) c) Adopted solution with introduced ventilation.

External Wall Type - north wing – THERM Isotherm and Colour Infrared Result and proposed ventilation - Inhabit

LOVELL CHEN

HYGROTHERMAL ASSESSMENT

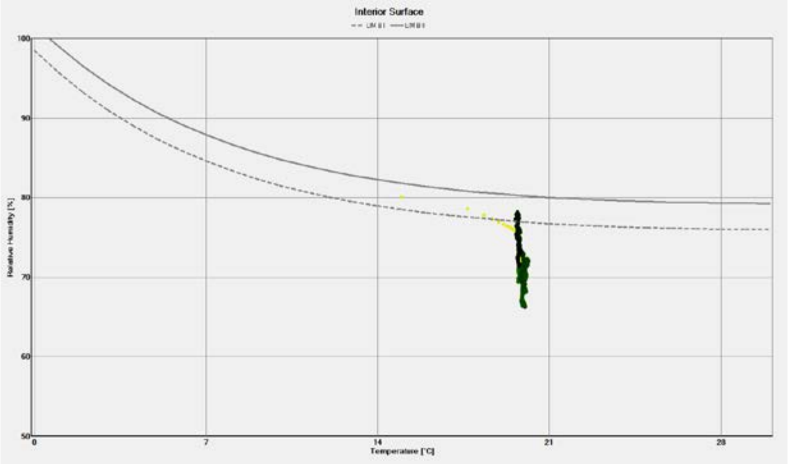




Water Content [kg/m³]

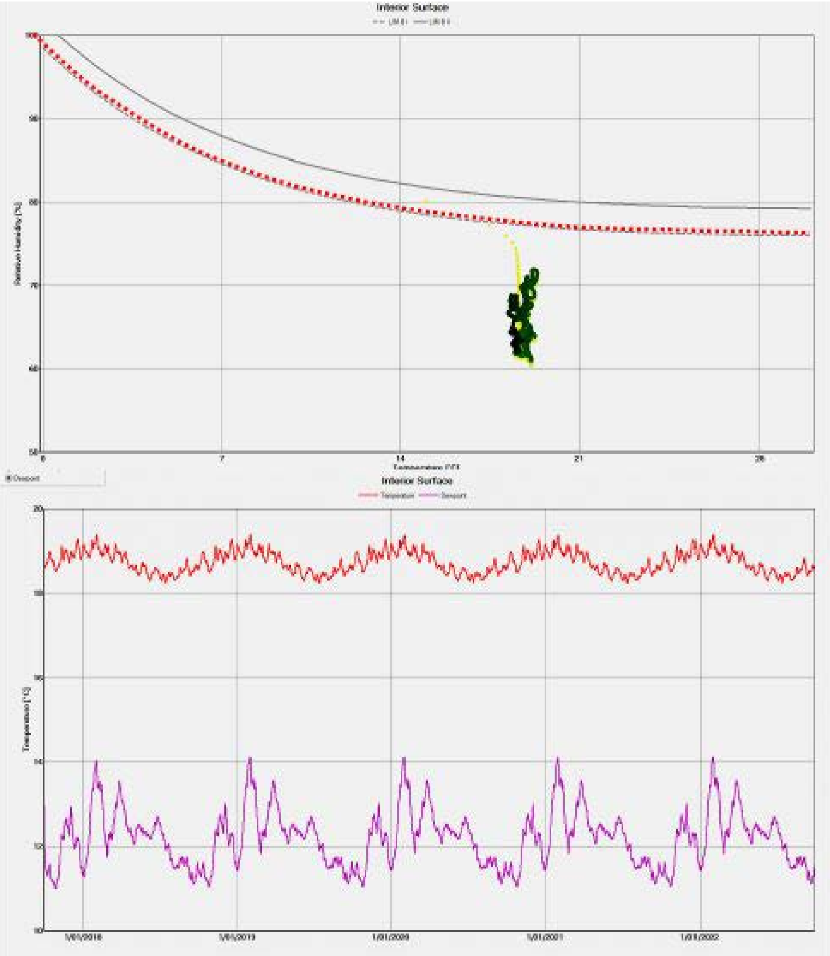
Layer/Material	Start	End	Min.	Max.
*Solid Brick, historical - unlocked	4.50	16.37	3.63	31.43
Air Layer 100 mm; without additional moisture cap	0.01	0.01	0.01	0.01
*Solitex Extasana	0.00	0.00	0.00	0.00
*OSB	96.00	93.20	81.38	96.00
*PIR	1.79	0.99	0.95	1.79
*OSB	96.00	70.15	70.05	96.00
*Intello	6.70	2.59	2.51	6.77
Plywood	96.50	69.24	68.21	96.59
*Gypsum Board	6.19	3.58	3.41	6.19

Walls- north wing – Interior surface temperature (ºC) relative humidity (%) (above) And water content (kg/m3) – Inhabit.



Interior surface temp (°C)/relative humidity (%), without Intello membrane – Inhabit.

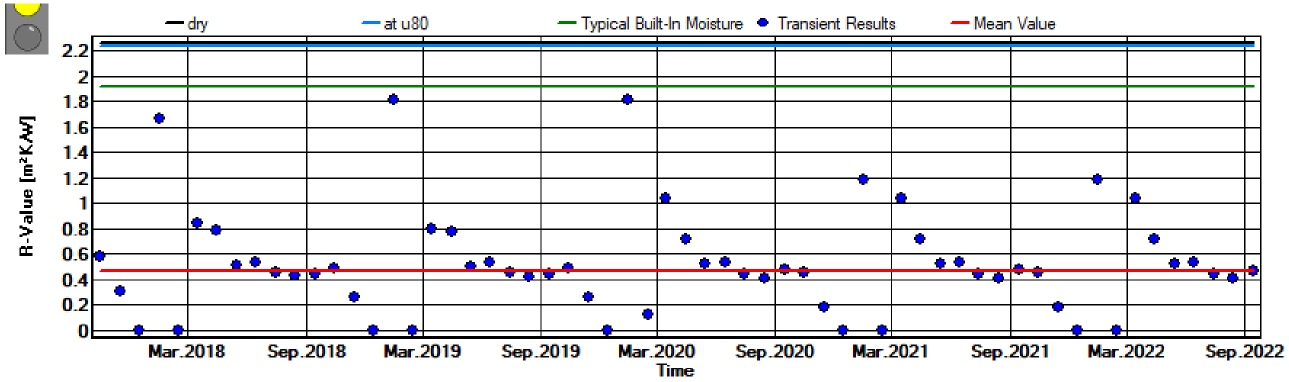
HYGROTHERMAL ASSESSMENT



Water Content [kg/m³]

Layer/Material	Start	End	Min.	Max.
Solid Brick, historical	4.50	16.85	3.72	32.15
Air Layer 30 mm; without additional moisture capa	0.01	0.01	0.01	0.01
*PIR	1.79	1.05	0.67	1.79
*Gypsum Board	6.19	4.14	3.69	6.19

a)



b)

b) Annualised Wet R – value Variation– Inhabit.

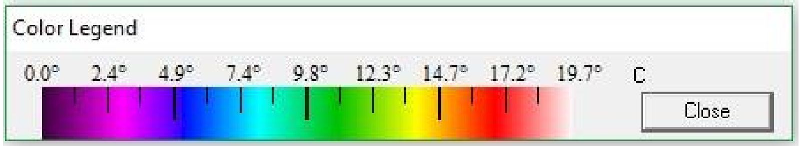
a) Walls- north annex – Interior surface temperature (ºC) relative humidity (%) (above) And water content (kg/m3) – Inhabit.

LOVELL CHEN

ANALYSIS

a)

b)

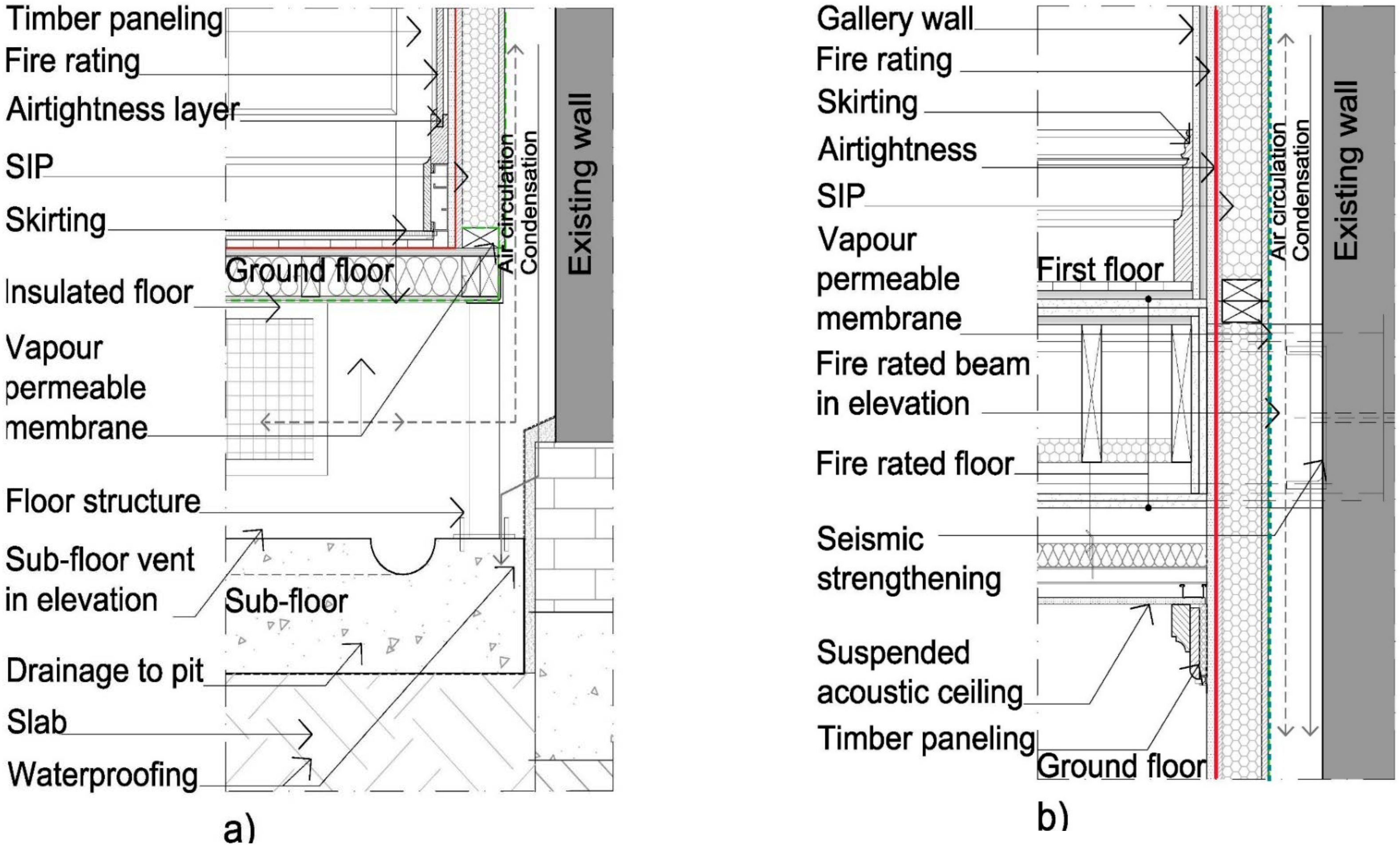


a) THERM Isotherm Result;
b) Colour Infrared Result;

Library roof – THERM Isotherm and Colour Infrared Result - Inhabit

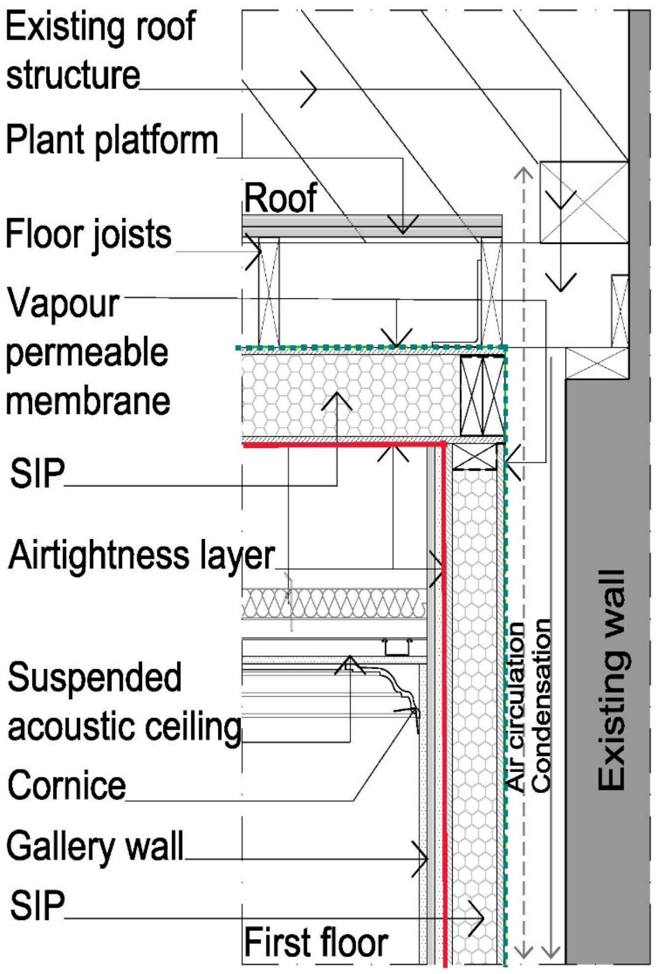
LOVELL CHEN

DOCUMENTATION



Typical wall connection details in north wing. a) Sub-floor and wall junction; b) First floor and wall junction; c) Roof and wall junction.

DOCUMENTATION



c)

Typical wall connection details in north wing. c) Roof and wall junction.

AIRTIGHTNESS

EnerPhit Criteria for airtightness is n_{50} 1.00 1/h.

Three interim, airtightness pressurization tests were conducted for the north wing to date achieving n_{50} 1.11 1/h and n_{50} 1.04 1/h and n_{50} 2.03 1/h, respectively. One test was conducted for the library achieving n_{50} 3.73 1/h.

The interim reports have identified several defects related to the airtightness of penetrations of the services as well as defects related to sealing of the new structures around the existing timber trusses. Defects rectification related to the airtightness including the final pressurisation test are scheduled for November 2019.

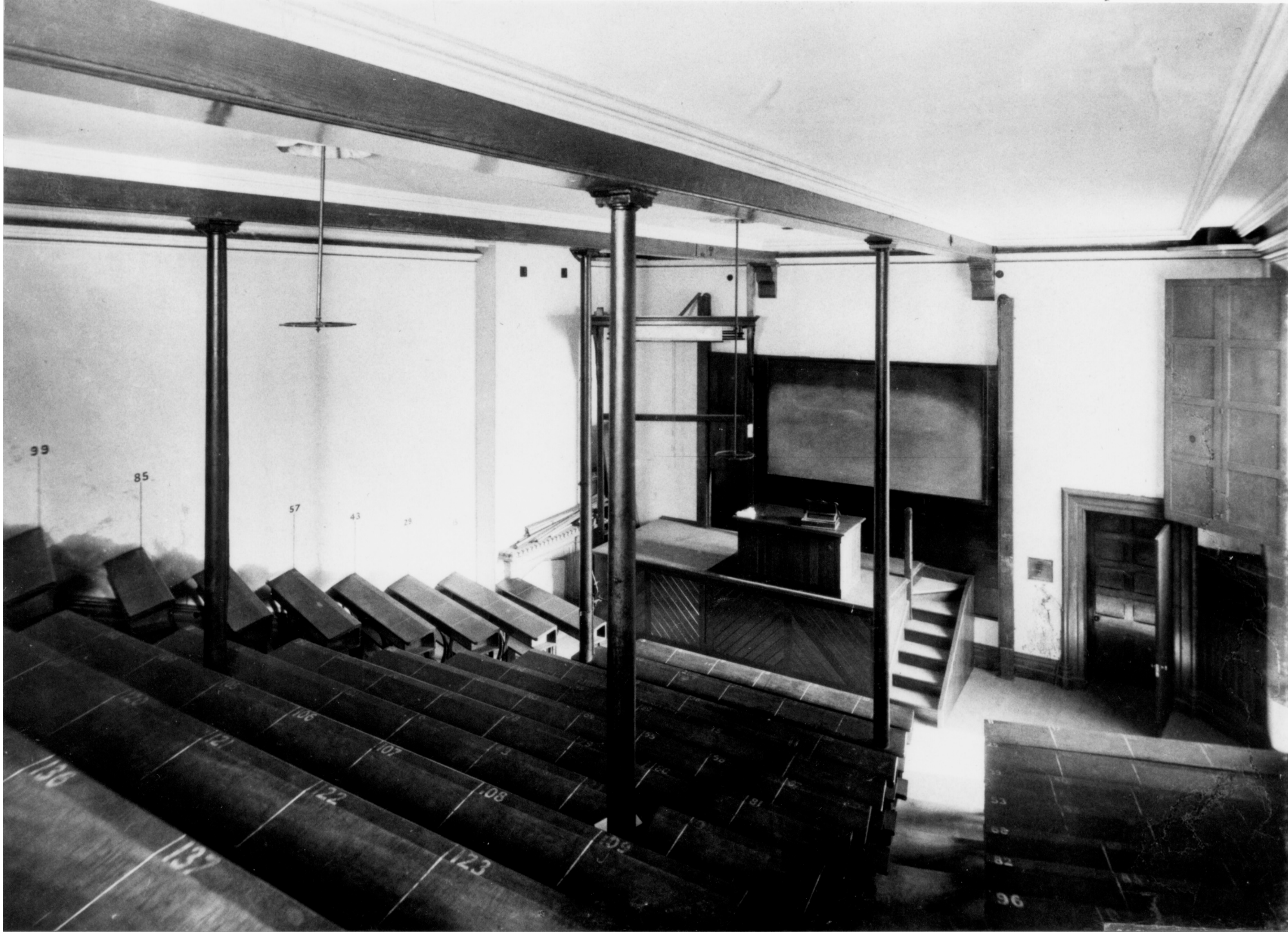
AIRTIGHTNESS APPLICATION

LOVELL CHEN

AIRTIGHTNESS APPLICATION

LOVELL CHEN

HISTORY

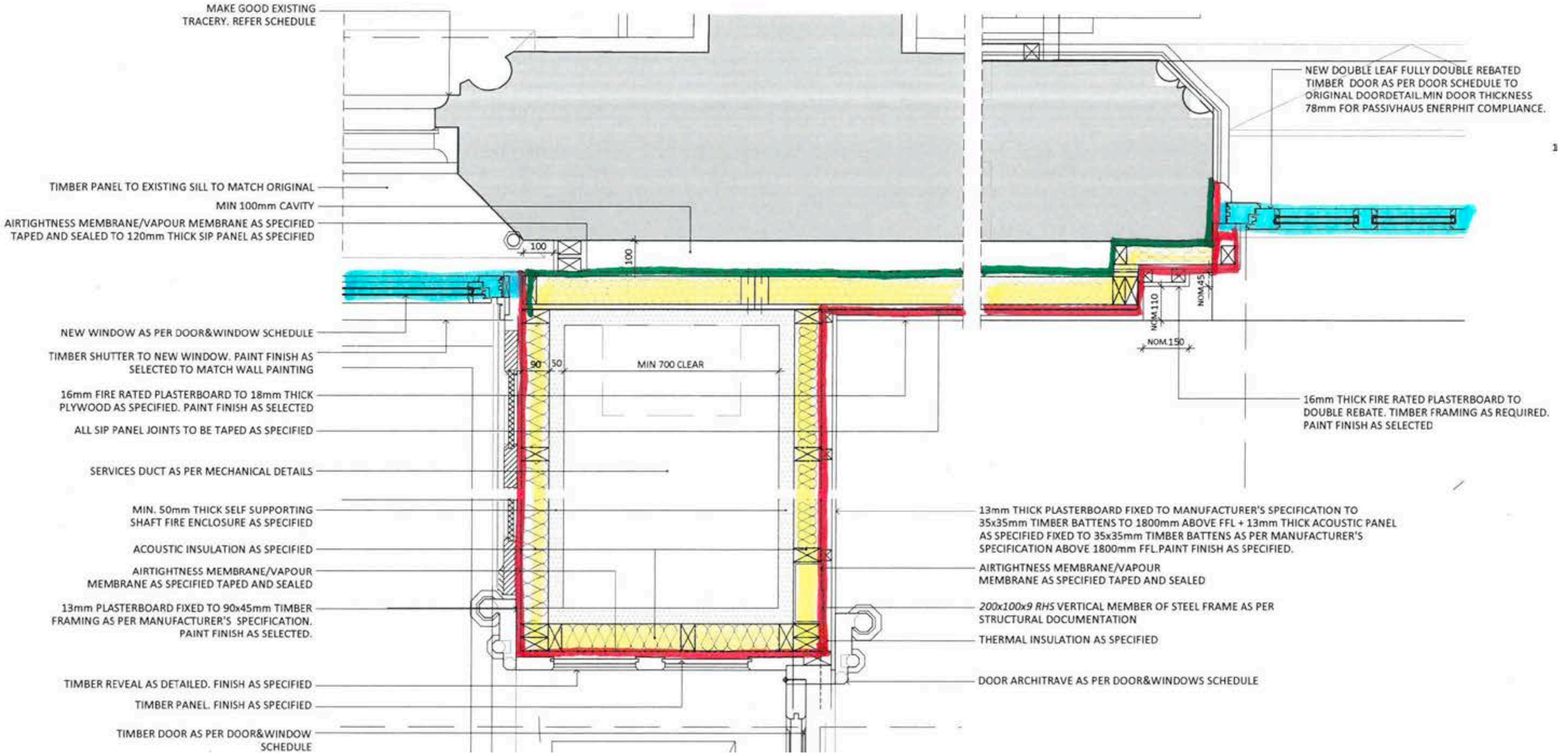


Amphitheatre
Source:
Tibbits, G.; Wark, G

CONDITION

VISION

DOCUMENTATION



WALL AND REISER DETAIL

LOVELL CHEN

CONSTRUCTION

OUTCOME

Exhibition
Source: Eve Wilson (photographer)

CONDITION

Source:
Hin Lim (photographer)

VISION

Treasury
Source: Unsigned Studio (formerly Squint Opera/ Studio Magnified - artist impression)

CONSTRUCTION

OUTCOME

Treasury
Source: Eve Wilson (photographer)

HISTORY

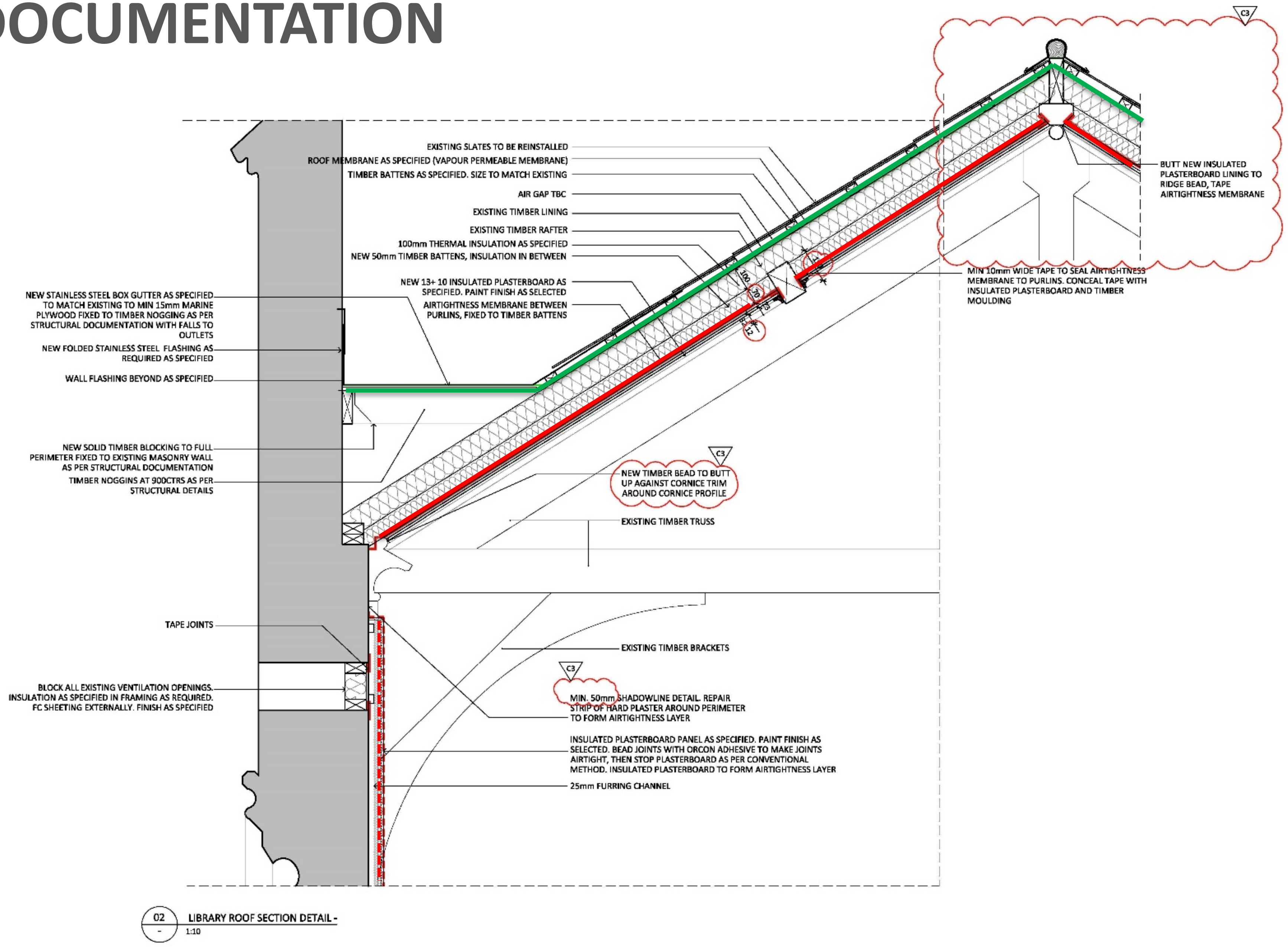
Central Library 1901
Source:
University of Melbourne Archives

CONDITION

VISION

Library
Source: Unsigned Studio (formerly Squint Opera/ Studio Magnified - artist impression)

DOCUMENTATION



Nominated material to form airtightness layer (i.e. plywood, render, insulated plasterboard)

Airtightness membrane, all joint taped

Vapour permeable membrane, all joints taped

LOVELL CHEN

OUTCOME

Library
Source: Eve Wilson (photographer)

NECESSARY COMPONENTS

Client:

- Informed and committed client

Design and Documentation:

- Right Consultancy Team - All disciplines without exception.
- WUFI modelling is a **must**
- Cost plan
- Building Surveyor
- Sufficient time for Consultation
- Sufficient time for Documentation
- Suppliers
- Detailed Specifications - All disciplines without exception
- Outline contractor’s obligations in detail
- Risk management plan
- Project Manager
- Superintendent

Procurement:

- Right contract
- Right contractor

Construction:

- Shop drawings
- Nominate Air-tightness champion and maintain continuity on the project.
- Training and Workshops for all trades and teams.
- Transfer of learning
- Regular site visits
- Dealing with latent conditions
- Early defects detection and rectification
- Photographic record

Occupation of the building:

- Occupant training
- Monitoring

LOVELL CHEN

PROJECT TEAM

Architect: Lovell Chen Architects

Structure: Irwinconsult

Passive Haus Consultant: Nick Mulvaney for Umow Lai

Building fabric analysis: Darren O'Dea for Inhabit

Services: Umow Lai

Building Surveyor: du Chateau Chun

Cost consultant: Slattery Australia

Superintendent: Aurecon

Contractor: Kane Constructions

REFERENCES

[Tibbits/Wark 1993]	Tibbits, G.; Wark, G.: *Old Quadrangle and North Extension Conservation Analysis and Policy*, September 1993; 1-19, 55-59.
[Lovell Chen 2015]	Lovell Chen: *Old Quadrangle Redevelopment Master Plan*, Melbourne, 2015.
[Lovell Chen 2017]	Lovell Chen: *Old Quad Redevelopment, Proposed Plans,* Melbourne, *2017*
[Umow Lai 2016]	Umow Lai:*The University of Melbourne Old Quadrangle Redevelopment Engineering Services Schematic MUOM0268/R001 Rev. 1 18/07/2016 Design Report*, Melbourne, 18 August 2016.
[Umow Lai 2017]	Umow Lai: *M.UOM 0268_Old Quad_EnerPHit PHPP_V9.3a_EN_Rev 2,* Melbourne, 10 May 2017.
[Inhabit 2018]	O'Dea, D.; Inhabit: *Old Quad Redevelopment Review of Construction Documentation*, Melbourne, January 2018.
[VHD 2017]	Victorian Heritage Database: Report*, 'Law School Building and Old Quadrangle',* 24 January 2017, unnumbered.

CONCLUSION

The building was completed and officially opened on 2 May 2019 with defects yet to be rectified in the Defects Liability Period finishing in April 2020.

The complexity of the project has been managed by a unified and coherent strategy for all aspects of the project from inception to completion. The project brings the building to a contemporary level of compliance and at the same time achieves best practice results in conservation, contemporary architecture and sustainability.

LOVELL CHEN