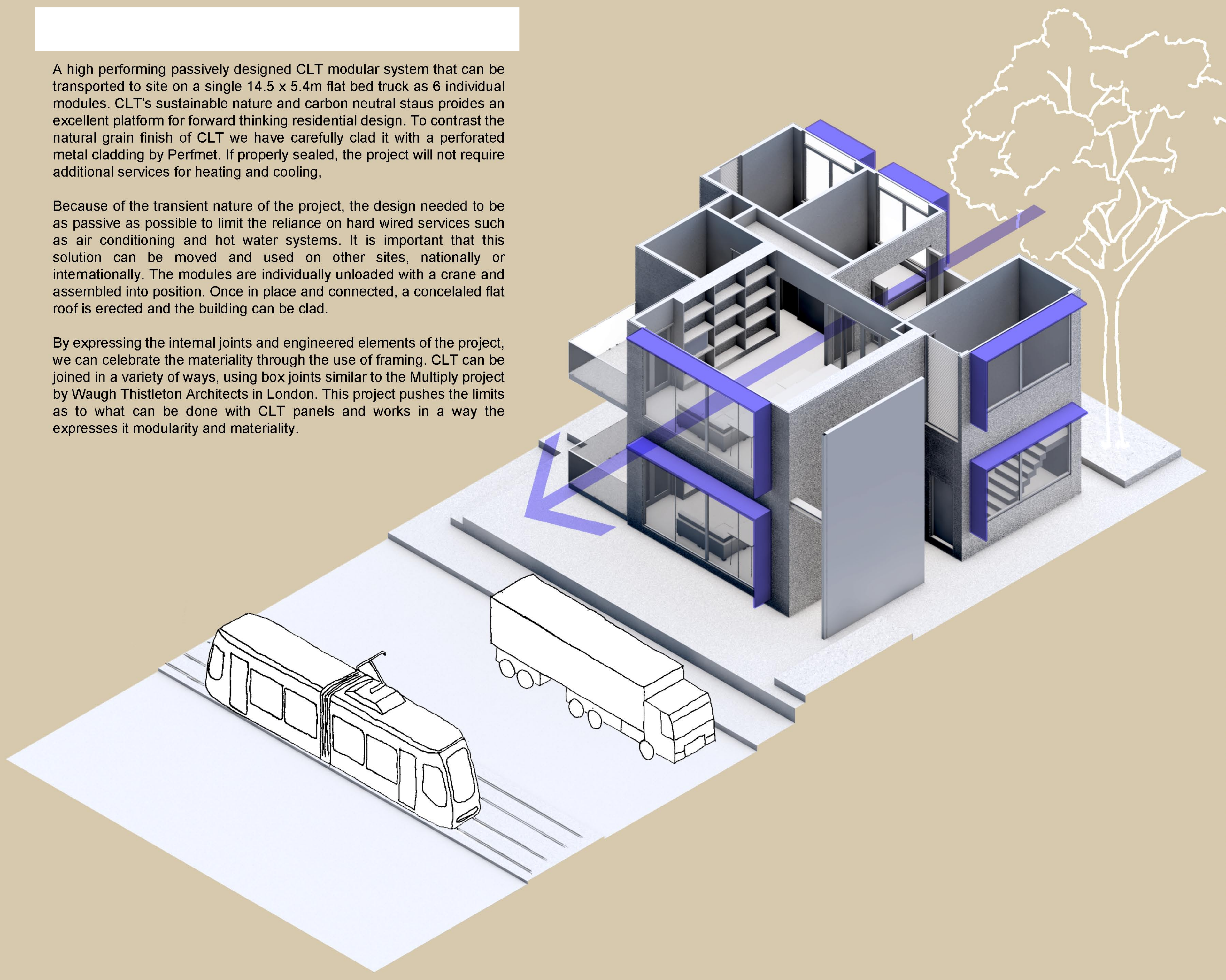
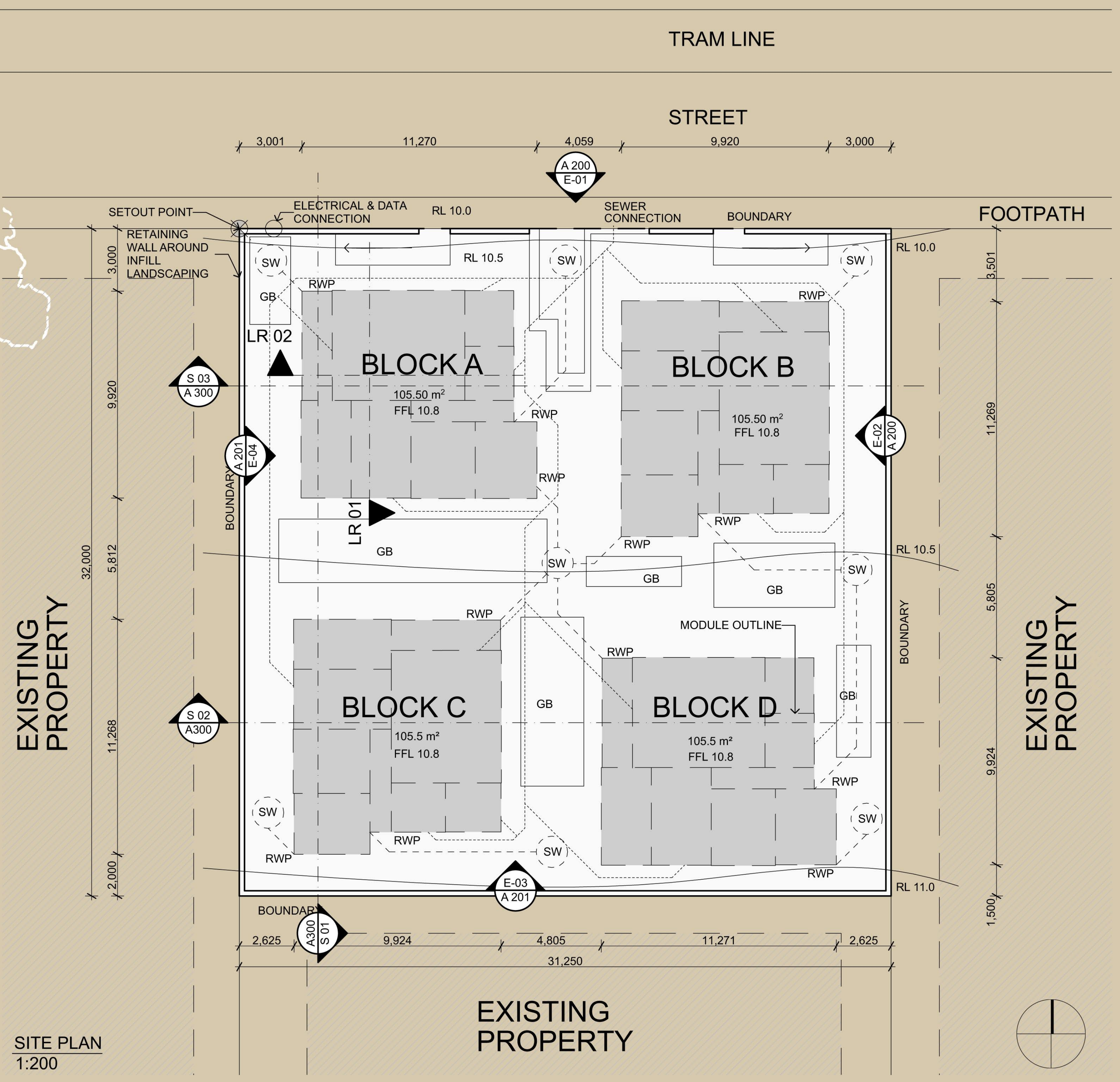
CROSS LAMINATED TOWNHOUSE

A high performing passively designed CLT modular system that can be transported to site on a single 14.5 x 5.4m flat bed truck as 6 individual modules. CLT's sustainable nature and carbon neutral staus proides an excellent platform for forward thinking residential design. To contrast the natural grain finish of CLT we have carefully clad it with a perforated metal cladding by Perfmet. If properly sealed, the project will not require additional services for heating and cooling,

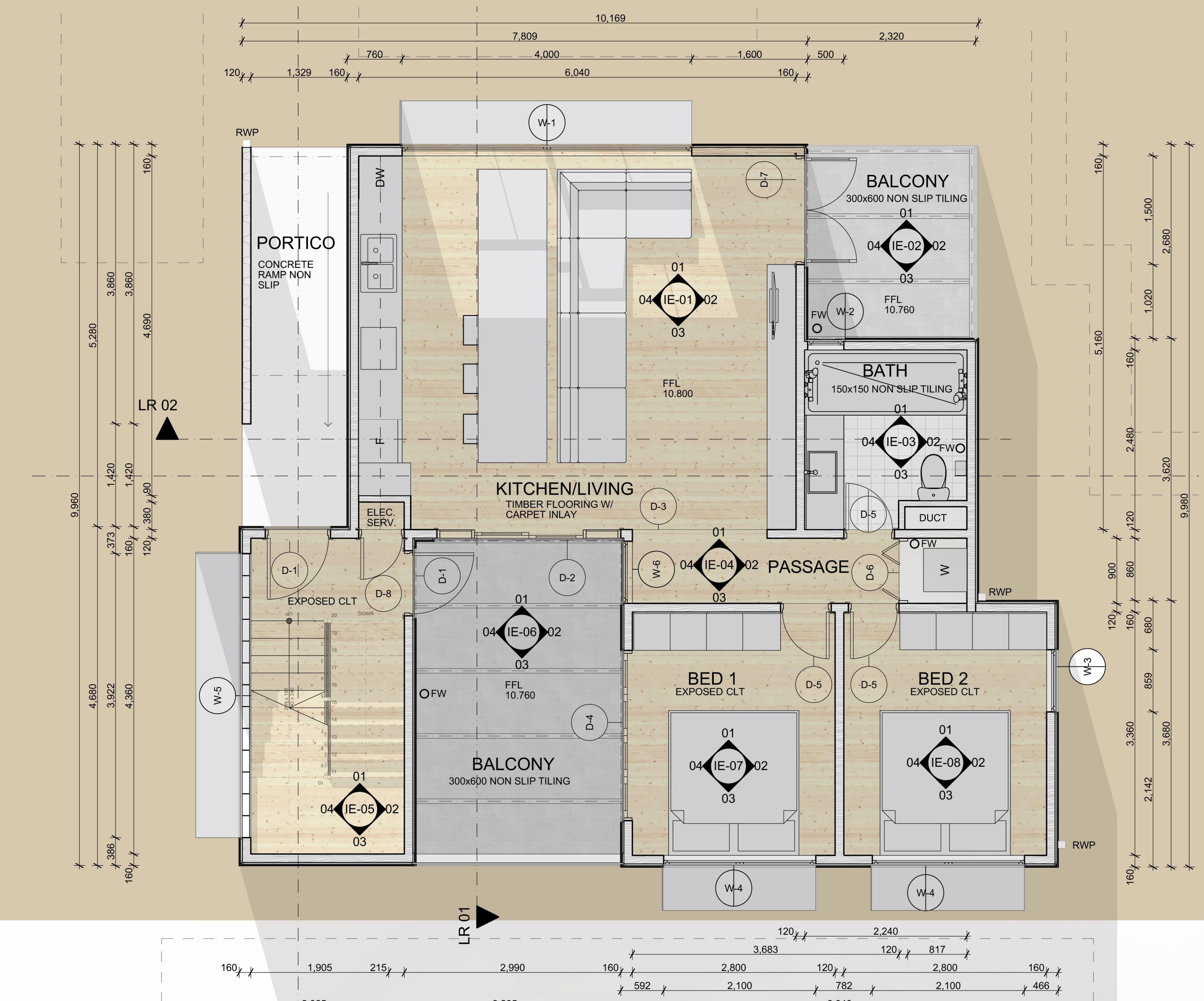
Because of the transient nature of the project, the design needed to be as passive as possible to limit the reliance on hard wired services such as air conditioning and hot water systems. It is important that this solution can be moved and used on other sites, nationally or internationally. The modules are individually unloaded with a crane and assembled into position. Once in place and connected, a concelaled flat roof is erected and the building can be clad.

By expressing the internal joints and engineered elements of the project, we can celebrate the materiality through the use of framing. CLT can be joined in a variety of ways, using box joints similar to the Multiply project by Waugh Thistleton Architects in London. This project pushes the limits as to what can be done with CLT panels and works in a way the expresses it modularity and materiality.

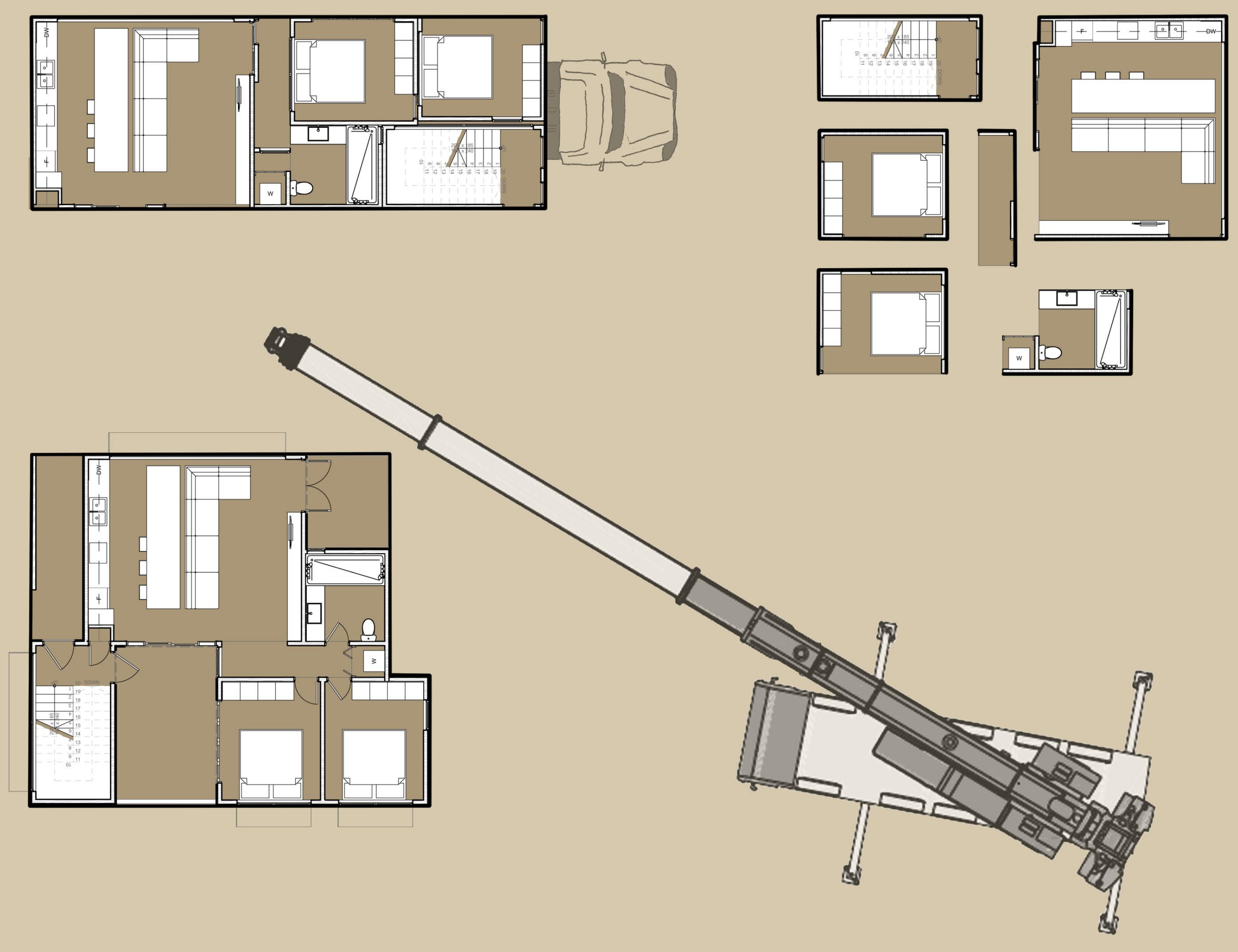




SITE PLAN
1:200

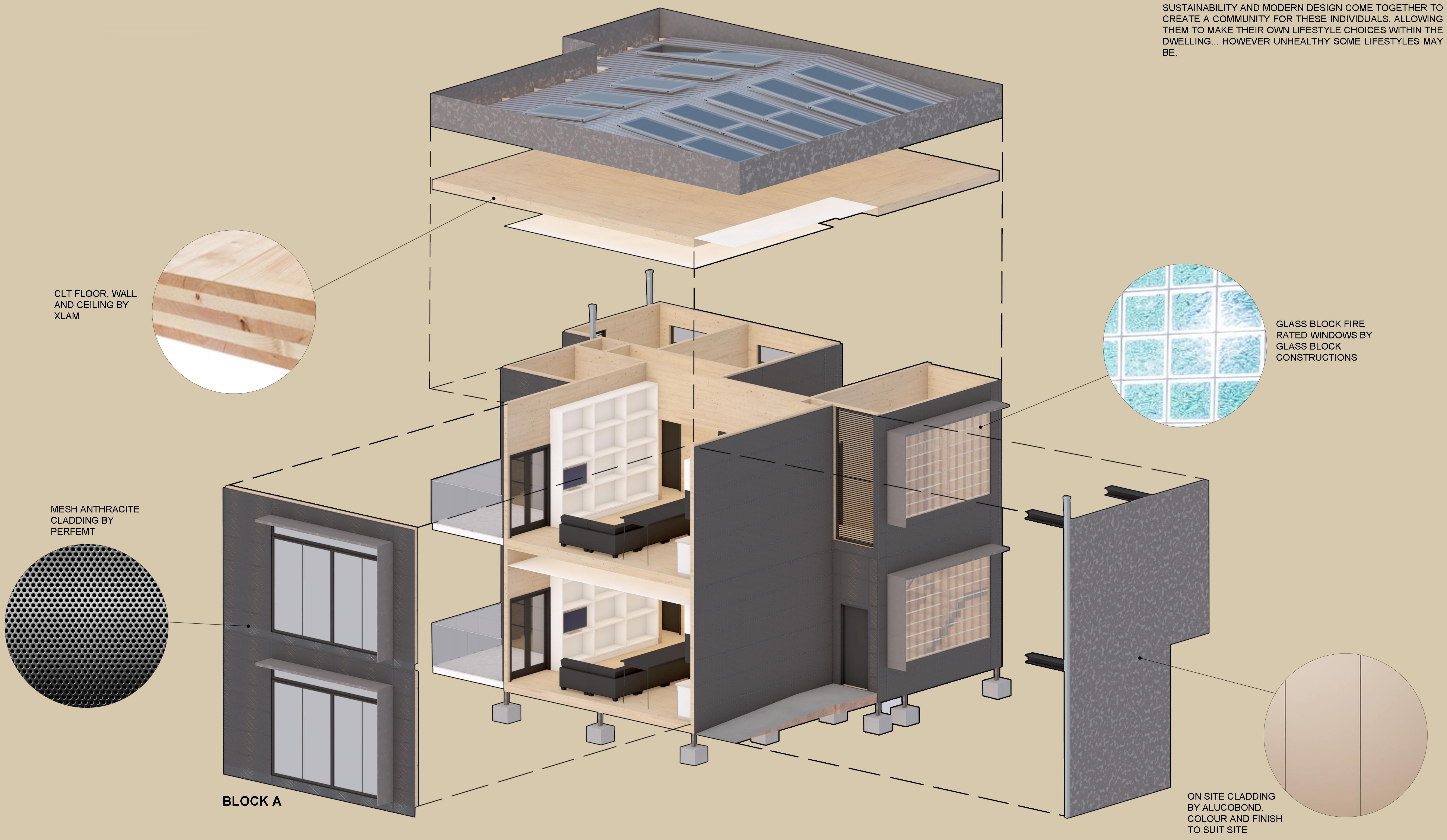


FLOOR PLAN
1:50



CLT MODULES TRANSPORTED TO SITE ON ONE TRUCK. CLADDING, SHADDING, BALCONIES AND ROOF TO SITE SPECIFICATIONS.

THE TEMPORARY NATURE OF THE PROJECT IS PERFECT FOR THE LIFESTYLES OF YOUNG INNER CITY PROFESSIONALS. SUSTAINABILITY AND MODERN DESIGN COME TOGETHER TO CREATE A COMMUNITY FOR THESE INDIVIDUALS. ALLOWING THEM TO MAKE THEIR OWN LIFESTYLE CHOICES WITHIN THE DWELLING... HOWEVER UNHEALTHY SOME LIFESTYLES MAY BE.



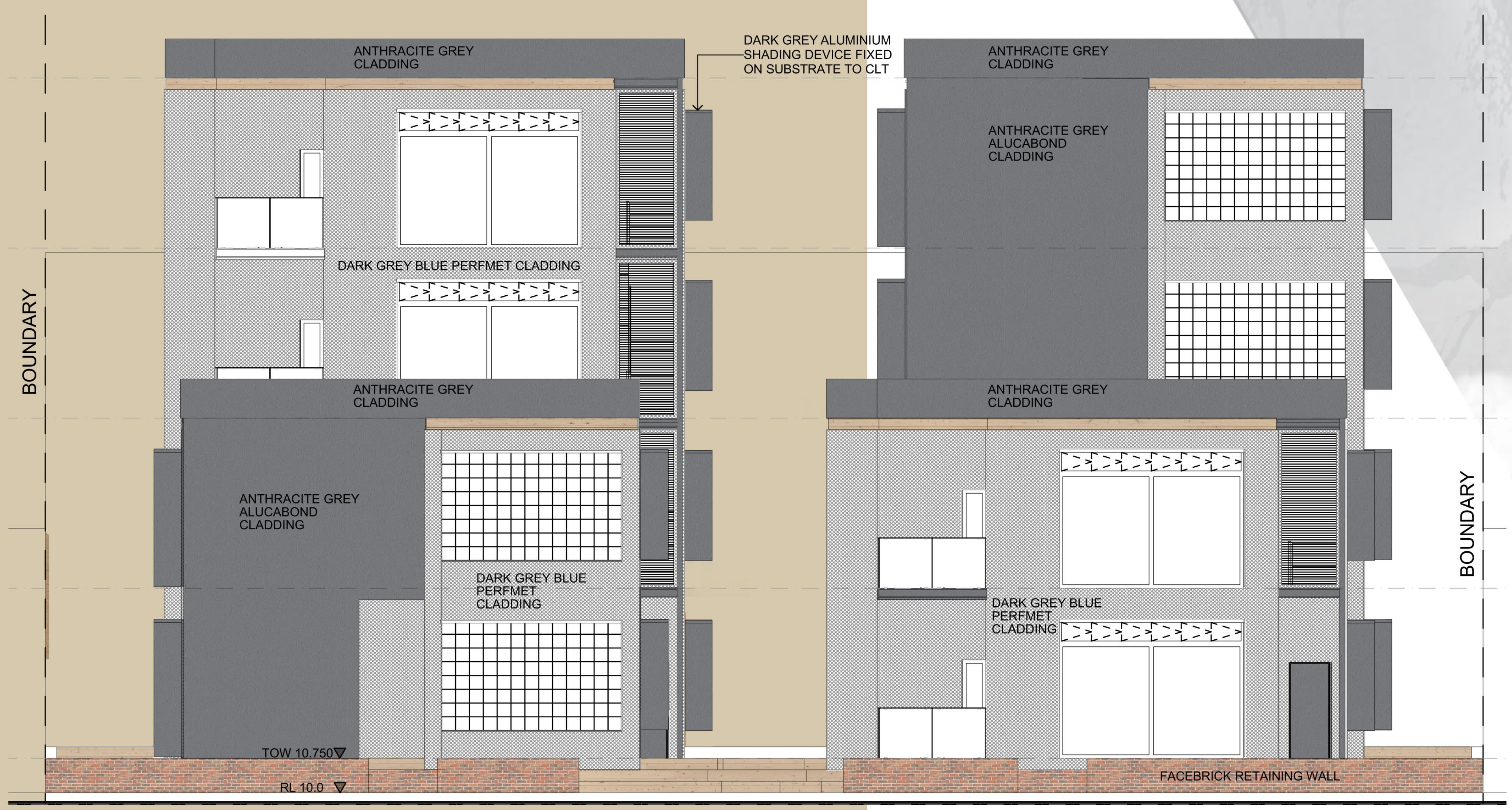
CLT FLOOR, WALL AND CEILING BY XLAM

GLASS BLOCK FIRE RATED WINDOWS BY GLASS BLOCK CONSTRUCTIONS

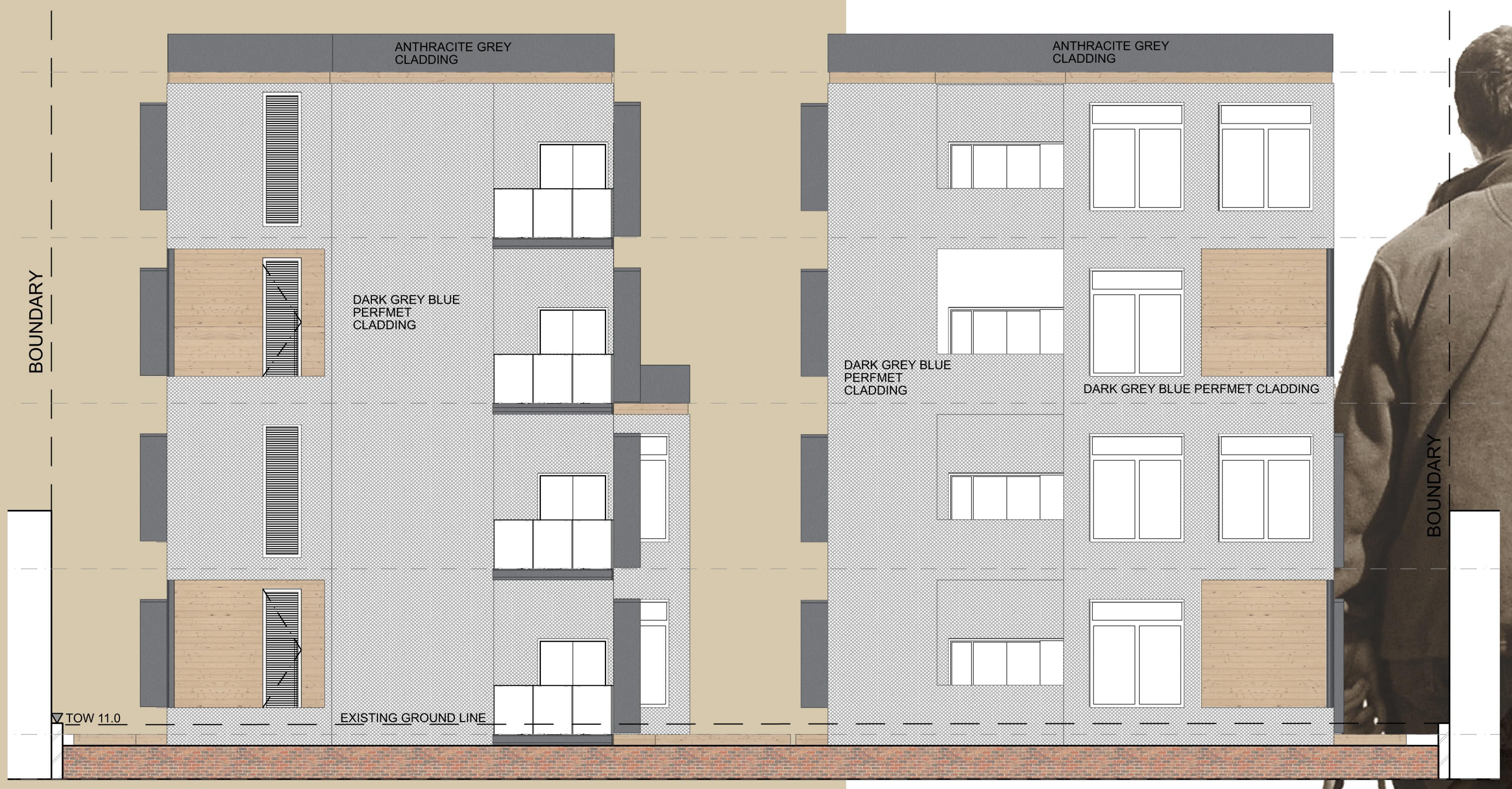
MESH ANTHRACITE CLADDING BY PERFEMT

BLOCK A

ON SITE CLADDING BY ALUCOBOND. COLOUR AND FINISH TO SUIT SITE



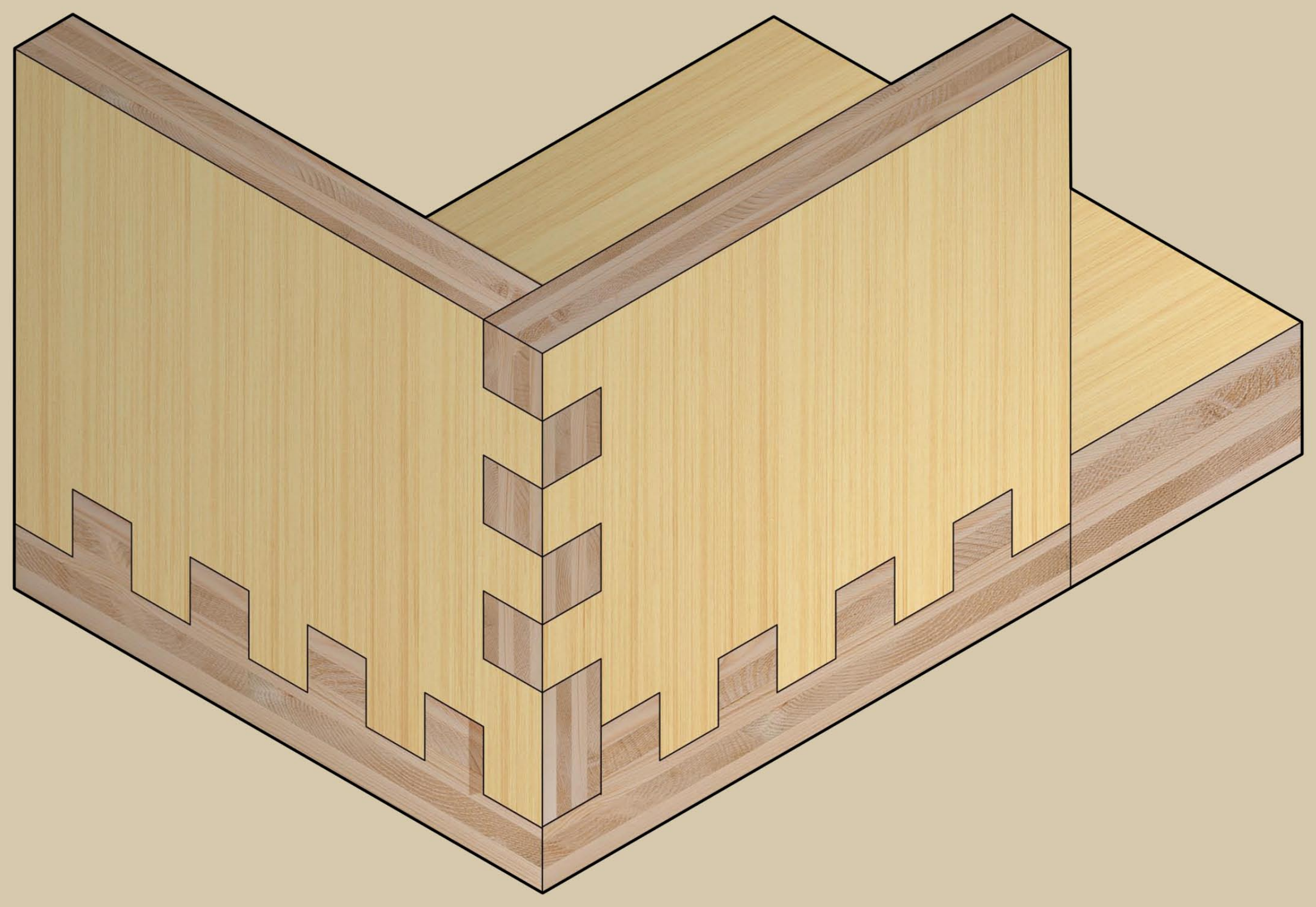
NORTH ELEVATION
1:100



SOUTH ELEVATION
1:100

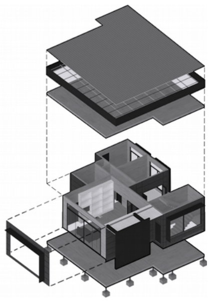
EAST ELEVATION
1:100

WEST ELEVATION
1:100



BOX JOINT FLOOR TO
WALL CONNECTION
NOT APPROVED BY
ENGINEERS

EXECUTIVE SUMMARY
Cross Laminated Townhouse
MELBOURNE



CONCEPT

My approach to the Fleetwood Challenge Cup has been to design a high performing CLT modular system that could be transported to site on a single 14.5 x 5.4m flat bed truck as 6 individual modules. CLT is an excellent sustainable product, that because of its properties has a carbon neutral status. CLT has a good base R value and the ratings of CLT panels used throughout the project are as follows; 85mm CLT R = 0.708 , 125mm CLT R = 1.04 and 245mm CLT R = 2.041. Although the R value is fairly good, insulation is still required externally and therefore a cladding has to be used. As a contrast to the timber I have opted for a perforated metal cladding by Perfmet. The CLT combined with an insulated cladding creates the opportunity for high building performance when combined with other technologies. If properly sealed it is likely the project will not require additional services for heating and cooling.

Because of the transient nature of the building, I wanted to make the design as passive as possible to limit the reliance on hard wired services such as air conditioning and hot water systems. It is important that this solution can be moved and used on other sites, nationally or internationally. The modules are individually unloaded with a crane and assembled into position on top of in situ footings. Once in place and connected, a concealed flat roof is erected and the building can be clad.

The aim is to celebrate and promote CLT as a sustainable product through the framing of connections and finish. CLT can be joined in a variety of ways, using box joints similar to the Multiply project by Waugh Thistleton Architects in London. This project pushes the limits as to what can be done with CLT panels and works in a way that expresses its modularity.

ENGINEERING CONSULTATION

As the project has advanced I have attempted to keep my engineering team involved with all my design decisions and progress so that my projects intent isn't affected by engineering issues. While I was able to convince my team that CLT is a great option for modular prefabricated design, I wasn't able to bring them round on box joint connections or the 'One Truck, One Apartment' concept. The solution was instead to split the apartment into two components and transport them with two trucks, and then connecting the modules with plates and screws. This isn't very groovy, and for the sake of my concept, I have ignored these recommendations. I have however used the engineering report as a way to size components such as wall and floor slabs.

Although the experience has been valuable, I don't think my engineering team and I shared the same goals for the project. In reality, we would need to engage engineers that were either specialised in CLT construction or had more drive in working with the project instead of against it.

ENGINEERING CALCULATIONS

Please see engineering report attached with submission.

CONSTRUCTION PROGRAMME

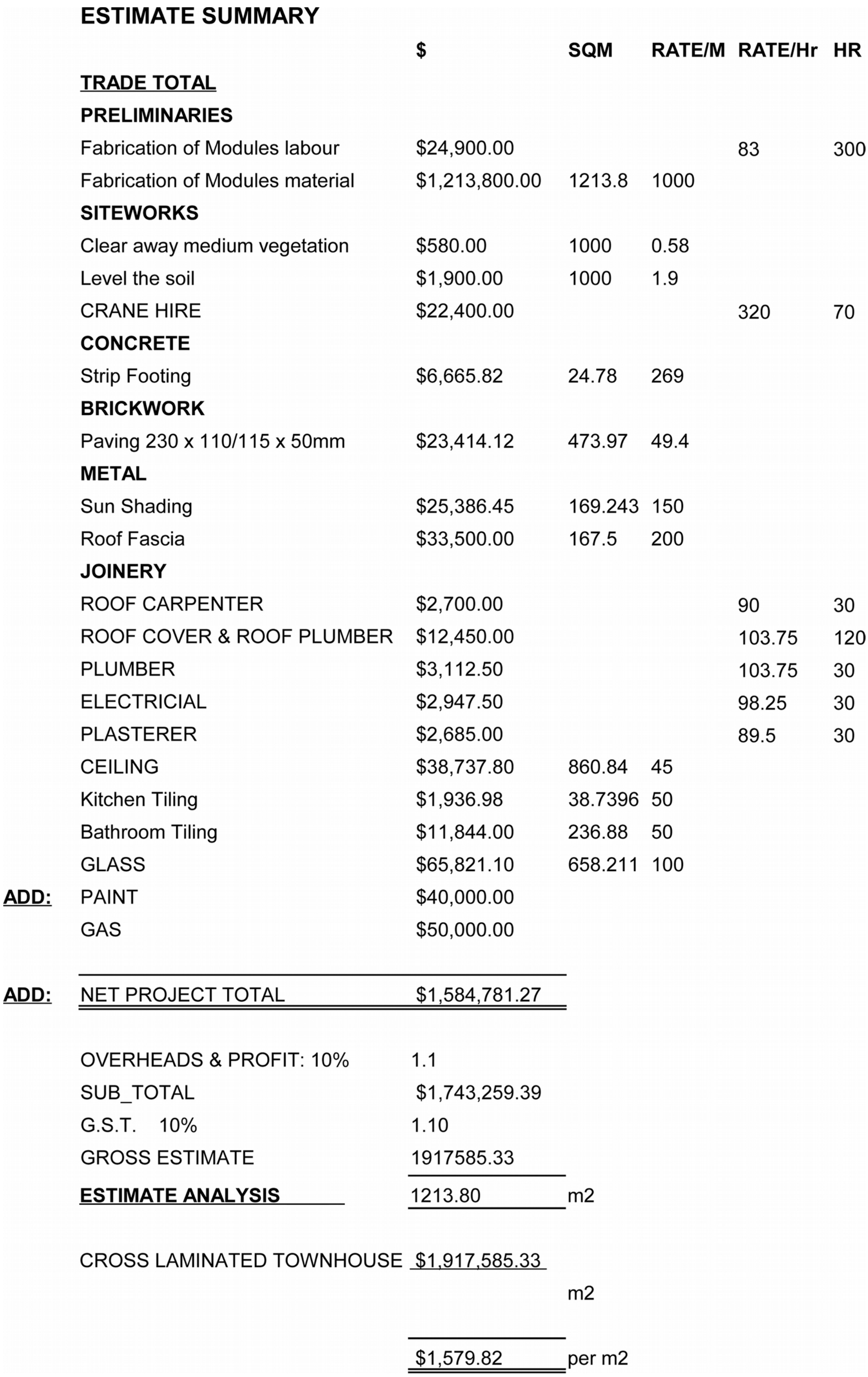
Before the modules can be erected, the site must cleared and levelled, this could potentially take 3 weeks of filling, during this time, footings for the module will be cast and embedded with posts. The 6 individual modules are craned from the truck directly onto the footings. All stories should be put into place before the next stage of construction.

Once the modules are in place, the roof can be constructed and then clad with a contextually appropriate material. Insulation and water proofing needs to be appropriately installed and designed for a Melbourne location. Additional elements to be installed are the photovoltaic panels, balconies, porticos and services that cannot be accommodated within the modules.

Constructing these elements on-site is a conscious design decision, as these elements were identified as the most likely to change under differing site conditions. For instance, the angle of the roofs fall will impact the orientation of the solar panels, which should face north. It is important that these aspects are option-able so that it can work on multiple sites outside of Melbourne.

BUDGET EVALUATIONS

Below is a preliminary costing for the fabrication and on-site construction of the Cross Laminated Townhouses.



ESTIMATE SUMMARY

		$	SQM	RATE/M	RATE/Hr	HR
	TRADE TOTAL					
	PRELIMINARIES					
	Fabrication of Modules labour	$24,900.00			83	300
	Fabrication of Modules material	$1,213,800.00	1213.8	1000		
	SITEWORKS					
	Clear away medium vegetation	$580.00	1000	0.58		
	Level the soil	$1,900.00	1000	1.9		
	CRANE HIRE	$22,400.00			320	70
	CONCRETE					
	Strip Footing	$6,665.82	24.78	269		
	BRICKWORK					
	Paving 230 x 110/115 x 50mm	$23,414.12	473.97	49.4		
	METAL					
	Sun Shading	$25,386.45	169.243	150		
	Roof Fascia	$33,500.00	167.5	200		
	JOINERY					
	ROOF CARPENTER	$2,700.00			90	30
	ROOF COVER & ROOF PLUMBER	$12,450.00			103.75	120
	PLUMBER	$3,112.50			103.75	30
	ELECTRICIAL	$2,947.50			98.25	30
	PLASTERER	$2,685.00			89.5	30
	CEILING	$38,737.80	860.84	45		
	Kitchen Tiling	$1,936.98	38.7396	50		
	Bathroom Tiling	$11,844.00	236.88	50		
	GLASS	$65,821.10	658.211	100		
ADD:	PAINT	$40,000.00				
	GAS	$50,000.00				
ADD:	NET PROJECT TOTAL	$1,584,781.27				
	OVERHEADS & PROFIT: 10%	1.1				
	SUB_TOTAL	$1,743,259.39				
	G.S.T. 10%	1.10				
	GROSS ESTIMATE	1917585.33				
	ESTIMATE ANALYSIS	1213.80	m2			
	CROSS LAMINATED TOWNHOUSE	$1,917,585.33				
			m2			
		$1,579.82	per m2			

Our preliminary cost works out to be $159 799 per apartment or $1579.82 per m2. Using Realestateview.com as a guide, we can assume the average sale value of each apartment is roughly $550 000, which is a 340% profit mark-up. It is unlikely that these margins could be achieved in a research and development project or in large scale production. With

Assignment 2 we will need to refine this and reassess our cost per square metre.

BUILDING STATUTORY AND REGULATORY COMPLIANCE

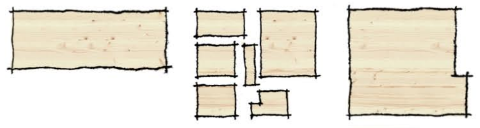
Defined as a type 2 - low rise walk up by the FMA Australia, our project is classified as a Class 2 building under the NCC and as such needs to meet the Australian Standards of this type of project. Because CLT is a relatively new product in the Australian market, it needs to be assessed by a relevant building surveyor before it can be approved for a building licence. This is applicable to the project as a whole, and building surveyors are often used for projects of this size. However it is important to have a sound grasp of the standards and technical specifications of the materials you are using to avoid design problems later on, such as spanning. As such I have designed the apartments so that the exit is less than 6m from the entrance of the apartment and less than 20m from any point in the apartment.

Because of the transient nature of the proposed buildings, there are difficulties in meeting disability access requirements, a ramp under the portico is erected on site to allow universal access to ground floor apartments. Lifts have also been avoided in the base model of the apartments because a lift pit would need to dug, making the site works more expensive and the future transportability difficult. If a lift was required in a future project over four storeys, the larger balcony of the two could be converted to a lift core and constructed on site.

The site we are using is rated RAC3-D by the City of Bayswater. The District Town Planning Scheme No 24 specifies a 3 metre setback from the primary street, there are no requirements for setbacks to the lot boundaries, however I have set our apartments back by 1500mm at the rear and 3000mm on the sides to allow for landscaping and green barriers to limit overlooking.

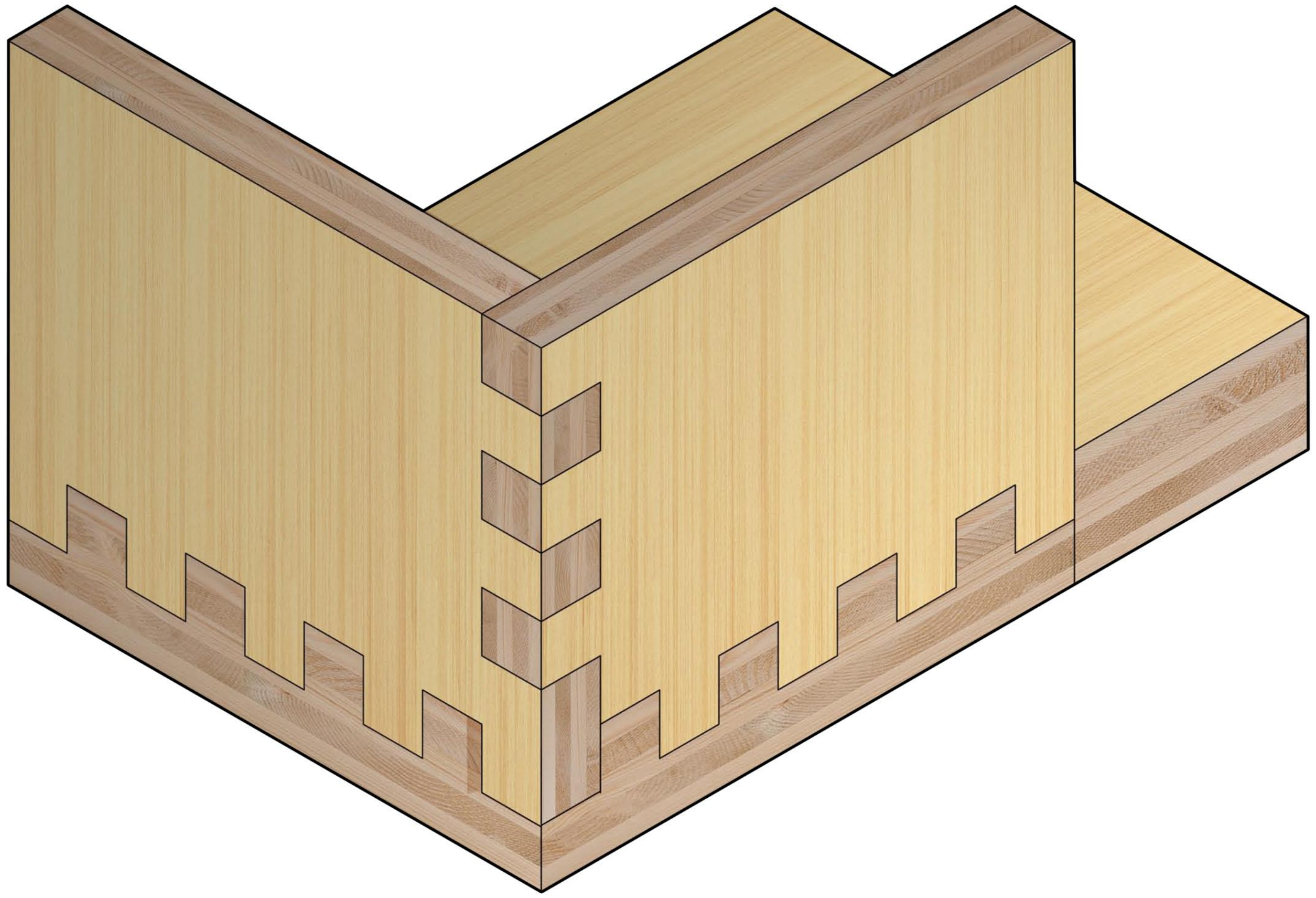
Please see attached a summary of relevant points from the NCC.

CROSS LAMINATED
TOWNHOUSE



FORWARD THINKING CITIES
FORWARD THINKING MATERIALS

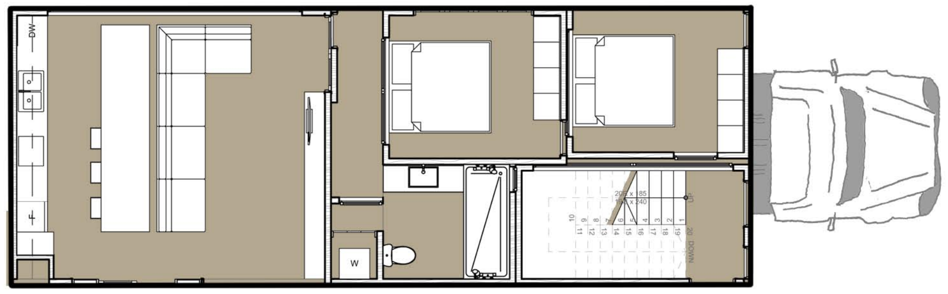
WHAT BETTER WAY TO TAKE ADVANTAGE OF MELBOURNES ‘COOL’ TAG BY
CHAMPIONING PREFABRICATION AND CLT. GROOVY!



MODERN TECH
ANCIENT CRAFT

DRAWING INSPIRATION FROM THE MultiPly PROJECT BY WAUGH THISTLETON ARCHITECTS, THE CLT IS CONNECTED THROUGH BOX JOINTS. IGNORING THE SENSIBLE BUT BORING SUGGESTIONS OF MY ENGINEERING TEAM, THE CLT IS CELEBRATED AND HONEST.

ONE TRUCK
ONE CRANE



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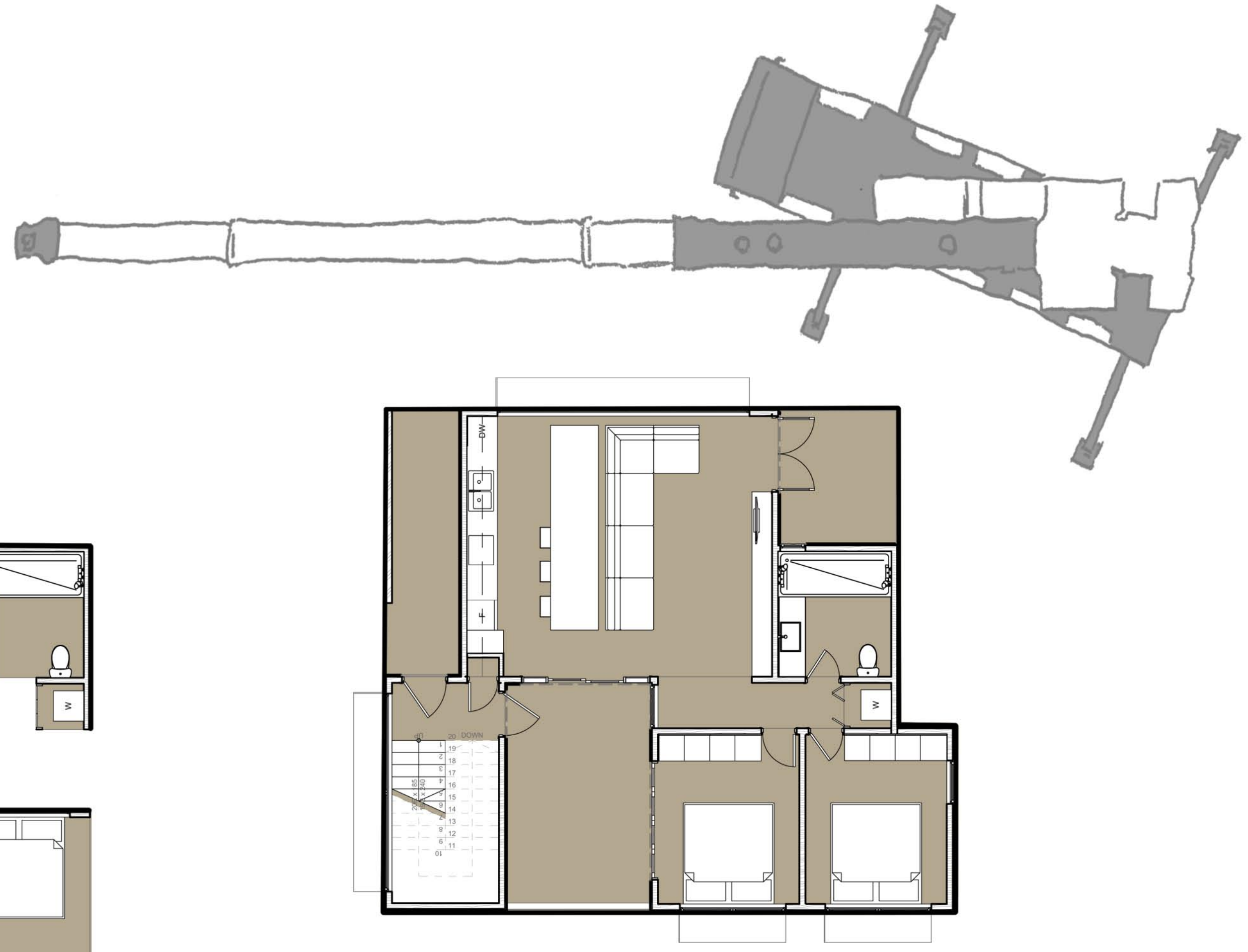

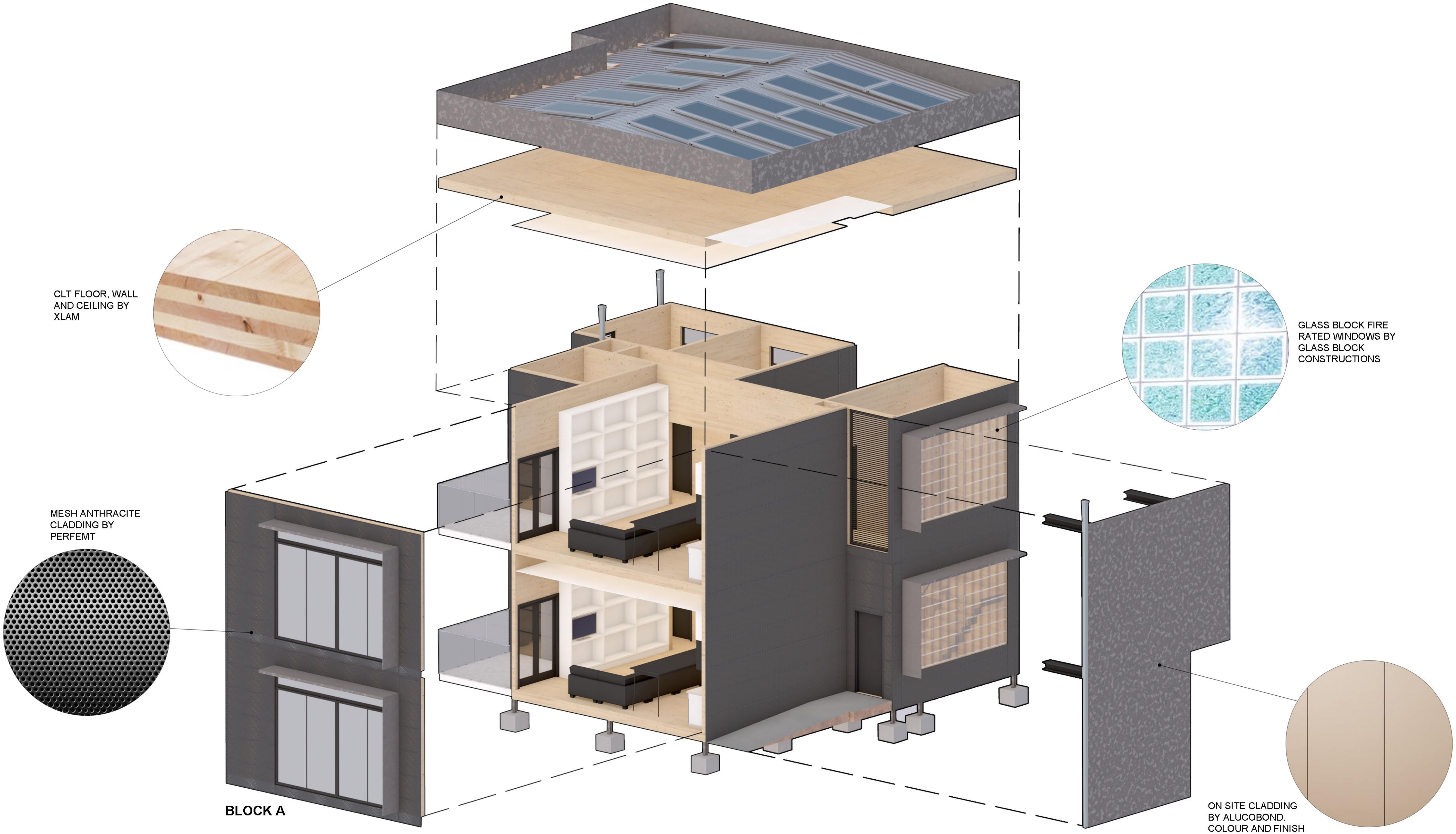
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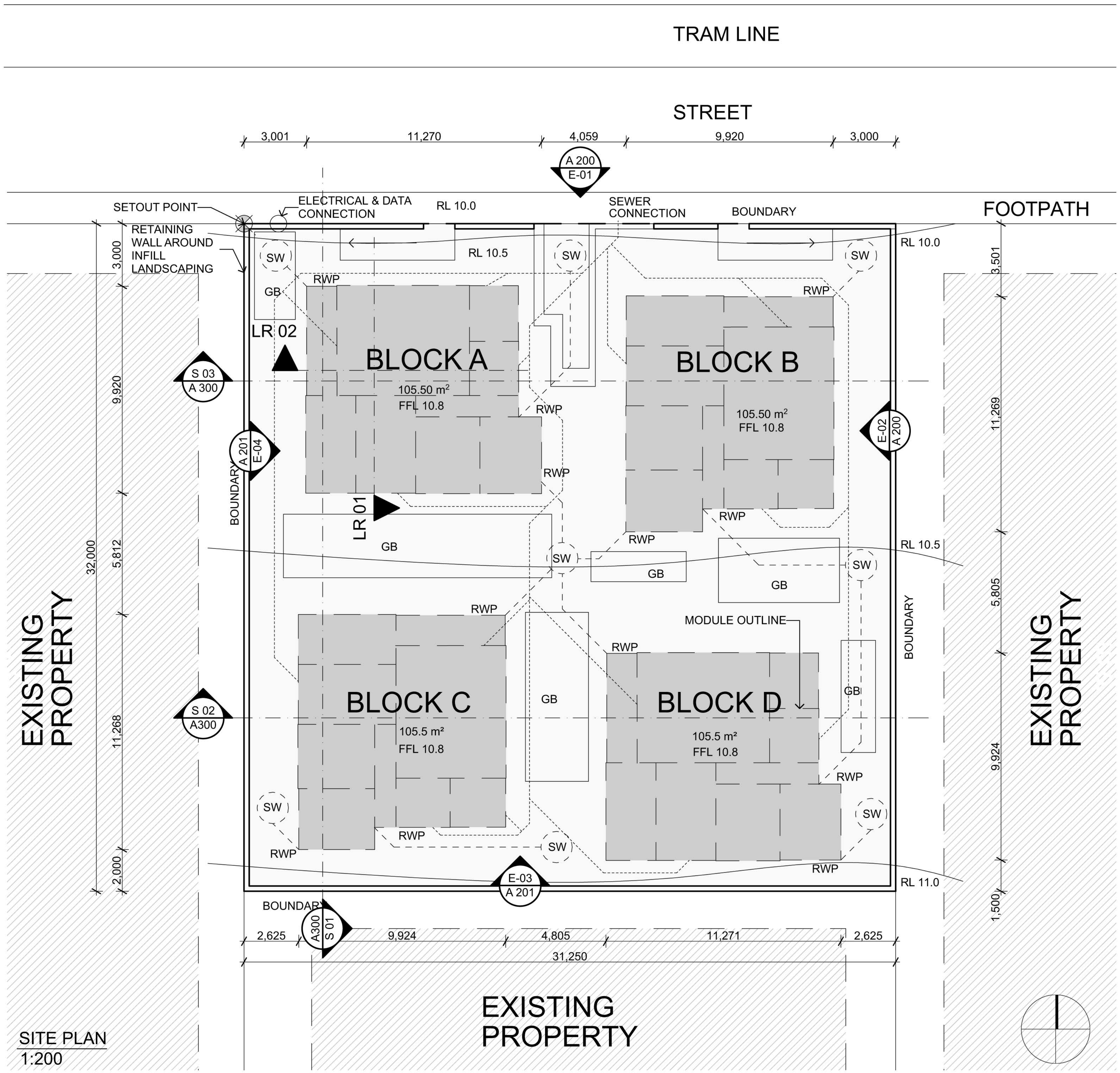
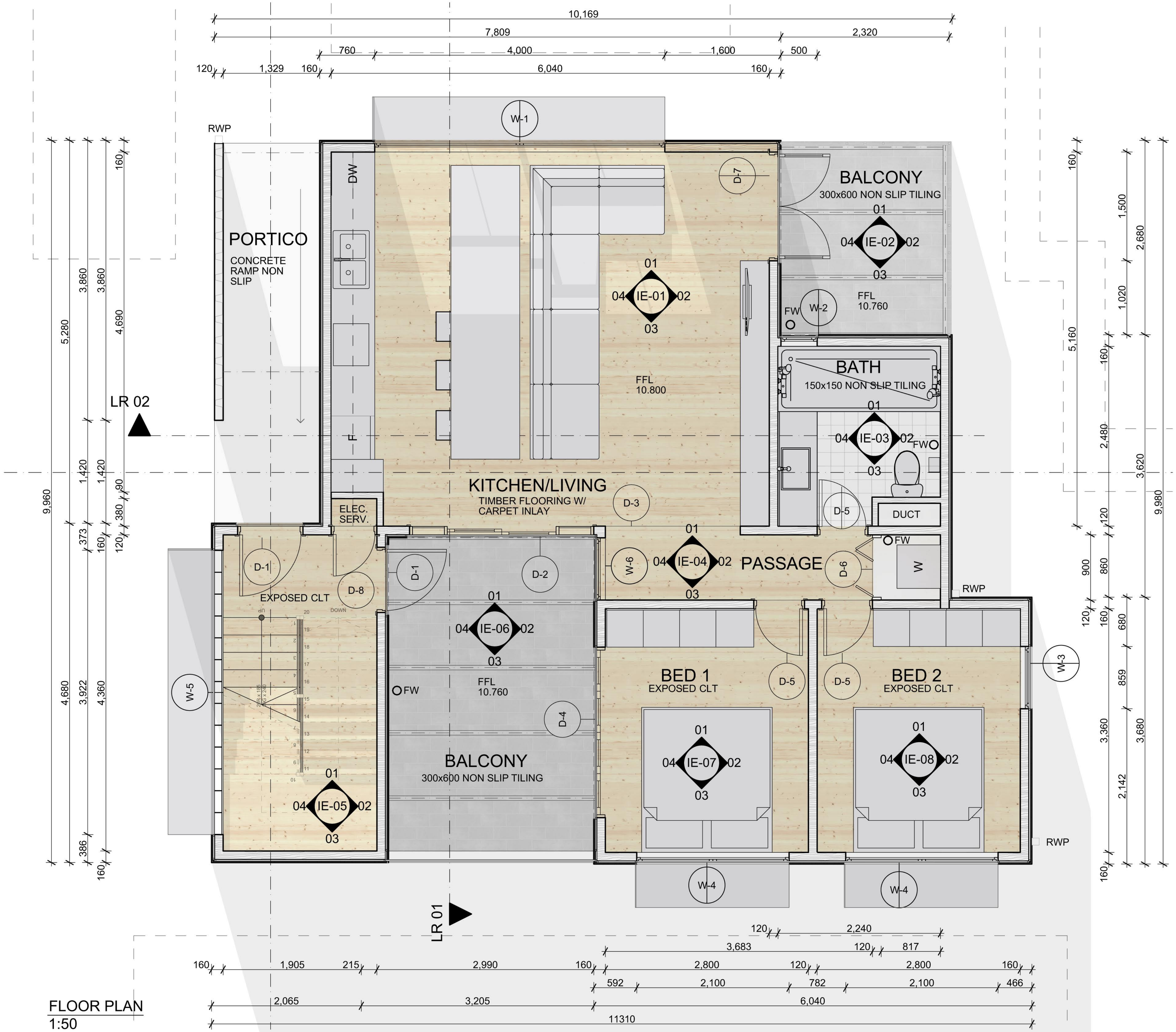
BLOCK A



SITE PLAN
1:200



FLOOR PLAN
1:50

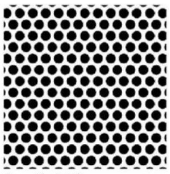
LIGHT AND BRIGHT

ICONIC BLUESTONE

SULTRY GLANCES

Material Specifications

Cross Laminated Townhouse

Code	Description	Manufacturer	Location	Image (Indicative)
CLT01	CLT 85mm, 125mm walls and 245mm floors	Xlam	Walls, floors, ceilings	
Perf01	Round Hole 60 Wall Cladding	Perfmet	External cladding for CLT walls	 Round hole 60
Alu01	Alucobond Anthracite Cladding for structures built on site	Alucobond	Portico and parapet wall	
GB01	Fire Rated Glass Brick	Glass Brick Constructions	Stairwell	
Shade01	Solar Shading over windows	Arcadia Group	Over all windows, except ones with vents	Custom
B01	Basin Mixer Black Wels 5*	Prima	Bathroom	
B02	Compact Twin Shower Black Wels 3 Star	Matrix	Bathroom	
B03	Fixed Shower Panel Satin Silver 1000x2000	Topaz	Bathroom	

B04	Murales Ice Rectified	Rondine	Bathroom floor and wall	
B05	Urbane Wall Face with Soft Close Seat	Caroma	Bathroom	
B06	1200 Polished mirror	Bevel Edge Mirror	Bathroom	
B07	Quad Square above counter ceramic basin no tap hole	Quad	Bathroom	
B08	900 Double Towel Rail – matte black	Delta	Bathroom	
B09	Toilet Roll Holder – matte black	Parker	Bathroom	
C01	Carpet Inlay	Carpet Call	Lounge	
K01	Kitchen Cabinetry	BAC Custom Cabinets & Kitchens	Kitchen	

L01	Aviation 152cm DC Fan in Brushed Nickel	Minka Aire	Lounge	
K02	Freestanding Cooktop – matte black	Glem	Kitchen	
K03	Freestanding Dishwasher – matte black	Glem	Kitchen	
K04	Top Mount Inverter Fridge	Mistubishi	Kitchen	
K05	Integrated Rangehood	Electrolux	Kitchen	
K06	Double Bowl Sink	Blanco Subline	Kitchen	
K07	Barn Metal Shade	Manor	Kitchen	
L01	GU10 Dish Tilt Downlight Frame	Podean	All throughout	
ET01	Bedford Grey	Tile Clearance Outlet	External Balconies	

NCC 2019 BCA Volume One

A6.2 Class 2a buildings

(1)A Class 2 building is a building containing two or more *sole-occupancy units*.
(2)Each *sole-occupancy unit* in a Class 2 building is a separate dwelling.

-Deemed to satisfy, single exit, under 25m effective height

C1.1 Type of construction required

(a)The minimum Type of *fire-resisting construction* of a building must be determined in accordance with Table C1.1, except as allowed for—
(i)certain Class 2, 3 or 9c buildings in C1.5; and
(ii)a Class 4 part of a building located on the top *storey* in C1.3(b); and
(iii)*open spectator stands* and indoor sports stadiums in C1.7.
SA C1.1(a)(iv) and *(v)*
(b)Each building element must comply with Specification C1.1 as applicable.
Table C1.1 Type of construction required
SA C1.1(c) and *(d)*

C1.5 Two storey Class 2, 3 or 9c buildings

A building having a *rise in storeys* of 2 may be of Type C construction if—
(a)it is a Class 2 or 3 building or a mixture of these classes and each *sole-occupancy unit* has—
(i)access to at least 2 *exits*; or
(ii)its own direct access to a road or *open space*; or
(b)it is a Class 9c building protected throughout with a sprinkler system (other than a FPAA101D or FPAA101H system) complying with Specification E1.5 and complies with the maximum compartment size specified in Table C2.2 for Type C construction.

CP2 Spread of fire

(a)A building must have elements which will, to the degree necessary, avoid the spread of fire—
(i)to *exits*; and
(ii)to *sole-occupancy units* and *public corridors*; and
Application:
CP2(a)(ii) only applies to a Class 2 or 3 building or Class 4 part of a building.
(iii)between buildings; and
(iv)in a building.

CP4 Safe conditions for evacuation

To maintain tenable conditions during occupant evacuation, a material and an assembly must, to the degree necessary, resist the spread of fire and limit the generation of smoke and heat, and any toxic gases likely to be produced, appropriate to—
(a)the *evacuation time*; and
(b)the number, mobility and other characteristics of occupants; and
(c)the function or use of the building; and
(d)any active *fire safety systems* installed in the building.

D1.3 When fire-isolated stairways and ramps are required

(a)**Class 2 and 3 buildings** — Every stairway or ramp serving as a *required exit* must be fire-isolated unless it connects, passes through or passes by not more than—
(i)3 consecutive *storeys* in a Class 2 building; or
(ii)2 consecutive *storeys* in a Class 3 building,
and one extra *storey* of any classification may be included if—
(iii)it is only for the accommodation of motor vehicles or for other ancillary purposes; or
(iv)the building has a sprinkler system (other than a FPAA101D system) complying with Specification E1.5 installed throughout; or
(v)the *required exit* does not provide access to or egress for, and is separated from, the extra *storey* by construction having—
(A)an FRL of –/60/60, if non-*loadbearing*; and
(B)an FRL of 90/90/90, if *loadbearing*; and
(C)no opening that could permit the passage of fire or smoke.

2.1 General requirements

(a)*Fire-protected timber* must—
(i)utilise a *non-combustible fire-protective covering* fixed in accordance with the system requirements to achieve an FRL not less than that *required* for the building element; and
(ii)have a *non-combustible fire-protective covering* fixed in accordance with system requirements—
(A)to achieve a resistance to the incipient spread of fire of not less than 45 minutes when tested in accordance with—
(aa)for horizontal elements — Section 4 of AS 1530.4; and
(bb)for other elements — the relevant test procedures from Section 4 of AS 1530.4 applied to the element lining; or
(B)which consists of not less than 2 layers of 13 mm thick, fire-protective grade plasterboard.
(b)For the purposes of (a), the *non-combustible fire-protective covering* provided under (a)(ii) may form all or part of the *non-combustible fire-protective covering* provided under (a)(i).

DP1 Access for people with a disability

Access must be provided, to the degree necessary, to enable—
(a)people to—
(i)approach the building from the road boundary and from any *accessible* carparking spaces associated with the building; and
(ii)approach the building from any *accessible* associated building; and
(iii)access work and public spaces, accommodation and facilities for personal hygiene; and
(b)identification of *accessways* at appropriate locations which are easy to find.

D1.2 Number of exits required

(a)**All buildings** — Every building must have at least one *exit* from each *storey*.
(b)**Class 2 to 8 buildings** — In addition to any *horizontal exit*, not less than 2 *exits* must be provided from the following:
(i)Each *storey* if the building has an *effective height* of more than 25 m.
(ii)A Class 2 or 3 building subject to C1.5.

D1.3 When fire-isolated stairways and ramps are required

(a)**Class 2 and 3 buildings** — Every stairway or ramp serving as a *required exit* must be fire-isolated unless it connects, passes through or passes by not more than—
(i)3 consecutive *storeys* in a Class 2 building; or
(ii)2 consecutive *storeys* in a Class 3 building,
and one extra *storey* of any classification may be included if—
(iii)it is only for the accommodation of motor vehicles or for other ancillary purposes; or
(iv)the building has a sprinkler system (other than a FPAA101D system) complying with Specification E1.5 installed throughout; or
(v)the *required exit* does not provide access to or egress for, and is separated from, the extra *storey* by construction having—
(A)an FRL of –/60/60, if non-*loadbearing*; and
(B)an FRL of 90/90/90, if *loadbearing*; and
(C)no opening that could permit the passage of fire or smoke.

D1.4 Exit travel distances

(a)**Class 2 and 3 buildings**—
(i)The entrance doorway of any *sole-occupancy unit* must be not more than—
(A)6 m from an *exit* or from a point from which travel in different directions to 2 *exits* is available; or
(B)20 m from a single *exit* serving the *storey* at the level of egress to a road or *open space*; and
(ii)no point on the floor of a room which is not in a *sole-occupancy unit* must be more than 20 m from an *exit* or from a point at which travel in different directions to 2 *exits* is available.

D1.5 Distance between alternative exits

Exits that are *required* as alternative means of egress must be—
(a)distributed as uniformly as practicable within or around the *storey* served and in positions where unobstructed access to at least 2 *exits* is readily available from all points on the floor including lift lobby areas; and
(b)not less than 9 m apart; and
(c)not more than—
(i)in a Class 2 or 3 building — 45 m apart; or
(ii)in a Class 9a *health-care building*, if such *required exit* serves a *patient care area* — 45 m apart; or

(iii)in all other cases — 60 m apart; and
(d)located so that alternative paths of travel do not converge such that they become less than 6 m apart.

D1.6 Dimensions of exits and paths of travel to exits

In a *required exit* or path of travel to an *exit*—
(a)the unobstructed height throughout must be not less than 2 m, except the unobstructed height of any doorway may be reduced to not less than 1980 mm; and
(b)the unobstructed width of each *exit* or path of travel to an *exit*, except for doorways, must be not less than —
(i)1 m; or

D1.7 Travel via fire-isolated exits

(a)A doorway from a room must not open directly into a stairway, passageway or ramp that is *required* to be fire-isolated unless it is from—
(i)a *public corridor*, public lobby or the like; or
(ii)a *sole-occupancy unit* occupying all of a *storey*; or
(iii)a *sanitary compartment*, airlock or the like.
(b)Each *fire-isolated stairway* or *fire-isolated ramp* must provide independent egress from each *storey* served and discharge directly, or by way of its own *fire-isolated passageway*—
(i)to a road or *open space*; or
(ii)to a point—
(A)in a *storey* or space, within the confines of the building, that is used only for pedestrian movement, car parking or the like and is open for at least 2/3 of its perimeter; and
(B)from which an unimpeded path of travel, not further than 20 m, is available to a road or *open space*; or
(iii)into a covered area that—
(A)adjoins a road or *open space*; and
(B)is open for at least 1/3 of its perimeter; and
(C)has an unobstructed clear height throughout, including the perimeter openings, of not less than 3 m; and
(D)provides an unimpeded path of travel from the point of discharge to the road or *open space* of not more than 6 m.
(c)Where a path of travel from the point of discharge of a fire-isolated *exit* necessitates passing within 6 m of any part of an *external wall* of the same building, measured horizontally at right angles to the path of travel, that part of the wall must have—
(i)an FRL of not less than 60/60/60; and
(ii)any openings protected internally in accordance with C3.4,
for a distance of 3 m above or below, as appropriate, the level of the path of travel, or for the height of the wall, whichever is the lesser.
(d)If more than 2 access doorways, not from a *sanitary compartment* or the like, open to a *required* fire-isolated *exit* in the same *storey*—
(i)a smoke lobby in accordance with D2.6 must be provided; or
(ii)the *exit* must be pressurised in accordance with AS 1668.1.
(e)A ramp must be provided at any change in level less than 600 mm in a *fire-isolated passageway* in a Class 9 building.

D1.10 Discharge from exits

(a)An *exit* must not be blocked at the point of discharge and where necessary, suitable barriers must be provided to prevent vehicles from blocking the *exit*, or access to it.
(b)If a *required exit* leads to an *open space*, the path of travel to the road must have an unobstructed width throughout of not less than—
(i)the minimum width of the *required exit*; or
(ii)1 m,
whichever is the greater.
(c)If an *exit* discharges to *open space* that is at a different level than the public road to which it is connected, the path of travel to the road must be by—
(i)a ramp or other incline having a gradient not steeper than 1:8 at any part, or not steeper than 1:14 if *required* by the *Deemed-to-Satisfy Provisions* of Part D3; or
(ii)except if the *exit* is from a Class 9a building, a stairway complying with the *Deemed-to-Satisfy Provisions* of the BCA.

D2.2 Fire-isolated stairways and ramps

A stairway or ramp (including any landings) that is *required* to be within a *fire-resisting shaft* must be constructed—

(a)of *non-combustible* materials; and
(b)so that if there is local failure it will not cause structural damage to, or impair the fire-resistance of, the *shaft*.

D2.8 Enclosure of space under stairs and ramps

(a)**Fire-isolated stairways and ramps** — If the space below a *required fire-isolated stairway* or *fire-isolated ramp* is within the fire-isolated *shaft*, it must not be enclosed to form a cupboard or similar enclosed space.
(b)**Non fire-isolated stairways and ramps** — The space below a *required* non *fire-isolated stairway* (including an external stairway) or non *fire-isolated ramp* must not be enclosed to form a cupboard or other enclosed space unless—
(i)the enclosing walls and ceilings have an FRL of not less than 60/60/60; and
(ii)any access doorway to the enclosed space is fitted with a *self-closing* –/60/30 fire door.

D2.13 Goings and risers

(a)A stairway must have—
(i)not more than 18 and not less than 2 risers in each *flight*; and
(ii)going (G), riser (R) and quantity (2R + G) in accordance with Table D2.13, except as permitted by (b) and (c); and
(iii)constant goings and risers throughout each *flight*, except as permitted by (b) and (c), and the dimensions of goings (G) and risers (R) in accordance with (a)(ii) are considered constant if the variation between—
(A)adjacent risers, or between adjacent goings, is no greater than 5 mm; and
(B)the largest and smallest riser within a *flight*, or the largest and smallest going within a *flight*, does not exceed 10 mm; and
(iv)risers which do not have any openings that would allow a 125 mm sphere to pass through between the treads; and
(v)treads which have—
(A)a surface with a slip-resistance classification not less than that listed in Table D2.14 when tested in accordance with AS 4586; or
(B)a nosing strip with a slip-resistance classification not less than that listed in Table D2.14 when tested in accordance with AS 4586; and
(vi)treads of solid construction (not mesh or other perforated material) if the stairway is more than 10 m high or connects more than 3 *storeys*; and
(vii)in a Class 9b building, not more than 36 risers in consecutive *flights* without a change in direction of at least 30°; and
(viii)in the case of a *required* stairway, no winders in lieu of a landing.

D2.14 Landings

In a stairway—
(a)landings having a maximum gradient of 1:50 may be used in any building to limit the number of risers in each *flight* and each landing must—
(i)be not less than 750 mm long, and where this involves a change in direction, the length is measured 500 mm from the inside edge of the landing; and
(ii)have—
(A)a surface with a slip-resistance classification not less than that listed in Table D2.14 when tested in accordance with AS 4586; or
(B)a strip at the edge of the landing with a slip-resistance classification not less than that listed in Table D2.14 when tested in accordance with AS 4586, where the edge leads to a *flight* below; and

D2.16 Barriers to prevent falls

(a)A continuous barrier must be provided along the side of—
(i)a roof to which general access is provided; and
(ii)a stairway or ramp; and
(iii)a floor, corridor, hallway, balcony, deck, verandah, *mezzanine*, access bridge or the like; and
(iv)any delineated path of access to a building,
if the trafficable surface is 1 m or more above the surface beneath.

D2.17 Handrails

(a)Except for handrails referred to in D2.18, handrails must be—
(i)located along at least one side of the ramp or *flight*; and
(ii)located along each side if the total width of the stairway or ramp is 2 m or more; and
(iii)in a Class 9b building used as a primary *school*—
(A)have one handrail fixed at a height of not less than 865 mm; and

(B)have a second handrail fixed at a height between 665 mm and 750 mm,
measured above the nosings of stair treads and the floor surface of the ramp, landing or the like; and
(iv)in any other case, fixed at a height of not less than 865 mm measured above the nosings of stair treads and the floor surface of the ramp, landing, or the like; and
(v)continuous between stair *flight* landings and have no obstruction on or above them that will tend to break a hand-hold; and
(vi)in a *required exit* serving an area *required* to be *accessible*, designed and constructed to comply with clause 12 of AS 1428.1, except that clause 12(d) does not apply to a handrail *required* by (a)(iii)(B).

D2.25 Timber stairways: Concession

(a)Notwithstanding D2.2(a), timber treads, risers, landings and associated supporting framework which—
(i)has a finished thickness of not less than 44 mm; and
(ii)has an average density of not less than 800 kg/m^3 at a moisture content of 12%, may be used within a *required fire-isolated stairway* or *fire-isolated passageway* constructed from *fire-protected timber* in accordance with C1.13 subject to—
(iii)the building being protected throughout by a sprinkler system (other than a FPAA101D system) complying with Specification E1.5 which extends to within the fire-isolated enclosure; and
(iv)fire protection being provided to the underside of stair *flights* and landings located immediately above a landing level which—
(A)is at or near the level of egress; or

EP1.4 Automatic fire suppression systems

NSW EP1.4
An *automatic* fire suppression system must be installed to the degree necessary to control the development and spread of fire appropriate to—
(a)the size of the *fire compartment*; and
(b)the function or use of the building; and
(c)the *fire hazard*; and
(d)the height of the building.

E1.6 Portable fire extinguishers

(a)Portable fire extinguishers must be—
(i)provided as listed in Table E1.6; and
(ii)for a Class 2, 3 or 5 building or Class 4 part of a building, provided—
(A)to serve the whole Class 2, 3 or 5 building or Class 4 part of a building where one or more internal fire hydrants are installed; or
(B)where internal fire hydrants are not installed, to serve any *fire compartment* with a *floor area* greater than 500 m^2, and for the purposes of this clause, a *sole-occupancy unit* in a Class 2 or 3 building or Class 4 part of a building is considered to be a *fire compartment*; and
(iii)subject to (b), selected, located and distributed in accordance with Sections 1, 2, 3 and 4 of AS 2444.
(b)Portable fire extinguishers provided in a Class 2 or 3 building or Class 4 part of a building must be—
(i)an ABE type fire extinguisher; and
(ii)a minimum size of 2.5 kg; and
(iii)distributed outside a *sole-occupancy unit*—
(A)to serve only the *storey* at which they are located; and
(B)so that the travel distance from the entrance doorway of any *sole-occupancy unit* to the nearest fire extinguisher is not more than 10 m.

2. Application of automatic fire sprinkler standards

Vic Spec E1.5 2.
Subject to this Specification, an *automatic* fire sprinkler system must comply with—
(a)for all building classifications: AS 2118.1; or
(b)for a Class 2 or 3 building with an *effective height* of not more than 25 m and a *rise in storeys* of 4 or more: Specification E1.5a and the relevant provisions of this Specification as applicable; or
(c)for Class 5, 6, 7, 8, 9a (other than a *residential care building*) or 9b parts of a building with an *effective height* not more than 25 m, which also contains Class 2 or 3 parts: a sprinkler system in accordance with Specification E1.5a as for a Class 2 or 3 building and the relevant provisions of this Specification except—
(i)a FPAA101D sprinkler system cannot be used where the Class 5, 6, 7, 8, 9a (other than a *residential care building*) or 9b parts—
(A)contain more than 2 *storeys*; or
(B)are more than 25% of the total floor area of the building; or
(C)are located above the fourth *storey*; and

(ii)a FPAA101D or FPAA101H sprinkler system cannot be used where the Class 7a part (other than an *open-deck carpark*) accommodates more than 40 vehicles; or
(d)for a combined sprinkler and fire hydrant system: AS 2118.6; or
(e)for a Class 9a *health-care building* used as a *residential care building*: AS 2118.4 as applicable; or
(f)for a Class 2, 3 or 9c building: AS 2118.4 as applicable.

EP2.1 Automatic warning for sleeping occupants

In a building providing sleeping accommodation, occupants must be provided with *automatic* warning on the detection of smoke so they may evacuate in the event of a fire to a *safe place*

3. Smoke alarm system

(a)**All Class 2 - 9 buildings—**
(i)A smoke alarm system must—
(A)consist of smoke alarms complying with AS 3786; and
(B)be powered from the consumer mains source.
(ii)In kitchens and other areas where the use of the area is likely to result in smoke alarms causing spurious signals—
(A)any other alarm deemed suitable in accordance with AS 1670.1 may be installed provided that smoke alarms are installed elsewhere in the *sole-occupancy unit* in accordance with Clause 3(b)(i) and Clause 3(b)(ii); or
(B)an alarm acknowledgement facility may be installed,
except where the kitchen or other area is in a building protected with a sprinkler system complying with Specification E1.5 (other than a FPAA101D system), the alarms need not be installed in the kitchen or other areas likely to result in spurious signals.

FP1.3 Rainwater drainage systems

A drainage system for the disposal of *surface water* resulting from a storm having an *average recurrence interval* of—
(a)20 years must—
(i)convey *surface water* to an appropriate *outfall*; and
(ii)avoid *surface water* damaging the building; and
(b)100 years must avoid the entry of *surface water* into a building.

FP1.4 Weatherproofing

A roof and *external wall* (including openings around *windows* and doors) must prevent the penetration of water that could cause—
(a)unhealthy or dangerous conditions, or loss of amenity for occupants; and
(b)undue dampness or deterioration of building elements.

FP1.5 Rising damp

SA FP1.5
Moisture from the ground must be prevented from causing—
(a)undue dampness or deterioration of building elements; and
(b)unhealthy or dangerous conditions, or loss of amenity for occupants.

GROUP DESIGN PROJECT

FLEETWOOD MODULAR

Table of Contents

1.0. Introduction

This project outlines the structural design of a transportable housing project for a four story apartment development on a suburban site.

The transportable modules will be prefabricated and fully finished prior to transportation. Offsite construction helping enable the project to address the shortage of affordable housing solutions in Australia by being efficient, high quality and cost effective.

2.0. Design Concept

2.1. Project information

The development is to be four stories, consisting of 8 two-bedroom and 4 one-bedroom apartments. The system consists of individual high performing CLT modules being prefabricated and fully finished offsite, then transported to site, craned into position and connected.

The design has been guided by architectural concept which has been developed concurrently. Figure 1 shows the initial concept, which has now been further developed through consultation between consultants. The architectural design covers the planning requirements for site placement, orientation and set back.

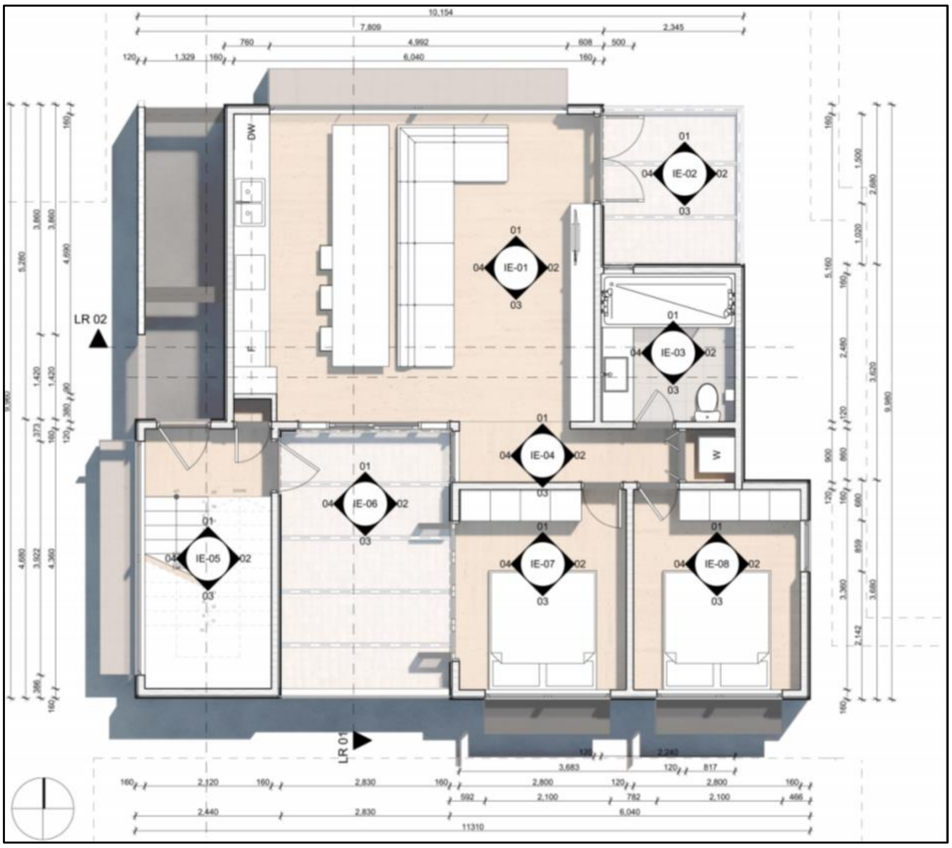


Figure 1 - Architectural Design Concept

2.2. Modular system

Due to the size of a single apartment being too large to fit onto a 14.5 x 5.4m flatbed truck as one module, we considered two options to transport the structure to site as can be seen in the below table.

	Advantages	**Disadvantages**
Option 1: Each apartment split into two modules	- Less time and complexity of crane lifts - Less onsite connections	- Require two trucks to transport each module
Option 2: Each apartment split into six modules	- Only require one truck to transport each apartment	- More time and complexity of crane lifts - More onsite connections

Although both options have advantages and disadvantages we decided to go with option 1, splitting each apartment into 2 modules. This decision has been based on the saving of cost and time.

The two modules will be connected onsite to form a single apartment. The apartments are then flexible to be joined in a variety of ways to suit a project-by-project basis.

2.3. Brief Specifications

2.3.1. Structural Members

To satisfy the clients need for high environmental credentials, it was decided a wood product would be used for the structural member’s due to it being a sustainable construction material.

According to AS1684, stud-frame construction is not recommended for structures over two stories, so the alternative of CLT which is recommended for midrise structures was considered.

After careful consideration, the decision was made to use CLT for the floors, walls and roof panels throughout the project.

CLT has a fairly good R value and when combined with insulated cladding it creates the opportunity for a high performing building. This reduces the reliance on additional heating and cooling systems which is a great advantage for reduced cost of living as well as being a transportable solution.

All CLT products have been chosen and referenced from the XLam Australian Cross Laminated Timber Structure Design Guide (see Appendix C.). Structural calculations have been made with reference to the section properties listed in this guide, due to there being no structural codes around the world which cover the design of CLT. However, strength and serviceability checks closely follow the provisions laid out for the design of timber in AS1720.1.

Detailed calculations show how the selection of the panels below have been derived.

- Walls – CL3/105 Panels
- Floor – CL7/245 Panels
- Roof – CL5/175 Panels

2.3.2. Connections

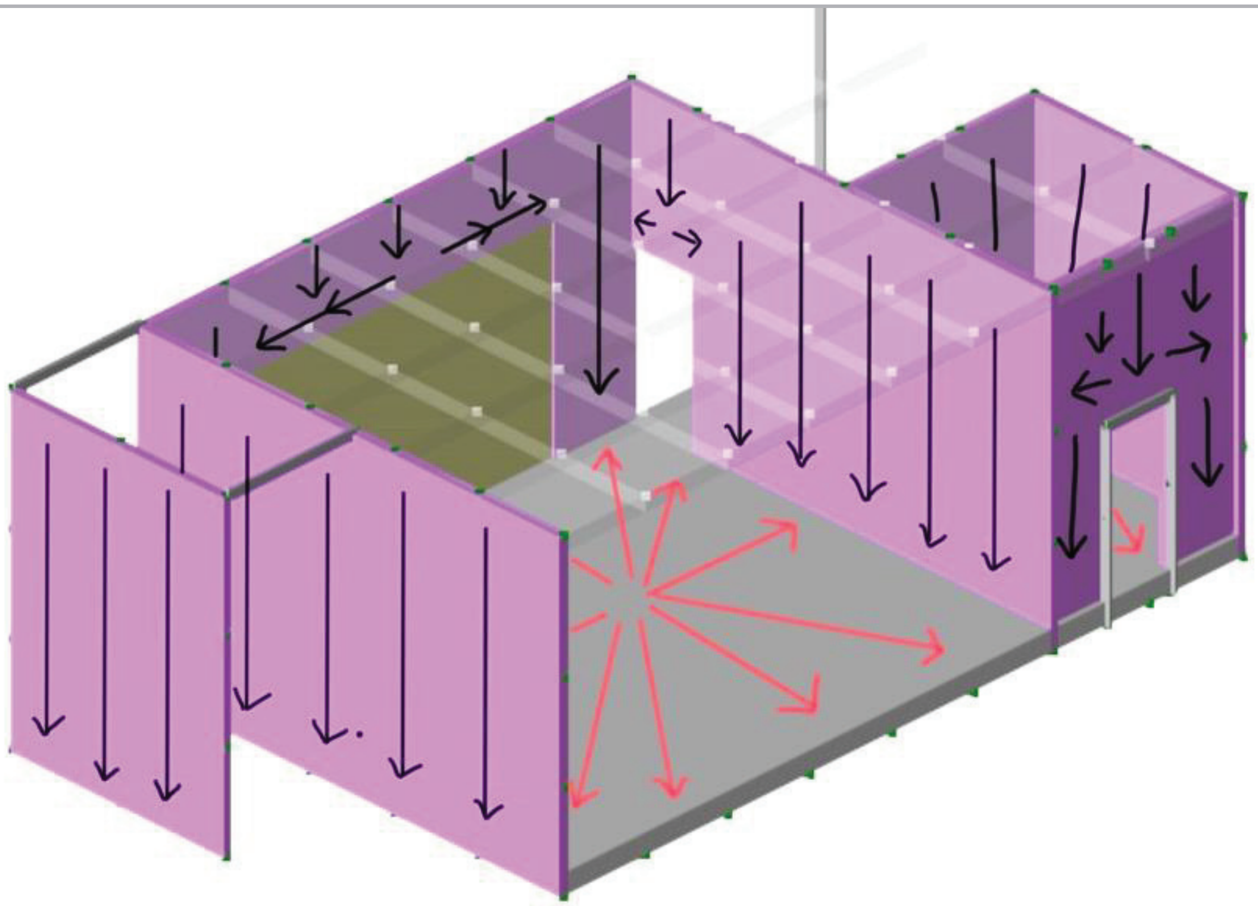
The majority of connections being used to join the CLT are steel connections.

The detailed drawings and calculations show the specific details of the connections made offsite and onsite. Each connection using either self-drilling screws, bolts, plates or a combination. The connections were designed using permanent and imposed loadings and wind loadings shown in Appendix A.

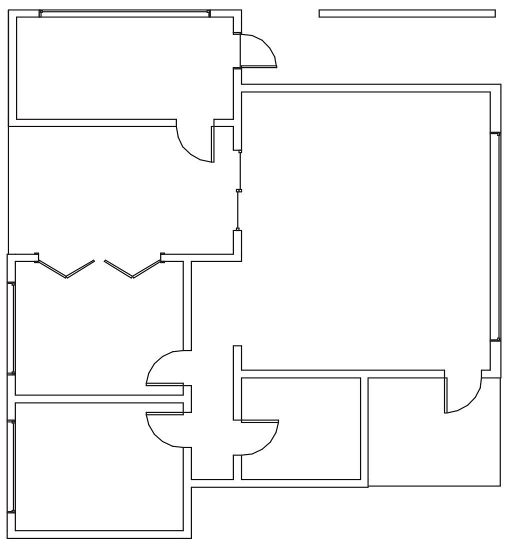
2.3.3. Cladding

The buildings cladding has been chosen in conjunction with the Architect. In contrast to the timber, perforated metal cladding by Perfmet has been selected.

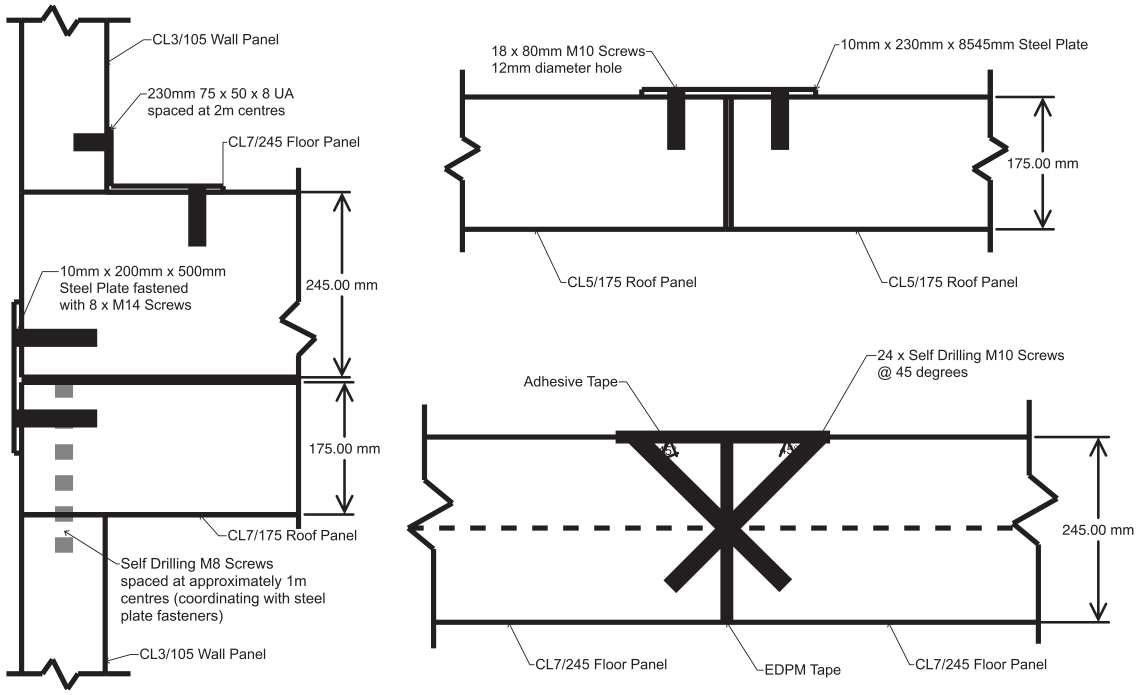
3.0. A3 Summary Page



Building Load Path Diagram Sketch



Plan – half roof, half first floor (1:400)



Key Connection Details - Level to Level Detail (left) & Module to Module Details (right) (1:10)

STRUCTURAL SYSTEM

The key feature that makes our structure unique is the use of CLT for the structural components. Panels are connected by various steel details, consisting of unequal angles, flat sections, self-drilling screws and bolts. T-beams have been utilised as lintels above windows and timber beams connect the feature wall to the rest of the structure.

Through the use of panels, the load is distributed from the floor slab to the walls in a uniform distribution, then vertically down the walls, framing around any openings as shown in the load path diagram.

INTERFACES

The interfaces between volumetric units consists of screws to connect the CLT walls, floor and roof together. Metal plates are used to transfer shear loads as connections between modules along with metal screws. A tolerance of up to 5mm between modules was what was aimed for, with prefabrication assisting minimising the tolerance by helping with moisture control when the CLT components are being constructed allowing all components of the module to be built together as it is built in a factory environment

CONSTRUCTION SEQUENCE

1. Prefabrication of volumetric unit off site
2. Site preparation
3. Delivery on truck
4. Installation of volumetric units and connections between apartments
5. Finishes on apartments where necessary

MATERIAL CHOICE

To satisfy the clients need for high environmental credentials, it was decided a wood product would be used for the structural member’s due to it being a sustainable construction material. Stud-frame construction is not recommended for structures over two stories, so the alternative of CLT has been used for the floors, walls and roof panels throughout the project. All CLT products have been chosen and referenced from the XLam Australian Cross Laminated Timber Structure Design Guide and the majority of connections that have been used are steel.

4.0. Detailed Calculations

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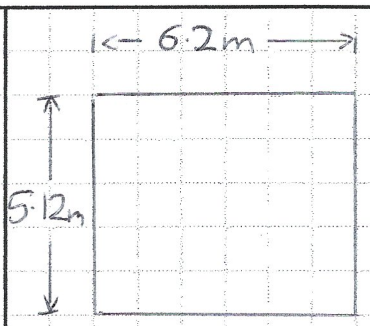
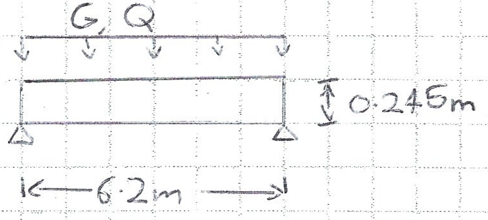


$g = 9.81\,m/s^2$ $E\cancel{I} = 6000\,MPa$

Bending Strength: 14 MPa

Density = 500 kg/m³

as largest span is 6.2m, using Xlam span table guides we have decided to use a CLT/245 for floor throughout.



$G: (0.245 \times 6.2) \times 500 \times 9.81$

$= 7.45\,kN/m$

superimposed: 0.5kPa = 3.1 kN/m

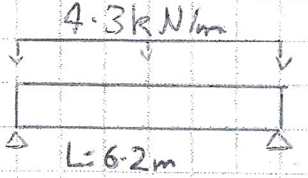
$G = 10.55\,kN/m$

Q: ~~1k~~1.5kPa → 9.3kN/m

1.35G: ~~10.05kN/~~ 14.24kN/m

$1.2G + 1.5Q = 26.61\,kN/m$

Take 1m wide Section →



$$M^* = \frac{4.3 \times 6.2^2}{8} = \underline{20.7\,kNm}$$

$$\sigma = \frac{M^* y}{I} \quad y = {}^{0.245}/_{2} = 0.1225\,m \qquad I = \frac{1 \times 0.245^3}{12}$$

$$= \frac{20.7 \times 10^3 \times 0.1225}{1.226 \times 10^{-3}} = 2.068\,MPa \qquad = 1.226 \times 10^{-3}\,m^4$$

14 MPa > 2.068 MPa ✓

Deflection - Simply Supported: $\delta = \frac{5\,wL^4}{384\,EI} = \frac{5 \times 4.3 \times 10^3 \times 6.2^4}{384 \times 6 \times 10^9 \times 1.226 \times 10^{-3}}$

$\delta = 11.3\,mm \rightarrow \frac{1}{551}$ ✓

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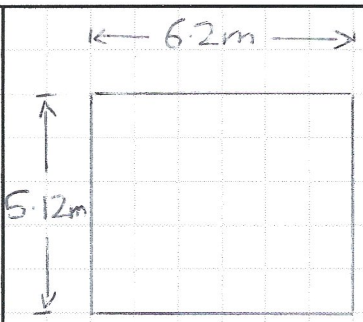
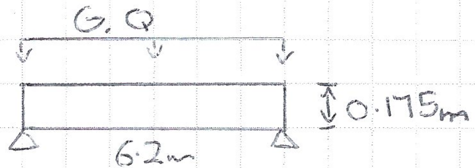


$g = 9.81 m/s^2$ density $= 500 kg/m^3$
$E = 6000 MPa$ Bending Strength $= 14 MPa$

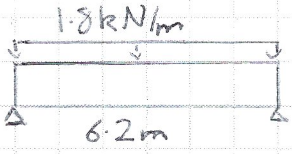
Largest span is 6.2m
Using XLam span guides are roof ~~tod~~ loads, decided to use CL5/175 for roof throughout



$G = 5.32 kN/m$
~~+0.5kPa superimposed~~
=
$Q = 0.5Pa \rightarrow 3.1 kN/m$

$1.35G = 7.182 kN/m$
$1.2G + 1.5Q = \underline{11.034 kN/m}$

Take 1m wide section: 11.034kN over 6.2m $w = 1.8 kN/m$



$M^* = \frac{1.8 \times 6.2^2}{8} = \underline{8.65 kNm}$

$y = \frac{0.175}{2} = 0.0875m$

$\delta = \frac{M^* y}{I}$

$I = \frac{1 \times 0.175^3}{12} = 0.447 \times 10^{-3} m^4$

$= \frac{8.65 \times 10^3 \times 0.0875}{0.447 \times 10^{-3}} = 1.69 MPa$

$14MPa > 1.69MPa$ ✓

Deflection - Simply Supported: $\delta = \frac{5wL^4}{384EI} = \frac{5 \times 1.8 \times 10^3 \times 6.2^4}{384 \times 6 \times 10^9 \times 0.447 \times 10^{-3}}$

$\delta = 12.9mm$

$\rightarrow \frac{1}{480}$ ✓

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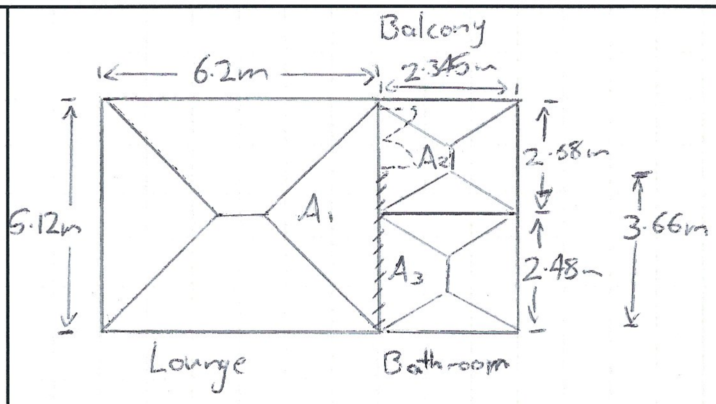

$g = 9.81 m/s^2$

$A_1 = 6.6 m^2$

$A_2 = 1.8 m^2$

$A_3 = 1.54 m^2$

$\Sigma A = 9.94 m^2$

$$\left.\begin{array}{l} Q_{lounge} = 1.5 kPa \rightarrow 9.9 kN \\ Q_{balcony} = 2 kPa \rightarrow 3.6 kN \\ Q_{bathroom} = 2 kPa \rightarrow 3.1 kN \end{array}\right\} Q_{floor}$$

$Q_{roof} = 0.5 kPa \rightarrow 5 kN$

G_{floor}: using CL7/245 @ $500 kg/m^3$

$\rightarrow (9.94 \times 0.245) \times 500 \times 9.81$

$= 12 kN$

$+$ superimposed load of $0.5 kPa \rightarrow 5 kN$

$G_{floor} = 17 kN$

G_{roof}: using CL5/175

$\rightarrow 8.6 kN$

For bottom level walls: $G = 3G_{floor} + 4 G_{roof}$

$Q = 3Q_{floor} + 1 Q_{roof}$ ← only imposed actions on top roof.

$G = 85.4 kN$

& $Q = 52.9 kN$

$1.35G = 115.3 kN$

$1.2G + 1.5Q = \underline{181.83 kN}$

So 181.83 kN acting on 3.66m length of wall, 3.28m height.

Using XLam Guides a CL3/105 wall will be used.

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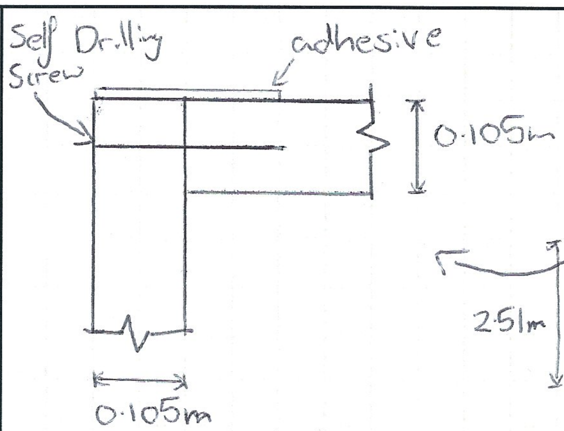
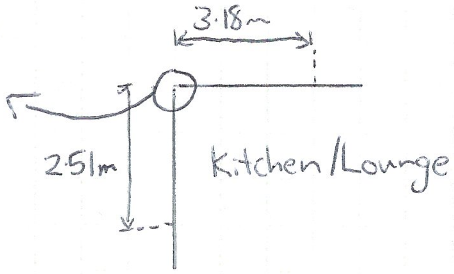
ϕ : 0.85 k_1=0.69





-Walls are 3.28m tall -Assume Aus Mixed Hardwood

-Assume greatest Wind Can act on Either Wall

Withdrawal = Shear = $W_u + \psi_c Q$ $(\psi_c = 0.4)$

W_u = 0.58 kPa -> 0.58 x 3.28 x 3.18 = 6.1 kN

Q = ~~0.6~~ 1 kPa -> 1 x 3.28 x 3.18 = 10.44 kN

$W_u + 0.4Q$ = 10.3kN

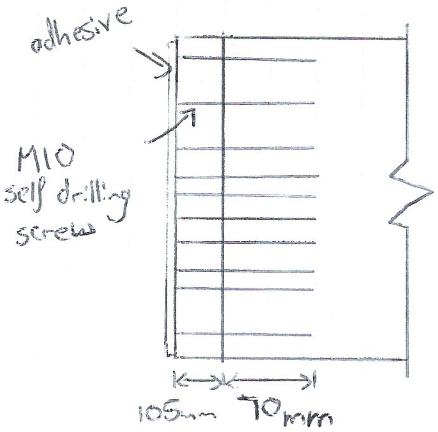
Using AS 1720.1

Shear Screws in End Grain (60% of side grain)

Using table 4.5(B) need 7x M10 screws to resist shear force.

as per <4.3.5> screw will need $t_p > 70$ into second member

$t_p > 70$mm to satisfy withdrawal ~~strength~~ spec



Withdrawal check

table 4.6(B) : 87x70x0.6x7

= 725.57kN ✓

For $1.\overset{0}{\cancel{2}}G + 1.5Q$

1.5Q = 15.66kN

$\boxed{\text{So need 16 M10 screws 175mm long}}$

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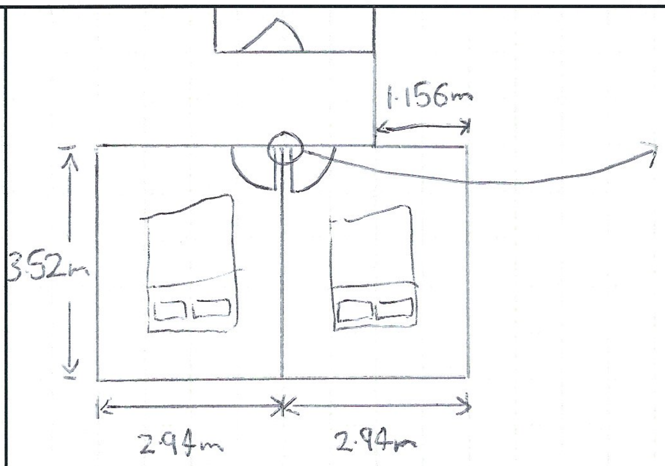
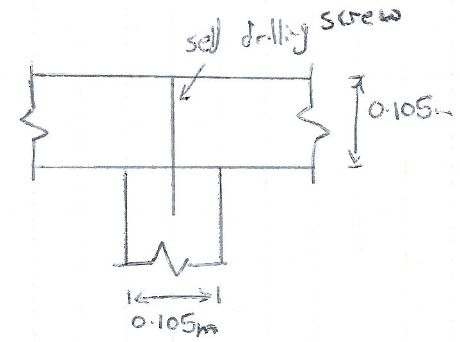
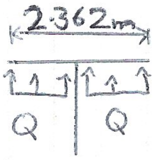




$\varnothing$:0.85 k_1:0.69

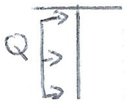
1.5Q (Withdrawal)
1.5Q (Shear)

Withdrawal



Q:1kPa = 7.75 kN
Using AS1720.1 <4.3.3.4>
$7.75kN < \varnothing k_{13} l_p n Q_k$
l_p:
Q_k:0.087kN for M10 screw l_p:70mm
k_{13}:0.6 $\varnothing$:0.85
7.75 < n3.1   n:3 N_{dj} = 9.3kN

Shear



Q:1kPa ⇒ 5.8kN
<4.3.3.2>
$5.8 < \varnothing k_1 k_{13} k_{14} k_{16} k_{17} n Q_k$

M10 screw: Q_k:2.8kN k_1:0.69 k_{13}:0.6
k_{14}:1 k_{16}:1 k_{17}:1 $\varnothing$:0.85
5.8 < n0.98   n:6

So will use 6x M10 screws, 175mm long

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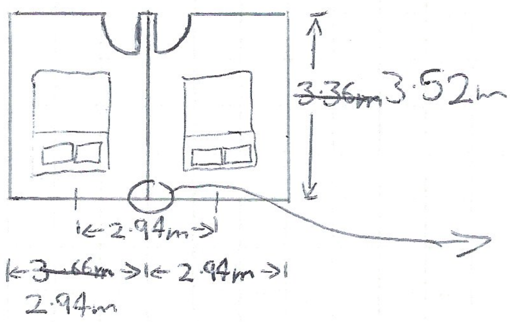
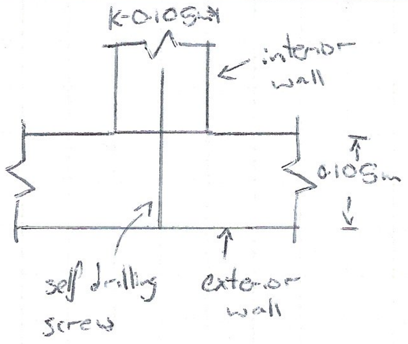


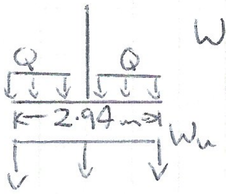


$W_u + \psi_c Q$ (Withdrawal)

$1.2G + 1.5Q$ (Shear)

$\phi = 0.85$ $k_1 = 0.69$

Withdrawal



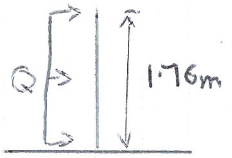
$W_u = 0.58kPa \rightarrow 5.6kN$

$Q = 1kPa \rightarrow 9.65kN$

$W_u + 0.4Q = 9.46kN$

Using AS 1720.1 <4.3.2.3>
Withdrawal will require ~~3~~ 4 x10M screws, 175mm long.

Shear



$Q = 1kPa \Rightarrow 5.8kN$

$1.5Q = 8.66kN$

Using AS 1720.1 <4.3.2.2> will require ~~8~~ 9 xM10 screws.

Hence Exterior Wall to Interior Wall will require:
~~9 6 x 10M self drilling screws~~, 175mm long.
~~M10~~
9 xM10 self drilling screws, 175mm long.

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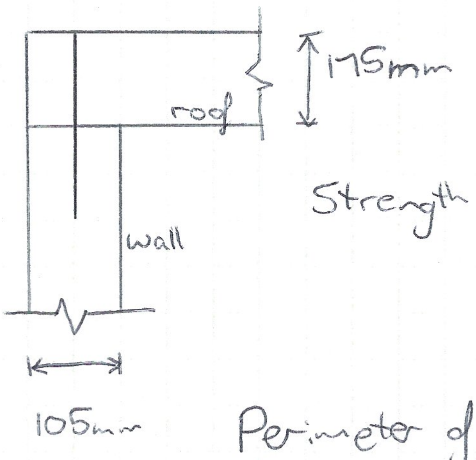
$\phi = 0.8$ $k_1 = 0.69$ $g = 9.81 m/s^2$



Assume Mixed Aus Hardwoods
<1720.1 CH2.3>
Joint Group JD3

Strength State : ~~Wa~~ $0.9G + W_{u\,roof}$ (Withdrawal)
: $W_{u\,wall} + \psi_c Q$ (Shear)

Perimeter of Roof ≃ 44m
Area ≃ 87.3m²

$W_u = 0.85$ kPa → 75 kN
G : 75 kN
$0.9G + W_u$ = 7.5 kN ↑ (Withdrawal
* ~~1.2G~~ + 1.5Q = 4.92kN (Shear) *
~~for~~ $W_{u\,wall}$: 0.693 kPa → 2.3 kN (1m width of wall)

Q = ~~3.28~~ 1kPa → 3.28kN (1m width of wall)

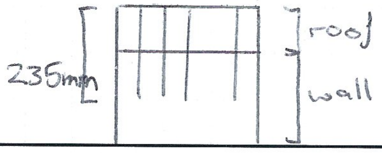
$W_u + \psi_c Q = 2.3 + (0.4)3.28 = 3.612$ kN ← (shear)
(1.5Q has greater shear)

As Screw will be in end grain, k_{13} = 60%
<4.3.2.2>
So will need ~~3~~ ~~4~~ 8 × ~~8mm Screws~~ M8 screws per m.
(strength of ~~3.816 kN~~) ~~5.1kN~~ 17kN

For Withdrawal, <4.3.5> $t_p > 7D$ penetration > 56mm
3 M8 screws with penetration 56mm = 7.35kN

So 8 ~~4~~ M8 screws every 1m
235mm long

8 × M8 screws every 1m, 235mm long



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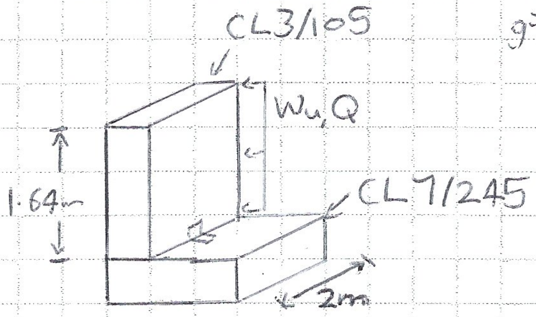
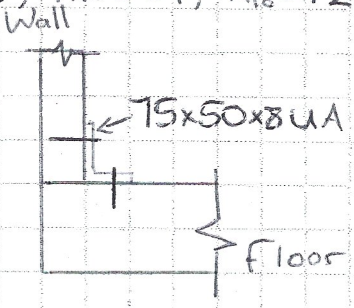
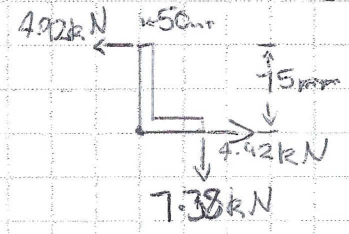
$g=9.81m/s^2$, $k_1=0.69$, $k_{16}=1.2$





Wu=0.58kPa → 1.903kN Q=1kPa → 3.28kN

Wu+0.4Q=3.215kN 1.5Q= 4.92kN

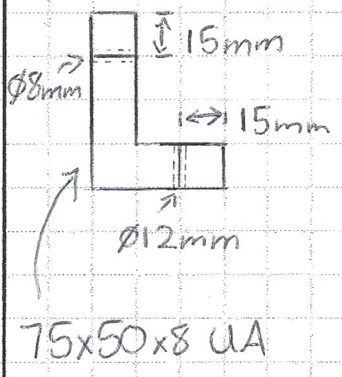


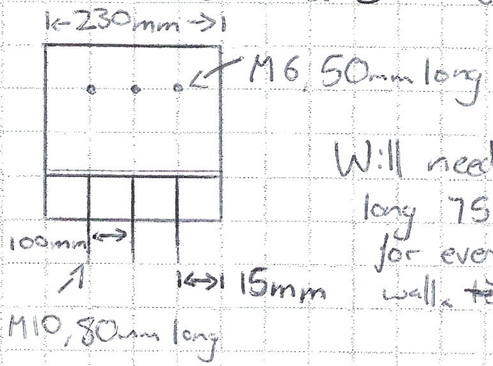
Withdrawal from wall: 4.92kN
using M6 screws
-need 3xM6 screws, 50mm long

M6 as needs to be >60mm from timber edge and >9mm from steel edge, so fits in UA.

Withdrawal from Floor: 7.38kN
using M10 screws.
Need 2xM10 screws, 80mm long

Shear of Floor: 4.92kN
using M10 screws
$\phi N_j = 0.8 \times 0.69 \times 1.2 \times 2.8 = 1.854kN$
so need 3xM10 screws, 80mm long





Will need a 230mm long 75x50x8 UA for every 2m ~~along~~ of wall ~~to~~

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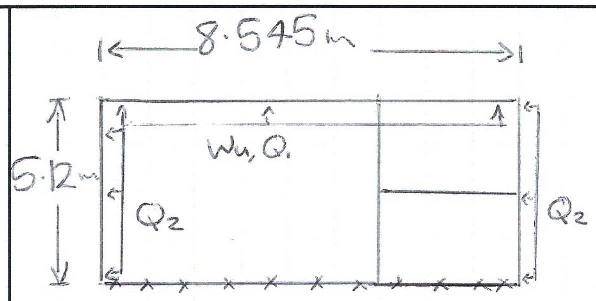


$g = 9.81 m/s^2$, Aus Mixed Hardwoods
$k_1 = 0.69$, $k_{13} = 0.6$, $\phi = 0.8$
height = 3.7m

Withdrawal: Wu, Q1
Shear: Q2

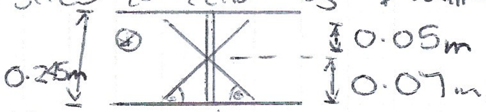
Wu: 0.58kPa → 18.34kN   Q1 = 1kPa = 31.62kN
Q2 = 1 kPa = 37.9kN

Withdrawal: Wu + 0.4Q1 = ~~30~~31kN   1.5Q1 = 47.43kN

Shear: 1.5Q = 56.85kN

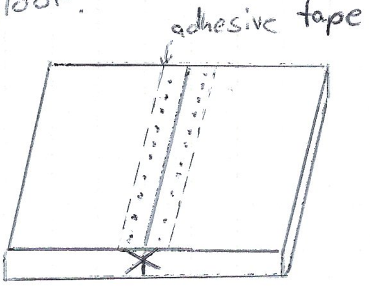
Withdrawal and ~~Shear~~ Shear force will be shared between floor & roof.
So for floor & roof: Withdrawal = 25kN
Shear = 30kN

Floor: Utilising same X screw connector as Wall-Wall but with $\phi = 45°$



So M10 screws with ϕ45°, $Q_k \rightarrow 1.41 Q_k$
Shear ~~reqd~~: 1.307kN → 23 screws
Withdrawal: 2.923kN → 9 screws

So will need 24 × M10 screws, 170mm to connect floor to floor.



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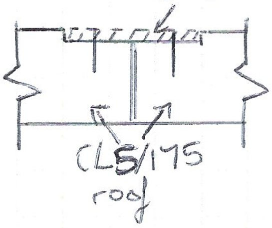
g: 9.81m/s² Mixed Aus Hardwoods, k_1 = 0.69 Ø = 0.8

as stated on previous page:
Withdrawal : 25kN
Shear : 30~~kg~~kN

Steel Plate (0.01m thick)



Will go for a steel plate design connecting to roof - roof.
→ k_{16} = 1.2
N_{dj} for M10 screws = 1.854 kN

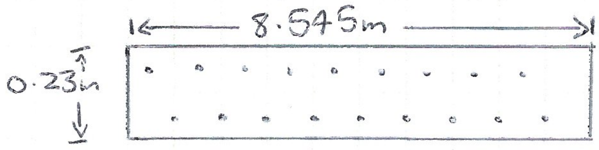
need 18 x M10 screws, 80mm long

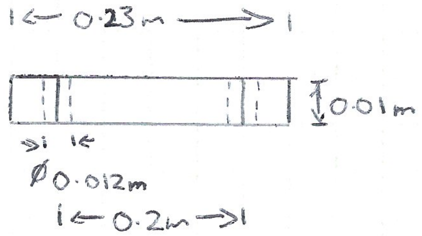
End distance = 100mm <4.3.4> of AS 1170.1

& 15mm from end of plate <9.6.2> of AS 4100
- So plate is 230mm wide
AS 3679.1 plate, steel grade 300 - f_y = 360MPa f_u = 480MPa

Tension Capacity due to Withdrawal : <7.2> of AS 4100.
Ø = 0.9 N_t = 27 685 kN

Shear Capacity & as per <5.11.4> of AS 4100
Ø = 0.9 V_w = 16 611 kN





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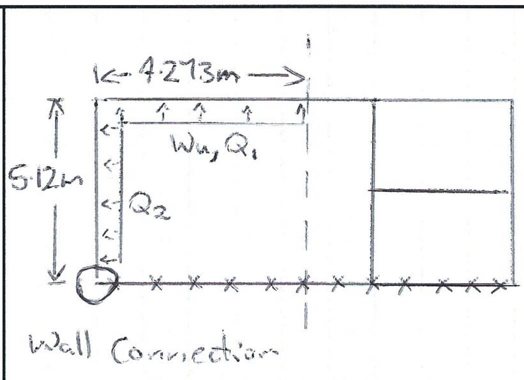


$g = 9.81$, Aus Mixed Hardwoods
$k_1 = 0.69$, $k_{13} = 0.6$ $\emptyset = 0.8$

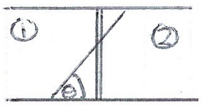
Withdrawal : W_u, Q_1
Shear : Q_2

$W_u = 0.58$ kPa $Q = 1$ kPa (Wall is 3.28m high)
$W_u = 8.13$ kN $Q_1 = 14.02$ kN $Q_2 = 16.8$ kN

Withdrawal : $W_u + 0.4Q = 13.74$ kN $1.5Q = \underline{21.03}$ kN

~~Can~~ Using M10 screw, 70mm into second member = 6.09kN
so need 4 screws.

Shear : $1.5Q = 25.2$ kN

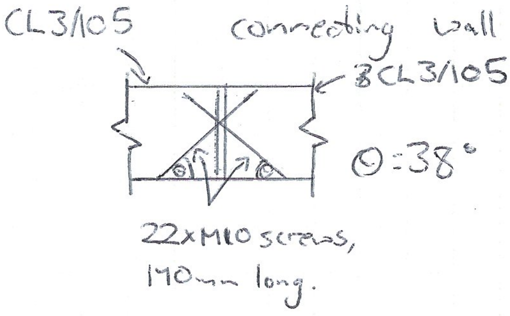


0.1m in first member
0.07m in second member
θ = 38°

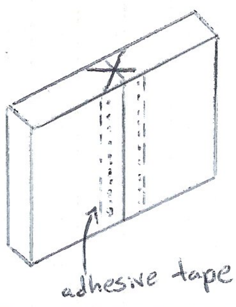
as screw enters at 38° angle instead of straight in, Q_k of <4.3.3.2> of AS 1170.1 increases to $1.26 Q_k$

so using M10 screws, strength to shear becomes = 1.168 kN

Will need 22 × M10 screws, 140mm long.
connecting wall of 1st module to wall of 2nd Module



θ = 38°



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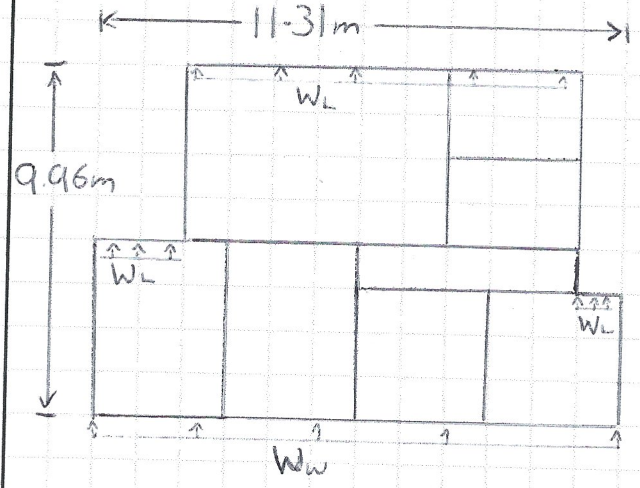

$g = 9.81 m/s^2$, Aus Mixed Hardwoods
$k_1 = 0.69$, $\phi = 0.75$
Assume frictionless.

Ww: Windward = 0.693 kPa
WL: Leeward = 0.462 kPa
WR: Roof = 0.85 kPa

$\Sigma A = 87.3 m^2$

Upward Lift: 0.85kPa → 74.205 kN
0.9G + Wu
⇒ G: floor weight: 104.9kN $0.9G_{floor} = 94.4kN$

$0.9G_{floor}$ is greater than uplift so uplift not relevance

Shear: 3.7m high structure
Ww = 0.693kPa → ~~28~~ 29 kN
WL = 0.462kPa → 19.4kN   Wu = 48.4 kN

Metal plate will be used to transfer shear load, $k_{16} = 1.2$
using M14: $48.4kN < 0.75 \times 0.69 \times 0.6 \times 1 \times 1.2 \times 1 \times n \times 4.38$
$n > 30$
~~so need 30×M14~~ so ~~15~~ $n > 15$ for each side.
Will use 16×M14 on each side of building
Will use 2 steel plates on each side, having 8×M14 screws each. Each plate required to resist 25kN shear.
~~Plates will be similar as used~~
Plates to be AS 3679.1, 10mm thick
$f_y = 360MPa$ $f_u = 480MPa$

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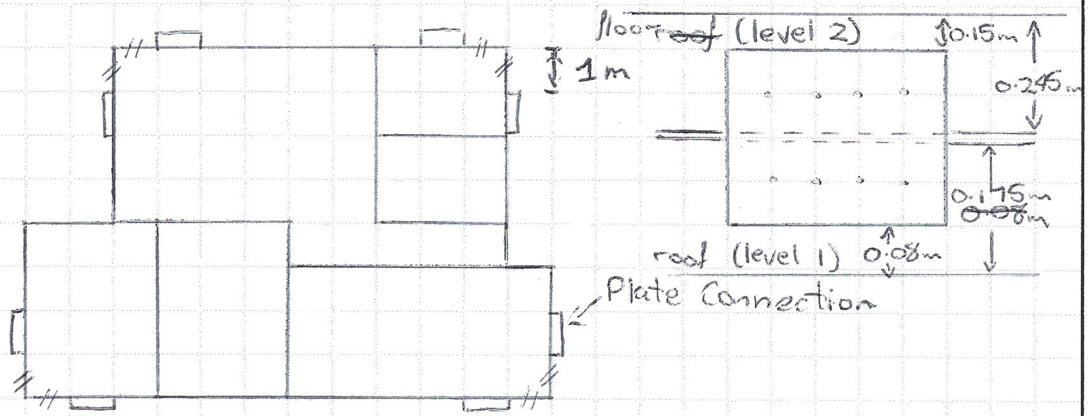


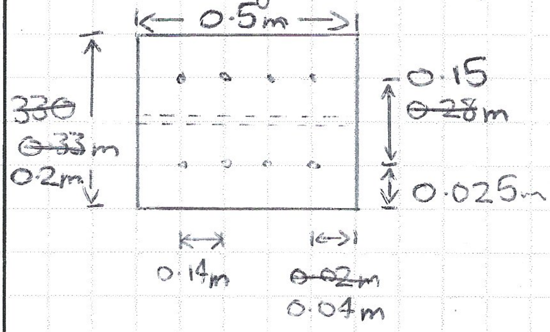
Plate Design, <4.3.4> of AS 1720.1

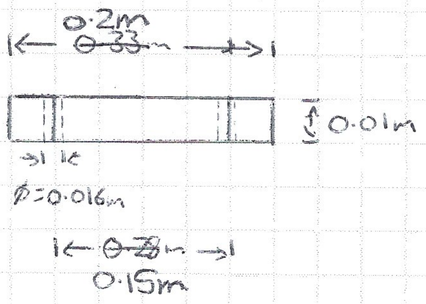
edge ~~end~~ distance = ~~10D~~ 5D

= ~~140mm~~ 70mm

dist between screws = 10D = 140mm

<9.6.2> of AS 4100, dist to edge of plate = 21m





<5.11.4> of AS 4100.

$\phi = 0.9$ $\phi V_w =$ ~~32 076 kN~~ 972kN > 25kN

Each plate will use 8xM14 screws, 110mm long

Plates will be 1m away from each corner.
(edge to edge)

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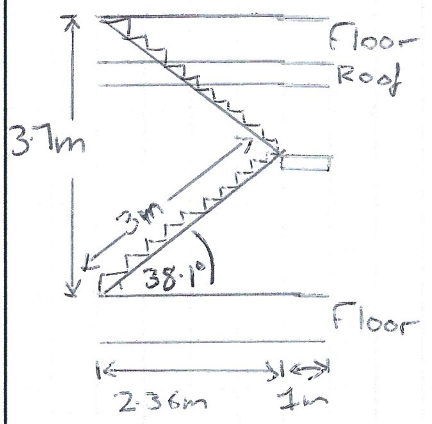


~~4 ϕ~~ $\phi = 0.75$ for category 3, $k_1 = 0.69$

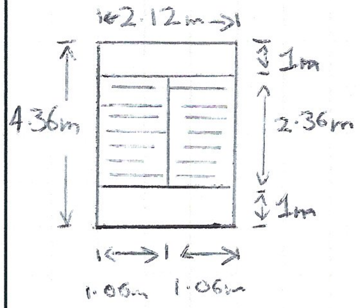
AS 1657: stair slope to horizontal is 20° - 45° ✓

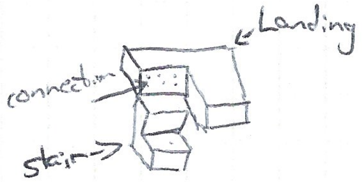
Using XLam Guides, 3 span Will need a CL3/105 Airstair

G: assume 0.2m avg thickness each flight = 3.2kN

Q: 2kPa = 6.36kN

$1.2G + 1.5Q = 13.38\text{kN}$



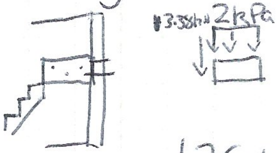


Landing will be CL3/105 based on span tables given in XLam

Connection

Based on a shear force of 13.38 kN, using AS1720.1 <4.3.2.2> 16 ~~8~~ x 10M self drilling screws will be used. Penetrating 70mm into landing

Landing Connection To Wall



~~⊖ G: 1~~ V: 1x2.12x0.105 = 0.23m³

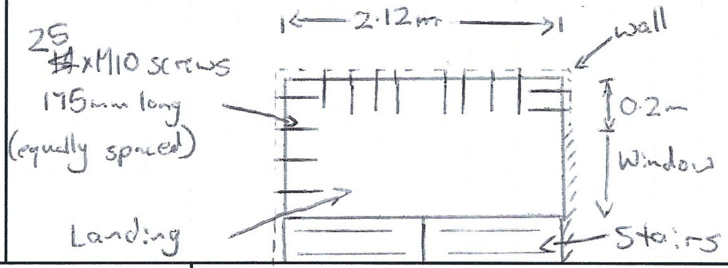
G: 1.13kN

Q: 4.24kN

$1.2G + 1.5Q$: 7.72kN + stair-load of 13.38 kN

= 21.1kN

as per AS 1720.1 <4.3.2.2> will use ~~14~~ 25 x M10 screws, 175mm long



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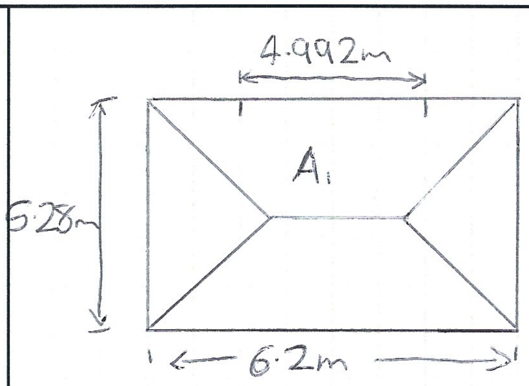
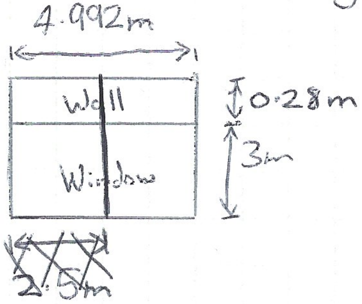
$g = 9.81 m/s^2$





$A_1 = 9.4 m^2$ $G_{floor} = 11.3 kN$ $G_{imposed} = 4.7 kN$

$G_{roof} = 8.1 kN$ $G_{wall} = 8.44 kN$

$Q_{floor} = 1.5 kPa \rightarrow 14.1 kN$

$Q_{roof} = 0.5 kPa \Rightarrow 4.7 kN$

$G = 107 kN$ $Q = 47 kN$

$1.35G = 145 kN$ $1.2G + 1.5Q = \underline{198.9 kN}$

~~Strength of CLT Lintel. using AS1720.1~~

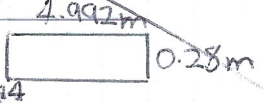
~~<2.3> $\phi = 0.85$~~

~~<3.2> $M_d = \phi k_1 k_4 k_6 k_9 k_{12} f'_b Z$~~

~~$k_1 = 0.8$ $k_4 = 1$ $k_6 = 1$ $k_9 = 1$ $k_{12} = 1$~~

~~f'_b is as given in XLam as 14MPa~~

~~#F $I = \frac{bh^3}{12} = 9.13 \times 10^{-3} m^4$~~



~~$M_d = 0.85 \times 0.8 \times \frac{14MPa \times 0.14}{9.13 \times 10^{-3}}$~~

~~Using a 305BT62.5 will be strong enough to support the load~~, ~~2.5m~~ span, ~~FLR~~

$\frac{198.9 kN}{6.2} = 32.1 kN/m$

$M^* = \frac{wL^2}{8} = \frac{32.1 \times \overset{4^2}{\cancel{4.992^2}}}{8} = \cancel{100k}\ 64.2 kNm$

- Window has changed to 4m Wide.
- 305BT62.5 will be utilised (FLR)

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Subject Feature Wall ~~to~~ Connection

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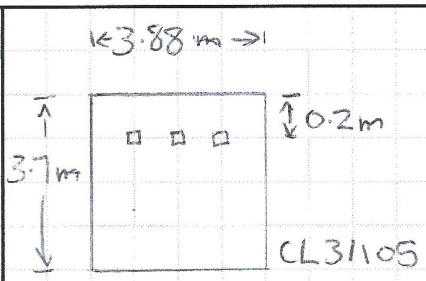
Chk

$g:9.81m/s^2$ Mxed Aus Hardwood



$W_u = 0.58kPa \rightarrow 8.33kN$

$Q : 1kPa \rightarrow 14.36kN$

$W_u + 0.4Q : 14.1kN$

$1.5Q : 21.54kN$

Force will be distributed to building through 3 ~~timber~~ sawn timber sections

<3.4.1> of AS 1720.1

$N_{d,t} = \phi k_1 k_4 k_6 f'_t A_t$

Using F14 grade timber section, 50x25mm

$f'_t : 25MPa$ as per AS 2796

$A_t : 1250mm$

$\phi : 0.9$, $k_1 : 0.69$, $k_4 : 0.7$ $k_6 = 1$

$N_{d,t} : 13.58kN$ each section, need ~~2~~ 3 sections.

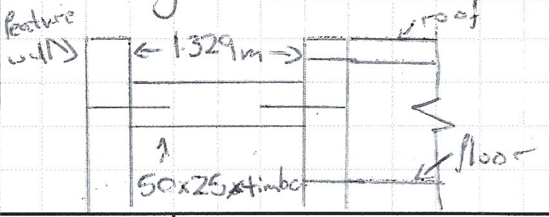
Withdrawal $f = 21.54/2 : 10.77kN$

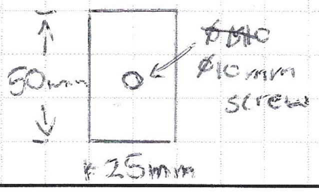
–Will use 3 sections for easier connections.

so $21.54/3 = 7.18kN$ each screw

M10 screw, 100mm into ~~a~~ section has 7.395kN of strength.

So each timber section will be connected by a M10 screw, 205mm long.

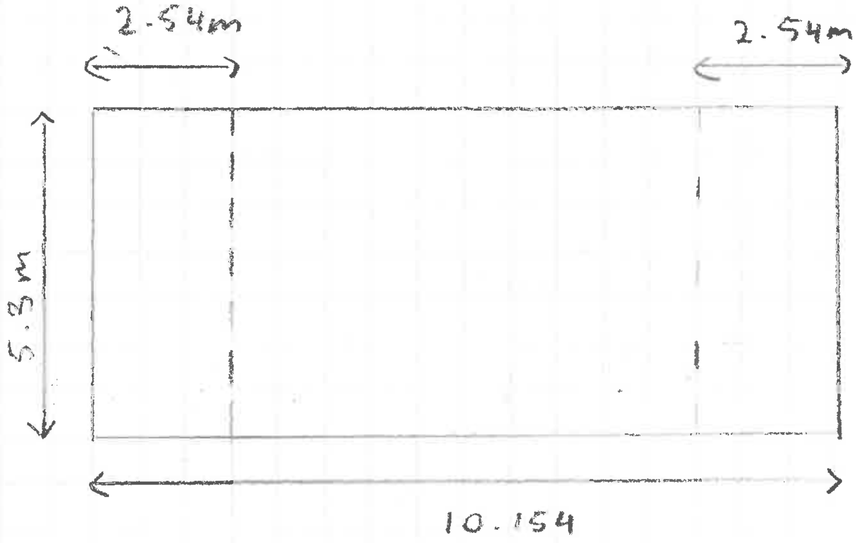




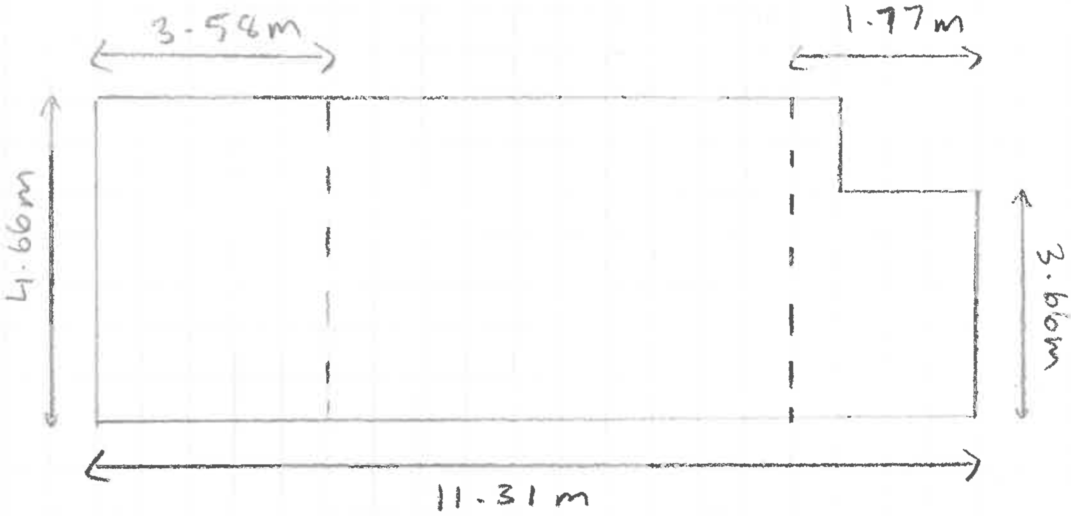
File		Customer / Project	Date
By	Reviewed	Subject Lifting Design	Page 1

Units Listed | Numbers Checked | Sources Referenced | Inputs Listed

Item | Chk



Module 1

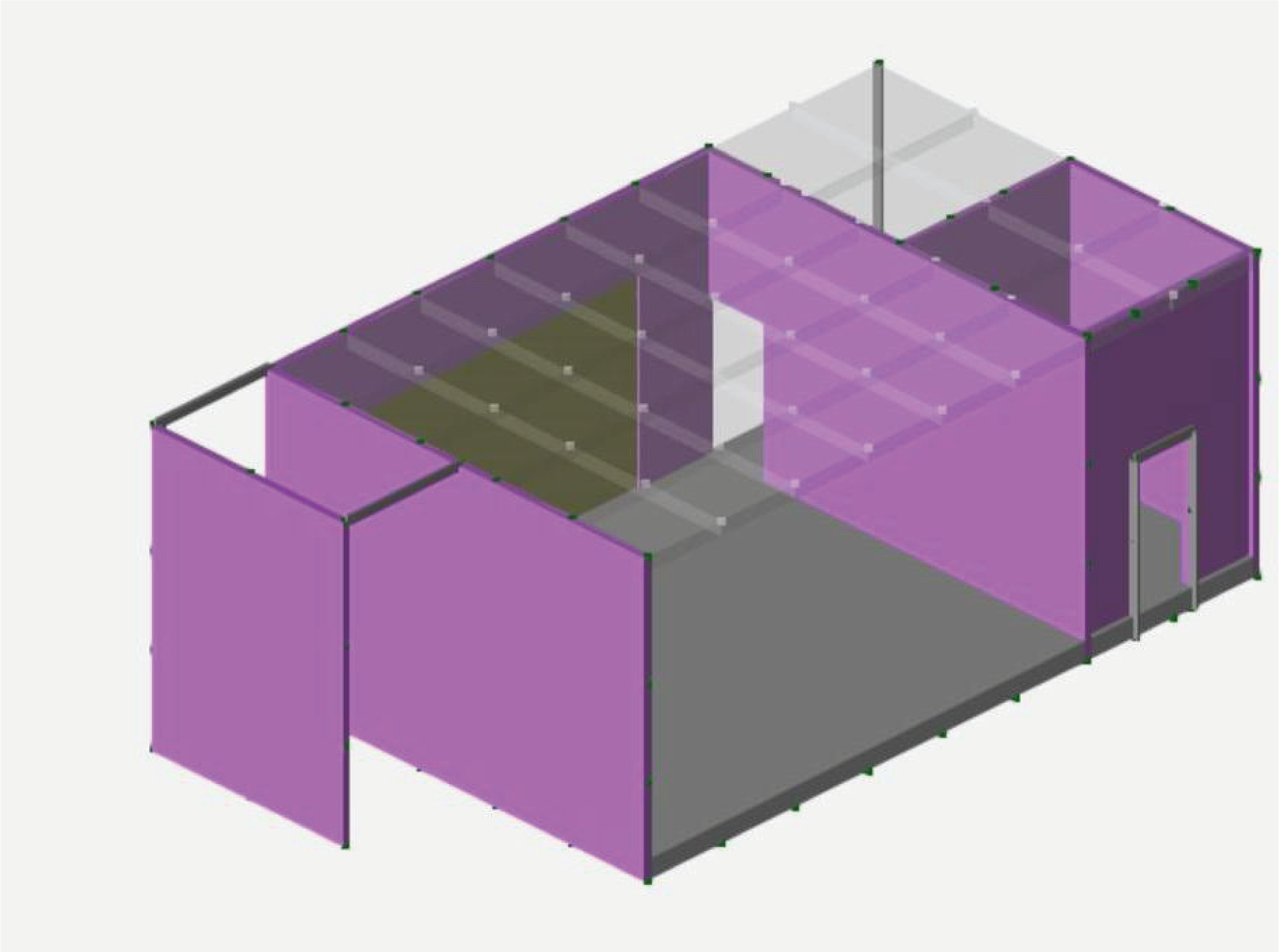


Module 2

Dotted lines show cable placement when lifting modules for construction

Assuming evenly distributed load across modules

5.0. Detailed Drawings



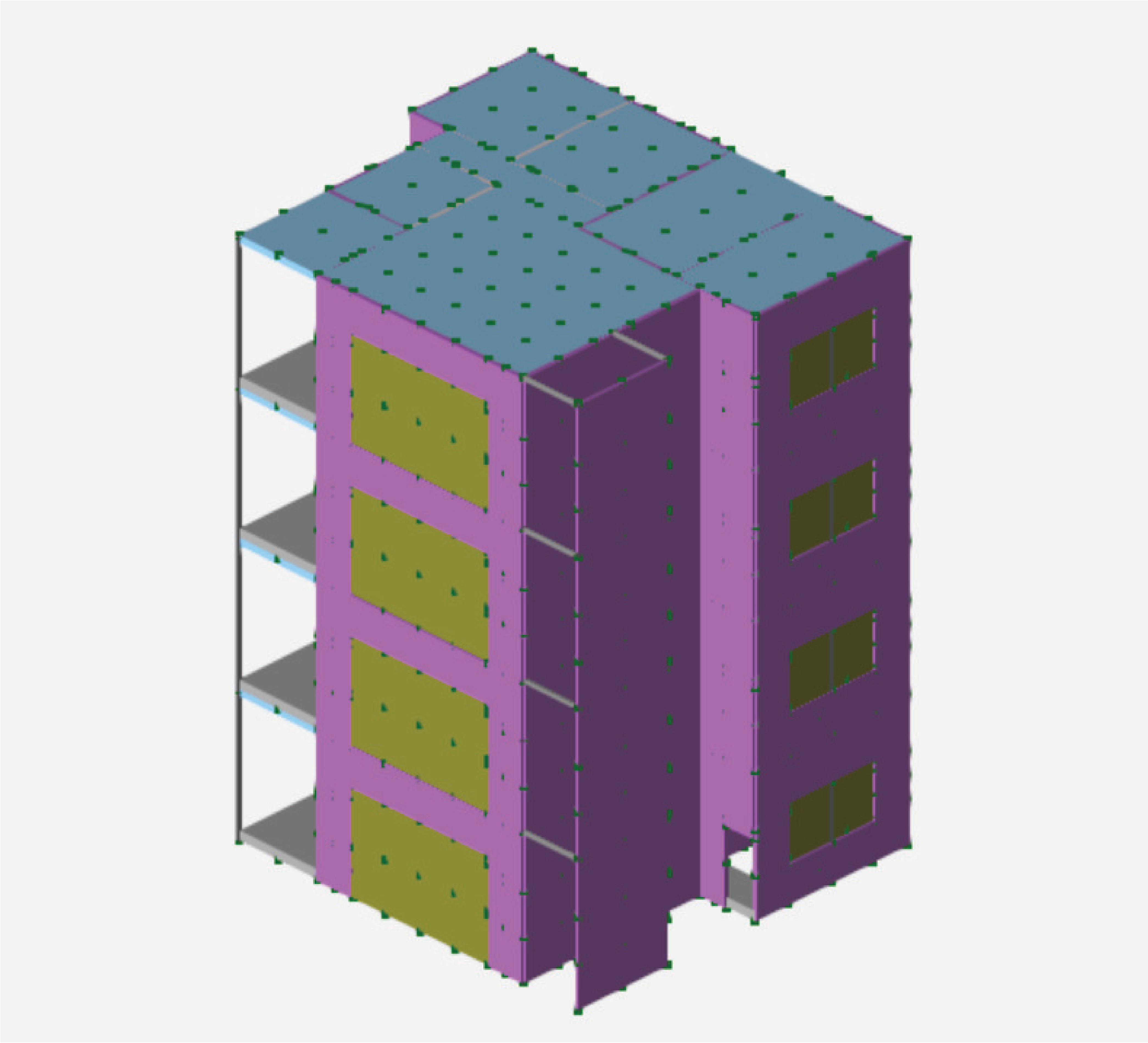
REV	DESCRIPTION	DATE
1	ISSUED FOR INFORMATION	04/05/2020

PROJECT
FLEETWOOD MODULAR

DRAWING TITLE
MODULE ORTHAGONAL VIEW

SCALE @ A3
NOT TO SCALE

DRAWING NUMBER
A 000
1



NOTES

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3. ALL DIMENSIONS SHALL BE VERIFIED BEFORE PROCEEDING WITH THE WORK.

4. THIS DRAWING MUST BE READ IN CONJUCTION WITH ALL RELEVENT CONTRACTS, SPECIFICATIONS AND DRAWINGS.

1	ISSUED FOR INFORMATION	04/05/2020
REV	**DESCRIPTION**	**DATE**

PROJECT

FLEETWOOD MODULAR

DRAWING TITLE

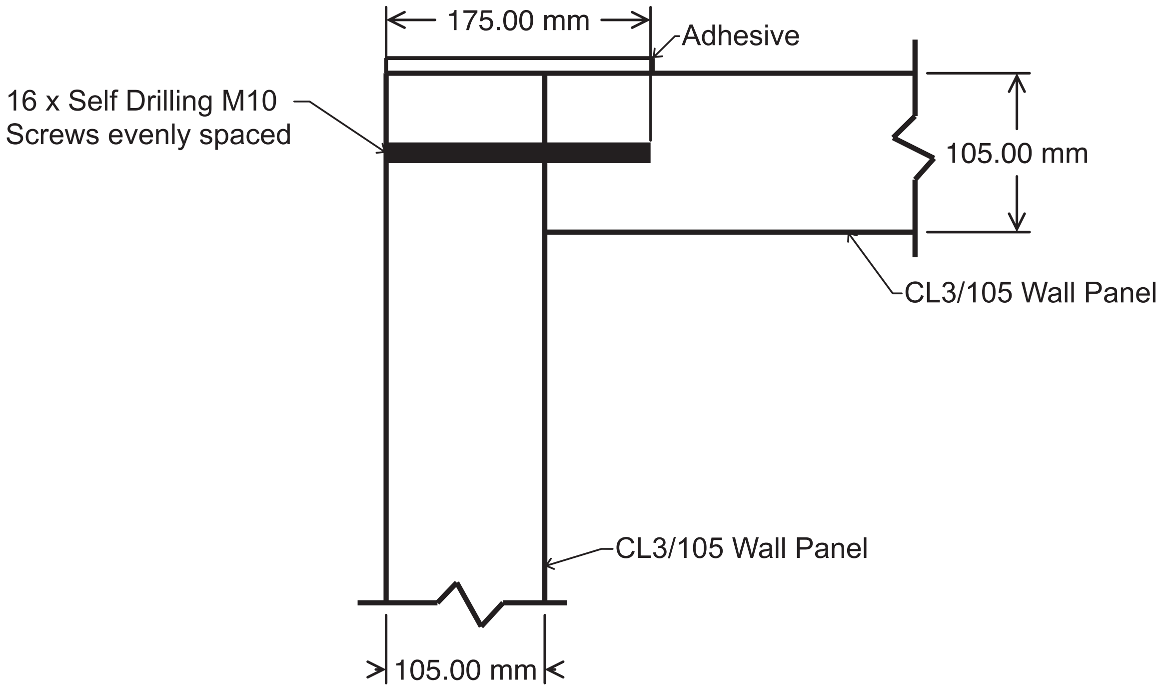
BUILDING ORTHAGONAL VIEW

SCALE @ A3

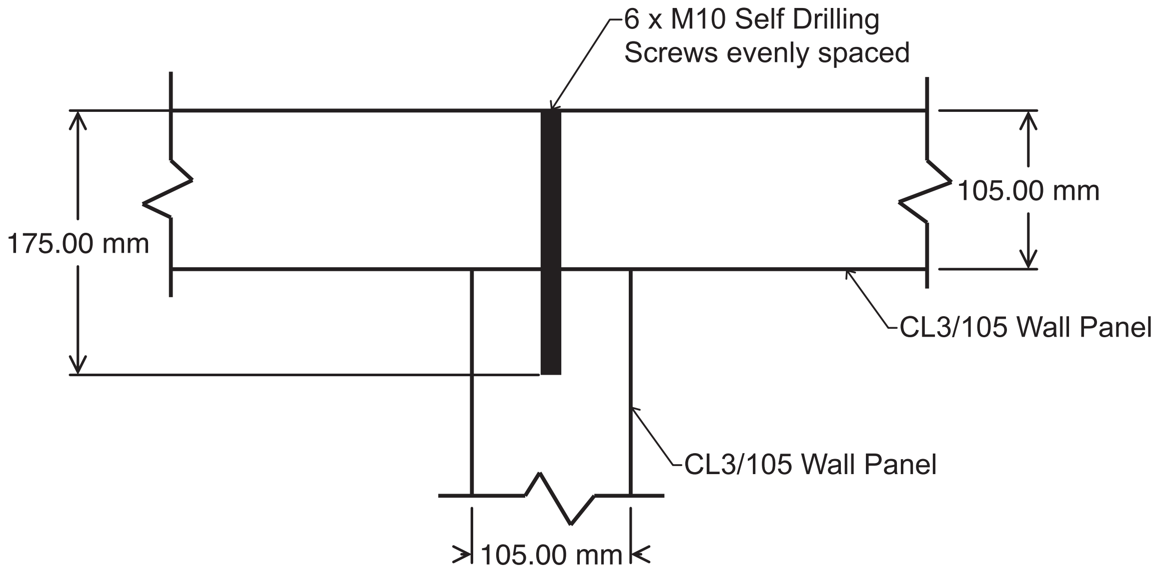
NOT TO SCALE

DRAWN	REVIEWED	APPROVED
	SA	DY

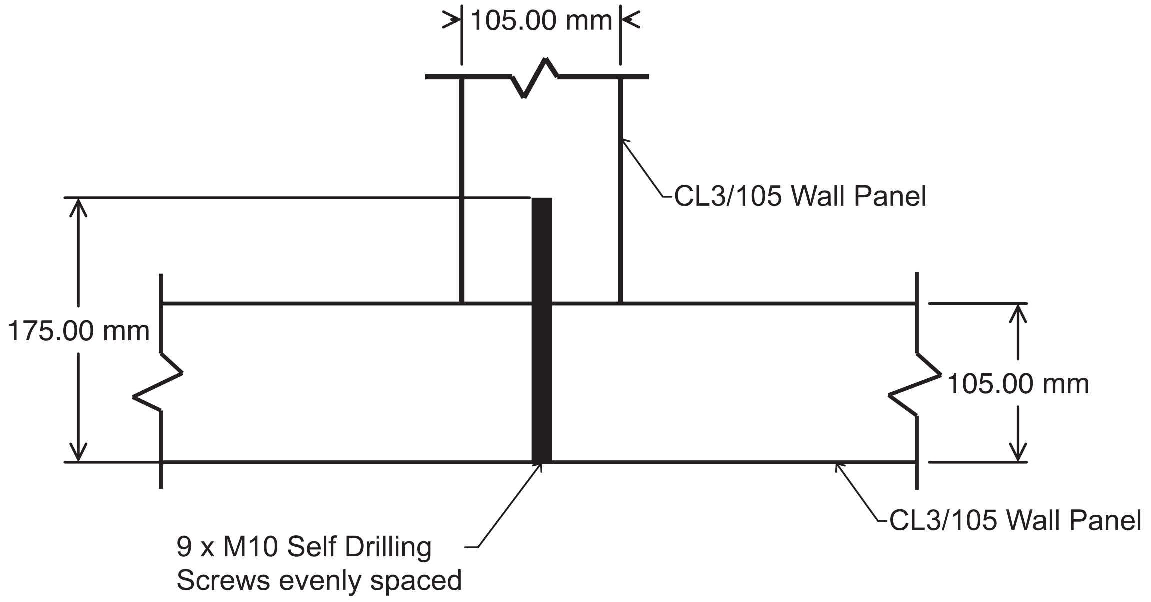
DRAWING NUMBER	REVISION
A 001	1



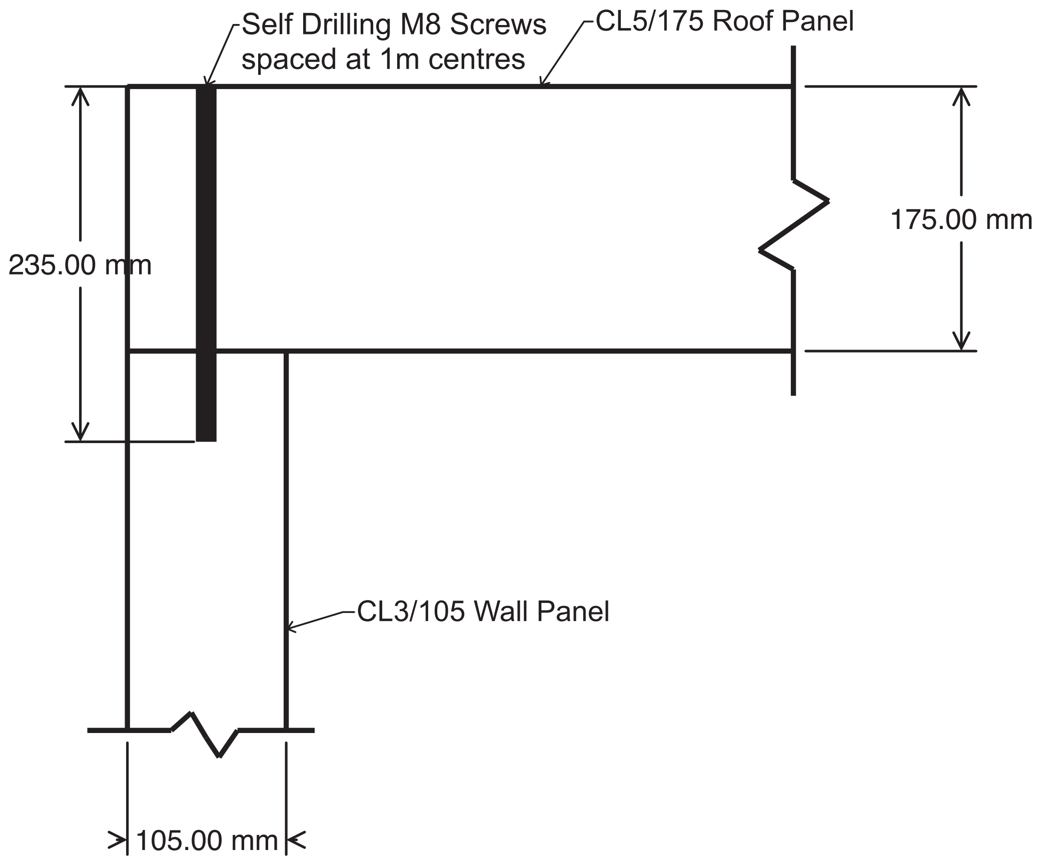
EXTERIOR WALL TO EXTERIOR WALL CONNECTION



INTERIOR WALL TO INTERIOR WALL CONNECTION



INTERIOR WALL TO EXTERNAL WALL CONNECTION



ROOF TO WALL CONNECTION

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REV	DESCRIPTION	DATE
1	ISSUED FOR INFORMATION	04/05/2020

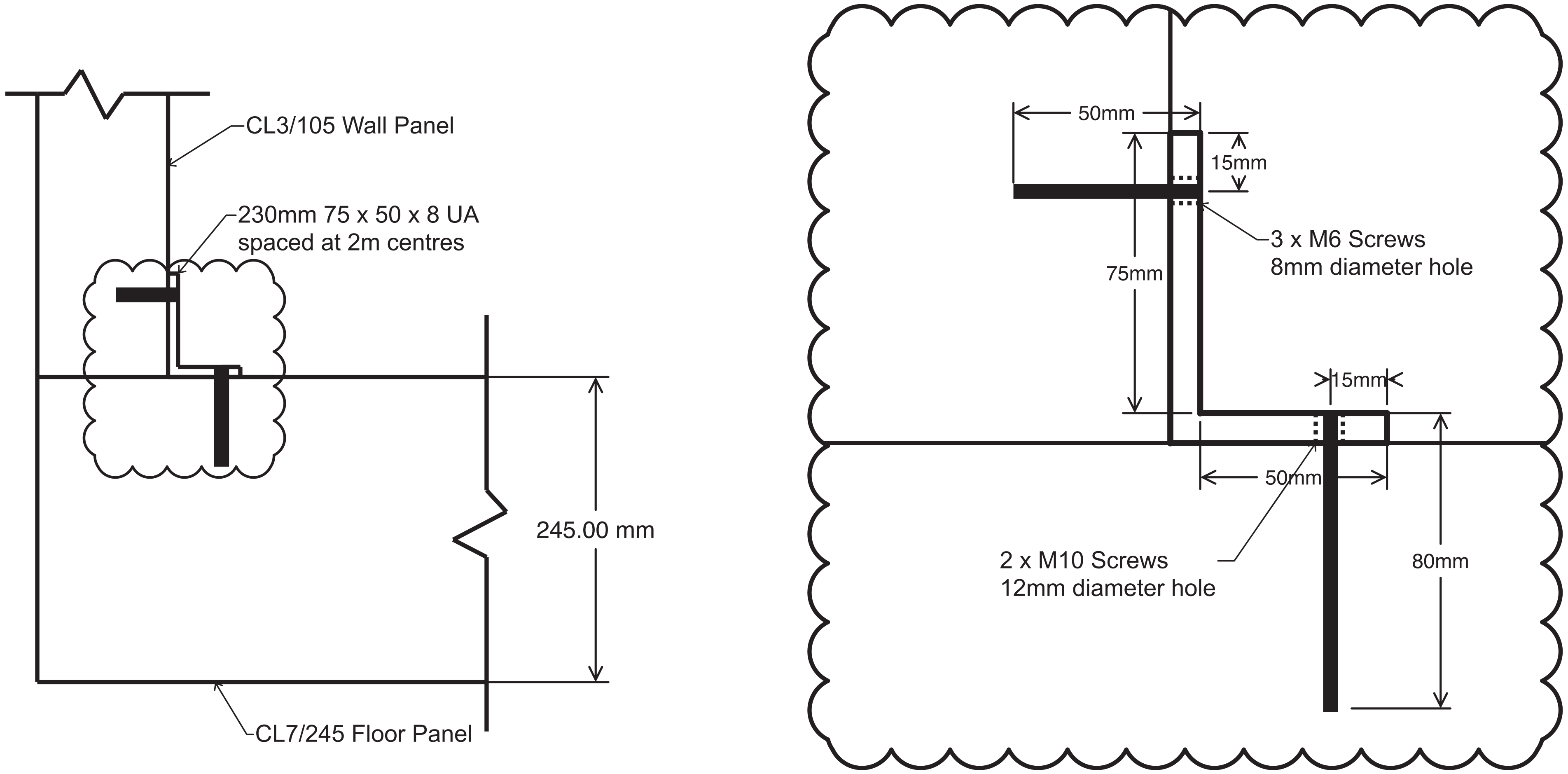
PROJECT
FLEETWOOD MODULAR

DRAWING TITLE
CONNECTION DETAILS
SHEET 1

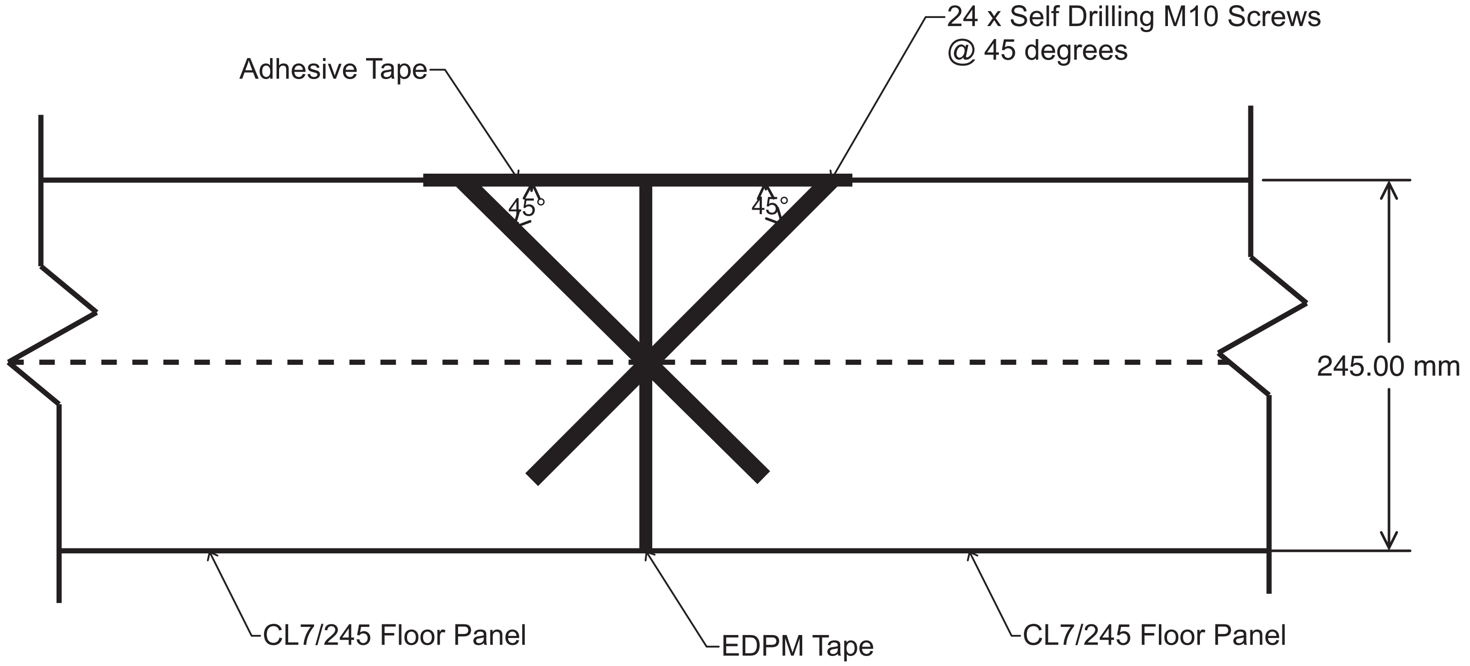
SCALE @ A3
1 : 5

DRAWN	REVIEWED	APPROVED
	SA	DY

DRAWING NUMBER	REVISION
A 100	1



FLOOR TO WALL CONNECTION



MODULE TO MODULE FLOOR CONNECTION

NOTES

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REV	DESCRIPTION	DATE
1	ISSUED FOR INFORMATION	04/05/2020

PROJECT
FLEETWOOD MODULAR

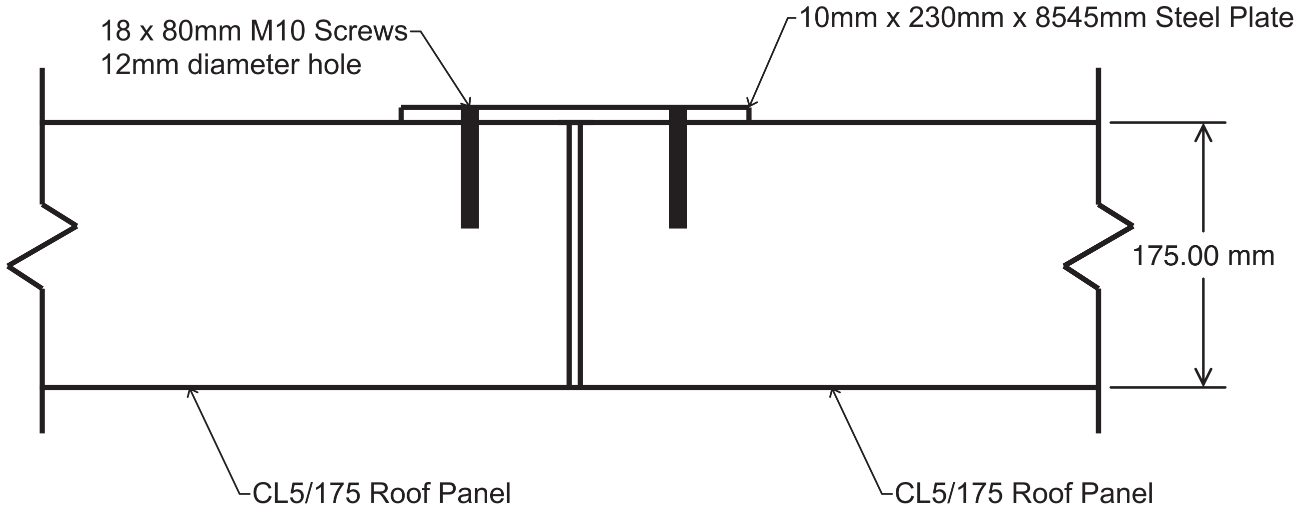
DRAWING TITLE
CONNECTION DETAILS
SHEET 2

SCALE @ A3
1 : 5

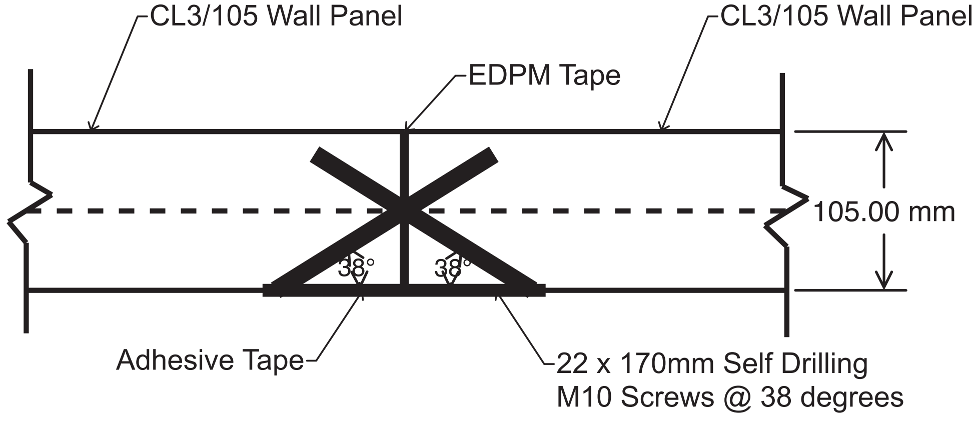
DRAWN
REVIEWED
APPROVED

DRAWING NUMBER
A 101

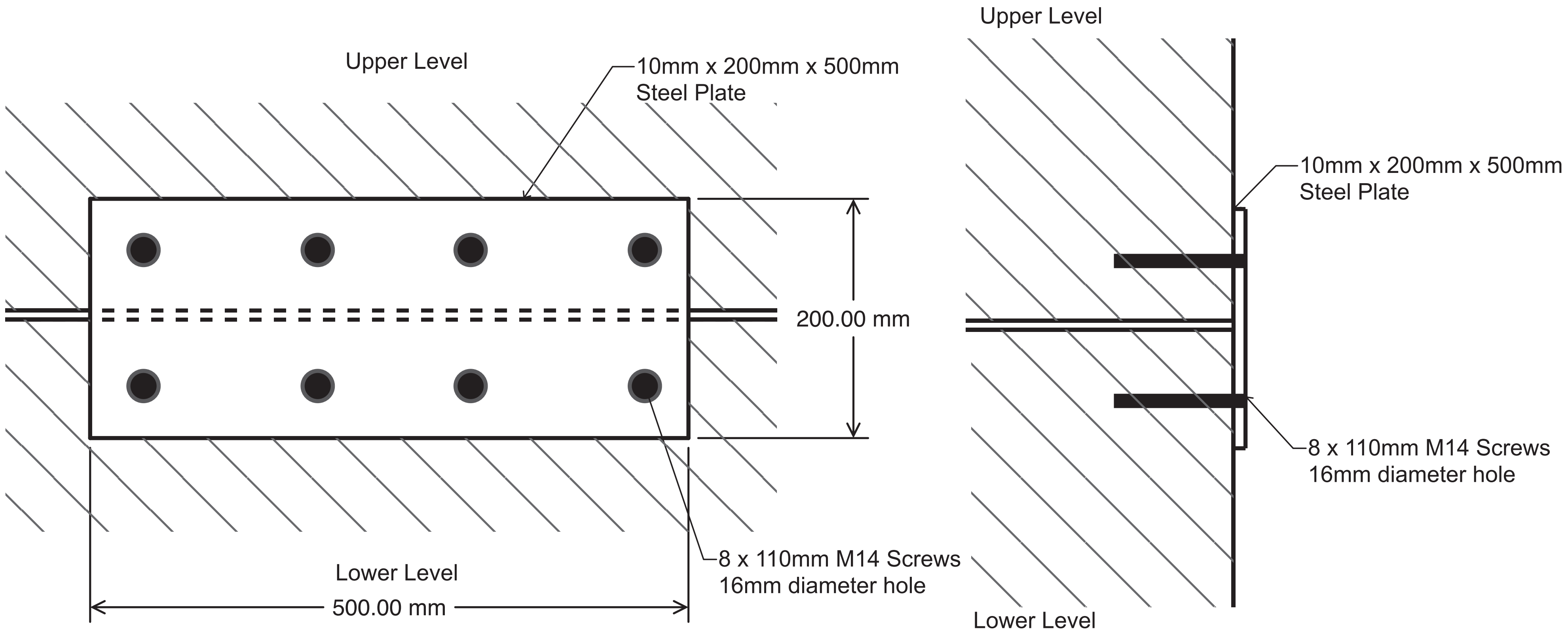
REVISION
1



MODULE TO MODULE ROOF CONNECTION



MODULE TO MODULE WALL CONNECTION



LEVEL TO LEVEL CONNECTION

NOTES

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1	ISSUED FOR INFORMATION	04/05/2020
REV	DESCRIPTION	DATE

PROJECT
FLEETWOOD MODULAR

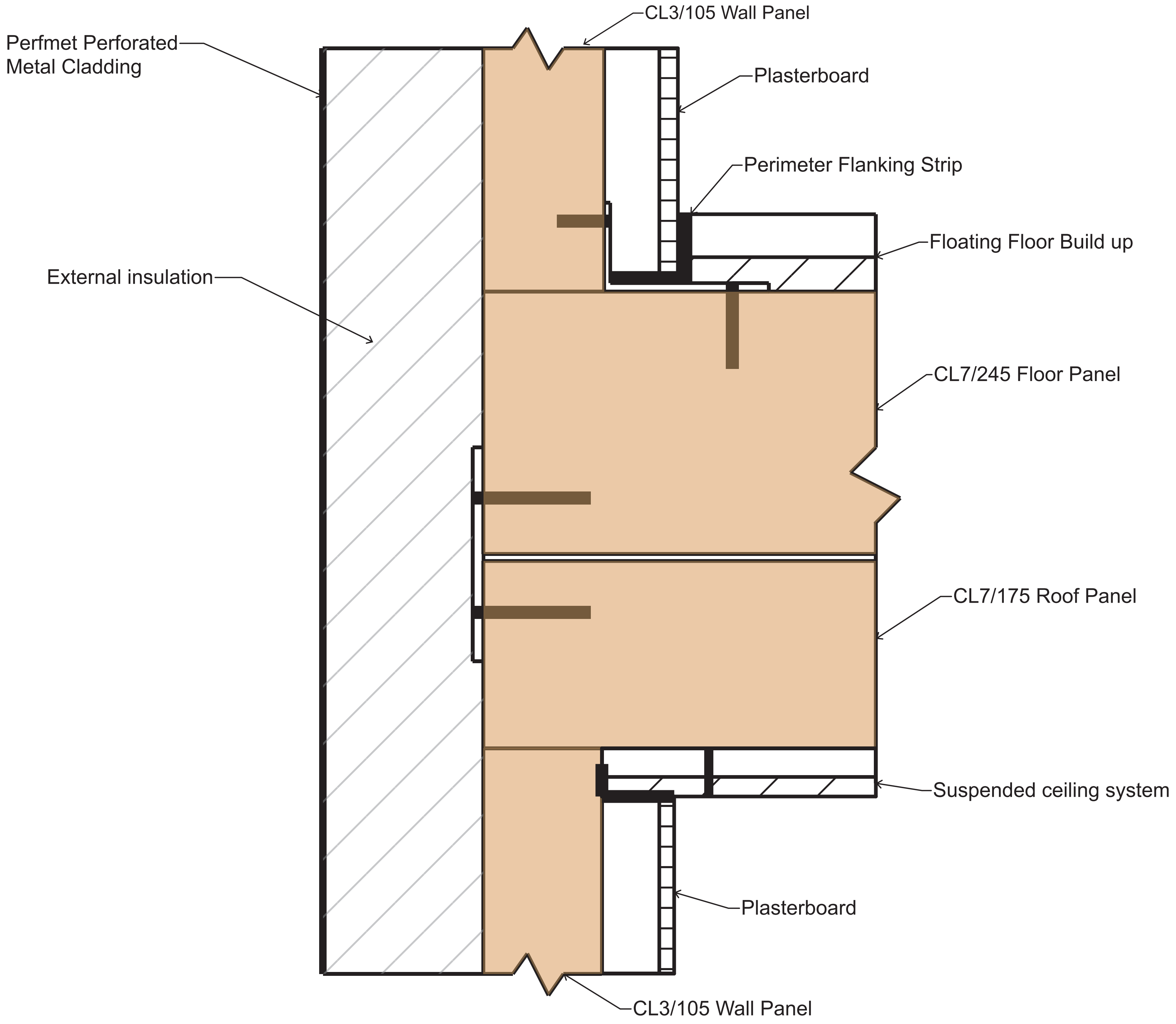
DRAWING TITLE
CONNECTION DETAILS
SHEET 3

SCALE @ A3
1 : 5

DRAWN
REVIEWED
APPROVED

DRAWING NUMBER
A 103

REVISION
1



NOTES

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REV	DESCRIPTION	DATE
1	ISSUED FOR INFORMATION	04/05/2020

PROJECT

FLEETWOOD MODULAR

DRAWING TITLE

CLADDING, FLOOR AND CEILING BUILDUP

SCALE @ A3

1 : 5

DRAWN	REVIEWED	APPROVED

DRAWING NUMBER	REVISION
A 104	1

6.0. Team work

All team members contributed equally to this assignment. Meeting minutes that show evidence of team work can be found in Appendix B.

7.0. Summary

Overall, with consultation between Architecture and Structural Engineering students a transportable housing project has been designed for the client. The solution is environmentally friendly, exploring the use of CLT, a fairly new construction material. The design is also cost-effective and flexible to meet relocation requirements.

8.0. References

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Appendix A – Wind Load Calculations

Description	**Formula**	**Symbol**	**Values**	**Unit**	**Notes / Assumptions**	**Code/Clause - AS1170.2**
					Design Wind Speeds	
wind region				A		
importance level			2			
design life			50	years		
annual probability of excedence			1 in 500	years		
regional wind speed						
		V25	37	m/s		
					Region A. Design working life 50 years.	
		V500	45	m/s	Importance level 2	T3.1
wind direction multiplier		Md	1		Most conservative	T3.2
roof height			14.8	m		
terrain category		TC	3		using architects brief	
terrain multiplier		Mz,cat	0.89		using h = 14.8m	T4.1
shuilding multiplier		Ms	1		No shielding (conservative)	4.4.1
topographical multiplier		Mt	1		No hill height (conservative)	4.4.2
wall dimensions			9.96	m		
			11.31	m		
Serviceability	Vsit = VR Md (Mz,cat Ms Mt)			where Vr = V25		2.2
			32.93	m/s		
Ultimate	Vsit = VR Md (Mz,cat Ms Mt)			where Vr = V500		2.3
			40.05	m/s		
dynamic response		Cdyn	1			
aerodynamic shape		Cfig	1			
air density		p,air	1.2	kg/m^3		
Wind pressure		P				
		p = (0.5 pair) [Vdes]^2 Cfig Cdyn				
		24.03				
					K factors	
Area reduction factors:						
leeward wall		Ka	1		tributary areas?	T5.4
windward wall		Ka	1			T5.4
roof		Ka	1		Kce x Ka must be greater than 0.8	5.4.3
sidewalls		Ka	1		Kce x Ka must be greater than 0.9	5.4.4
external effective surfaces		Kc,e	0.8		4 effective surfaces - pressures from windward and leeward walls in combination with roof pressures and internal pressures	T5.5 (b)
internal effective surfaces		Kc,i	0.8			T5.5 (b)
load pressure factor		Kl	1			5.4.5
permeable cladding reduction		Kp	1		external surface does not consist of permeable cladding	5.4.5

Description	Formula	Symbol	Values	Unit	Notes / Assumptions	Code/Clause - AS1170.2
					Roof Wind Pressure	
Height of Building		h	14.8	m		
Width of Building		d	9.96	m	smallest width	
h/d ratio		h/d	1.48594			
density of air			1.2	kg/m^3		2.4.1
		Cdyn	1		structure is not dynamically wind sensitive	2.4.1
External Pressure Coefficient +		Cp,e	-0.3			T5.3A
External Pressure Coefficient -		Cp,e	-1.3		occurs 0m from the windward edge of roof	T5.3A
horizontal distance from						
windward edge of roof	0 to 0.5h	-1.3	-0.6			T5.3A
	0.5 to 1h	-0.7	-0.3			T5.3A
Internal Pressure Coefficient +		Cp,i	0.2		ratio of openings on one surface to sum of total	T5.1B
Internal Pressure Coefficient -		Cp,i	-0.1		open area = 1	T5.1B
	+	Cfig,e	-0.24		Cfig,e = Cp,e x Ka x Kl x Kp	5.2 (1)
	-	Cfig,e	-1.04		Cfig,e = Cp,e x Ka x Kl x Kp	5.2 (1)
	+	Cfig,i	0.16		Cfig,i= Cp,i x Kc,i	5.2 (2)
	-	Cfig,i	-0.08		Cfig,i= Cp,i x Kc,i	5.2 (2)
					Windward wall	
height of building		h	14.8			
External Pressure Coefficient +		Cp,e	0.7		Less than 25m tall, wind speed when h = z	T5.2(A)
External Pressure Coefficient -		Cp,e	0.7		Less than 25m tall, wind speed when h = z	T5.2(A)
Internal Pressure Coefficient +		Cp,i	0.2		ratio of openings on one surface to sum of total	T5.1(B)
Internal Pressure Coefficient -		Cp,i	-0.1		open area = 1	T5.1(B)
	+	Cfig,e	0.56		Cfig,e = Cp,e x Ka x Kl x Kp	5.2 (1)
	-	Cfig,e	0.56		Cfig,e = Cp,e x Ka x Kl x Kp	5.2 (1)
	+	Cfig,i	0.16		Cfig,i= Cp,i x Kc,i	5.2 (2)
	-	Cfig,i	-0.08		Cfig,i= Cp,i x Kc,i	5.2 (2)
					Leeward Wall	
Roof Pitch		a	<10	degrees		
Width of building		d	9.96	m		
Length of building		b	11.31	m		
d/b ratio			0.88064			
h/d ratio			1.48594			
External Pressure Coefficient +		Cp,e	-0.5		using d/b ratio and roof pitch	T5.2B
External Pressure Coefficient -		Cp,e	-0.5		using d/b ratio and roof pitch	T5.2B
Internal Pressure Coefficient +		Cp,i	0.2		ratio of openings on one surface to sum of total	T5.1B
Internal Pressure Coefficient -		Cp,i	-0.1		open area = 1	T5.1B
	+	Cfig,e	-0.4		Cfig,e = Cp,e x Ka x Kl x Kp	5.2 (1)
	-	Cfig,e	-0.4		Cfig,e = Cp,e x Ka x Kl x Kp	5.2 (1)
	+	Cfig,i	0.16		Cfig,i= Cp,i x Kc,i	5.2 (2)
	-	Cfig,i	-0.08		Cfig,i= Cp,i x Kc,i	5.2 (2)

Description	**Formula**	**Symbol**	**Values**	**Unit**	**Notes / Assumptions**	**Code/Clause - AS1170.2**
					Side Walls	
Roof Pitch		a	<10			
h/d ratio			1.48594			
External Pressure Coefficient +		Cp,e	-0.65		Occurs at 0m from windward edge	T5.C
External Pressure Coefficient -		Cp,e	-0.65		Occurs at 0m from windward edge	T5.C
Internal Pressure Coefficient +		Cp,i	0.2		ratio of openings on one surface to sum of total	T5.1B
Internal Pressure Coefficient -		Cp,i	-0.1		open area = 1	T5.1B
	+	Cfig,e	-0.52		Cfig,e = Cp,e x Ka x Kl x Kp	5.2 (1)
	-	Cfig,e	-0.52		Cfig,e = Cp,e x Ka x Kl x Kp	5.2 (1)
	+	Cfig,i	0.16		Cfig,i= Cp,i x Kc,i	5.2 (2)
	-	Cfig,i	-0.08		Cfig,i= Cp,i x Kc,i	5.2 (2)
					Most Positive External + Most Negative Internal	
Roof Adjusted Cfig		Cfig	-0.32			
Windward wall adjusted Cfig		Cfig	0.48			
Leeward Wall adjusted Cfig		Cfig	-0.48			
Side Walls adjusted Cifg		Cfig	-0.6			
Roof Design Wind Pressure		p	-307.968	pa	p = 0.5 x pair x (Vdes)^2 x Cfig x Cdyn	2.4.1
Windward wall design wind pressure		p	461.953	pa	p = 0.5 x pair x (Vdes)^2 x Cfig x Cdyn	2.4.1
Leeward wall design wind pressure		p	-461.953	pa	p = 0.5 x pair x (Vdes)^2 x Cfig x Cdyn	2.4.1
Side wall design wind pressure		p	-577.441	pa	p = 0.5 x pair x (Vdes)^2 x Cfig x Cdyn	2.4.1
					Most Negative External + Most Positive Internal	
Roof Adjusted Cfig		Cfig	-0.88			
Windward wall adjusted Cfig		Cfig	0.72			
Leeward Wall adjusted Cfig		Cfig	-0.24			
Side Walls adjusted Cifg		Cfig	-0.36			
Roof Design Wind Pressure		p	-846.913	pa	p = 0.5 x pair x (Vdes)^2 x Cfig x Cdyn	2.4.1
Windward wall design wind pressure		p	692.929	pa	p = 0.5 x pair x (Vdes)^2 x Cfig x Cdyn	2.4.1
Leeward wall design wind pressure		p	-230.976	pa	p = 0.5 x pair x (Vdes)^2 x Cfig x Cdyn	2.4.1
Side wall design wind pressure		p	-346.465	pa	p = 0.5 x pair x (Vdes)^2 x Cfig x Cdyn	2.4.1

General: *Engineering process-management records diary* (with line-management/ team-member signatures)

Task: **Prepare for weekly-review & then final-submission, a Process-Diary/ record of groups' activities.**

Group Number

Line-Manager Name.

Date (Week No): 4/3/20

Team-Member Names:	
	Team's perceived overall contribution out of 33.3%: 3/3
	Team's perceived overall contribution out of 33.3%:
	Team's perceived overall contribution out of 33.3%:

Line-Manager Meeting				no-show name
- Attendance:	[✓ *Full*]	*Partial*	*Nil*	Met Arch.
- design-task rotation	*suitable design-task sharing*		*unsuitable design-task sharing*	
Line-Manager's perceived equity	*Equitable*	*could-do-better*	*Inequitable*	

Show evidence (in-brief) related to:	**Rating Scale / comments** *Appropriate*	*Getting there*	*Missed opportunity*	**Comments** continue overleaf note if not-applicable N/A
Actions Pending/ Completed				
- minutes of member-member liaison	|	|	/0	
- *Media (BIM)* preparation activities	|	|	/0	
- activities completed recently	|	|	/0	
- tasks identified as pending	|	|	/0	
- record of group-to-group bid-liaison	|	|	/0	
Line-Manager issues in-brief				
Project Progress				
- Problem identification(s)	|	|	/0	
- Potential alternative solutions	|	|	/0	
- Justifications of best solution	|	|	/0	
- hand-calculations prior to software	|	|	/0	
- BQ / costing / scheduling progress	|	|	/0	
- Procurement progress	|	|	/0	
- *Media (BIM) Submissions Activities*	|	|	/0	
Line-Manager issues in-brief				
Process Management Generally				
- leadership; conflict management…	|	|	/0	
Line-Manager issues in-brief				
- **Line-Manager's Check-List for next Meeting** *continue over-leaf…*				

Signatures:				

General: *Engineering process-management records diary* (with line-management/ team-member signatures)

Task: Prepare for weekly-review & then final-submission, a Process-Diary/ record of groups' activities.

Group Number: 16

Line-Manager Name:

Date (Week No): 11/3

Team-Member Names:	
	Team's perceived overall contribution out of 33.3%: YES
	Team's perceived overall contribution out of 33.3%: YES
	Team's perceived overall contribution out of 33.3%: NO

Line-Manager Meeting				no-show name
• Attendance:	Full	[✓ Partial]	Nil	
• design-task rotation	[✓ suitable design-task sharing]		unsuitable design-task sharing	
Line-Manager's perceived equity	[✓ Equitable]	could-do-better	Inequitable	

Show evidence (in-brief) related to:	**Rating Scale / comments** *Appropriate* / *Getting there* / *Missed opportunity*	**Comments** continue overleaf note if not-applicable N/A
Actions Pending/ Completed		
• minutes of member-member liaison	Met with Arch. ✓ /0	Recommend Minutes.
• *Media (BIM)* preparation activities	/0	
• activities completed recently	/0	
• tasks identified as pending	/0	
• record of group-to-group bid-liaison	/0	
Line-Manager issues in-brief		
Project Progress		
• Problem identification(s)	/0	
• Potential alternative solutions	/0	
• Justifications of best solution	/0	
• hand-calculations prior to software	/0	
• BQ / costing / scheduling progress	/0	
• Procurement progress	/0	
• *Media (BIM) Submissions* Activities	/0	
Line-Manager issues in-brief		
Process Management Generally		
• leadership; conflict management…	/0	
Line-Manager issues in-brief		
• **Line-Manager's Check-List for next Meeting** *continue over-leaf…*		

Signatures:			

General: *Engineering process-management records diary* **(with line-management/ team-member signatures)**

Task: **Prepare for weekly-review & then final-submission, a Process-Diary/ record of groups' activities.**

Group Number:

Line-Manager Name:

Date (Week No):

[redacted]	*Team's perceived overall contribution out of* [✓ 33.3%:]
	Team's perceived overall contribution out of [✓ 33.3%:]
	Team's perceived overall contribution out of [✓ 33.3%:]

Line-Manager Meeting	-			*no-show name*
- Attendance:	[✓ *Full*]	*Partial*	*Nil*	
- design-task rotation	[✓ *suitable design-task sharing*]		*unsuitable design-task sharing*	
Line-Manager's perceived equity	*Equitable*	*could-do-better*	*Inequitable*	

Show evidence (in-brief) related to:	**Rating Scale / comments** *Appropriate* *Getting there* *Missed opportunity*	**Comments** *continue overleaf* *note if not-applicable N/A*
Actions Pending/ Completed	-	See minutes attached.
- minutes of member-member liaison	- /------------------------------------|------------------------------------/0	
- *Media (BIM)* preparation activities	- /------------------------------------|------------------------------------/0	
- activities completed recently	- /------------------------------------|------------------------------------/0	
- tasks identified as pending	- /------------------------------------|------------------------------------/0	
- record of group-to-group bid-liaison	- /------------------------------------|------------------------------------/0	
Line-Manager issues in-brief		
Project Progress	-	
- Problem identification(s)	- /------------------------------------|------------------------------------/0	
- Potential alternative solutions	- /------------------------------------|------------------------------------/0	
- Justifications of best solution	- /------------------------------------|------------------------------------/0	
- hand-calculations prior to software	- /------------------------------------|------------------------------------/0	
- BQ / costing / scheduling progress	- /------------------------------------|------------------------------------/0	
- Procurement progress	- /------------------------------------|------------------------------------/0	
- *Media (BIM) Submissions Activities*	- /------------------------------------|------------------------------------/0	
Line-Manager issues in-brief		
Process Management Generally	-	
- leadership; conflict management…	- /------------------------------------|------------------------------------/0	
Line-Manager issues in-brief		
- **Line-Manager's Check-List for next Meeting** *continue over-leaf…*		

Signatures:				

General: *Engineering process-management records diary* **(with line-management/ team-member signatures)**

Task: **Prepare for weekly-review & then final-submission, a Process-Diary/ record of groups' activities.**

Group Number: [redacted]

Line-Manager Name: [redacted]

Date (Week No):

Team-Member Names:	
[redacted]	*Team's perceived overall contribution out of* [✓ 33.3%]:
	Team's perceived overall contribution out of [✓ 33.3%]:
	Team's perceived overall contribution out of [✓ 33.3%]:

Line-Manager Meeting	-	*no-show name*
Attendance:	*[✓ Full]* *Partial* *Nil*	
design-task rotation	*[✓ suitable design-task sharing]* *unsuitable design-task sharing*	
Line-Manager's perceived equity	*Equitable* *could-do-better* *Inequitable*	

Show evidence (in-brief) related to:	**Rating Scale / comments** *Appropriate* *Getting there* *Missed opportunity*	**Comments** *continue overleaf* *note if not-applicable N/A*
Actions Pending/ Completed	-	Please see minutes attached.
• minutes of member-member liaison	/------------------|------------------/0	
• *Media (BIM)* preparation activities	/------------------|------------------/0	
• activities completed recently	/------------------|------------------/0	
• tasks identified as pending	/------------------|------------------/0	
• record of group-to-group bid-liaison	/------------------|------------------/0	
Line-Manager issues in-brief		
Project Progress	-	" "
• Problem identification(s)	/------------------|------------------/0	
• Potential alternative solutions	/------------------|------------------/0	
• Justifications of best solution	/------------------|------------------/0	
• hand-calculations prior to software	/------------------|------------------/0	
• BQ / costing / scheduling progress	/------------------|------------------/0	
• Procurement progress	/------------------|------------------/0	
• *Media (BIM) Submissions Activities*	/------------------|------------------/0	
Line-Manager issues in-brief		
Process Management Generally	-	" "
• leadership; conflict management...	/------------------|------------------/0	
Line-Manager issues in-brief		
• **Line-Manager's Check-List for next Meeting** *continue over-leaf...*		

Signatures:	[redacted]	[redacted]	[redacted]	

Meeting Minutes – 25/03/2020 10:08am – 11:35am

Present:

All team members – [redacted]

Topics of Discussion:

- Discussed drawing and structural analysis software
- Allocated jobs to complete by next meeting
- Broke down the assignment criteria
- Broke down architect drawings
- Discussed materials and overall structural design
- Module stacking, prefabrication/assembly and transportation
- Plumbing and electrical in apartments
- Email [redacted] about definition of module and accessing software required for design/analysis (STAAD pro)
- Asked architect for site plans

Minutes submitted by [redacted]

General: *Engineering process-management records diary* **(with line-management/ team-member signatures)**

Task: **Prepare for weekly-review & then final-submission, a Process-Diary/ record of groups' activities.**

Group Number:

Line-Manager Name:

Date (Week No):

Team-Member Names:	
	Team's perceived overall contribution out of [✓ 33.3%:]
	Team's perceived overall contribution out of [✓ 33.3%:]
	Team's perceived overall contribution out of [✓ 33.3%:]

Line-Manager Meeting	-			*no-show name*
- Attendance:	[✓ *Full*]	*Partial*	*Nil*	
- design-task rotation	[✓ *suitable design-task sharing*]		*unsuitable design-task sharing*	
Line-Manager's perceived equity	*Equitable*	*could-do-better*	*Inequitable*	

Show evidence (in-brief) related to:	**Rating Scale / comments** *Appropriate* *Getting there* *Missed opportunity*	**Comments** *continue overleaf* *note if not-applicable N/A*
Actions Pending/ Completed	-	
- minutes of member-member liaison	- /--------------------|--------------------/0	
- *Media (BIM)* preparation activities	- /--------------------|--------------------/0	
- activities completed recently	- /--------------------|--------------------/0	
- tasks identified as pending	- /--------------------|--------------------/0	
- record of group-to-group bid-liaison	- /--------------------|--------------------/0	
Line-Manager issues in-brief		
Project Progress	-	
- Problem identification(s)	- /--------------------|--------------------/0	“ ”
- Potential alternative solutions	- /--------------------|--------------------/0	
- Justifications of best solution	- /--------------------|--------------------/0	
- hand-calculations prior to software	- /--------------------|--------------------/0	
- BQ / costing / scheduling progress	- /--------------------|--------------------/0	
- Procurement progress	- /--------------------|--------------------/0	
- *Media (BIM) Submissions Activities*	- /--------------------|--------------------/0	
Line-Manager issues in-brief		
Process Management Generally	-	“ ”
- leadership; conflict management…	- /--------------------|--------------------/0	
Line-Manager issues in-brief		
- **Line-Manager's Check-List for next Meeting** ***continue over-leaf…***		

Signatures:				

Group [redacted] Meeting Minutes

Date & Time:	Wednesday 08/04/2020 1:30pm
Location:	Online
Present:	
Absent:	

Topic	Performed By	Completion Date
Approval of previous minutes	Everyone	08/04/2020
Assignment 1:		
Wall material calculations - CLT Preliminary design of connections between buildings Drawings and Modelling of design Wind Calculations Structural calculations		15/04
Assignment 2:		
Risk Management Plan Scheduling Bill of Quantities Project and Works estimates		15/04
Architects Design:		
Changing design height – 3.7m Where to split apartment in half Implementing column and balustrades for balcony	Architect & Engineers	15/04

Adjournment	
Finish time:	2:00pm
Minutes Written By:	

Next Meeting	
Date & Time:	Wednesday 15/04/2020 1:00pm

Group 16 Meeting Minutes

Date & Time:	Wednesday 28/04/2020 1:00pm
Location:	Online
Present:	
Absent:	

Topic	Performed By	Completion Date
Approval of previous minutes	Everyone	28/04/2020
Assignment 1:		
• Floor Design • Lifting Points • Preliminary design of connections between buildings • Drawings and Modelling of design • Structural calculations • A3 Summary		• 03/05
Assignment 2:		
• Risk Management Plan • Scheduling • Approximate Analysis • Bill of Quantities • Project and Works estimates		• 03/05
Architects Design:		
• Reasons for design choices • Where to split apartment in half • Implementing column and balustrades for balcony		• 03/05

Adjournment

Finish time:	2:00pm
Minutes Written By:	

Next Meeting

Date & Time:	Saturday 02/05/2020 10:00am

Appendix C – XLam Australian Cross Laminated Timber Structure Design Guide

XLam

XLam
Australian Cross Laminated Timber Panel Structural Guide

This pre-analysis guide provides key information necessary for the preliminary assessment of XLam structures. It covers material properties, design principles, connections, and includes pre -analysis span tables derived from extensive product testing.

XLam Australia Pty Ltd | www.xlam.com.au

Use of this Structural Guide

Application

This design guide has been prepared for use by suitably qualified construction professionals to assist in the design and specification of XLam panels. Products referred to in this document other than XLam panels are presented for information purposes only and due regard should be given to the relevant Australian Standards and other manufacturer's literature. Advice on overall building design issues including, but not limited to: stability, loading, temporary stability during construction, fixings, waterproofing, fire engineering and overall acoustic performance are not covered by this guide and advice should be sought from suitably qualified professionals.

It is the responsibility of the user to ensure that the use of this Design Guide is appropriate and to exercise their own professional judgement when using the document. Full responsibility for the design and compliance with the Building Code of Australia and all relevant Australian Standards rests with the design professional specifying and certifying the product. XLam will not accept any liability for the failure of any other elements of the building which cause a subsequent failure of an XLam product.

Structural Design in CLT

At present there are no structural codes in use around the world which cover the design of CLT, including AS1720.1 (Timber Structures: part 1 Design Methods). Therefore, the design of CLT is not covered under the deemed-to-satisfy provisions of the BCA and it will be necessary for consulting engineers or XLam Design to certify the design as part of a performance solution. Performance solutions are significantly more common than many engineers might appreciate with some frequently used products, such as concrete anchors, not being covered by an Australian Standard.

The primary difference for many design checks will come in the calculation of the section properties of the CLT panel and more information is given later in this guide. The rest of the principles of strength and serviceability checks closely follow the provisions laid out for the design of timber in AS1720.1.

The guide is aimed to provide a high-level overview of the structural design of a simple CLT building consisting of walls, floors and roofs and covers many standard situations. Simple span tables for walls, floors, roofs and stairs have been provided to give an indication of expected panel sizes for particular applications, although project specific design checks will need to be completed for each. More detailed design information can be found in XLam Technical Notes which are available by contacting XLam's technical department.

Updates and Version Control

This design guide is identified with a version number and date of issue. The latest issue is always on the XLam website. Access to the XLam design guides requires user registration for the purpose of disseminating updates. XLam will notify registered users of updates by email. It is the user's responsibility to ensure that the latest version is in use at all times. Unless otherwise stipulated, the XLam design guides will be provided to registered users in electronic format. Bound hard copies can be made available by XLam on request.

Structural Documentation & Certification Process

XLam strives to provide as much design and detailing assistance as our clients require. Our design phase involvement varies significantly across projects depending on our clients' preferences.

1. Concept and scoping

At the concept stage, XLam Design can carry out a scoping design for the project. This service is intended to provide high level advice on panel thicknesses and types to suit your project, as well as design considerations and where other materials will be required. Our clients are welcome to take this concept to a consulting engineer to complete the detailed design and construction documentation if preferred, the intention is to get the project off on the right foot. We encourage our clients obtain our input early to ensure the design adopted is economical, and suits both manufacturing and erection processes. The pre-analysis tables in this guide can be used at this stage to inform the concept and scoping phase of projects, however project specific design is required for all projects.

2. Detailed design and construction documentation

If the concept phase identifies CLT to be the preferred structural option, there are two options to proceed the design:

1. Engage a suitably qualified consulting structural engineer to carry out the detailed design and construction documentation for the entire project, including the CLT elements. In this instance, the structural certification would be signed by the appointed consulting engineer for all structural elements.
2. Engage a suitably qualified consulting structural engineer to carry out the detailed design and construction documentation for any non-timber elements in the project, and engage Xlam Design to carry out the design and documentation of the timber and CLT elements. This is common practice, and we work in conjunction with your consulting engineer to ensure a fully coordinated package. Two structural certifications would be issued, one by the consulting engineer covering the elements they have designed, and one by XLam Design to cover the CLT and other timber elements on the project.

The team at XLam Design has a vast background of CLT experience not only in Australia and New Zealand but internationally. We strive to produce economical and buildable design solutions, leveraging off a comprehensive understanding of the manufacturing and installation process. This understanding of the manufacturing and installation process allows Xlam Design to detail panels and connections in the most efficient way possible, reducing machining time and hence project CLT supply costs.

3. Shop detailing and supply of panels

After detailed design is completed, should the client wish to proceed with XLam for supply of panels, an agreement would be entered into. This agreement would cover shop drawings and associated detailing based on the construction documentation. In some instances, if XLam Design are engaged for the detailed design phase, the detailed design process may overlap with the shop drawing phase, allowing us to expedite program. This will depend on terms of engagement, and should be discussed with your sales representative.

XLam Structural Design Guide

XLam Panel Specification

XLam have manufacturing facilities in both Wodonga, Victoria and Nelson, New Zealand and the potential to use panels from either facility exists on most XLam projects completed in Australia unless otherwise directed by the client. Both factories use feedstock with similar characteristic properties and will have the same structural performance but are pressed using different technology.

XLam Panel Properties

XLam will manufacture all panels in Australia from locally grown plantation pine. All material is supplied to XLam pre-graded but we also conduct our own in house testing of the timber to ensure that the specifications below are met. XLam can manufacture panel with the following feedstock thicknesses, in 20mm, 35mm and 45mm thick feedstock.

Structural Properties (Timber Grade XLam Proprietary method)	**XLG1**	**XLG2**
Structural Property	External Lamellas	Internal Lamellas
Modulus of Elasticity (parallel to the grain)	8000 MPa	6000 MPa
Bending Strength (parallel to the grain) $f_{b,0}$	14.0 MPa	10.0 MPa
Compression Strength (parallel to grain) $f_{c,0}$	18.0 Mpa	15.0 MPa
Compression Strength (perpendicular to grain) $f_{c, 90}$	8.9 MPa	8.9 MPa
Tension Strength (parallel to grain) $f_{t,0}$	6.0 MPa	4.0 MPa
Shear Strength (parallel to grain) $f_{s,0}$	3.8 MPa	3.8 MPa
Rolling Shear Strength (perpendicular to grain) $f_{s,90}$	1.2 Mpa	1.2 MPa
Shear Modulus (parallel to grain) G_0	533 MPa	400 MPa
Rolling Shear Modulus (perpendicular to grain) G_R	38 MPa	29 MPa
Mean Density γ	500 kg/m^3	500 kg/m^3

Note: Strength properties are given as a characteristic value, while stiffness and densities are given as mean values as defined in AS/NZS 4063.

This guide provides a standard set of panel build-ups based on these sizes but within reason it is possible to create any combination of these if required provided a few rules are followed:

1. All panels must have layers alternating at 90 degrees

2. Structural sections must be symmetrical and an odd number of layers (it is possible to add sacrificial outer layers if required, only two thicknesses of feedstock [options are 20mm, 35mm and 45mm] can be used in any one panel].

3. A panel with a single 20mm central cross-layer is difficult to handle and only used for non-structural applications

4. Any non-standard panel sizes will not be covered by our fire assessments

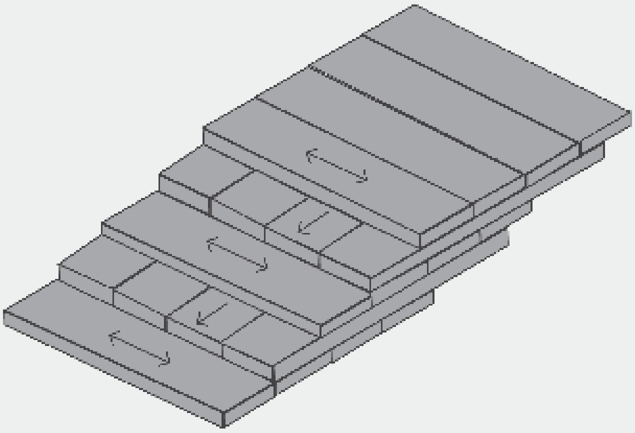
XLam Standard Panel Sizes

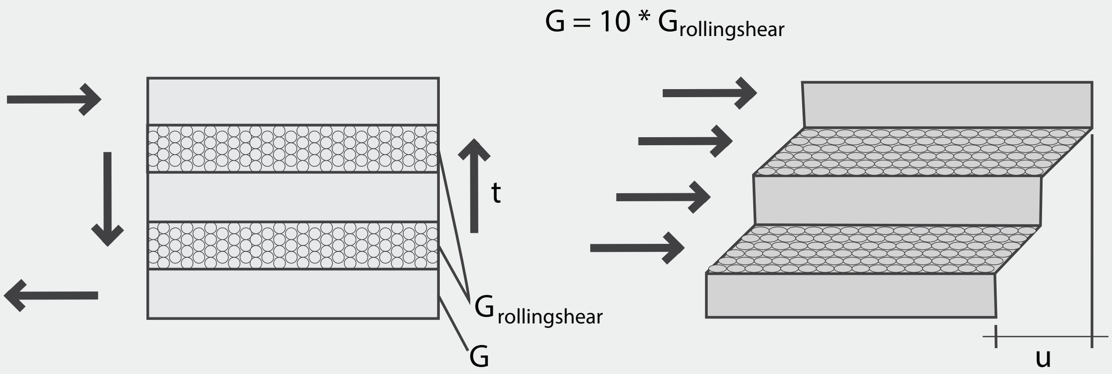
Panel Designation	Layer 1 (mm)	Layer 2 (mm)	Layer 3 (mm)	Layer 4 (mm)	Layer 5 (mm)	Layer 6 (mm)	Layer 7 (mm)	Total Thickness (mm)	Selfweight (kPa)
3 Layer Panels									
CL3/85	20	45	20					85	0.4
CL3/105	35	35	35					105	0.5
CL3/115	35	45	35					115	0.6
CL3/125	45	35	45					125	0.6
CL3/135	45	45	45					135	0.7
5 Layer Panels									
CL5/145	35	20	35	20	35			145	0.7
CL5/160	35	35	20	35	35			160	0.9
CL5/175	45	20	45	20	45			175	1.0
CL5/195	45	35	35	35	45			195	1.1
CL5/205	45	35	45	35	45			205	1.2
CL5/225	45	45	45	45	45			225	
7 Layer Panels									
CL7/245	35	35	35	35	35	35	35	245	1.3
CL7/265	45	35	35	35	35	35	45	265	1.4
CL7/275	45	35	35	45	35	35	45	275	1.4
CL7/295	45	35	45	45	45	35	45	295	1.6
CL7/315	45	45	45	45	45	45	45	315	1.7

CLT Section Properties

The structural performance of CLT is relatively unique due to the deformation caused by the cross-layers' relative shear stiffness. This phenomenon, known as rolling shear, reduces the effectiveness of the outer layers and hence the section properties of CLT panels. It is crucial that this is accounted for in the design of CLT.

There are several different methods of calculating the section properties of a CLT panel adopted around the world, most of which end up at an answer within a few percent of each other. XLam has used the Shear Analogy Method in the development of the span tables contained in this document and more information on this model and others can be obtained through XLam's technical department.





Floor and Roof Design

The design of most CLT floors will be governed by serviceability requirements (typically deflection and vibration) and it is rare for a design to push the structural capacity of the panels unless there are large openings or notches. The choice of appropriate limits for deflections or vibration performance will be subjective and dependent on project specific requirements. It is important for designers to be aware of the limits chosen to produce the span tables contained in this guide so that designers can make judgement on their suitability for specific projects. For floor and roof panels, the outer layers need to be oriented in the direction of the span. Panels do have minor direction bending stiffness, however this bending stiffness is greatly reduced.

Vibration

The dynamic performance of a floor is governed by three factors: stiffness (stiffer floors perform better), mass (heavier floors perform better) and damping (floors with additional layers, furniture etc. perform better). Timber is a relatively lightweight form of construction and therefore requires more consideration of vibration in design than a more conventional concrete floor. In most commercial scale buildings CLT floor design will be governed by vibration so these checks are important to carry out to ensure the performance of the floor meets client expectations.

Human perception of vibration is subjective issue and different people will experience varied responses to the same floor vibration, particularly depending on what activity they are engaged in. Different criteria will apply to residential buildings when compared to offices, for example, and various parameters are well published across the world.

The pre-analysis tables contained within this document have been prepared using the following vibration criteria based on research into long span timber floors carried out in Europe. Further references and information can be made available for designers wishing to understand these checks in more detail. It should be noted that these checks are relatively stringent and another set of tables with some more relaxed limits is published in XLam Technical Note XLTN-5.3.

1. The natural frequency of the floor is checked based on the dead load of the floor (including super-imposed dead loads). If the natural frequency is greater than 8Hz then skip to step 3.

2. If natural frequencies are lower than 8Hz then a more detailed determination of the acceleration is made based on the following equation

$$\boxed{a = 0.4\frac{P_0\alpha_1(f_1)}{M_{gen}}\frac{1}{\sqrt{\left[\left(\frac{f_1}{f_F}\right)^2 - 1\right]^2 + \left(2D\frac{f_1}{f_F}\right)^2}} \leq 0.05m/s^2}$$

Where:

- P_0 = 700N (mass of one person)
- a_i = Fourier coefficient
- f_1 = natural frequency
- f_F = forcing frequency
- D = Damping (taken as 1.5% for a lightly finished floor)
- M_{gen} = Generalised mass $M_{gen} = m\, {}^{L}/_{2}\, b_{eff}$

Fundamental Frequency, f_1 Hz	Fourier Coefficients a_1	Forcing Frequency f_F Hz
$3.4 < f_1 < 4.6$	0.2	f_1
$4.6 < f_1 < 5.1$	0.2	f_1
$5.1 < f_1 < 6.9$	0.006	f_1
$f_1 > 6.9$	0.006	6.9

3. Check the deflection of the floor under a 1kN point load is less than 1mm based on an effective floor width of b_{eff}

$$\boxed{b_{eff} = \frac{L}{1.1} \sqrt[4]{\frac{EI_T}{EI_L}}}$$

Where:

- EI_T = Transverse stiffness of panel
- EI_L = Longitudinal stiffness of panel

For Cantilevers, the pre-analysis tables provide cantilever spans that satisfy both of these requirements:

1. Natural frequency of floor is checked based on the dead load of the floor (including super-imposed dead loads). The natural frequency must be greater than 8Hz

2. The cantilever is checked for a 1kN point load on its tip, and a maximum 1.5mm deflection is allowed for.

Deflection

The allowable deflection of floor and roof panels is dependent on the application, type of finishes and any other building elements supported by them. These requirements need to be understood prior to the design. The shear deformation of timber can be a significant proportion of the overall deflection of a floor or roof and this therefore needs to be considered. The Shear Analogy method used by XLam to develop the tables in this document includes this within its calculation method.

Similarly to concrete, timber is a material which creeps over time and the long term deflection of a floor should be calculated. Both the duration of loading and moisture content of the timber is important to the long-term deflection of the panel. AS1720.1 uses a modification factor for the long-term deflection of timber (j_2) which provides a multiplier for use in calculations. For timber with a moisture content of 15% or less the maximum j_2 factor is 2 which has been used in the development of all span tables contained in this document. XLam does not recommend the use of their panels in any environments where the moisture content is greater than 15%.

Refer to the 'CLT and Other Structural Materials' section for deflection considerations when using CLT with other structural materials.

Pre-Analysis Span Tables

Floor Span Table Notes

Terminology

G = Dead Load (inclusive of superimposed dead load and panel self-weight)

G_{SDL} = Superimposed dead load (floor finishes / ceiling etc.)

Q = Live Load

Wu = Wind ultimate

Ws = Wind service

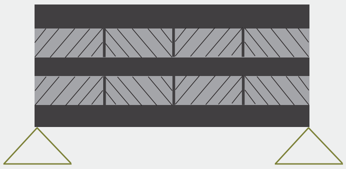
- Self-weight of the panels is included within the tables. All additional applied dead loads should be included in the value chosen for G_{SDL}
- Span tables assume uniformly distributed loads across the whole panel and no pattern loading has been accounted for.
- Any penetrations or routing of panels could reduce the allowable spans in these tables
- The cantilever design assumes a backspan of 1.5 times the cantilever length. Different backspan lengths can have a large effect on the cantilever span.
- Pattern live loading on the cantilever and backspan has not been considered in these tables. These tables account only for the uniform load on both cantilever and backspan.
- Long term deflection factors are taken as $j_2 = 2$ for all situations.
- These tables assume panels are supported on walls, and do not consider compound deflections if panels are supported on beams or spanning elements. Refer to "CLT and other structural materials" section for limitations when using with other structural materials.

Floor deflection checks included for in the tables:

Case	Span	Cantilever
Short-term dead, δ_G	Span/200	Span/200
Short-term live, δ_Q	Span/360	Span/200
Long-term dead and live $j_2(G+0.4Q)$, $\delta_{LT:G+Q}$	Span/300 or 25mm	Span/200

Pre-Analysis Span Tables

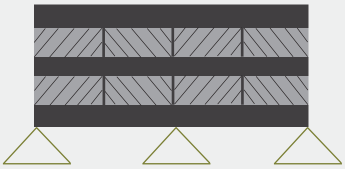
Floor Simply-Supported [maximum panel span in metres]



Panel Designation	Q = 2kPa SDL				Q = 3kPa SDL				Q = 5kPa SDL			
	OkPa	0.5kPa	1kPa	2kPa	OkPa	0.5kPa	1kPa	2kPa	OkPa	0.5kPa	1kPa	2kPa
3 Layer Panels												
CL3/85	2.8	2.8	2.5	2.2	2.7	2.6	2.4	2.1	2.3	2.3	2.1	1.9
CL3/105	3.4	3.4	3.2	2.8	3.4	3.3	3.1	2.7	2.9	2.9	2.8	2.5
CL3/115	4.1	3.8	3.5	3.1	3.9	3.5	3.3	2.9	3.2	3.2	3	2.7
CL3/125	4.2	4.2	3.8	3.4	4.2	3.9	3.6	3.2	3.5	3.5	3.3	3
CL3/135	4.9	4.4	4.1	3.6	4.5	4.1	3.9	3.4	3.8	3.7	3.5	3.2
5 Layer Panels												
CL5/145	5.1	4.6	4.3	3.8	4.7	4.4	4.1	3.7	4	3.9	3.7	3.4
CL5/160	5.4	4.9	4.5	4	5	4.6	4.3	3.9	4.3	4.1	3.9	3.6
CL5/175	5.9	5.3	4.9	4.4	5.6	5.2	4.9	4.4	4.9	4.7	4.5	4.1
CL5/195	6.2	5.6	5.2	4.7	6	5.6	5.2	4.7	5.3	5.1	4.8	4.4
CL5/205	6.4	5.8	5.4	4.9	6.2	5.8	5.4	4.9	5.6	5.3	5	4.6
CL5/225	6.6	6.1	5.7	5.1	6.6	6.1	5.7	5.1	5.9	5.6	5.4	4.9
7 Layer Panels												
CL7/245	6.8	6.2	5.9	5.3	6.8	6.2	5.9	5.3	6.2	5.8	5.6	5.2
CL7/265	7.2	6.7	6.3	5.7	7.2	6.7	6.3	5.7	6.8	6.4	6.2	5.7
CL7/275	7.4	6.8	6.4	5.8	7.4	6.8	6.4	5.8	7	6.6	6.3	5.8
CL7/295	7.6	7.1	6.7	6.1	7.6	7.1	6.7	6.1	7.4	7	6.7	6.1
CL7/315	7.8	7.3	6.9	6.3	7.8	7.3	6.9	6.3	7.6	7.3	6.9	6.3

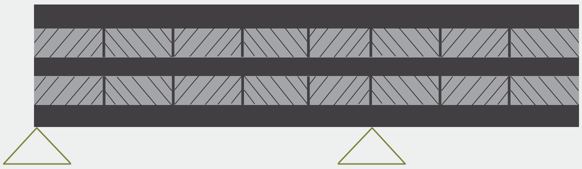
Pre-Analysis Span Tables

Floor Continuous [maximum panel span in metres, double equal span]



Panel Designation	Q = 2kPa				Q = 3kPa				Q = 5kPa			
	SDL				SDL				SDL			
	OkPa	0.5kPa	1kPa	2kPa	OkPa	0.5kPa	1kPa	2kPa	OkPa	0.5kPa	1kPa	2kPa
3 Layer Panels												
CL3/85	4.1	3.3	3.0	2.6	3.6	3.3	3.0	2.6	2.9	2.9	2.8	2.5
CL3/105	4.7	3.9	3.5	3.1	4.7	3.9	3.5	3.1	3.8	3.8	3.5	3.1
CL3/115	4.9	4.1	3.7	3.2	4.9	4.1	3.7	3.2	4.2	4.1	3.7	3.2
CL3/125	5.1	4.4	4.0	3.5	5.1	4.4	4.0	3.5	4.6	4.4	4.0	3.5
CL3/135	5.3	4.6	4.1	3.6	5.3	4.6	4.1	3.6	4.9	4.6	4.1	3.6
5 Layer Panels												
CL5/145	5.4	4.7	4.3	3.8	5.4	4.7	4.3	3.8	5.2	4.7	4.3	3.8
CL5/160	5.5	4.9	4.5	4.0	5.5	4.9	4.5	4.0	5.5	4.9	4.5	4.0
CL5/175	5.9	5.3	4.9	4.4	5.9	5.3	4.9	4.4	5.9	5.3	4.9	4.4
CL5/195	6.2	5.6	5.2	4.7	6.2	5.6	5.2	4.7	6.2	5.6	5.2	4.7
CL5/205	6.4	5.8	5.4	4.9	6.4	5.8	5.4	4.9	6.4	5.8	5.4	4.9
CL5/225	6.6	6.1	5.7	5.1	6.6	6.1	5.7	5.1	6.6	6.1	5.7	5.1
7 Layer Panels												
CL7/245	6.8	6.2	5.9	5.3	6.8	6.2	5.9	5.3	6.8	6.2	5.9	5.3
CL7/265	7.2	6.7	6.3	5.7	7.2	6.7	6.3	5.7	7.2	6.7	6.3	5.7
CL7/275	7.4	6.8	6.4	5.8	7.4	6.8	6.4	5.8	7.4	6.8	6.4	5.8
CL7/295	7.6	7.1	6.7	6.1	7.6	7.1	6.7	6.1	7.6	7.1	6.7	6.1
CL7/315	7.8	7.3	6.9	6.3	7.8	7.3	6.9	6.3	7.8	7.3	6.9	6.3

Pre-Analysis Span Tables



Floor Cantilever [maximum cantilever in metres]

[No allowance for any point load on cantilever]

Panel Designation	Q = 2kPa SDL				Q = 3kPa SDL				Q = 5kPa SDL			
	0kPa	0.5kPa	1kPa	2kPa	0kPa	0.5kPa	1kPa	2kPa	0kPa	0.5kPa	1kPa	2kPa
3 Layer Panels												
CL3/85	1	1	1	0.9	1	1	0.9	0.9	1	0.9	0.9	0.8
CL3/105	1.3	1.3	1.2	1.1	1.3	1.2	1.1	1	1.2	1.1	1.1	1
CL3/115	1.5	1.3	1.3	1.1	1.4	1.3	1.2	1.1	1.2	1.2	1.1	1
CL3/125	1.6	1.4	1.4	1.2	1.5	1.4	1.3	1.2	1.3	1.3	1.2	1.1
CL3/135	1.6	1.5	1.4	1.3	1.5	1.4	1.3	1.2	1.4	1.3	1.2	1.2
5 Layer Panels												
CL5/145	1.7	1.6	1.5	1.3	1.6	1.5	1.4	1.3	1.4	1.4	1.3	1.2
CL5/160	1.8	1.6	1.5	1.4	1.7	1.5	1.5	1.3	1.5	1.4	1.4	1.3
CL5/175	1.9	1.8	1.7	1.5	1.8	1.7	1.6	1.5	1.7	1.6	1.5	1.4
CL5/195	2	1.9	1.8	1.6	1.9	1.8	1.7	1.6	1.7	1.6	1.6	1.5
CL5/205	2.1	1.9	1.8	1.7	2	1.8	1.8	1.6	1.8	1.7	1.6	1.5
CL5/225	2.1	2	1.9	1.7	2	1.9	1.8	1.7	1.9	1.8	1.7	1.6
7 Layer Panels												
CL7/245	2.2	2.1	2	1.8	2.1	2	1.9	1.7	1.9	1.8	1.8	1.7
CL7/265	2.3	2.2	2.1	1.9	2.2	2.1	2	1.9	2	2	1.9	1.8
CL7/275	2.4	2.2	2.1	2	2.3	2.1	2	1.9	2.1	2	1.9	1.8
CL7/295	2.5	2.3	2.2	2	2.4	2.2	2.1	2	2.2	2.1	2	1.9
CL7/315	2.5	2.4	2.3	2.1	2.4	2.3	2.2	2	2.2	2.1	2.1	1.9

Pre-Analysis Span Tables

Roof Pre-Analysis Span Table Notes

Terminology

G = Dead Load (inclusive of superimposed dead load and panel self-weight)

G_{SDL} = Superimposed dead load (floor finishes / ceiling etc.)

Q = Live Load

Wu = Wind ultimate

Ws = Wind service

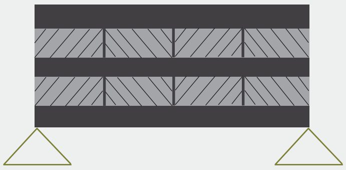
- Selfweight of the panels is included within the tables. All additional applied dead loads should be included in the value chosen for G_{SDL}
- Span tables assume uniformly distributed loads across the whole panel and no pattern loading has been accounted for.
- Any penetrations or routing of panels could reduce the allowable spans in these tables
- The cantilever design assumes a backspan of 1.5 times the cantilever length. Different backspan lengths can have a large effect on the cantilever span.
- Long term deflection factors are taken as j_2 = 2 for all situations.
- Roof tables include for the following:
  - Ultimate wind loads of 1.3kPa (uplift) and 0.55kPa (down)
  - Serviceability wind loads of 0.9kPa (uplift) and 0.4kPa (down)
  - No allowance is made for snow loading in the design tables
  - Refer to "CLT and Other Structural Materials" section for limitations when using other structural materials. Floor panels are assumed to be supported on walls.

Roof deflection checks included for in the tables:

Case	Span	Cantilever
Short-term dead, δ_G	Span/300	Span/150
Short-term live, δ_Q	Span/300	Span/150
Wind load (uplift), δ_{ws}	Span/300	Span/150
Long-term dead and live $j_2(G+0.4Q)$, $\delta_{LT:G+Q}$	Span/300 or 25mm	Span/150
Short-term dead and wind $(G+0.7W_s)$, δ_{G+Ws}	Span/300	Span/150

Pre-Analysis Span Tables

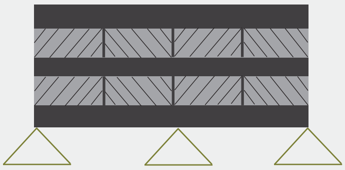
Roof Simply-Supported [maximum panel span in metres]



Panel Designation	Q = 0.25kPa SDL			Q = 1kPa SDL			Q = 2kPa SDL		
	0kPa	0.5kPa	1kPa	0kPa	0.5kPa	1kPa	0kPa	0.5kPa	1kPa
3 Layer Panels									
CL3/85	4.1	3.4	2.9	3.6	3.1	2.7	3.2	2.8	2.5
CL3/105	5.2	4.2	3.7	4.5	3.9	3.5	4	3.5	3.2
CL3/115	5.5	4.5	4	4.8	4.2	3.7	4.3	3.8	3.5
CL3/125	5.9	4.9	4.3	5.2	4.5	4.1	4.7	4.2	3.8
CL3/135	6.2	5.2	4.6	5.5	4.8	4.4	4.9	4.4	4.1
5 Layer Panels									
CL5/145	6.4	5.4	4.8	5.7	5	4.6	5.1	4.6	4.3
CL5/160	6.6	5.7	5.1	6	5.3	4.8	5.4	4.9	4.5
CL5/175	7.3	6.4	5.7	6.7	6	5.5	6.1	5.5	5.1
CL5/195	7.6	6.7	6.1	7.1	6.3	5.8	6.5	5.9	5.5
CL5/205	7.8	7	6.3	7.3	6.6	6.1	6.7	6.1	5.7
CL5/225	8.1	7.4	6.7	7.6	7	6.4	7.1	6.5	6.1
7 Layer Panels									
CL7/245	8.2	7.5	6.9	7.8	7.2	6.6	7.3	6.7	6.3
CL7/265	8.7	8	7.6	8.3	7.7	7.3	7.8	7.4	6.9
CL7/275	8.8	8.2	7.7	8.4	7.9	7.5	8	7.5	7.1
CL7/295	9	8.5	8	8.7	8.2	7.8	8.3	7.9	7.5
Cl7/315	9	8.7	8.2	8.9	8.4	8	8.5	8.1	7.7

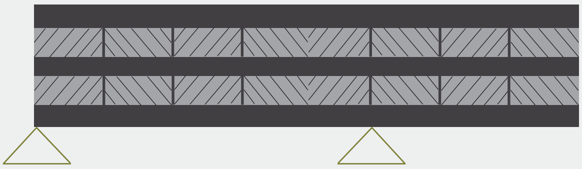
Pre-Analysis Span Tables

Roof Continuous [maximum panel span in metres]



Panel Designation	Q = 0.25kPa SDL			Q = 1kPa SDL			Q = 2kPa SDL		
	0kPa	0.5kPa	1kPa	0kPa	0.5kPa	1kPa	0kPa	0.5kPa	1kPa
3 Layer Panels									
CL3/85	5.4	4.5	3.8	4.8	4	3.6	4.2	3.7	3.3
CL3/105	6.9	5.6	4.9	6	5.1	4.6	5.3	4.7	4.2
CL3/115	7.3	6	5.2	6.4	5.5	4.9	5.6	5	4.6
CL3/125	7.7	6.5	5.7	6.9	6	5.4	6.1	5.5	5
CL3/135	8	6.9	6.1	7.3	6.3	5.7	6.5	5.8	5.3
5 Layer Panels									
CL5/145	8.2	7.2	6.4	7.6	6.7	6	6.8	6.1	5.7
CL5/160	8.4	7.5	6.7	7.8	7	6.3	7.1	6.4	5.9
CL5/175	9	8.2	7.6	8.5	7.8	7.2	7.9	7.3	6.8
CL5/195	9	8.5	7.9	8.8	8.1	7.6	8.2	7.7	7.2
CL5/205	9	8.7	8.1	9	8.3	7.8	8.5	7.9	7.5
CL5/225	9	9	8.5	9	8.7	8.2	8.8	8.3	7.8
7 Layer Panels									
CL7/245	9	9	8.7	9	8.9	8.4	9	8.5	8.1
CL7/265	9	9	9	9	9	9	9	9	8.6
CL7/275	9	9	9	9	9	9	9	9	8.8
CL7/295	9	9	9	9	9	9	9	9	9
Cl7/315	9	9	9	9	9	9	9	9	9

Pre-Analysis Span Tables



Roof Cantilever [maximum cantilever in metres]

[No allowance for any point load on cantilever]

Panel Designation	Q = 0.25kPa			Q = 1kPa			Q = 2kPa		
	SDL			SDL			SDL		
	OkPa	0.5kPa	1kPa	OkPa	0.5kPa	1kPa	OkPa	0.5kPa	1kPa
3 Layer Panels									
CL3/85	1.9	1.6	1.4	1.6	1.4	1.2	1.4	1.2	1.1
CL3/105	2.3	1.9	1.7	2	1.8	1.6	1.8	1.6	1.5
CL3/115	2.3	2	1.8	2.1	1.9	1.7	1.9	1.7	1.6
CL3/125	2.5	2.2	2	2.2	2	1.9	2	1.9	1.7
CL3/135	2.6	2.3	2.1	2.3	2.1	2	2.1	2	1.8
5 Layer Panels									
CL5/145	2.6	2.3	2.1	2.4	2.2	2	2.2	2	1.9
CL5/160	2.7	2.4	2.2	2.5	2.3	2.1	2.3	2.1	2
CL5/175	2.9	2.6	2.4	2.7	2.5	2.3	2.5	2.3	2.2
CL5/195	3	2.7	2.5	2.8	2.6	2.4	2.6	2.4	2.3
CL5/205	3.1	2.8	2.6	2.9	2.7	2.5	2.7	2.5	2.4
CL5/225	3.2	2.9	2.7	3	2.8	2.6	2.8	2.6	2.5
7 Layer Panels									
CL7/245	3.3	3	2.8	3	2.8	2.7	2.8	2.7	2.6
CL7/265	3.5	3.2	3	3.2	3	2.9	3	2.9	2.8
CL7/275	3.5	3.2	3	3.3	3.1	2.9	3.1	2.9	2.8
CL7/295	3.6	3.4	3.2	3.4	3.2	3.1	3.2	3.1	2.9
Cl7/315	3.7	3.4	3.2	3.5	3.3	3.1	3.3	3.1	3

Wall Design

Vertical Load Design

CLT walls have high vertical load capacity when compared to more traditional timber structures and this has enabled the construction of otherwise not possible tall timber buildings. In the majority of cases the CLT wall should be designed so that the outer layers are vertical and the grain of the majority of the cross-section is running in the direction of the applied load. The cross-layers running perpendicular to the load are ignored in the axial design checks for the wall, although they can be useful to form lintel or header panels above doors and windows.

Section properties can again be calculated through several methods and the design checks are covered in detail in the FP Innovations guide. The capacity of the walls is governed by their slenderness which can be calculated through the equations for composite cross-sections in AS1720.1, E4.4. The design capacities presented in this guide have been calculated using these methods. Slender walls will naturally be more sensitive to issues like eccentric loading and construction imperfections and a suitable allowance for these should be made in the design.

When designing a multi-storey building for vertical loads consideration must be given to the floor connection and how loads are transferred through the floor. The most common form of CLT construction (known as platform construction) uses wall panels measuring a storey in height, and the floor is continuous over the top of them. This will cause compression across the grain in the floor panels, and this is significantly weaker and less stiff than the walls. For high loads or buildings more than five stories in height, we recommend the stiffness should be calculated. A significant proportion of the overall shortening of the building could come from the floor and this may need to be controlled through detailing during the structural design process. Please contact us for further guidance on detailing in these locations.

Lateral Load Design

The light weight and high shear resistance of CLT panels enable CLT buildings to be designed for excellent resistance to earthquakes. As with other materials in moderate or high seismic regions, it is essential to carry out “capacity design” to ensure that the brittle elements of the structure are never loaded to their full capacity, and that inelastic deformations occur in selected ductile elements; the weak links in the overall structure.

For CLT structures, it is essential to design the connections between panels as the ductile weak links. A hierarchy of strength can be applied between the various connections to ensure that the desired failure mechanism is achieved. Diaphragm capacity must also be checked to ensure the load can be sufficiently distributed to the lateral load resisting system.

Ductility in the connections comes from ductile behaviour of the fasteners themselves, which are the nails, screws or rivets used to connect the CLT panels together. These fasteners have a reasonable level of ductility, but their capacity can drop suddenly after the individual fasteners fail and crushing of wood occurs behind the individual fasteners during cyclic loading. This results in a very pinched hysteresis loop. Design for a higher level of ductility may be possible with ductile yielding of specialised hold-downs rather than relying on yielding of the nail or screw fixings. However, until further testing is carried out, it is suggested the designer uses conventional connection details which have been well tested for ductility (e.g. nails, dowels or rivets).

Depending on the support conditions and location of the wall, the reduction on axial capacity can be significant with combined axial and bending actions. The axial capacity span tables apply an accidental eccentricity of 10% of the wall thickness. Although the capacity tables provide guidance, CLT wall structures must be subject to specific engineering design.

Pre-Analysis Axial Capacity Tables

Wall Capacity [maximum axial capacity in kN per metre]

Panel Designation	Wall Height			
3 Layer Panels	2.8m	3.00m	3.50m	4.0m
CL3/85	129	115	85	71
CL3/105	250	226	171	144
CL3/115	302	274	209	178
CL3/125	386	352	272	231
CL3/135	446	412	321	275
5 Layer Panels				
CL5/145	505	467	364	312
CL5/160	565	526	416	358
CL5/175	756	713	590	512
CL5/195	812	776	670	602
CL5/205	883	846	736	665
CL5/225	953	919	817	751
7 Layer Panels				
CL7/245	858	841	760	707
CL7/265	1021	1004	932	874
CL7/275	1043	1027	967	910
CL7/295	1147	1130	1077	1020
CL7/315	1167	1152	1104	1064

Note: The combined loading check completed in calculating the values in the table above allows for moment induced by eccentricity in addition to a simultaneous wind load of 0.5kPa.

CLT Connections

Much of the engineering in a CLT building is focussed on the connections between panels. XLam is committed to assisting where possible and have made available on their website a set of their most used typical details in both CAD and Revit format. These details are based on XLam's depth of experience on past projects and are intended to streamline the manufacturing and installation process. Utilising these details will ensure economical manufacturing costs for our clients and ease of assembly on-site. There are many suppliers who have developed products tailor-made for CLT and mass timber construction and have some excellent technical literature available which makes design simpler for the engineer. XLam can procure proprietary fixings from these suppliers and could also arrange for the fabrication of other custom brackets and fixings if the project requires them.

CLT fixing suppliers:

- Rothoblaas
- Sherpa
- Simpson Strongtie
- Spax

Screw Connections

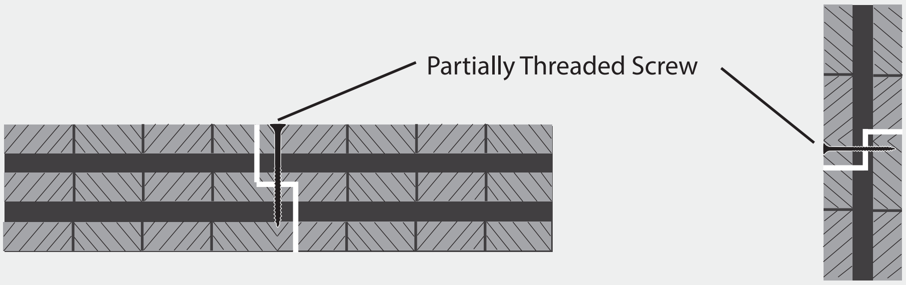
The capacity of screw connections is calculated using the European Yield Method (EYM) in Eurocode 5. The EYM considers a number of different failure mechanisms based on the shear capacity of the timber and the yield strength of the fastener.

Generally, self-tapping wood screws are recommended for connecting CLT floor and wall elements together. The screws come in a variety of lengths and diameters either fully threaded, or partially threaded, and do not require pre-drilling. Provided no thread extends beyond the receiving panel, partially threaded screws are able to pull the panels tight together, but fully threaded screws provide greater shear and withdrawal capacities.
If fully threaded screws are required for additional strength, it is recommended that panels be firstly pulled tight together using partially threaded screws.

The appropriate European Technical Approval (ETA) documentation specific to each screw supplier shall be used to determine the specific characteristic strengths. The capacity of each specific screw may vary slightly from each screw supplier. Higher shear capacities can be achieved using steel to timber connections, timber in double shear, or greater embedment depths.

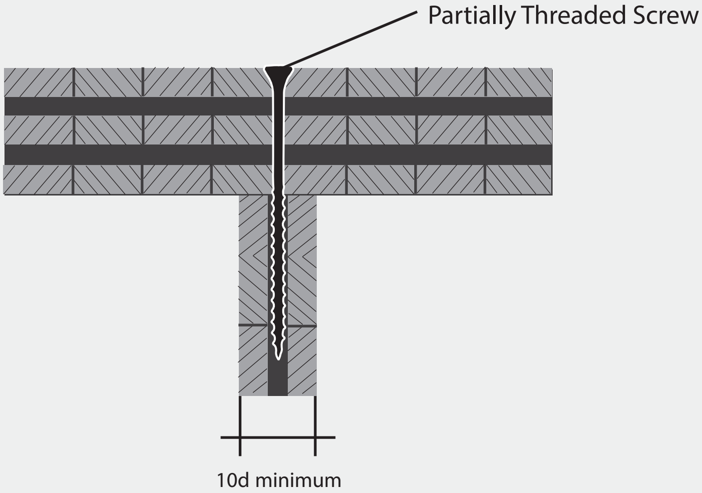
Panel to Panel Connections

Solid CLT panels are typically fixed together with a half lap joint connection. The screw spacing at the joint should be specified to resist the shear flow between panels to achieve diaphragm action. It is recommended that partially threaded screws are specified to ensure the panels are pulled tight together during site assembly. The half lap joint can resist transverse loading but is not considered to be a moment-resisting connection.



Wall and Floor Fixings

Wall-to-wall fixings and floor-to-wall fixings can also be efficiently achieved using engineered wood screws. However, the capacity of screws on the narrow edge is less than in the face grain orientation. Again it is recommended that partially threaded screws are specified to help pull the panels tight together.



Durability of Fixings

It is recommended that designers consult with the manufacturer of screws, nails and proprietary brackets to ensure they have sufficient coatings to ensure a design life that exceeds the building design life. Wood Solutions "Timber Service Life Design" publication provides very detailed information and methods to assess the suitability of fixings for durability.

Designers should pay careful attention to fixings in wet areas and fixings that are externally exposed, and design accordingly. Consideration should also be given to screws and fixings being used in treated panels. As an example, based on the Wood Solutions publication a typical screw with 12 microns of galvanic protection could have a design life of less than 5 years in treated timber panels, depending on the location in Australia and application. Coating technology is advancing, and some manufacturers have their own proprietary protection systems and can provide test results and advice for design life of these products.

Edge Distance Diagrams

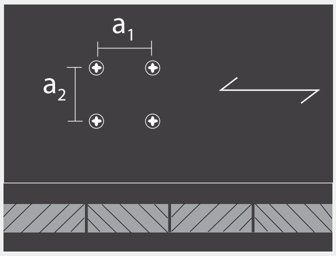
The following recommended edge distances are as specified in the Spax European Technical Approval (ETA - 12/0114) and are presented in this document for guidance only. Self tapping screws of the same length and diameter from different suppliers may have different capacities and edge distance requirements. Reference must be made to the ETA specific to each supplier.

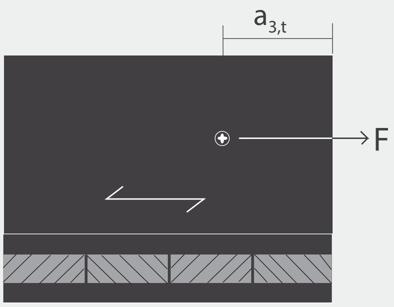
Screw Edge Distance Requirements

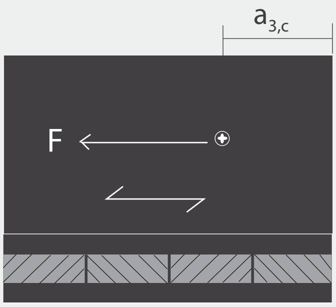
	Face Grain	On Edge
Minimum panel thickness	t_{min} = 10d	t_{min} = 10d
Spacing a_1 parallel to grain	a_1 = 4d	a_1 = 10d
Spacing a_2 perpendicular to grain	a_2 = 2.5d	a_2 = 4d
Distance $a_{3,c}$ to unloaded end grain	$a_{3,c}$ = 6d	$a_{3,c}$ = 7d
Distance $a_{3,t}$ to loaded end grain	$a_{3,t}$ = 6d	$a_{3,t}$ = 12d
Distance $a_{4,c}$ to unloaded edge	$a_{4,c}$ = 2.5d	$a_{4,c}$ = 3d
Distance $a_{4,t}$ to loaded edge	$a_{4,t}$ = 6d	$a_{4,t}$ = 6d

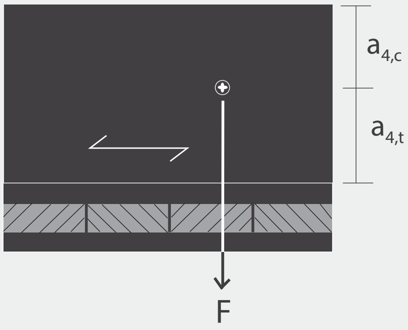
Edges Distances

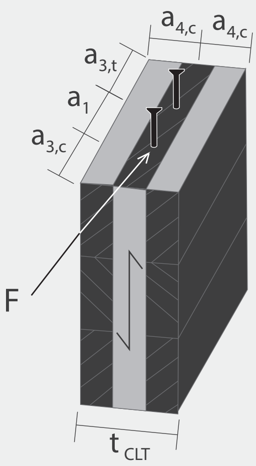
While the yielding failure mode of the fastener is a dominant failure mechanism, there is potential for brittle block tear-out failure, or tensile splitting of the timber. Care must be taken when specifying minimum edge distances of the fasteners.

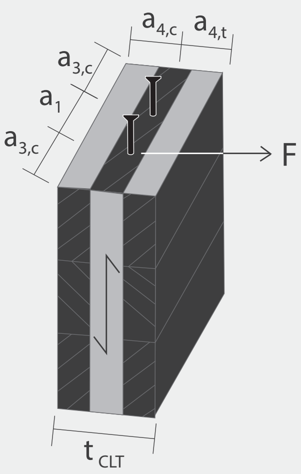












AirStair

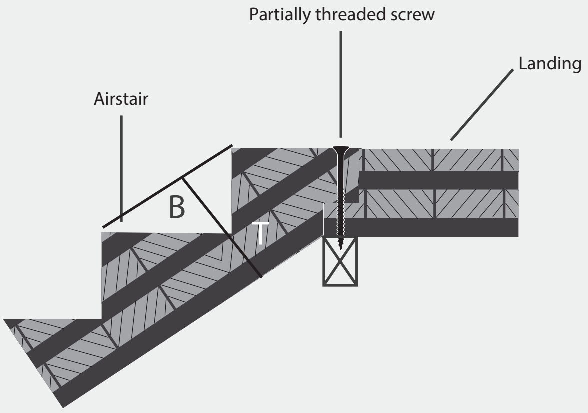
The design of the AirStair follows a similar methodology to floor panels, with the exception that no long term live load is expected for stairs. The formula for deflection therefore becomes:
$j_2(G) + 0.7Q < \text{span}/400$

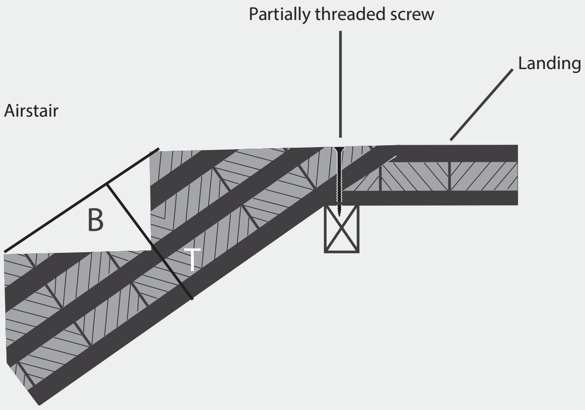
Where G is the self-weight of the AirStair panel, including the mass of the treads. The vibration checks are the same as outlined in the floor design section of this document.

Connection details shown are suitable for single occupancy residential dwellings only. Connection details for stairs in multistorey commercial or residential structures must take into account requirements for sliding, inter-storey drift, and construction tolerance.

The billet for an Airstair is made at the thickness of the tread, plus the riser thickness, and the voids are cut away using a circular saw. The panel designations are the throat thickness. E.g. A CL3/105 Airstair has a 105mm throat

AirStair Typical Connection Details





T = throat thickness

B = tread and riser thickness

Pre-Analysis Span Tables

Airstair [maximum span on incline in metres]

Panel Designation	Q = 0.2kPa SDL			Q = 4kPa SDL		
	OkPa	0.25kPa	0.5kPa	OkPa	0.25kPa	0.5kPa
3 Layer Panels						
CL3/85	2.9	2.8	2.7	2.6	2.5	2.4
CL3/105	3.7	3.5	3.4	3.3	3.2	3.1
CL3/115	4	3.8	3.6	3.5	3.4	3.3
CL3/125	4.4	4.2	4	3.9	3.8	3.6
CL3/135	4.6	4.4	4.3	4.1	4	3.9
5 Layer Panels						
CL5/145	4.8	4.6	4.5	4.3	4.2	4.1
CL5/160	5.1	4.9	4.7	4.6	4.5	4.3
CL5/175	5.7	5.5	5.3	5.2	5.1	4.9
CL5/195	5.9	5.7	5.5	5.6	5.4	5.3
CL5/205	6.1	5.9	5.7	5.8	5.6	5.5
CL5/225	6.7	6.5	6.3	6.2	6	5.8
7 Layer Panels						
CL7/245	7	6.7	6.5	6.4	6.2	6.1
CL7/265	7.6	7.4	7.2	7	6.8	6.7
CL7/275	7.7	7.5	7.4	7.2	7	6.9
CL7/295	8	7.9	7.7	7.6	7.4	7.3
Cl7/315	8.2	8.1	7.9	7.8	7.6	7.5

CLT and other structural materials

The use of CLT in conjunction with other structural materials is commonplace but particular consideration should be given to the interface between them. The manufacture of CLT involves tolerances to millimetre accuracy whereas tolerances for the typical construction of steel, concrete and masonry could be up to 10-15mm in certain situations. Given the shop drawings and fabrication of CLT panels takes place significantly in advance of the completion of other materials on site it is important to allow for tolerance in the connections and joints.

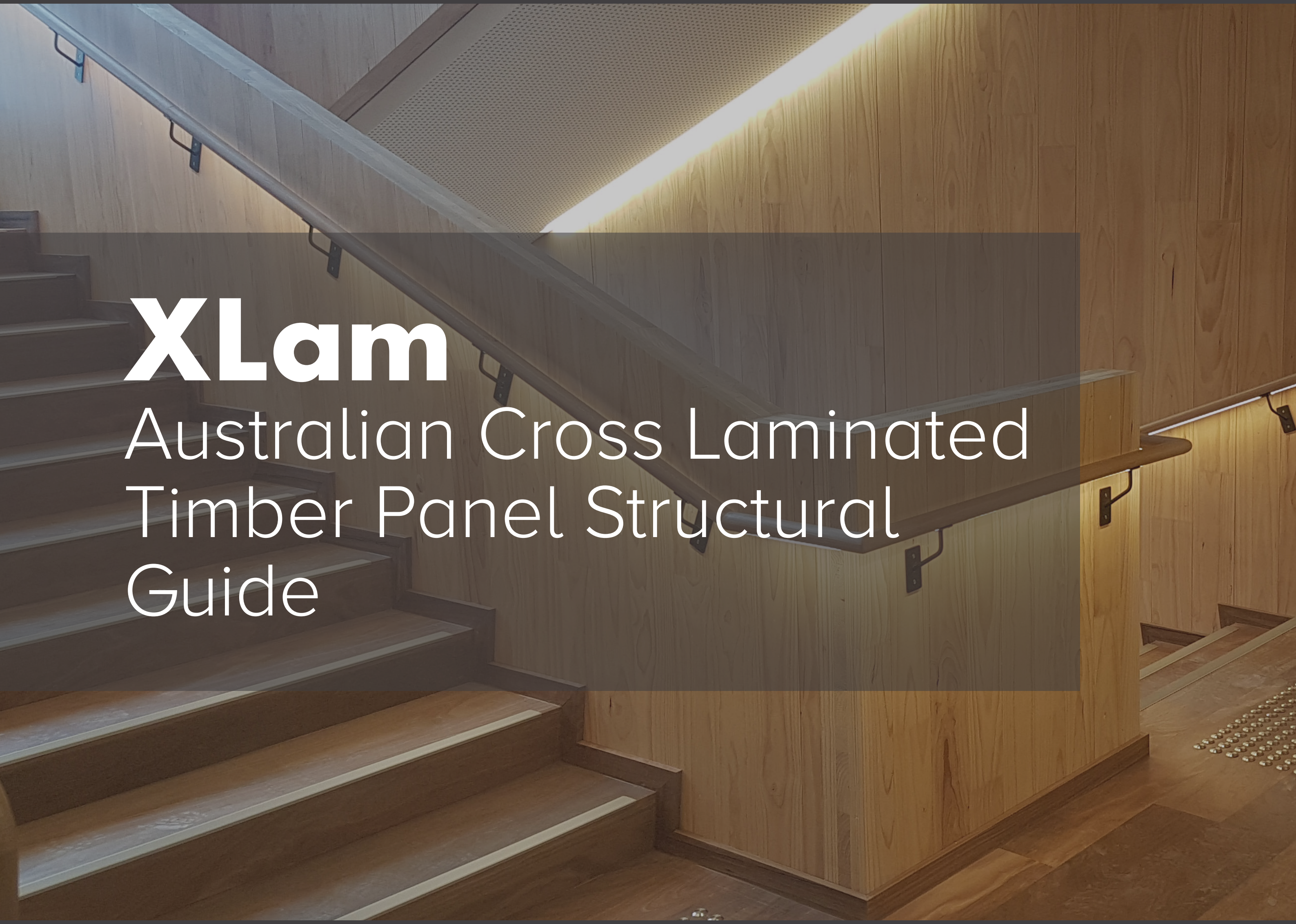
The speed of construction benefits of mass timber could be difficult to realise if there are significant amounts of site modifications required to panels to ensure they fit and careful detailing can assist in this. For instance, many CLT buildings sit on a concrete slab which may have a tolerance in level of +/- 10mm so it is usually sensible to set the CLT above the concrete by 15mm and pack up and grout underneath the wall. Once this initial connection has been made the building can continue swiftly with timber to timber connections fitting together accurately.

A major design consideration when considering hybrid structures is the different movement characteristics between CLT and other materials and how they behave in the long term. Timber is a material which behaves very differently to steel and concrete and issues like creep, shrinkage and thermal movements need to be calculated in many situations. For example, the axial shortening of a wall on a ten storey building could be in the order of 50mm due to creep and shrinkage and this may be very different to a steel or concrete core structure.

Consideration should also be given to compound deflections when using CLT with other structural materials. The floor pre-analysis span tables in this guide are applicable to floor panels supported on the walls. Should panels be supported on steel beams, the compounding deflection should be considered for the steel beam and the floor panels. This is outside of the scope of these pre-analysis span tables, and usually considered by the structural engineer during the design process.

Details also need to consider constructability. Understanding where screws and brackets need to be installed from and how they’re accessed is important to a safe and efficient construction site. Pre-installation of brackets, plates, bolts and screws can improve efficiency on site provided the allowance for tolerances is still maintained. The long-term performance of details is also something to bear in mind, particularly with respect to moisture, and details with the potential to trap water against the timber should be avoided.

XLam

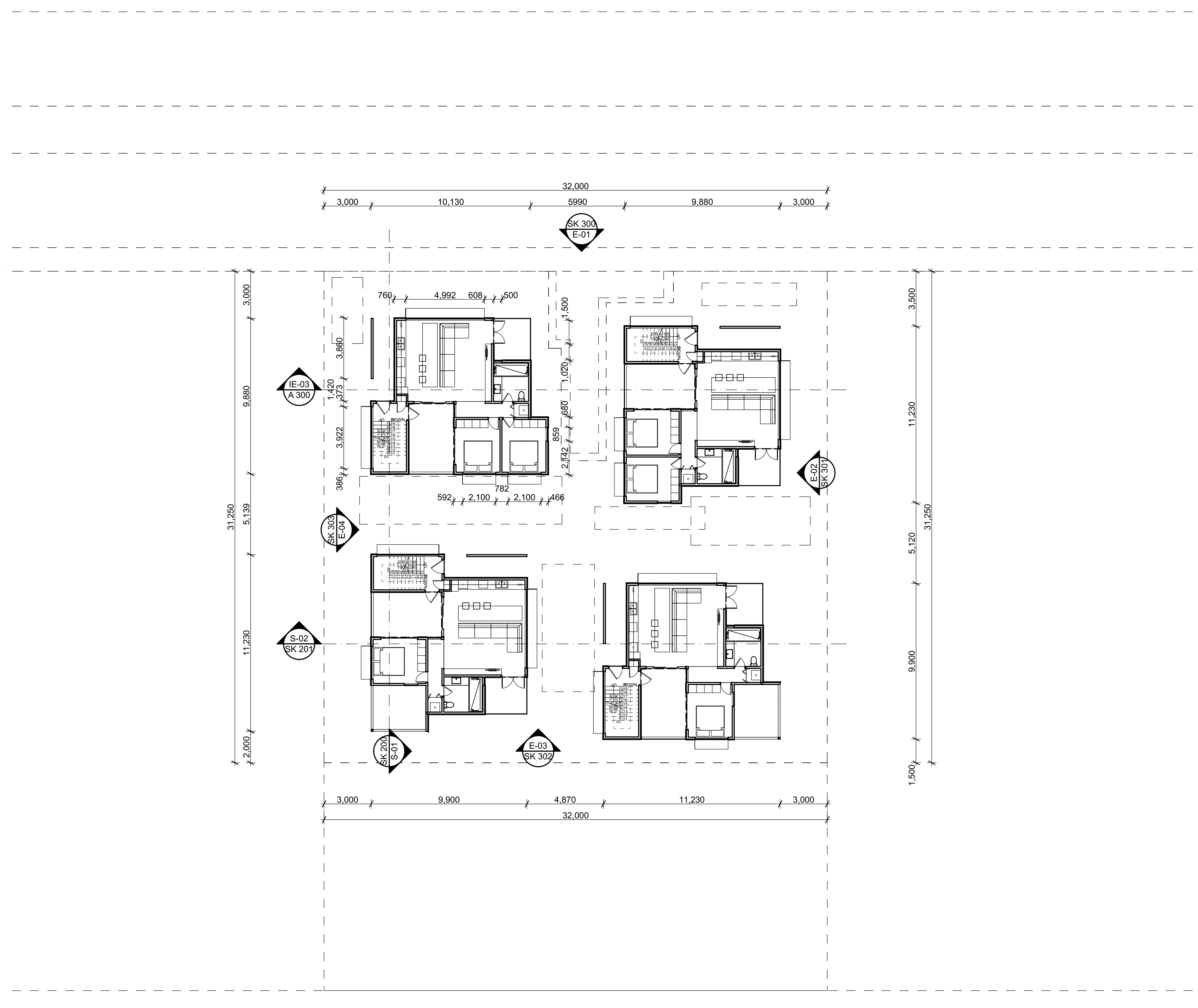


XLam
Australian Cross Laminated Timber Panel Structural Guide

This pre-analysis guide provides key information necessary for the preliminary assessment of XLam structures. It covers material properties, design principles, connections, and includes pre -analysis span tables derived from extensive product testing.

XLam Australia Pty Ltd | www.xlam.com.au

Appendix D – Architects Drawings



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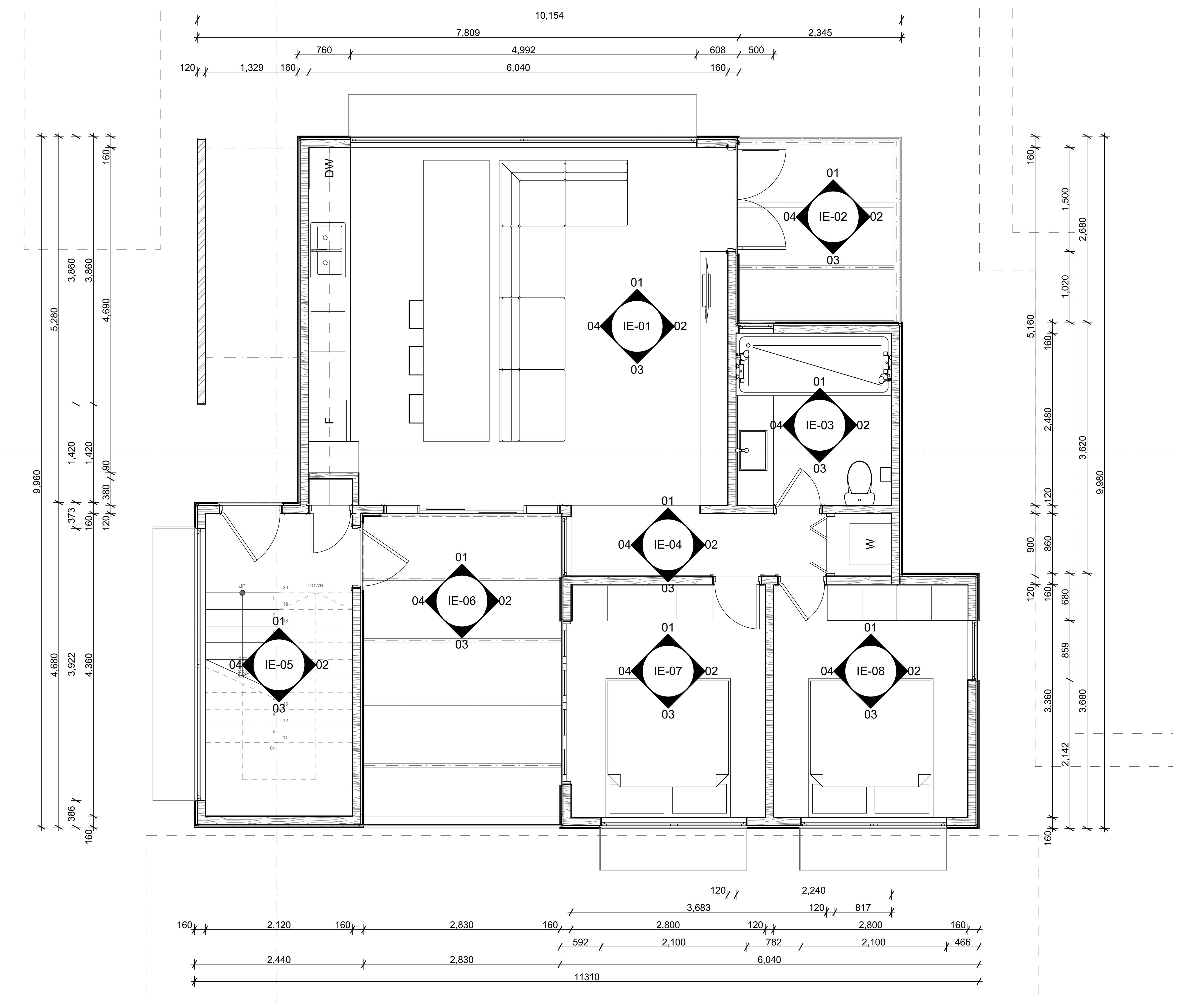

IE-01
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LAYOUT PLAN
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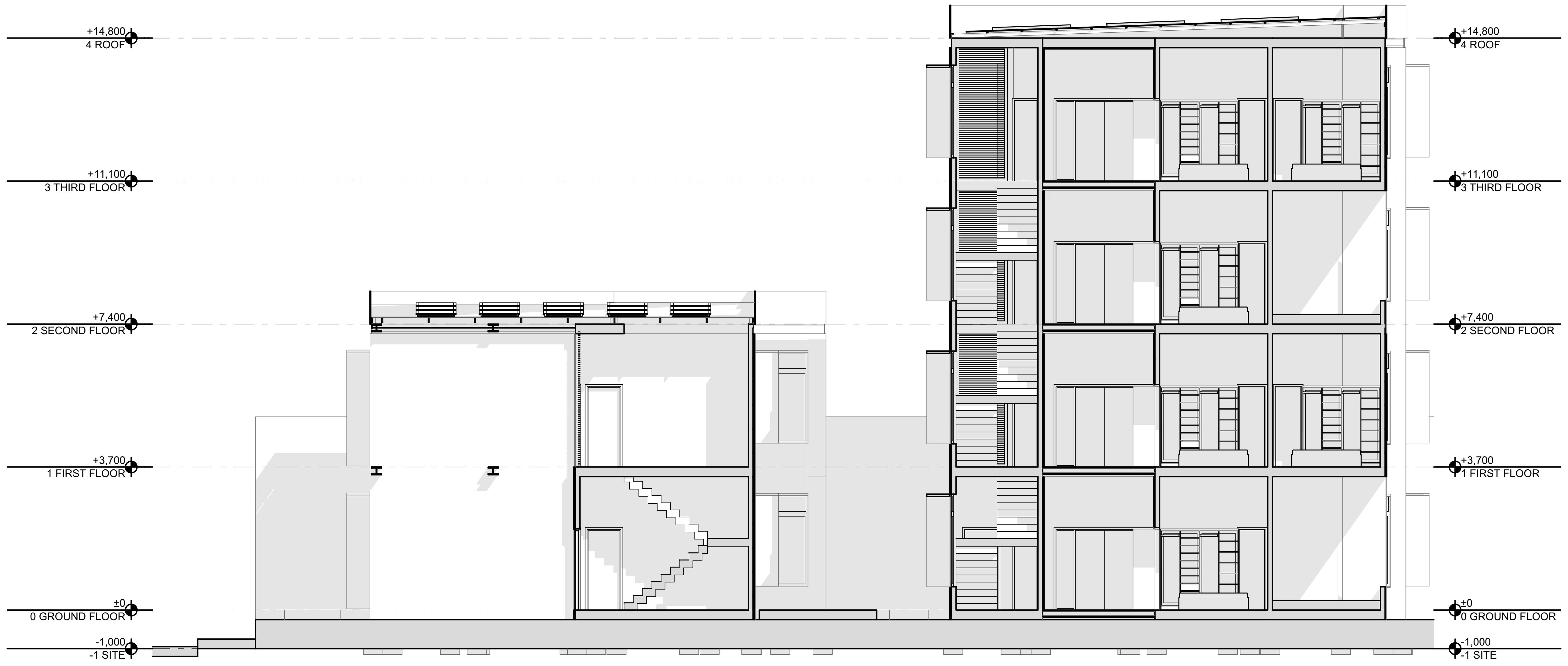

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IE-02
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SECTION
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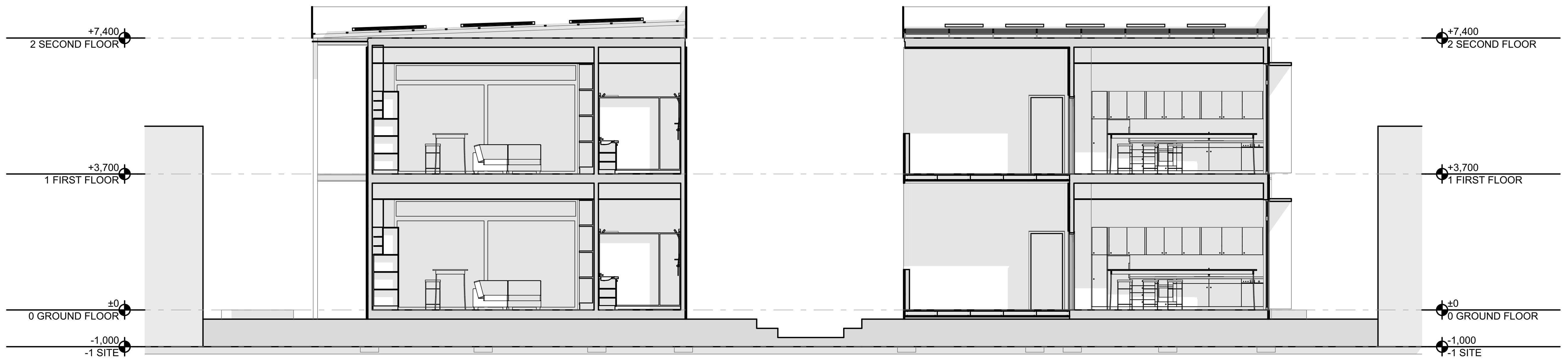

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E-01
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ELEVATION
1:100

E-02
-

ELEVATION
1:100

E-03
-

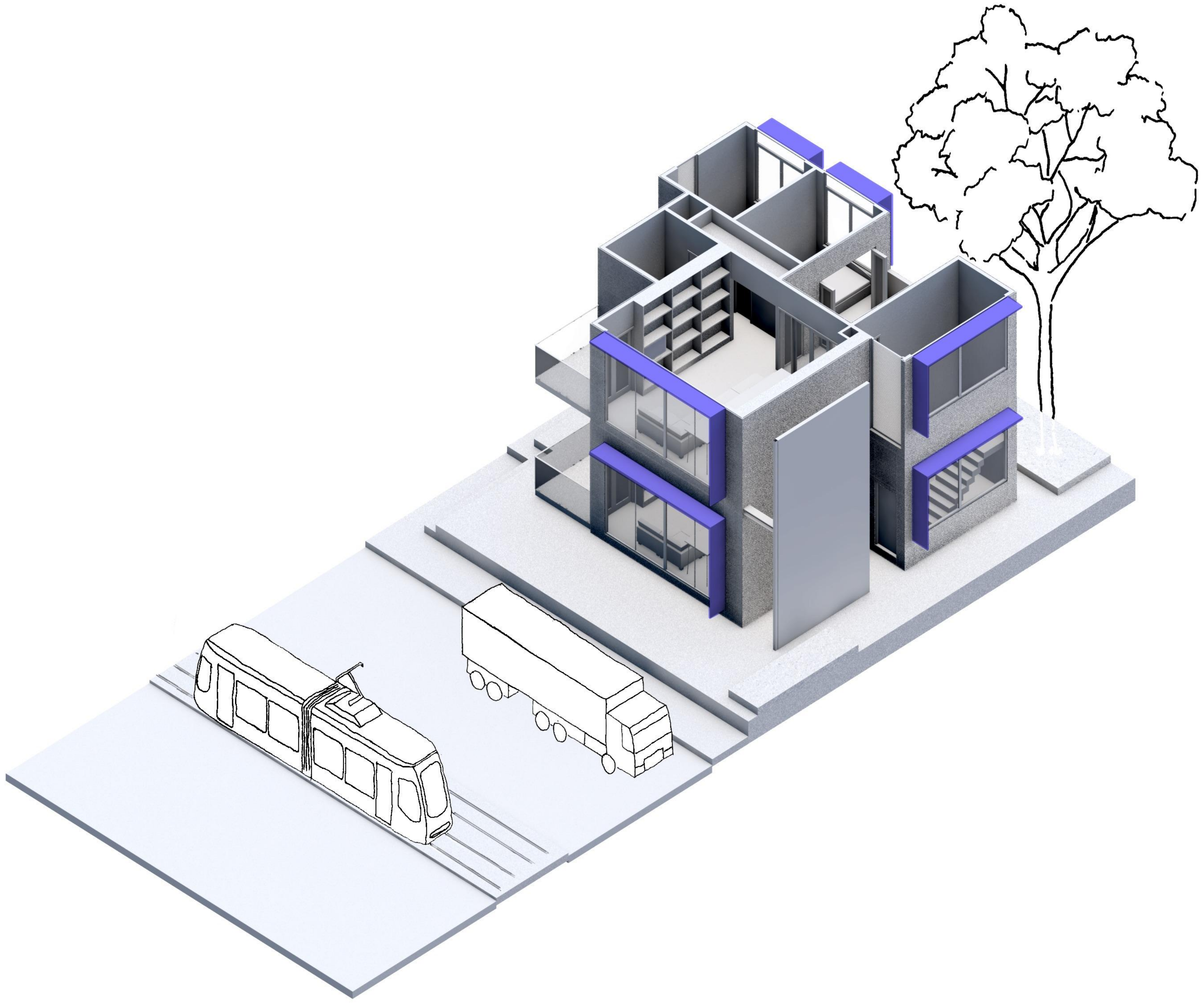
ELEVATION
1:100

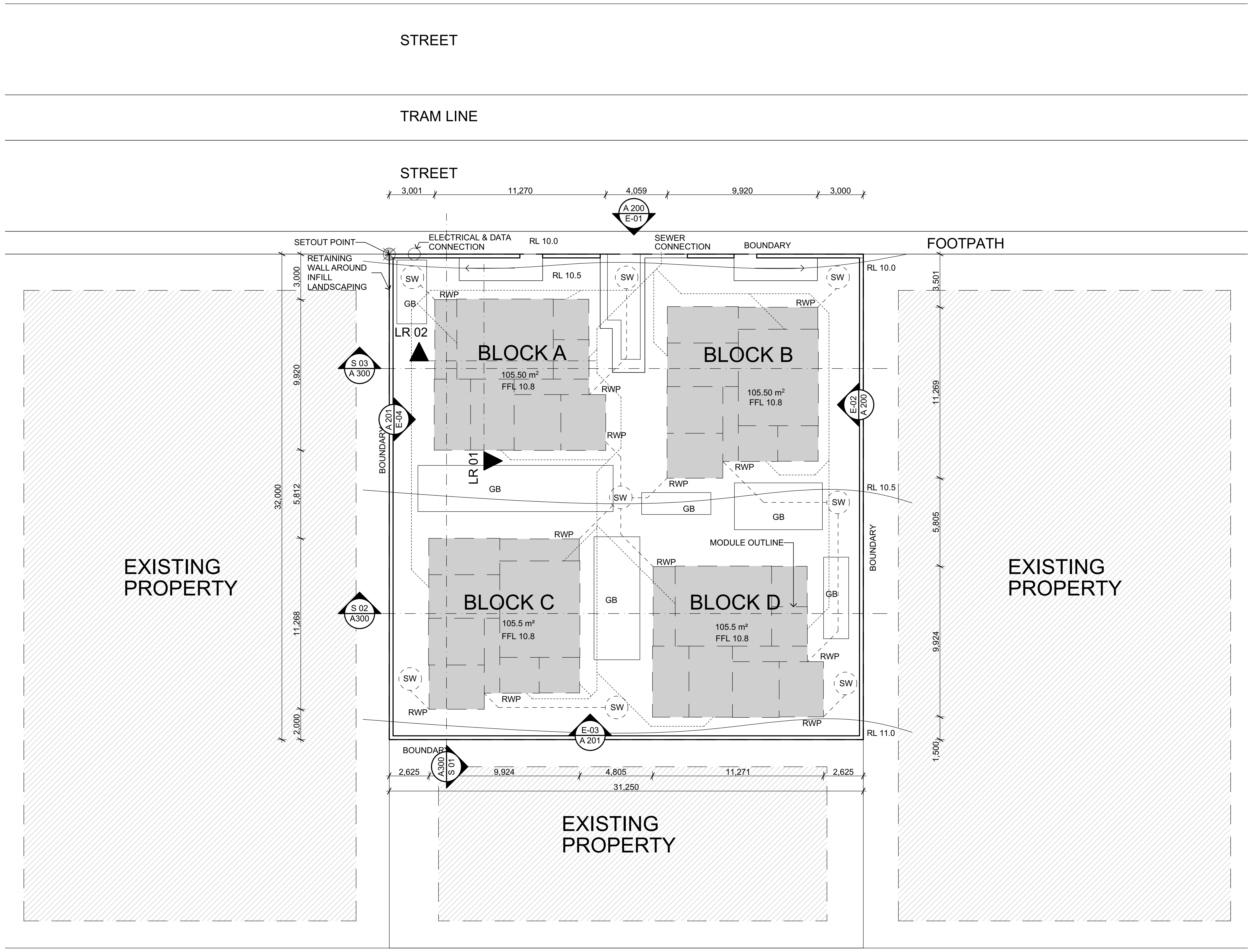
E-04
-

ELEVATION
1:100

DRAWING LIST

- A 000 SITE PLAN
- A 100 PLAN
- A 101 ROOF PLAN
- A 200 ELEVATION
- A 201 ELEVATION
- A 300 SECTIONS
- A 301 LOUNGEROOM SECTION
- A 302 LOUNGEROOM SECTION
- A 500 INTERIOR ELEVATIONS
- A 501 INTERIOR ELEVATIONS
- D1 DOOR SCHEDULE
- W1 WINDOW SCHEDULE
- A 700 DETAILS





A000
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SITE PLAN
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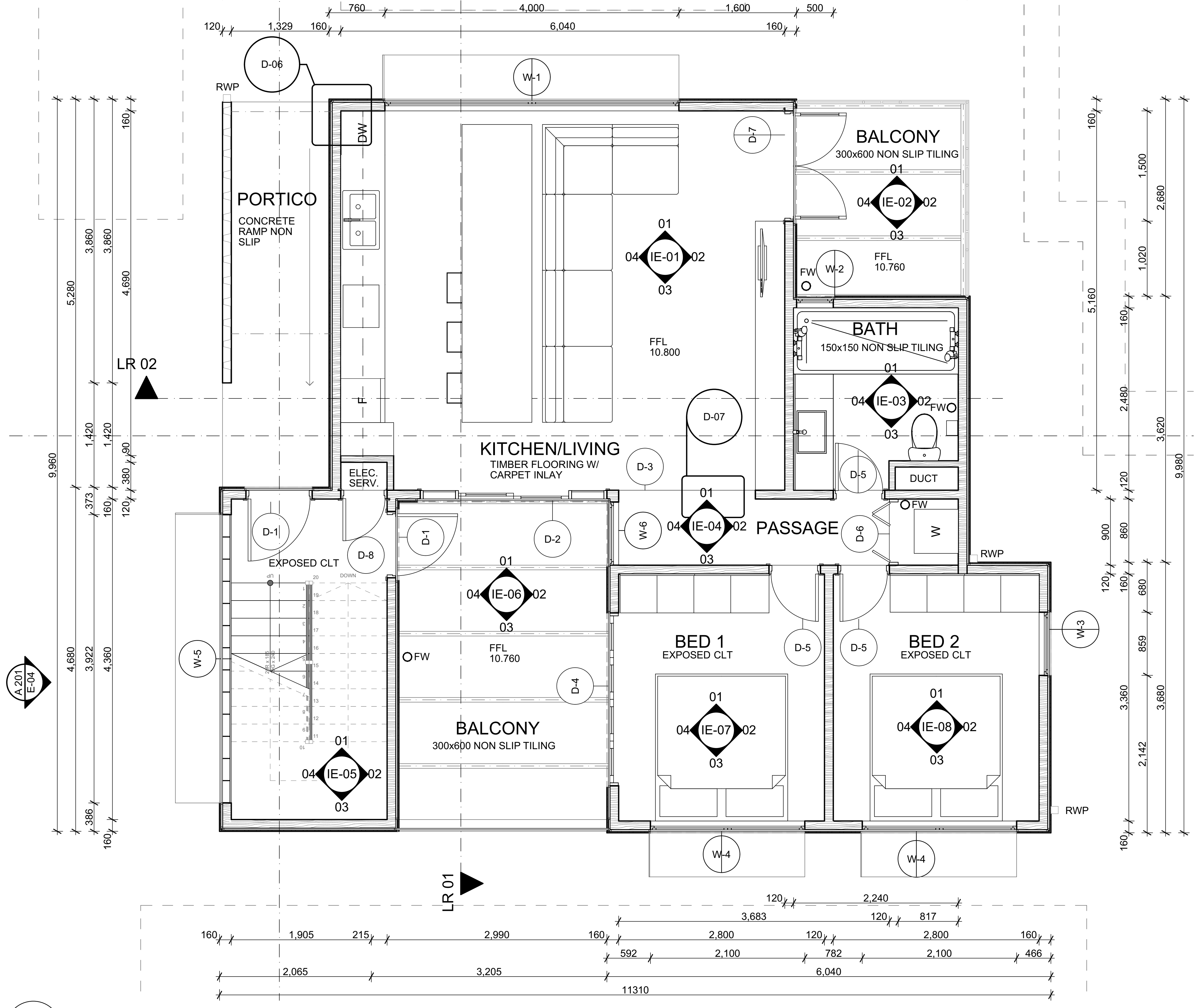
101
-
LAYOUT PLAN
1:200



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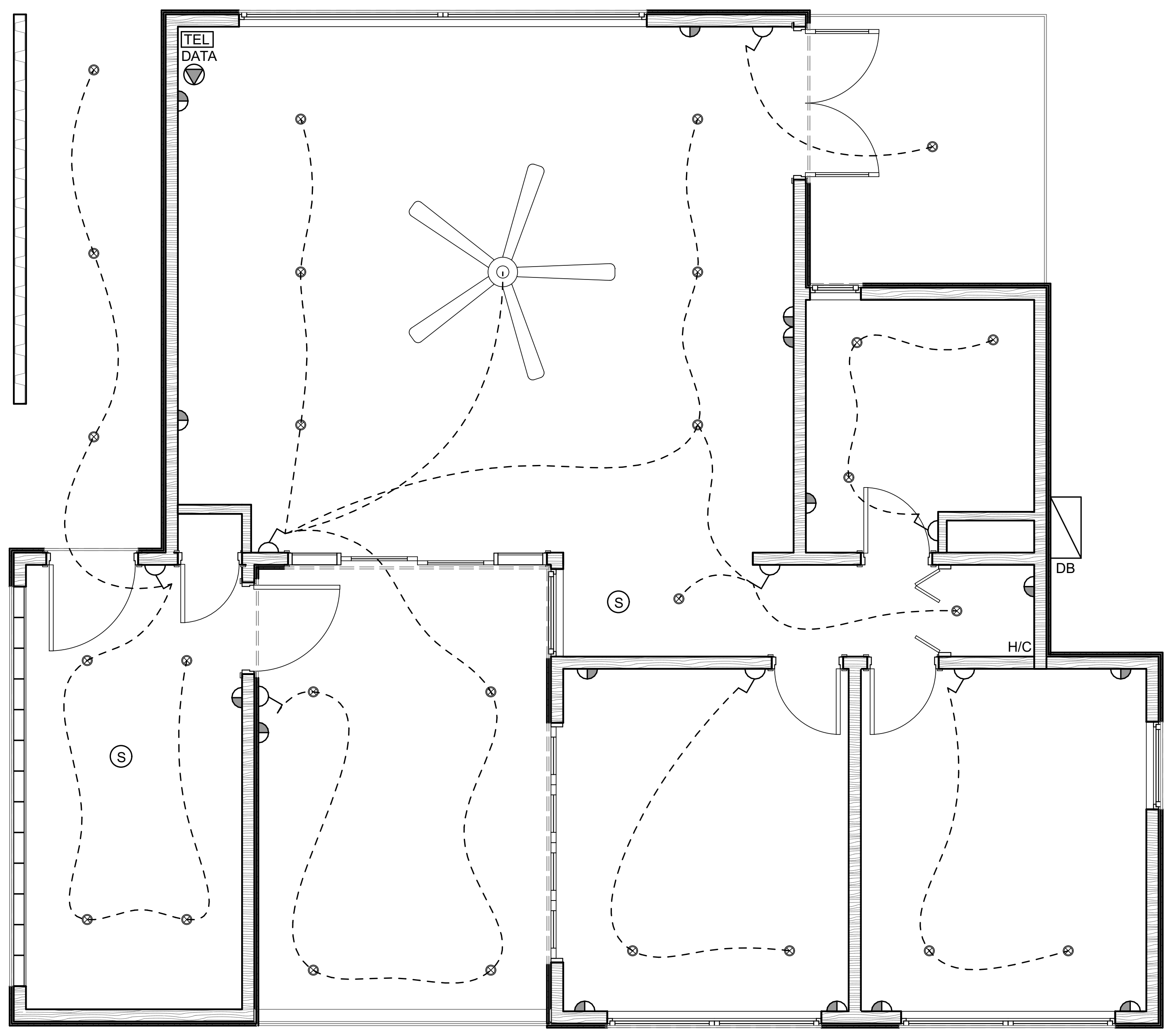

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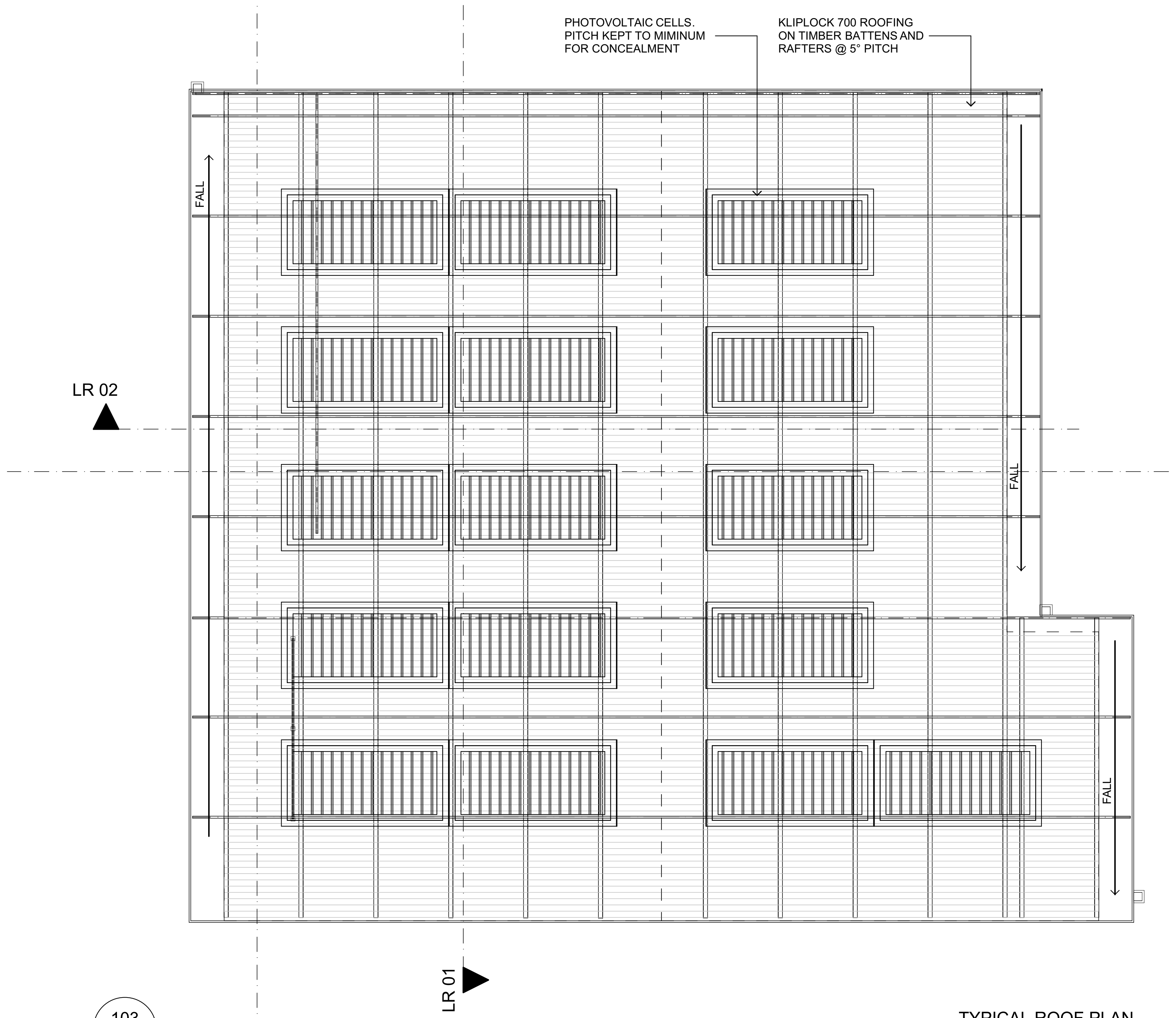

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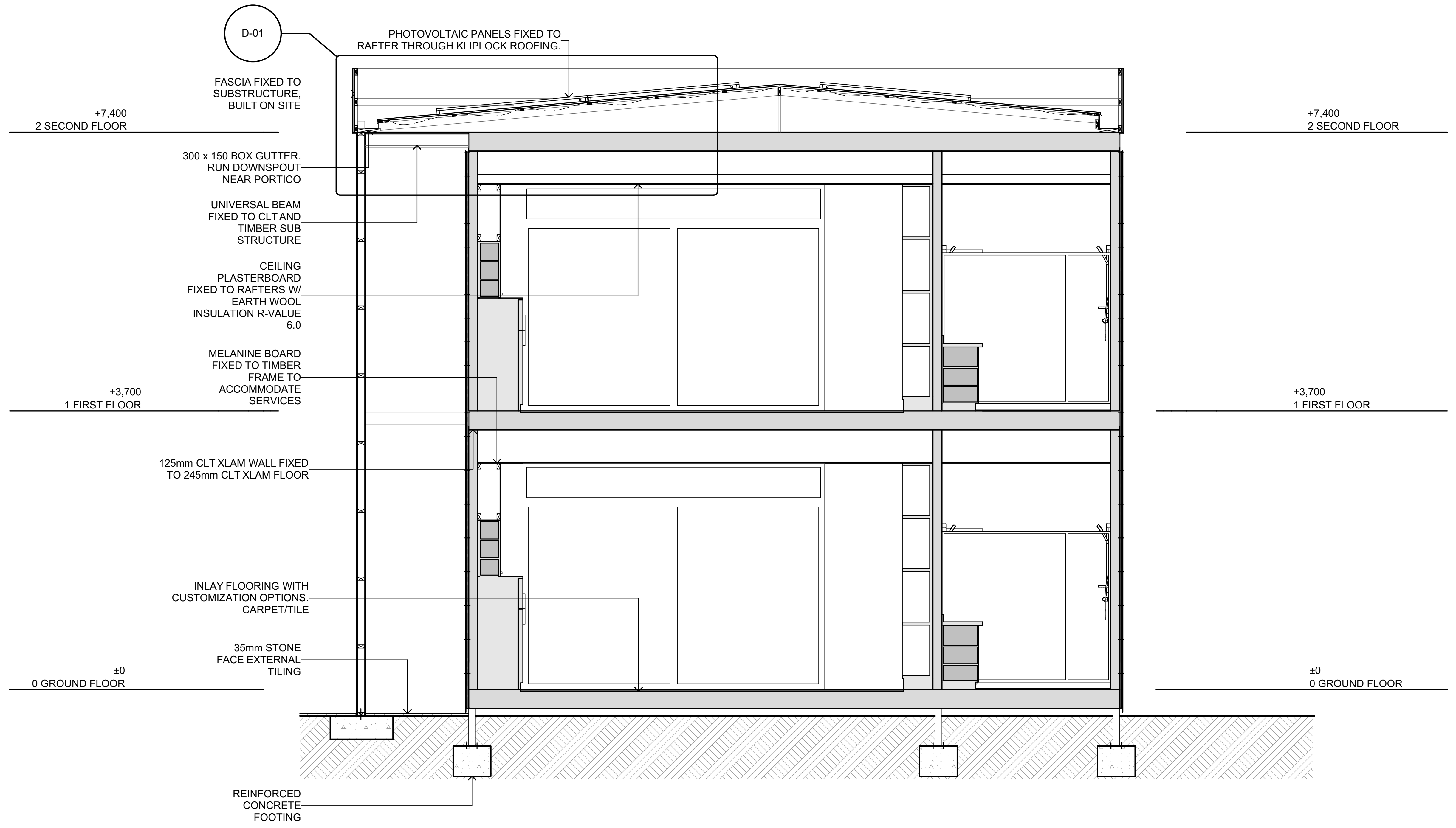

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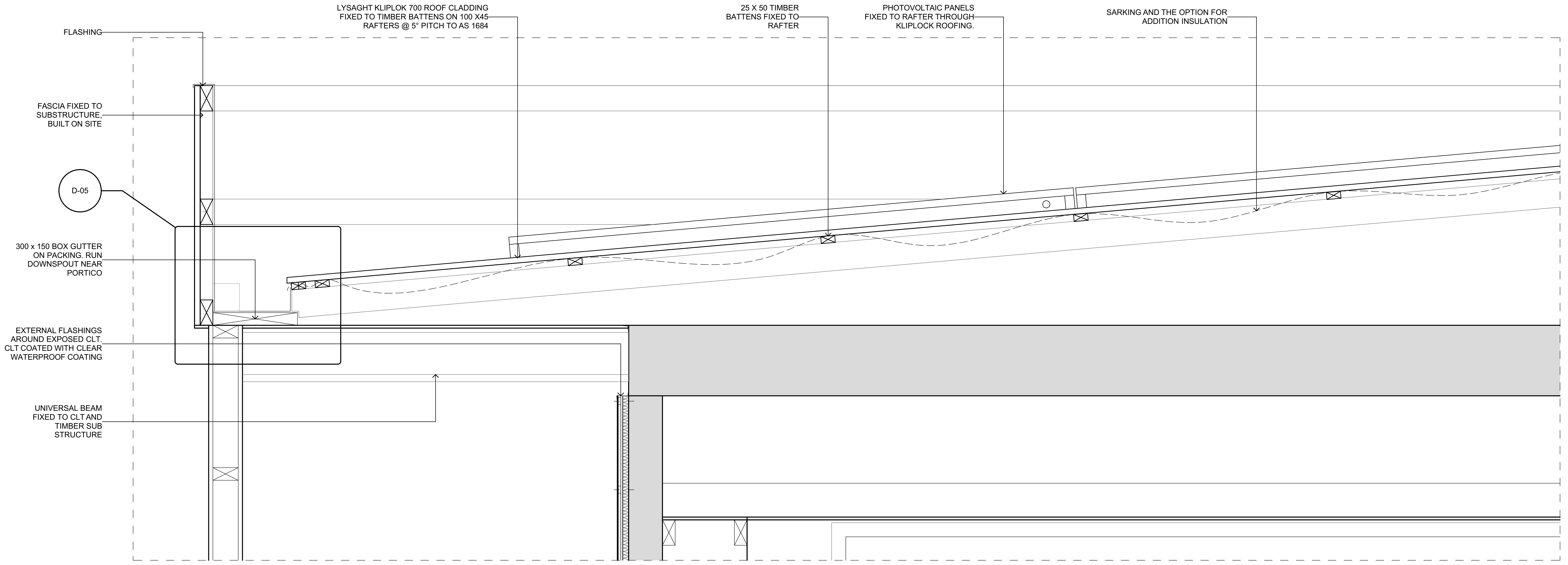

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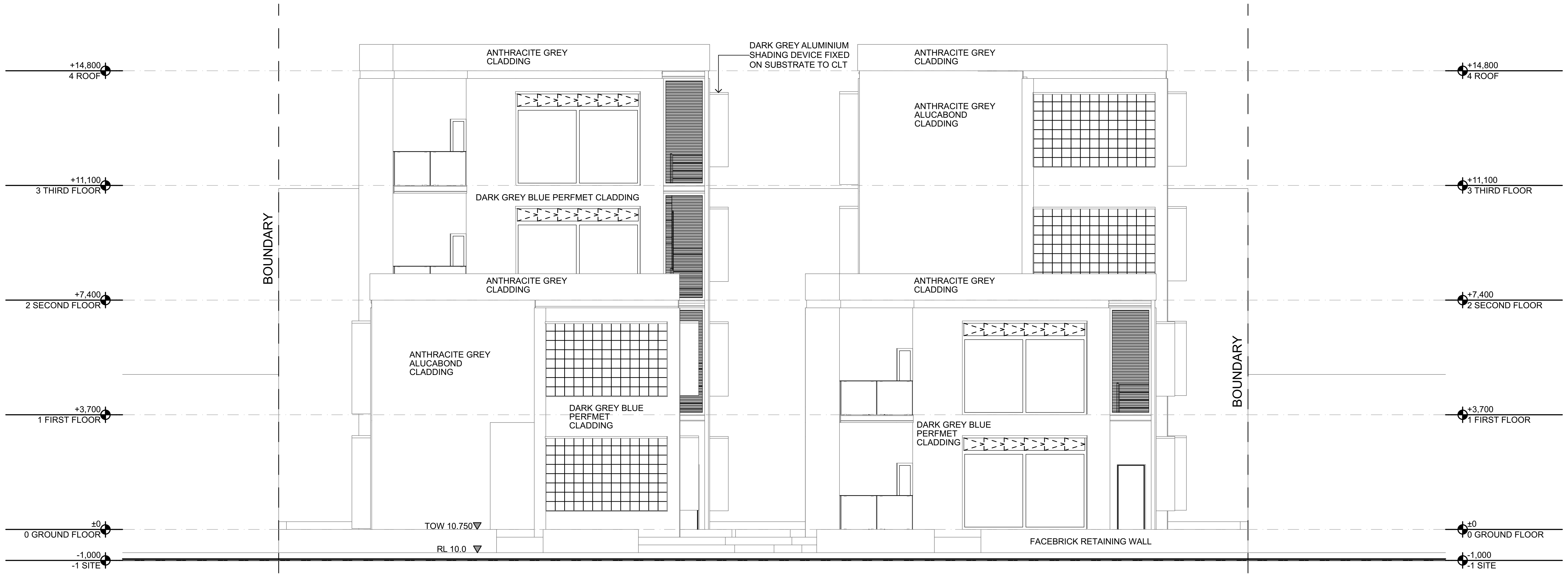

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NORTH ELEVATION
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E-02
-

EAST ELEVATION
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E-03
-

SOUTH ELEVATION
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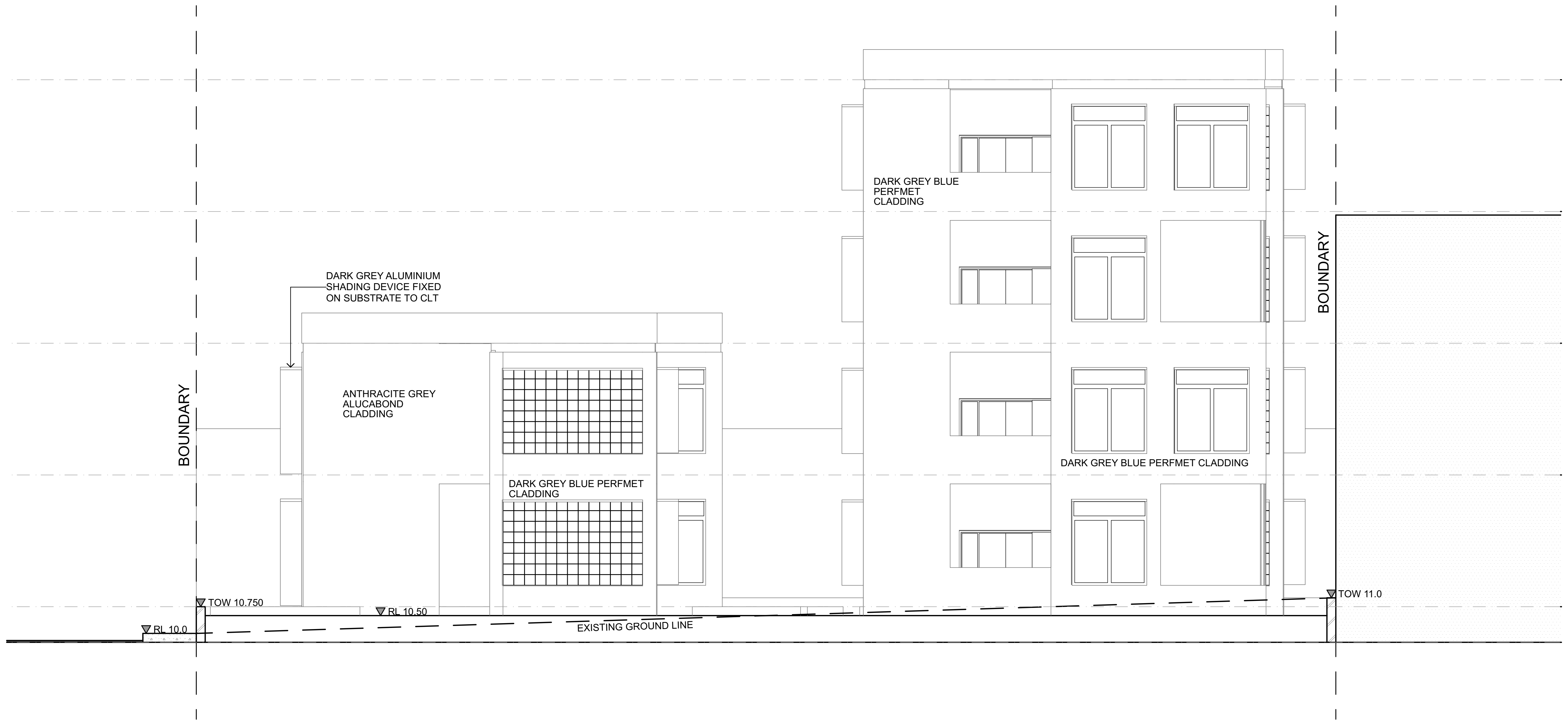

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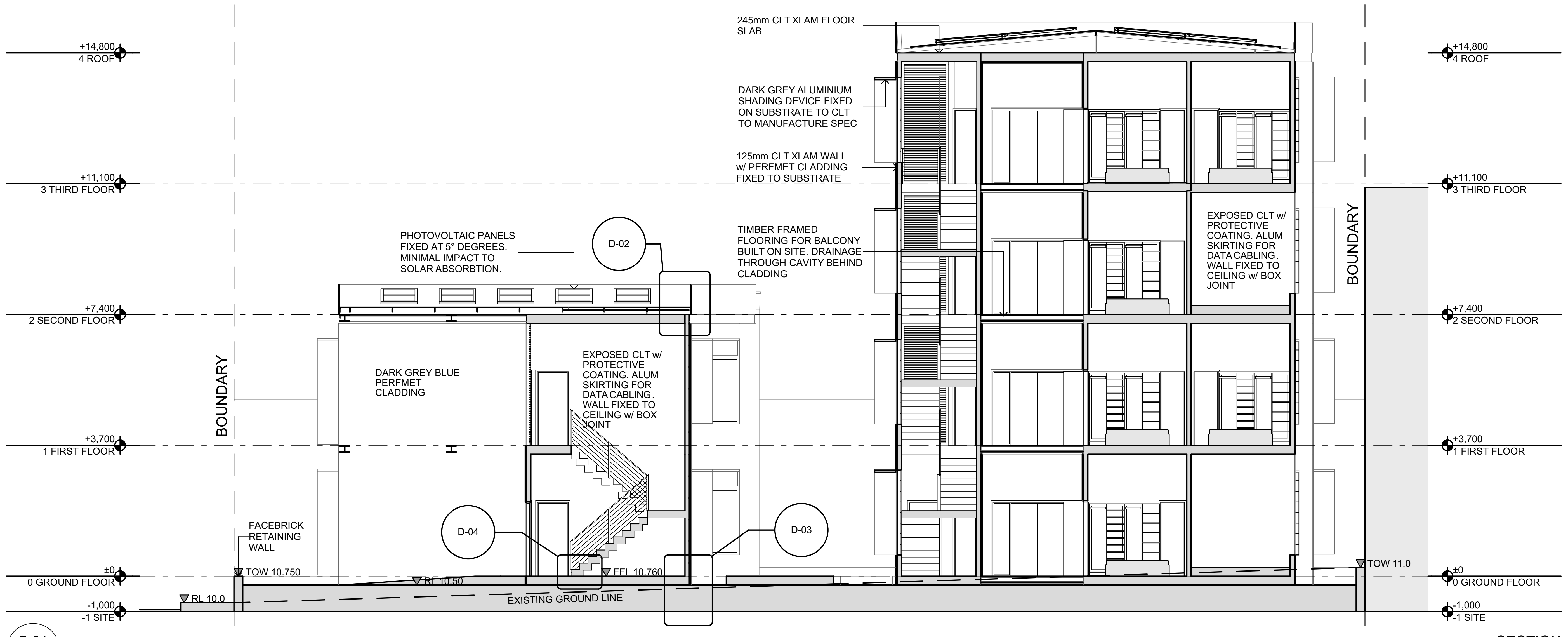

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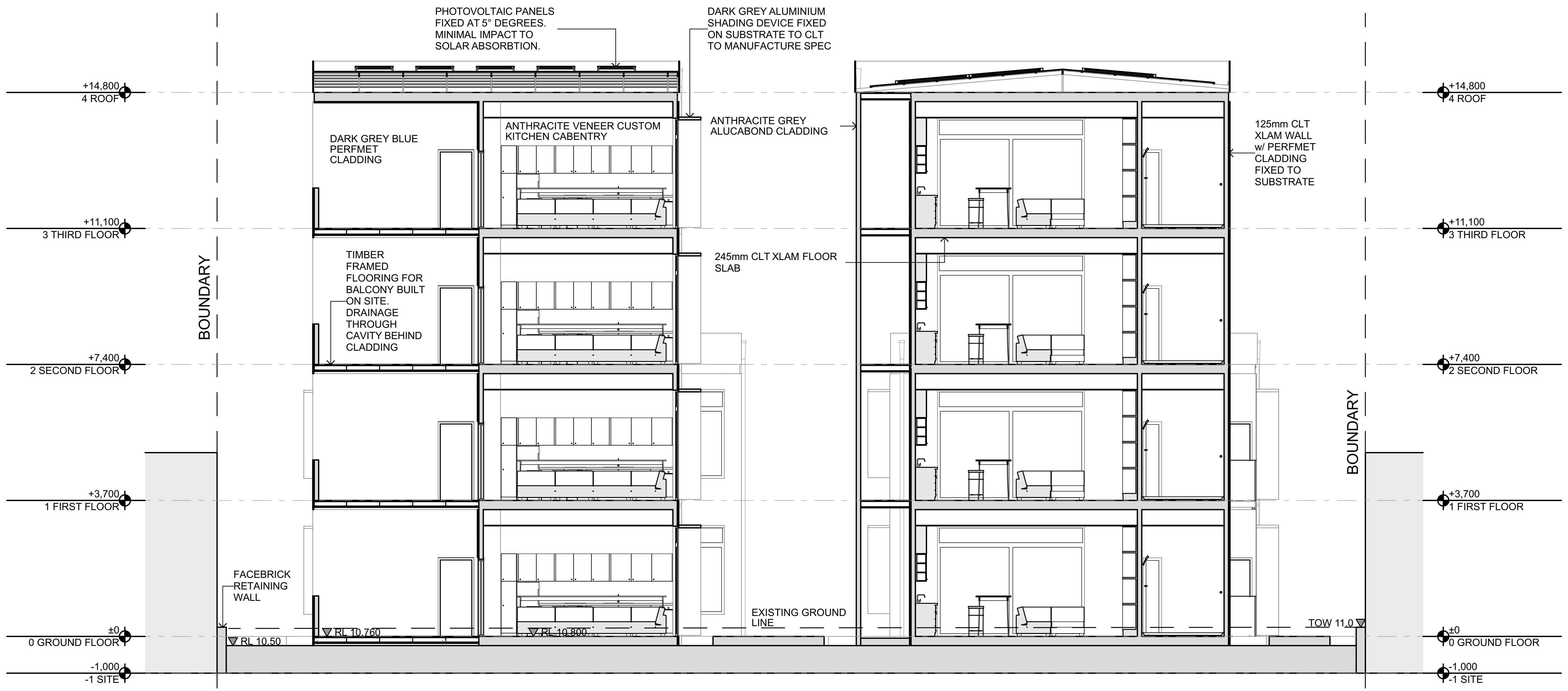

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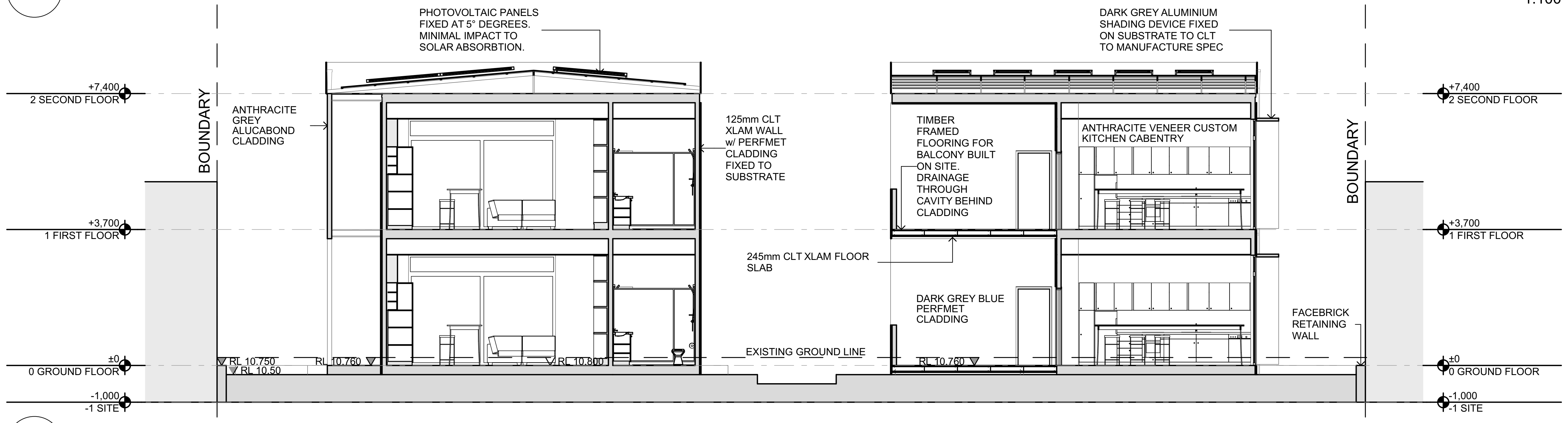

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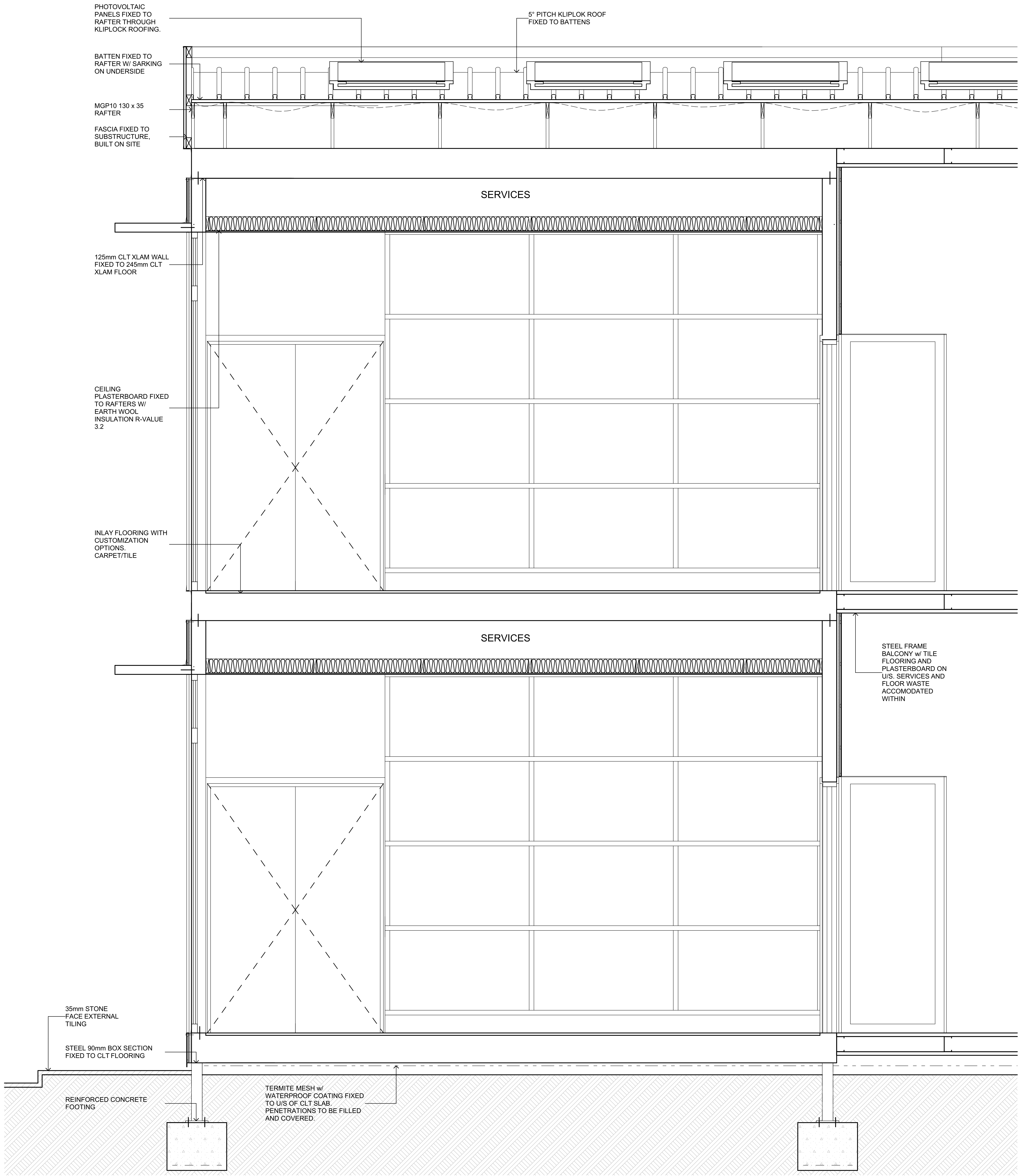

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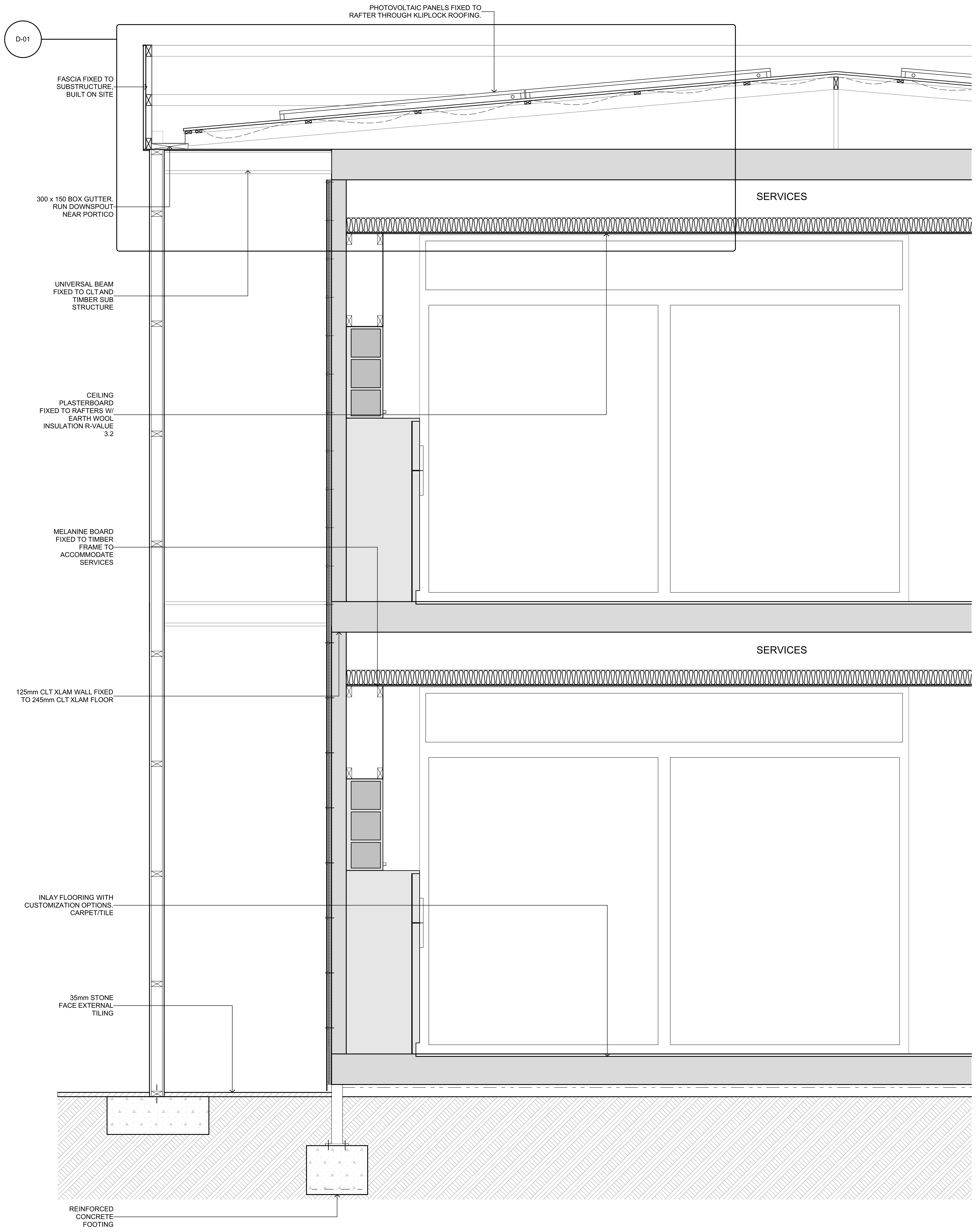

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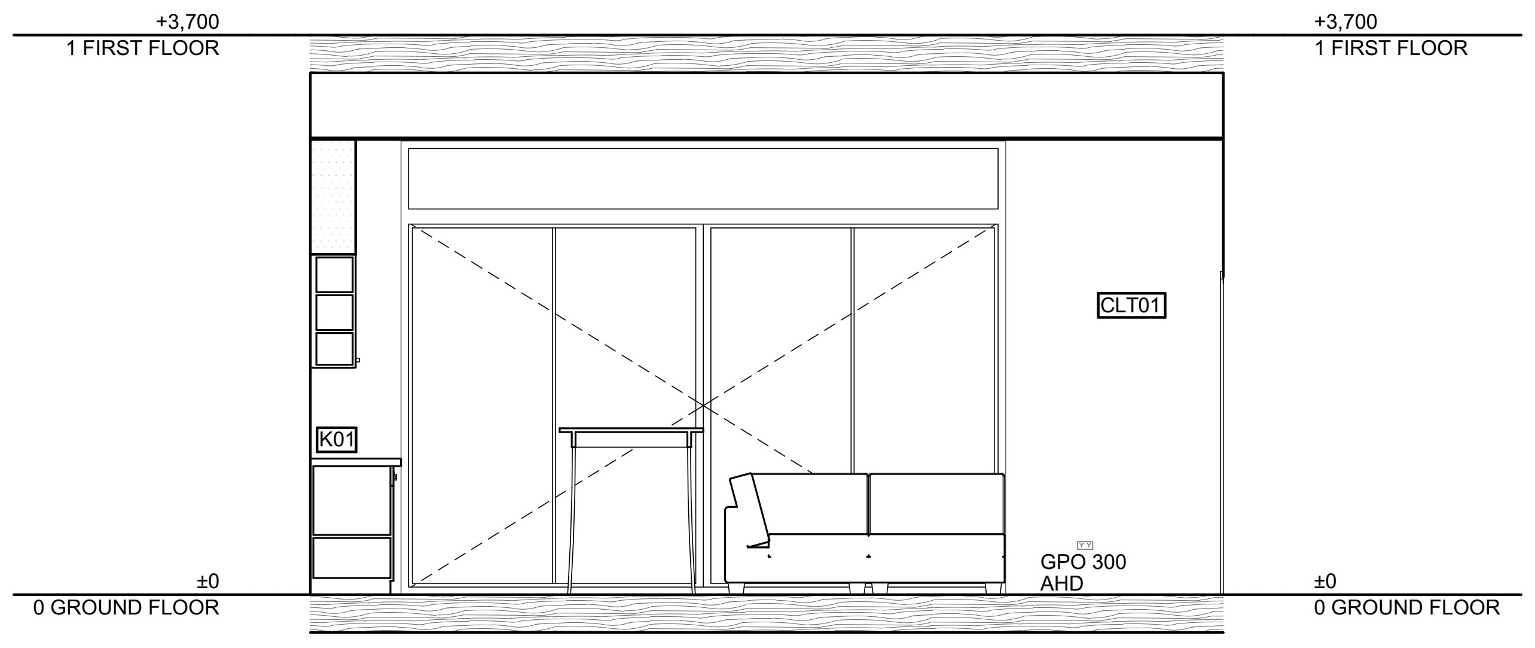

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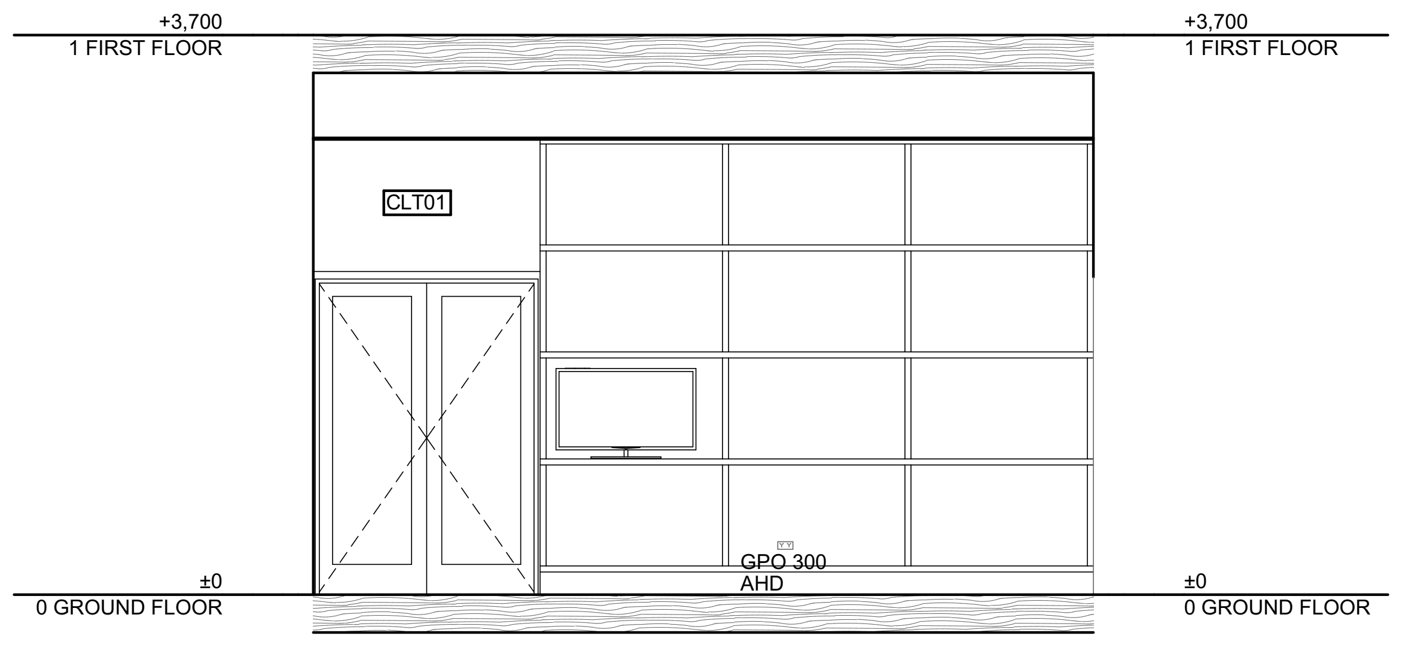

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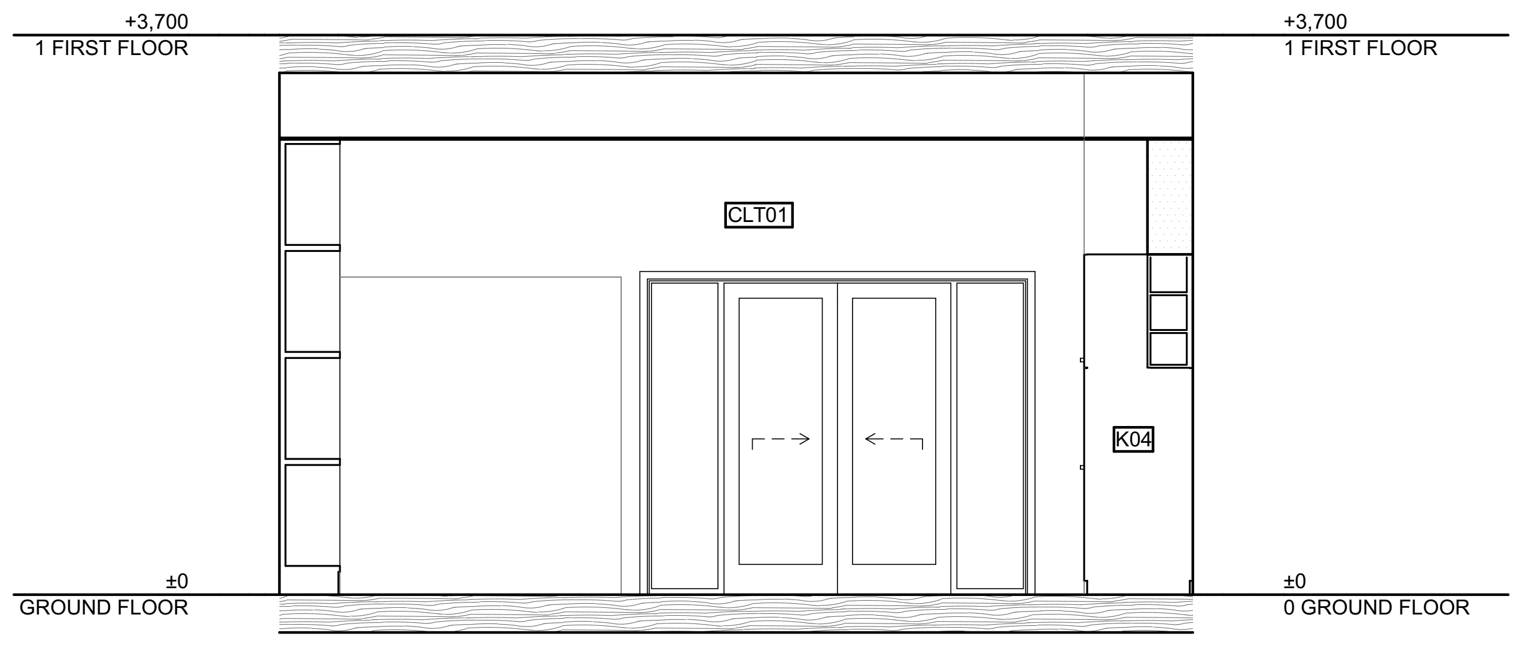

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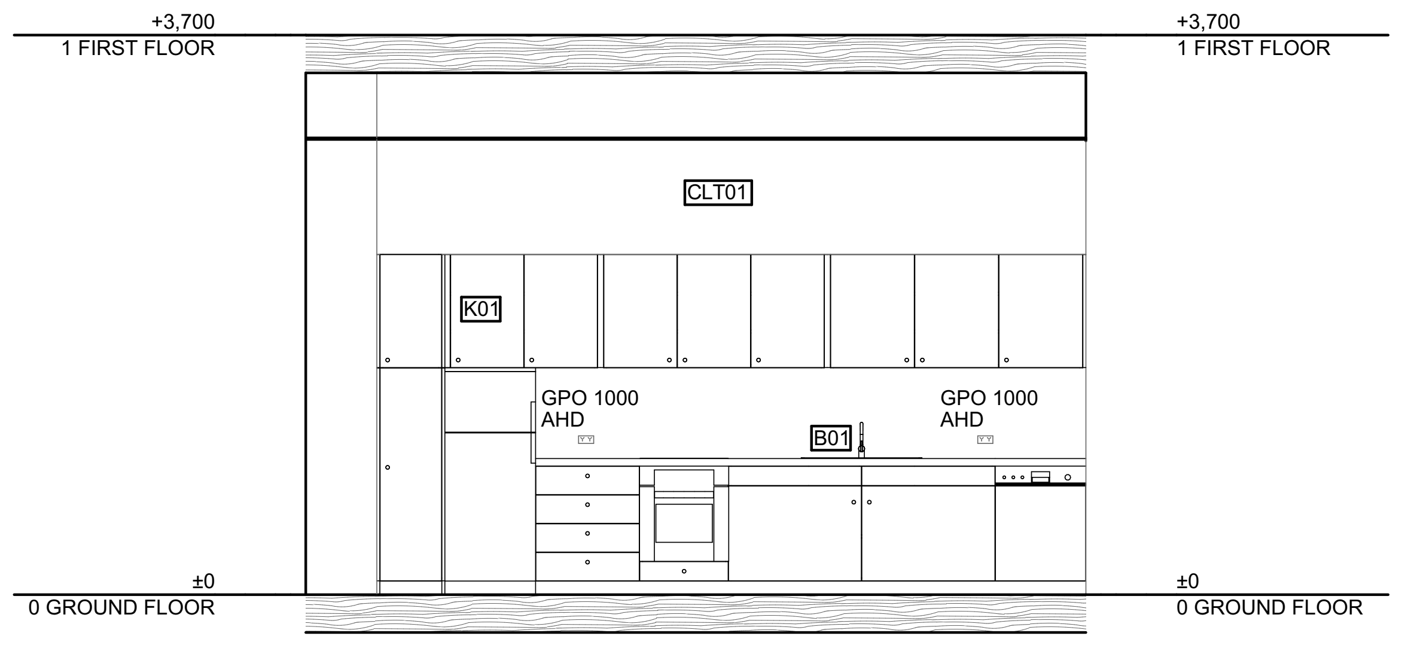

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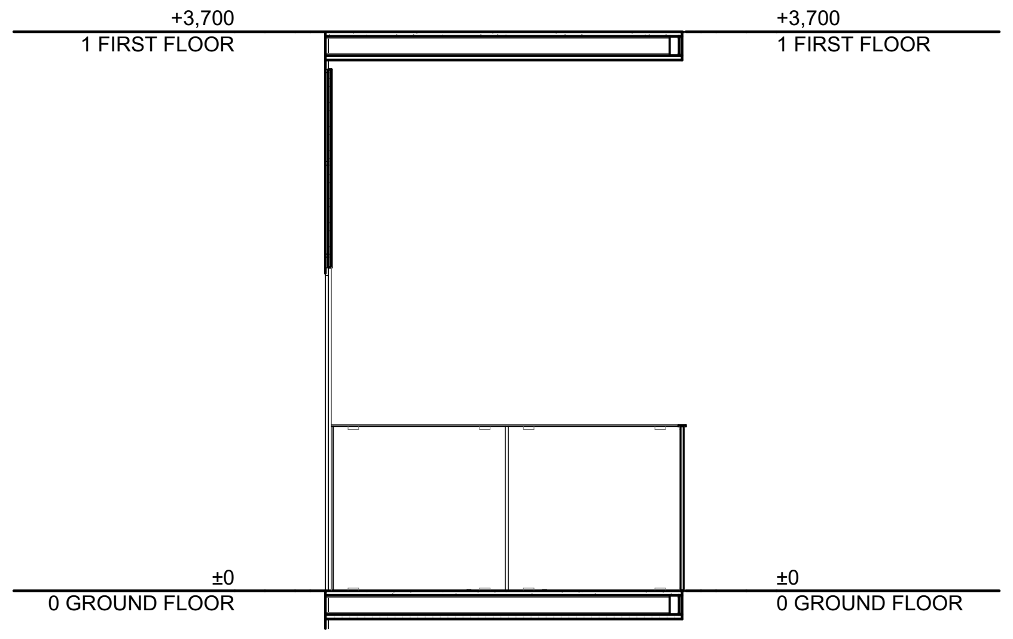

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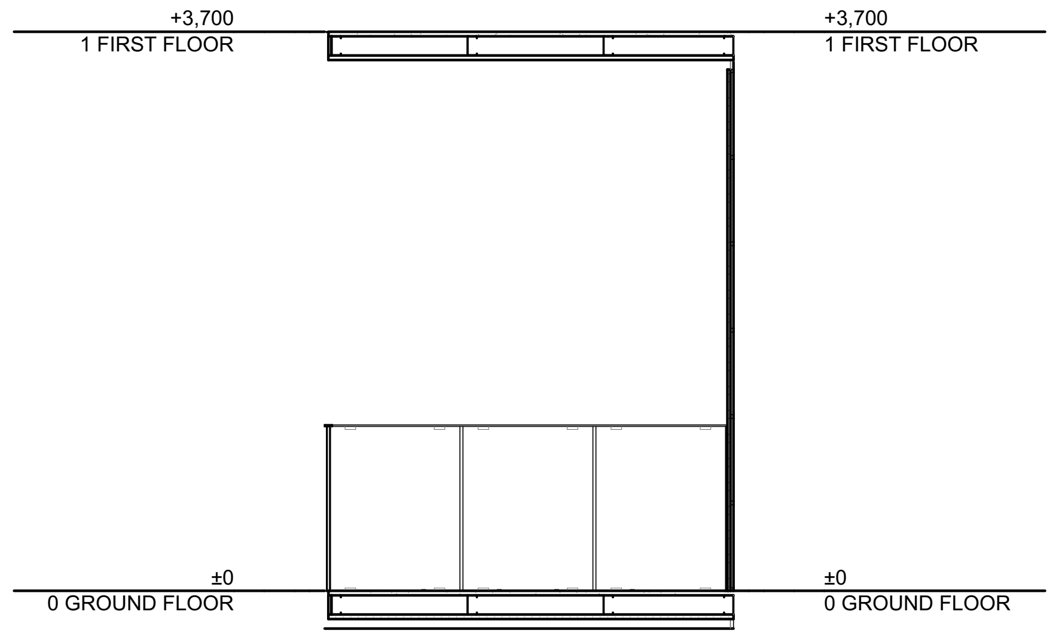

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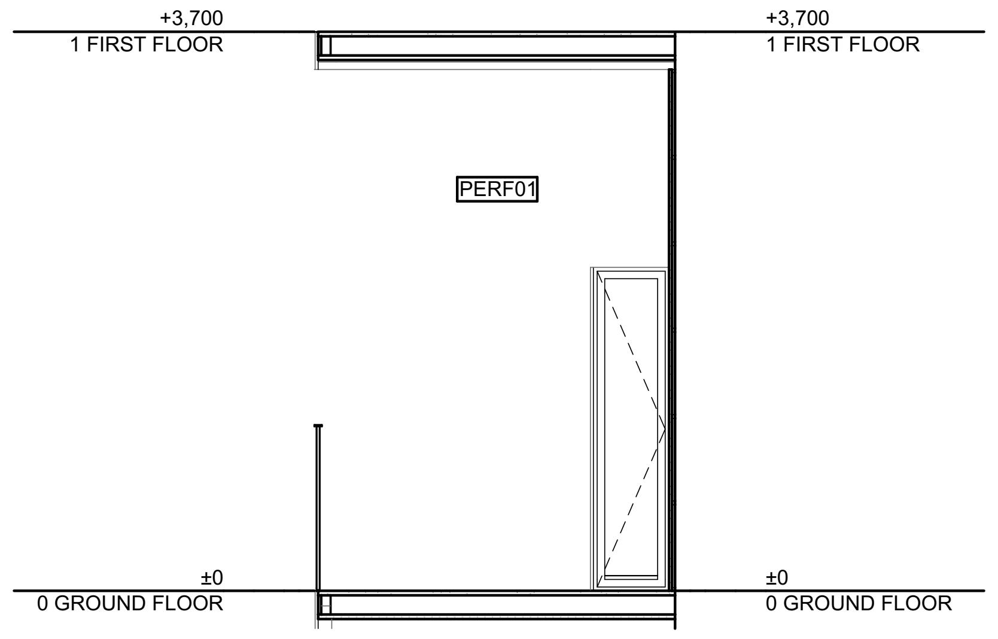

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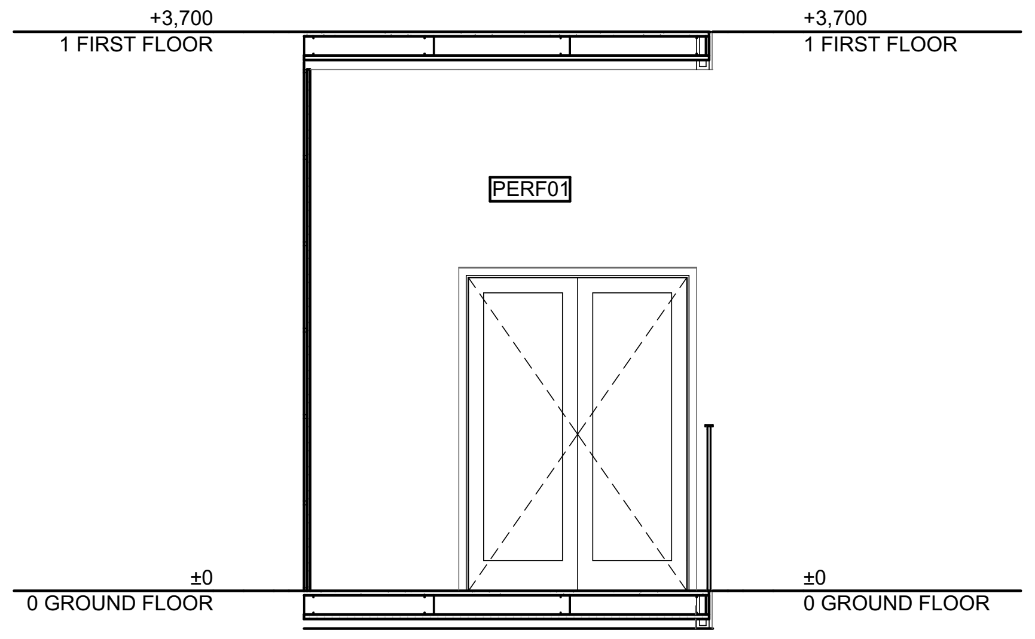

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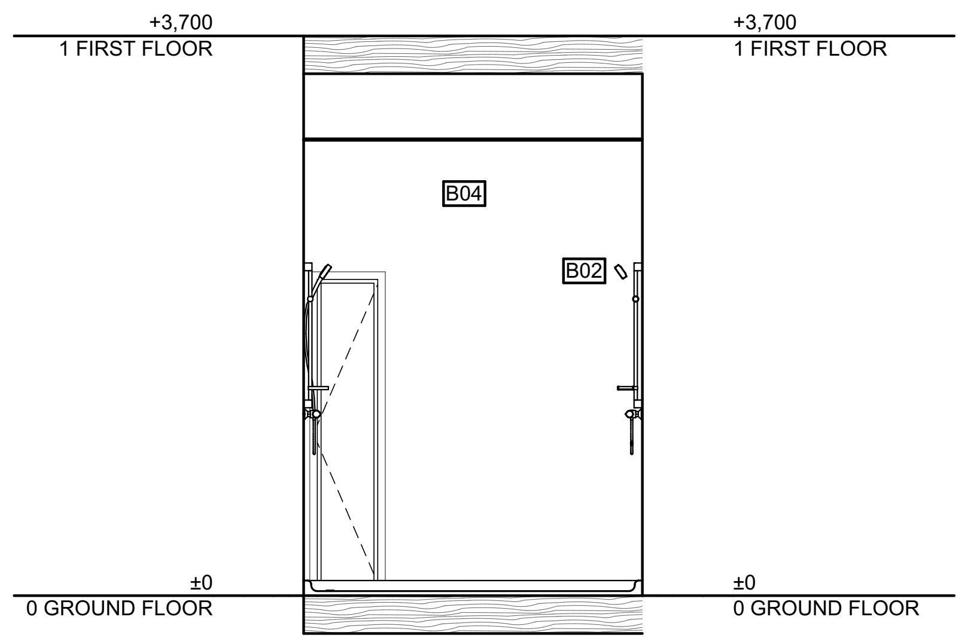

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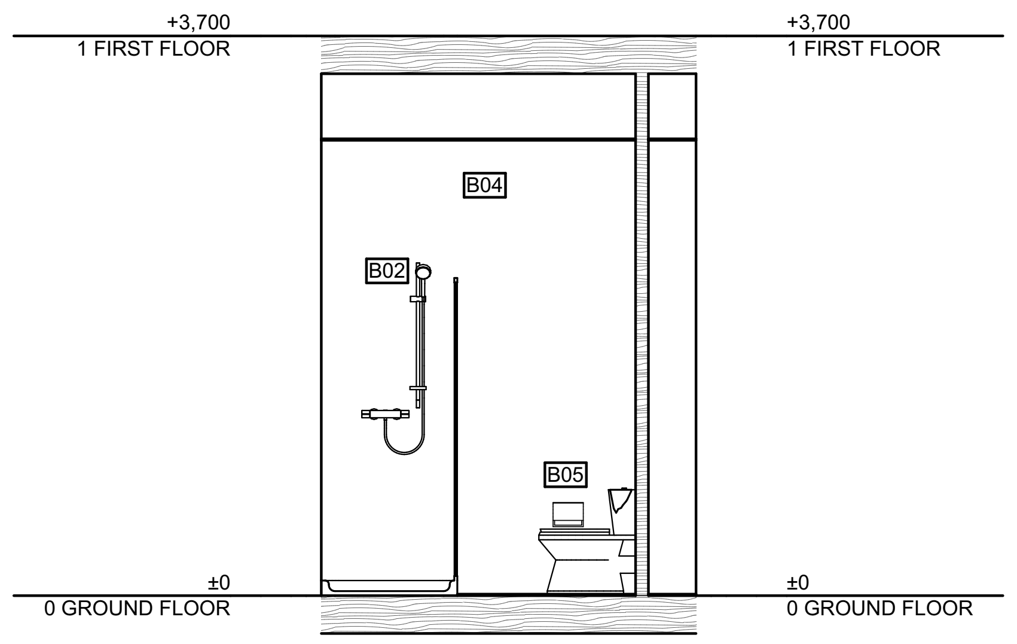

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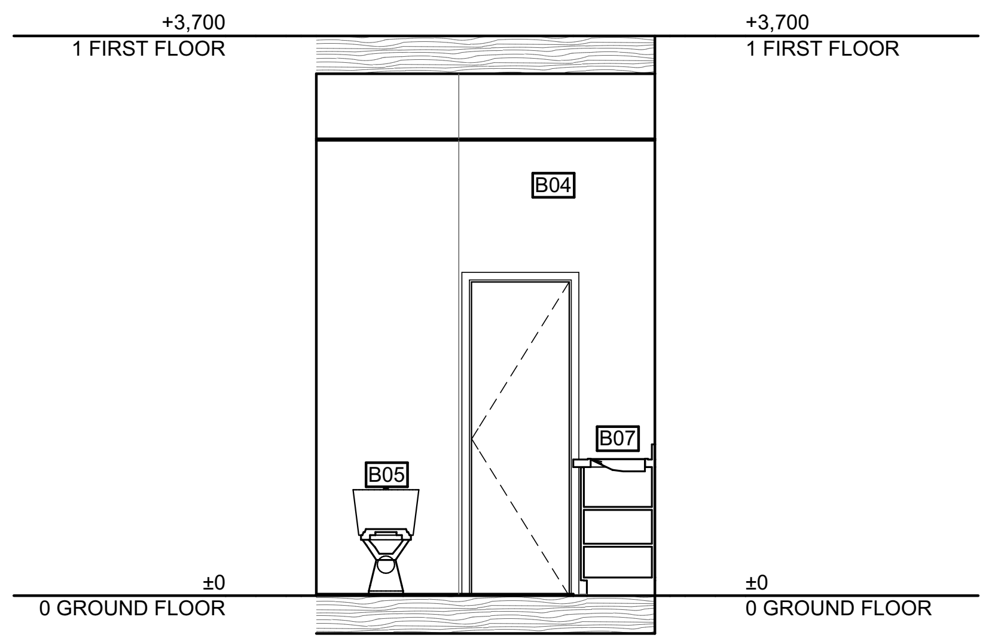

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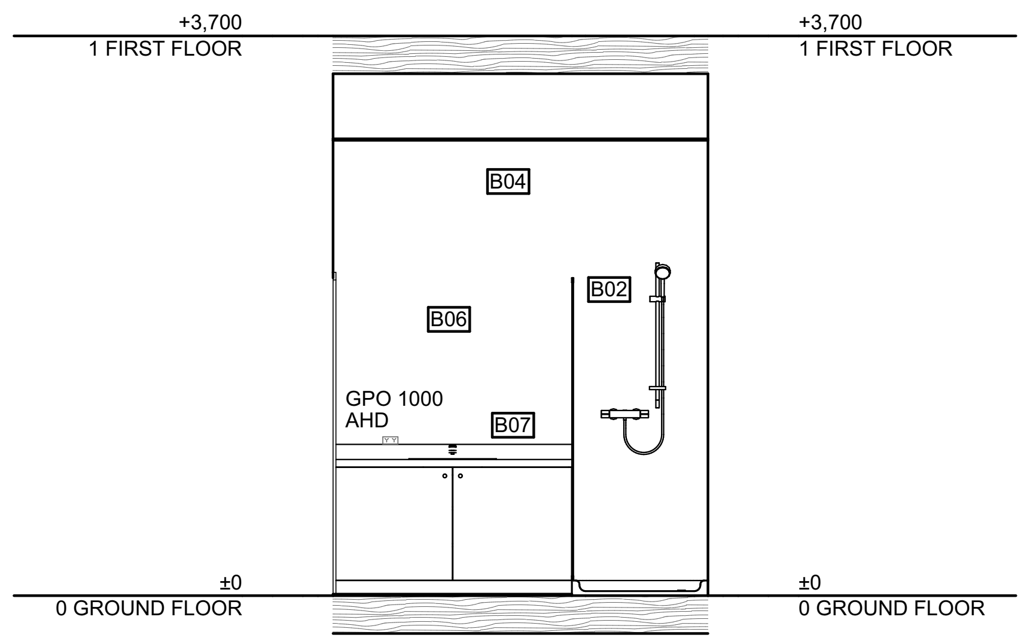

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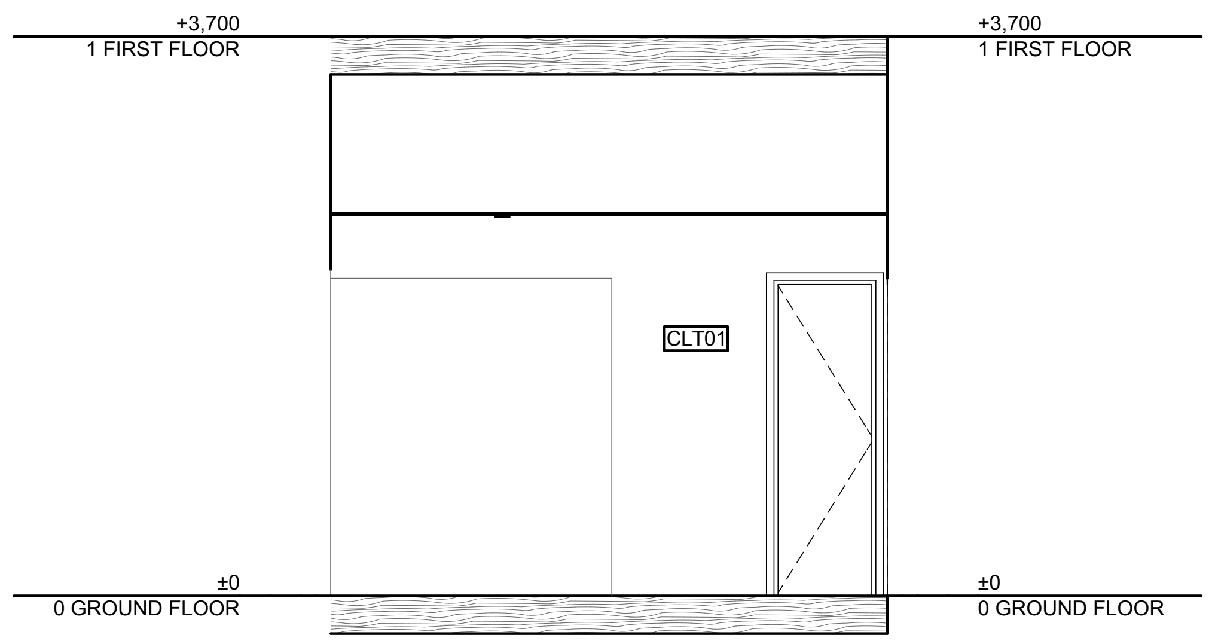

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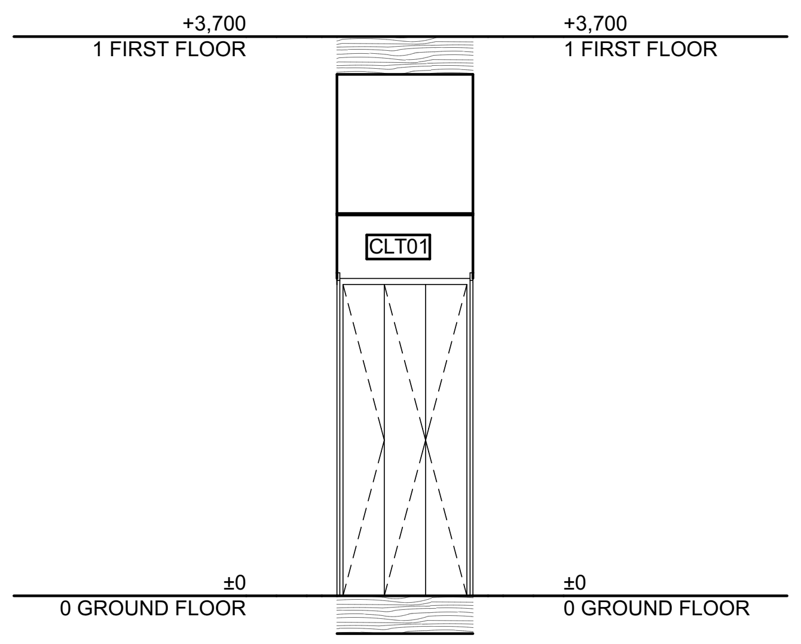

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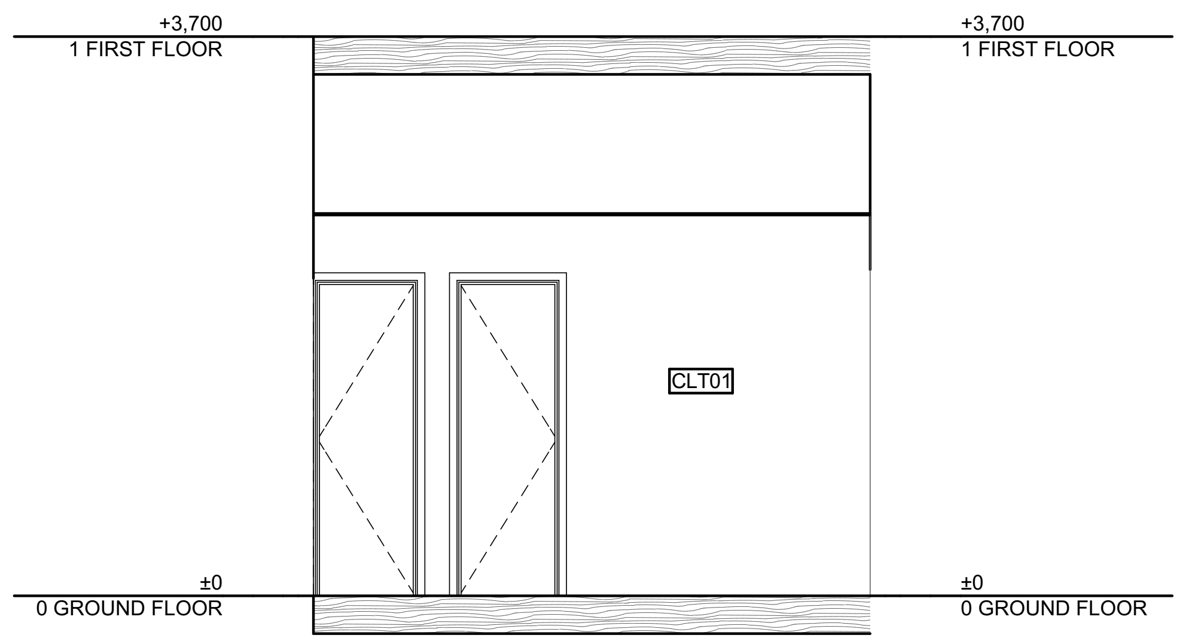

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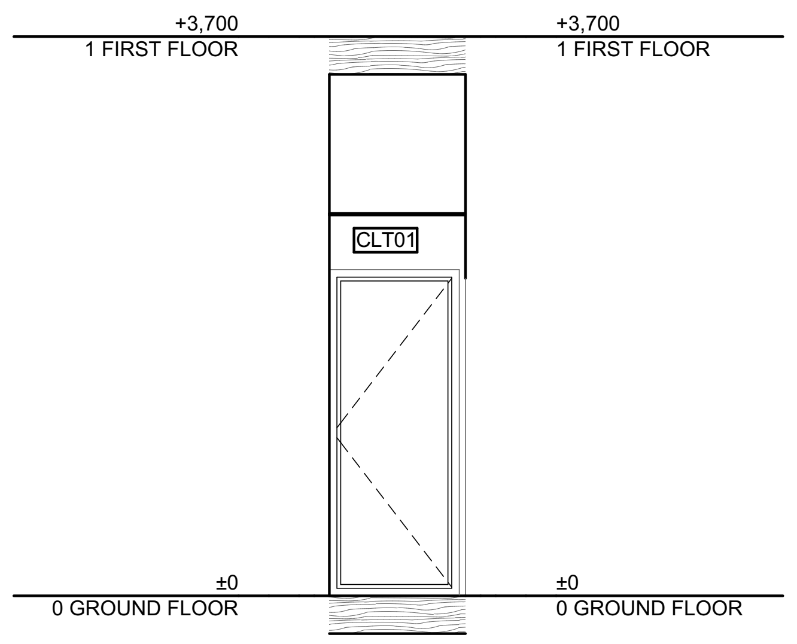

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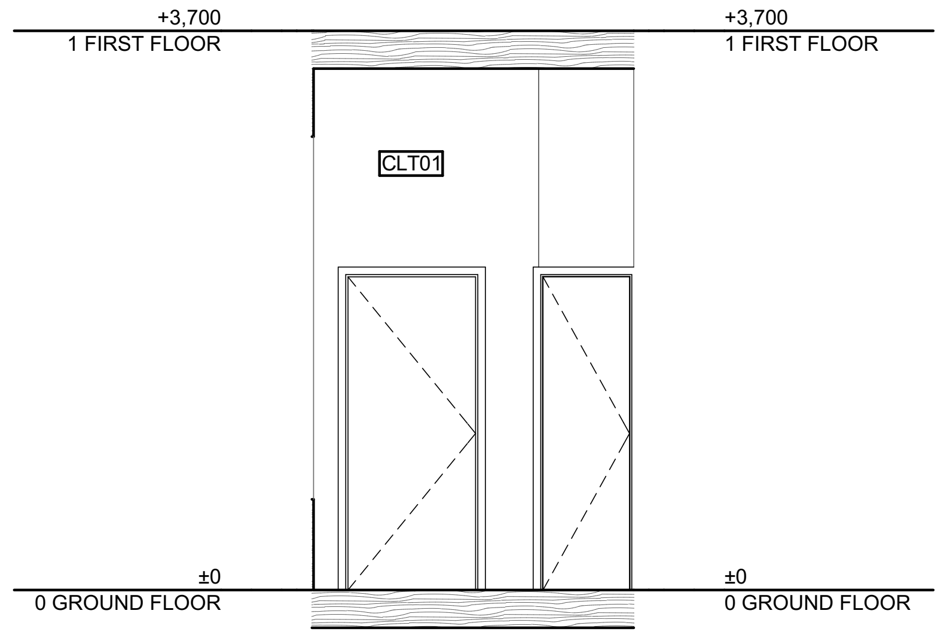

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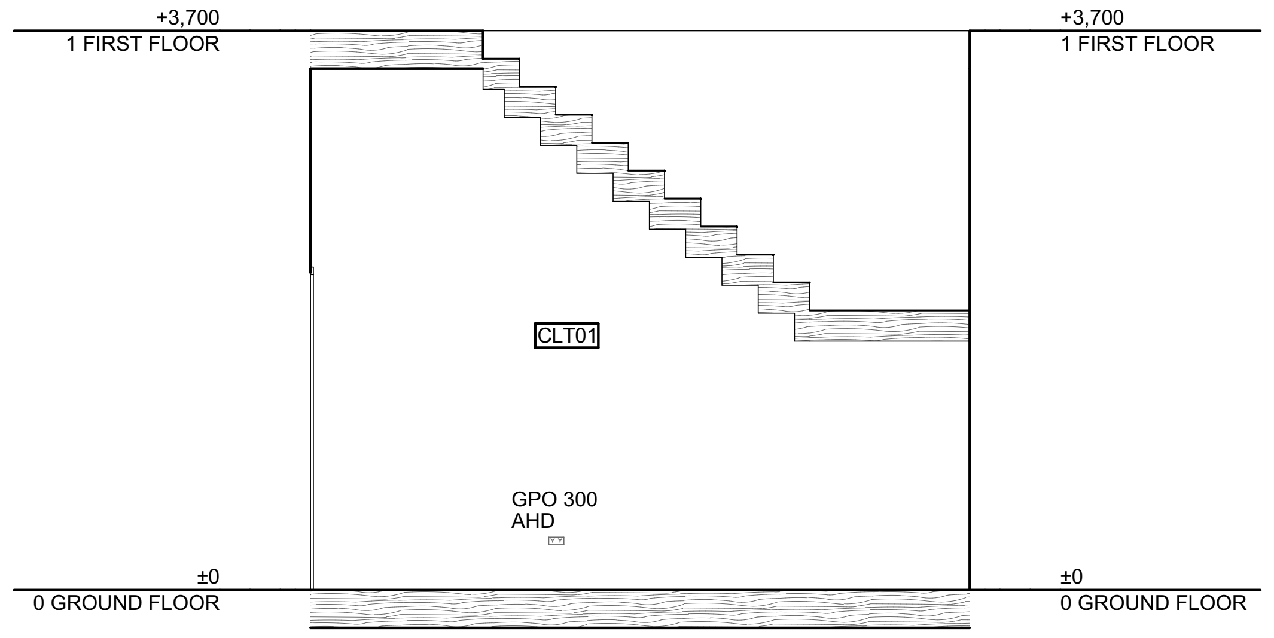

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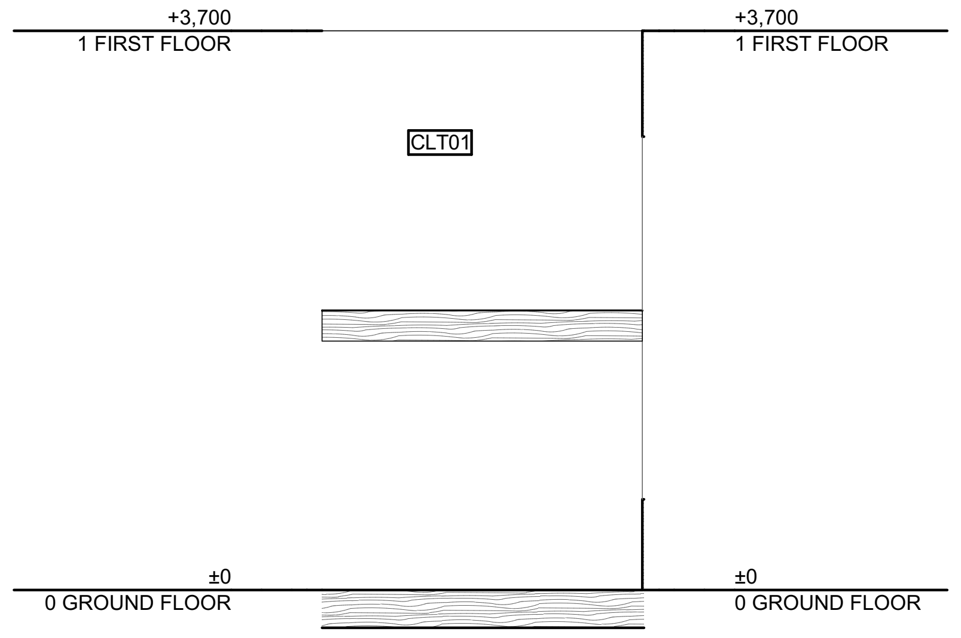

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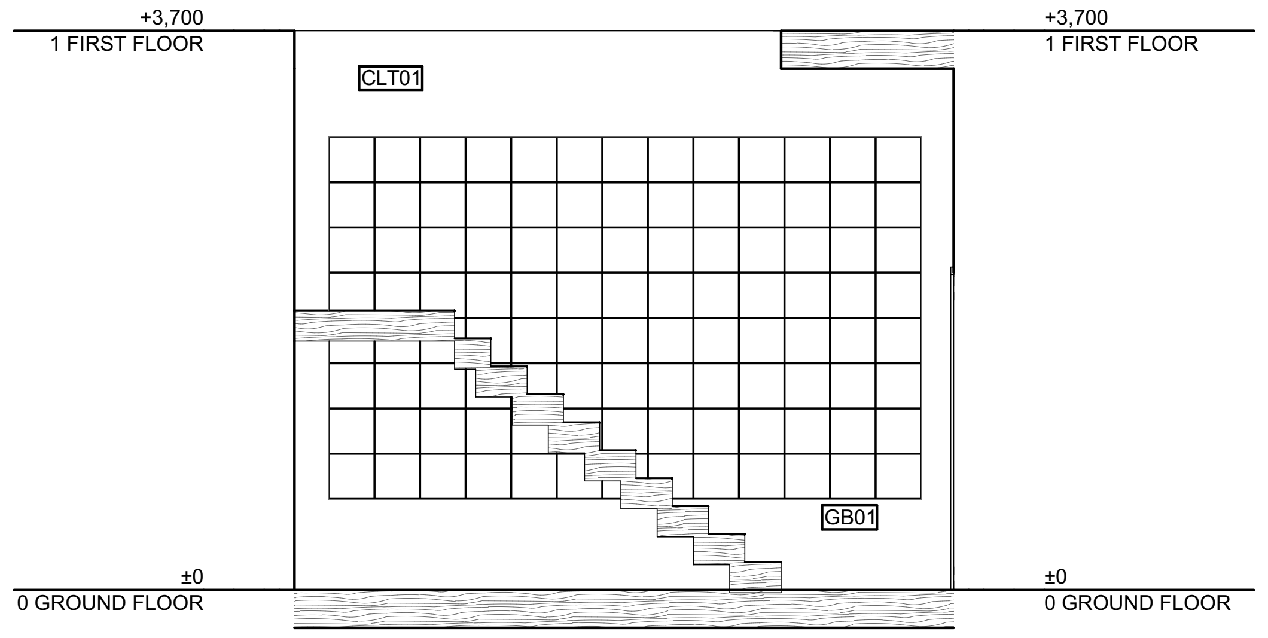

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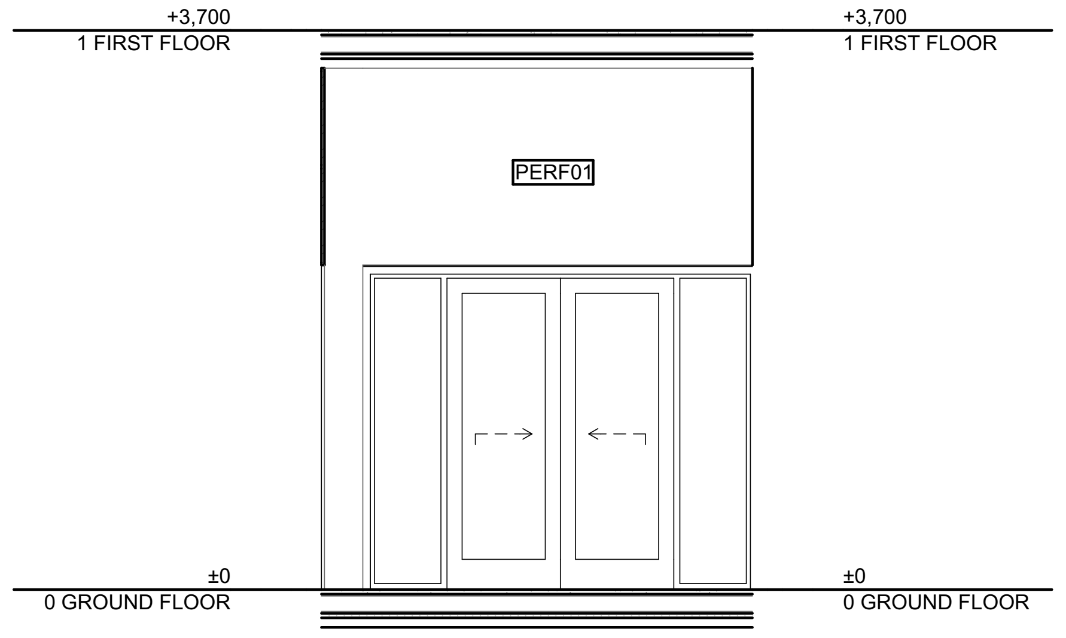

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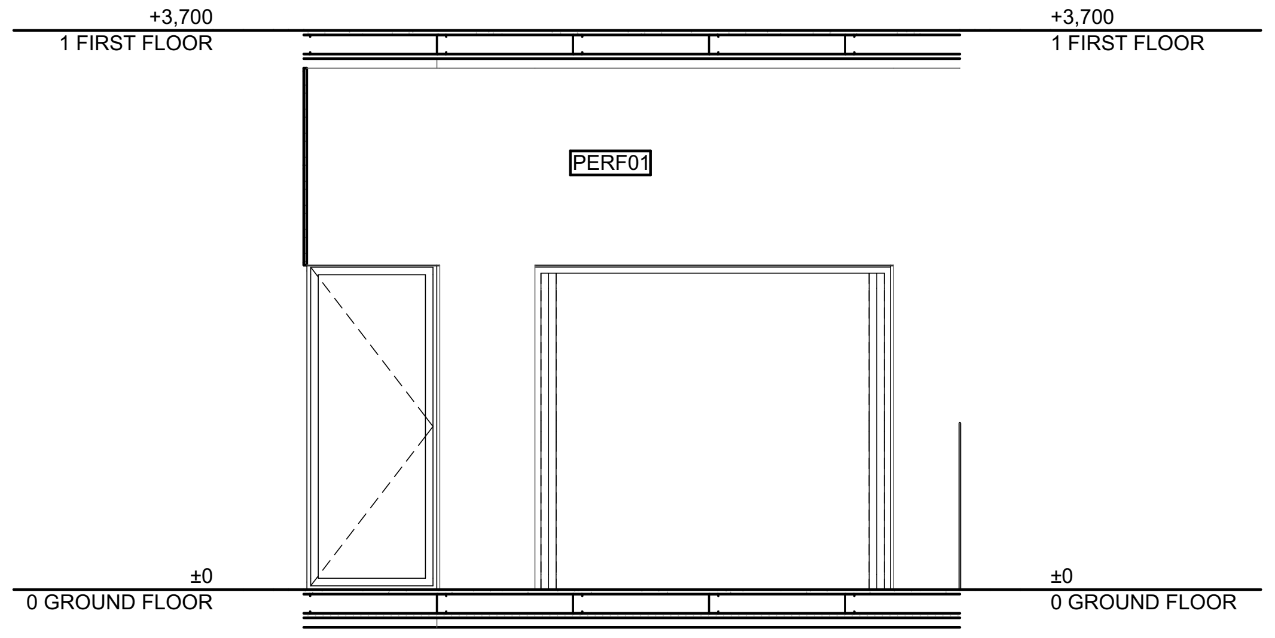

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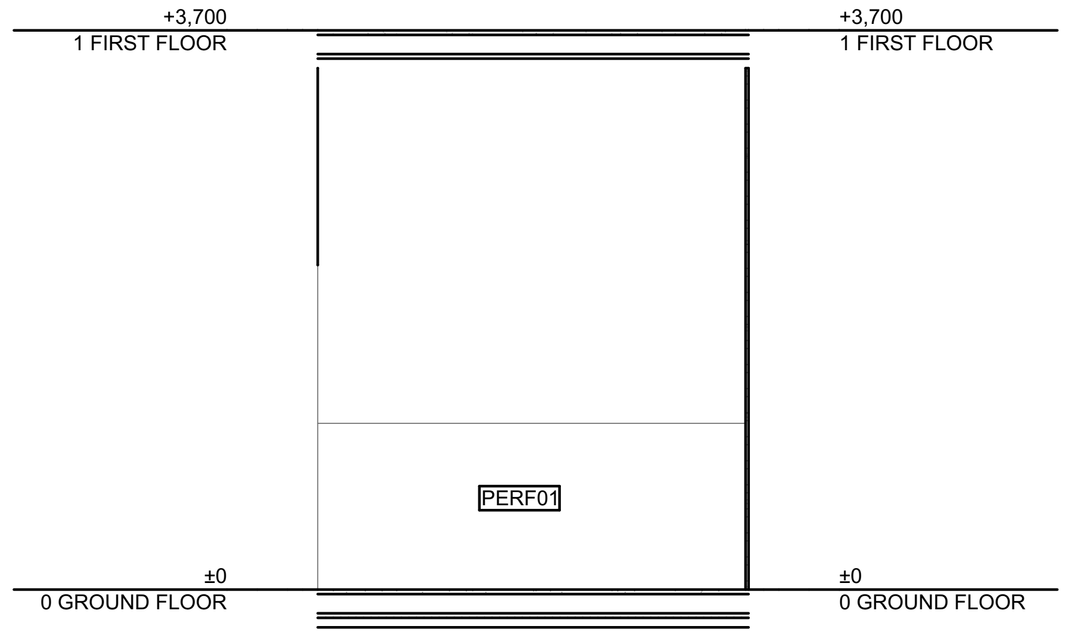

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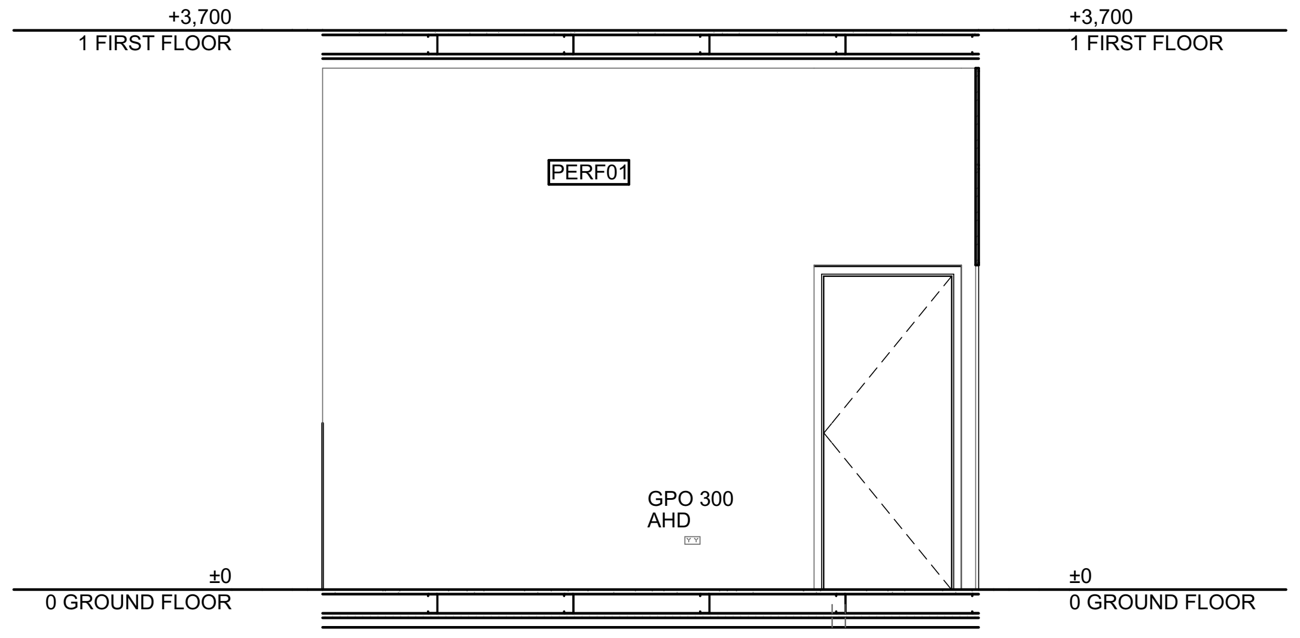

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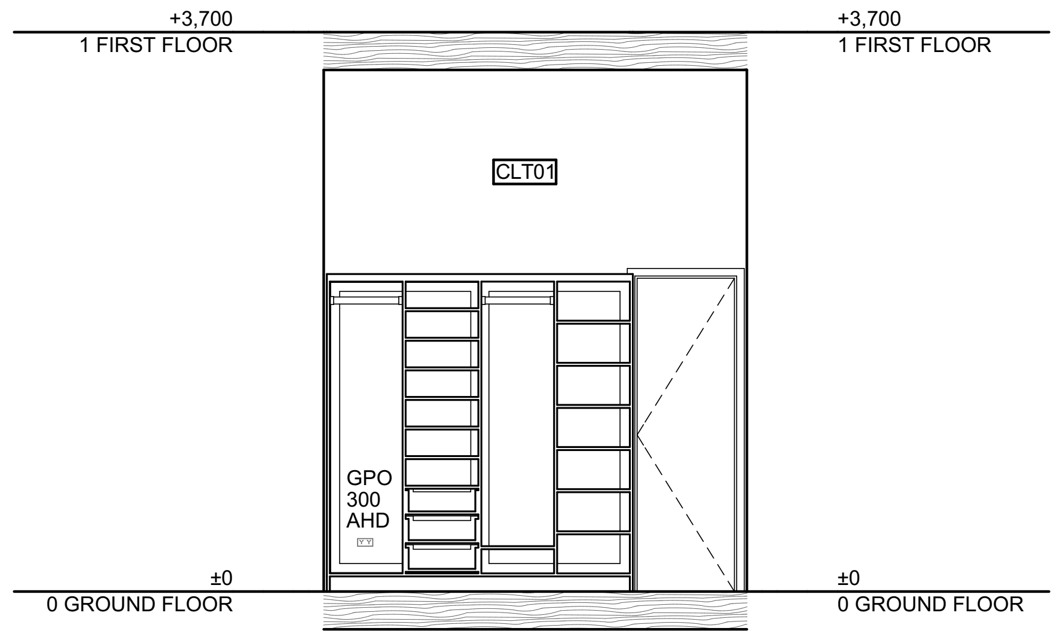

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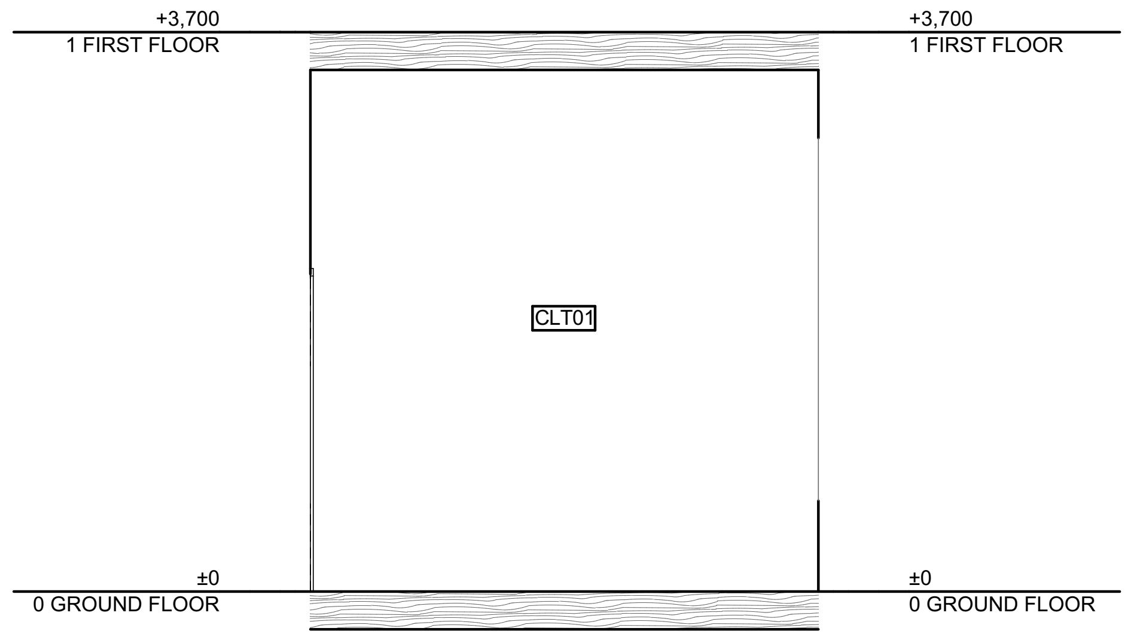

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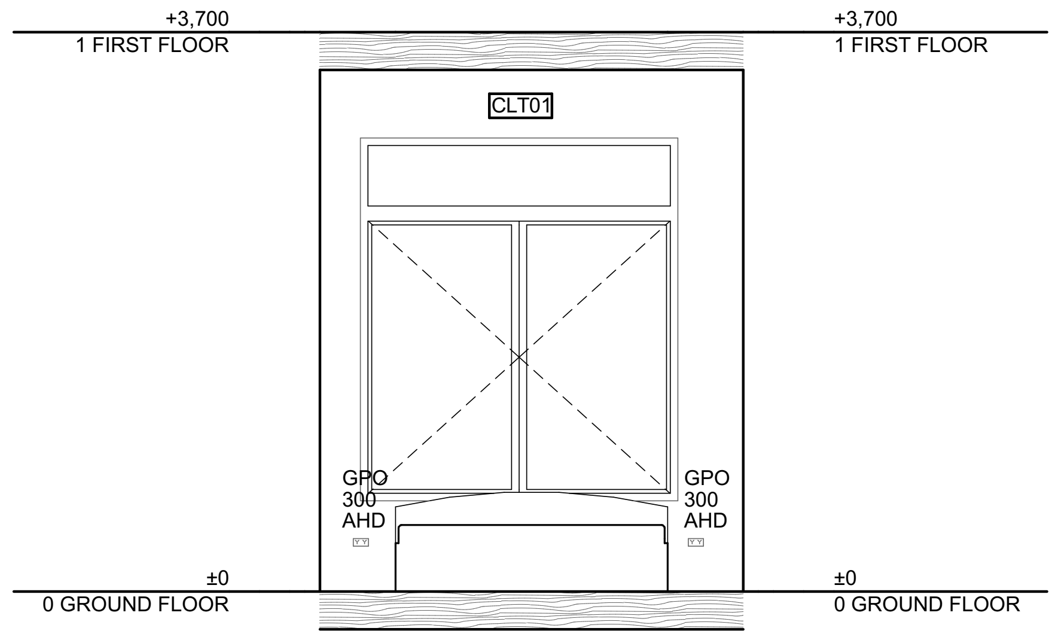

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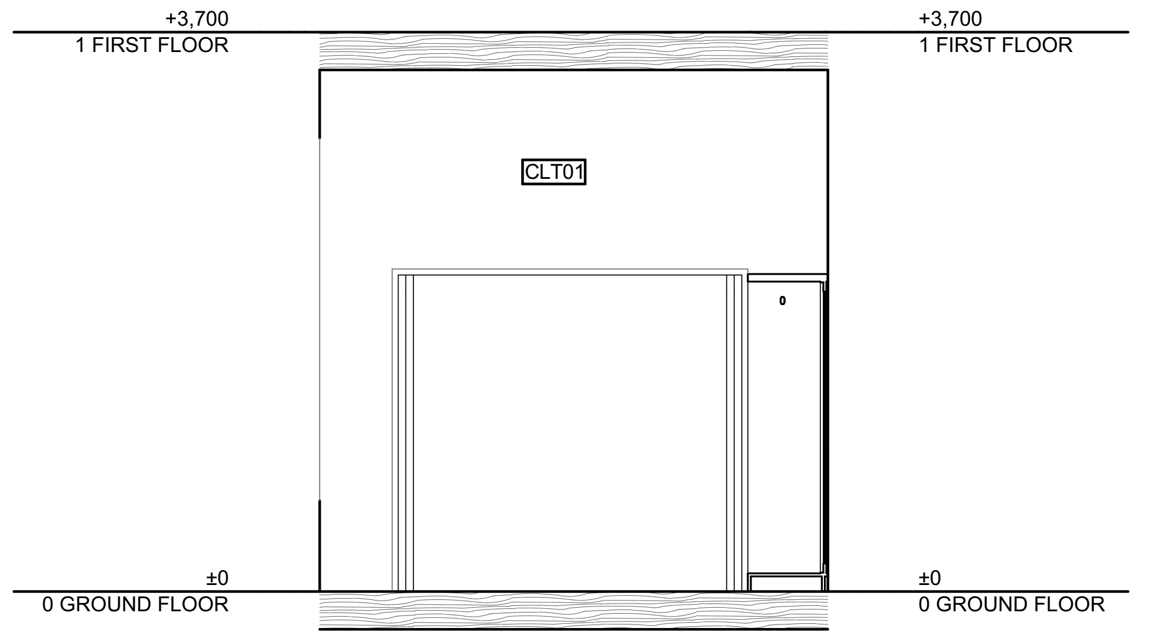

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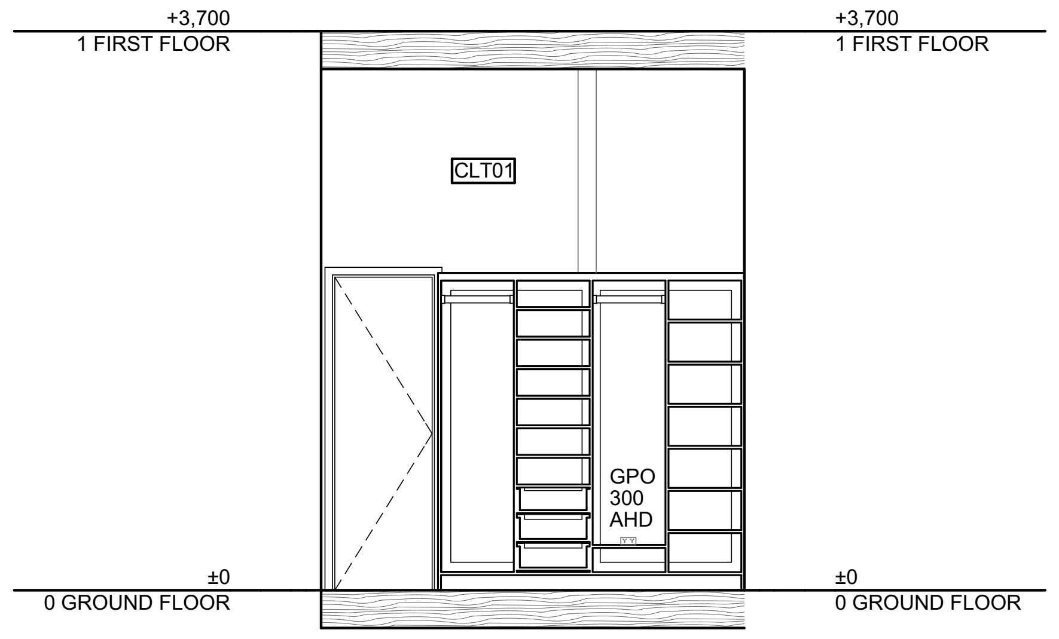

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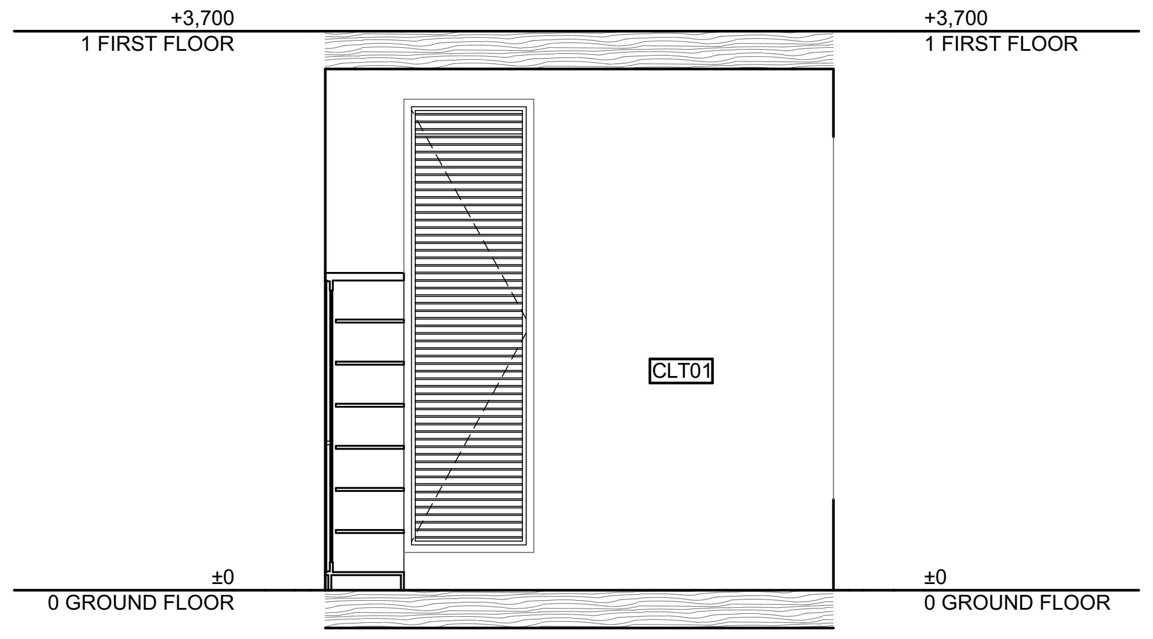

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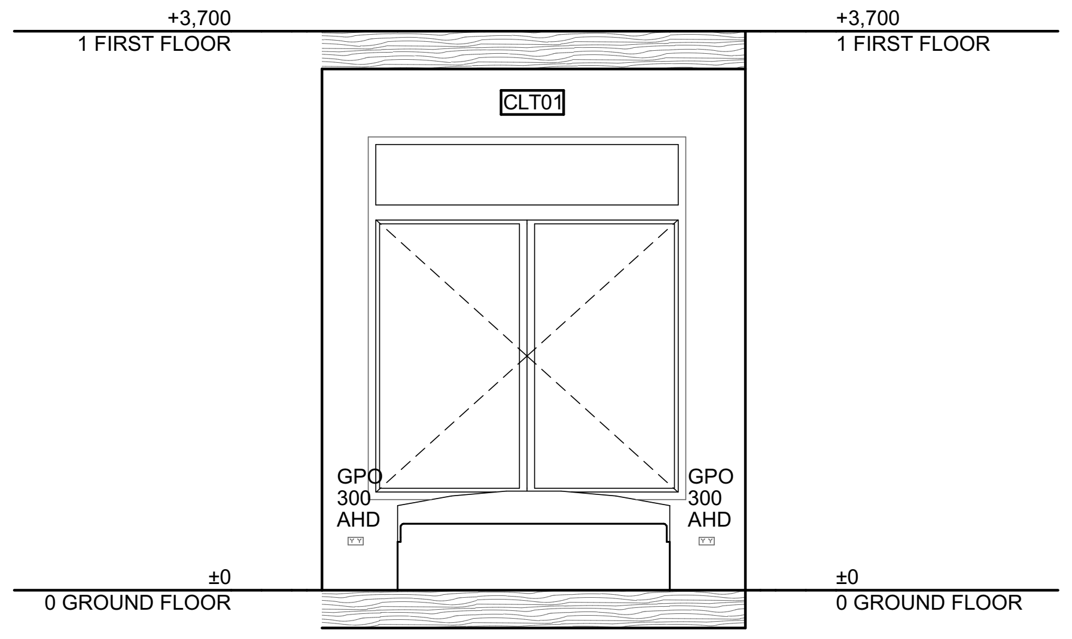

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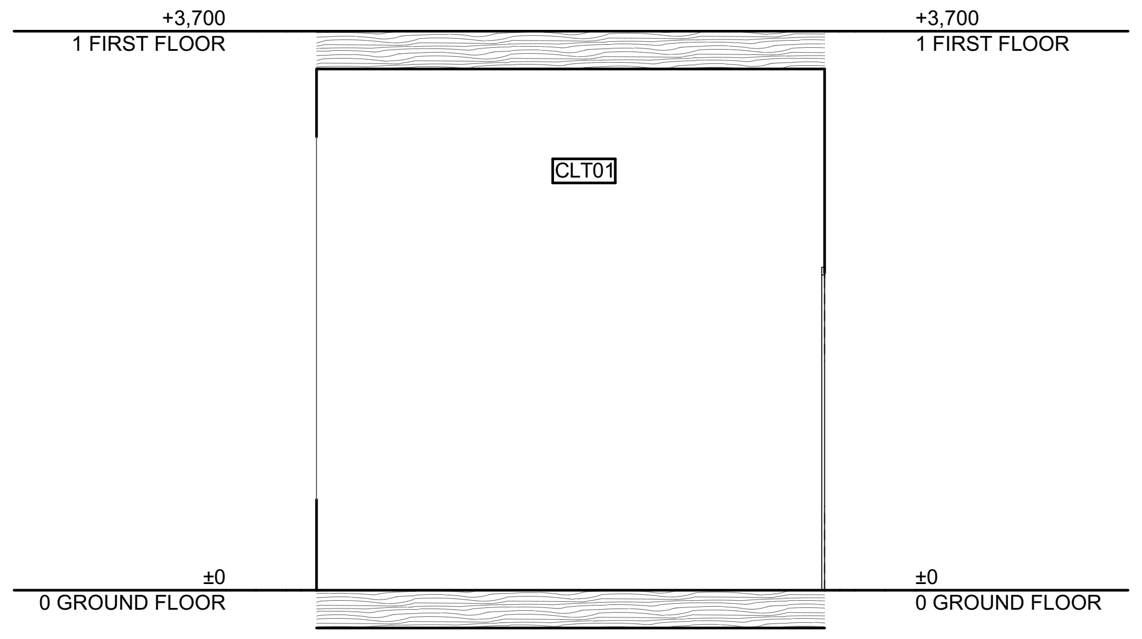

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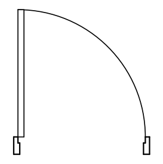
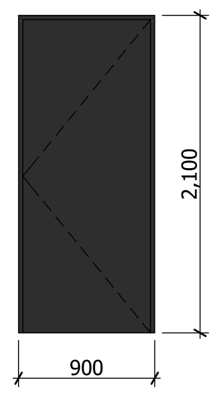
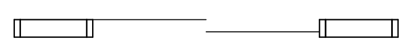
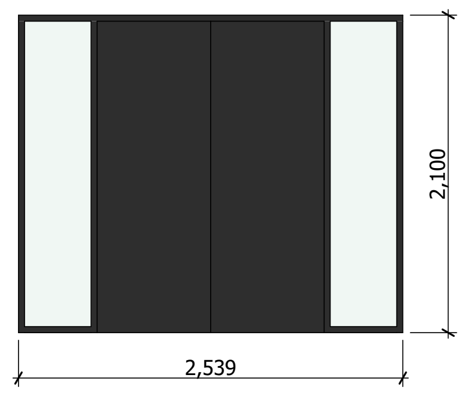
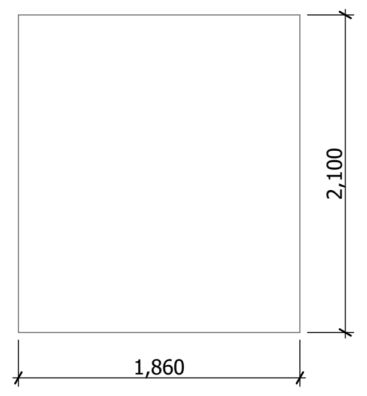
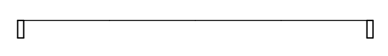
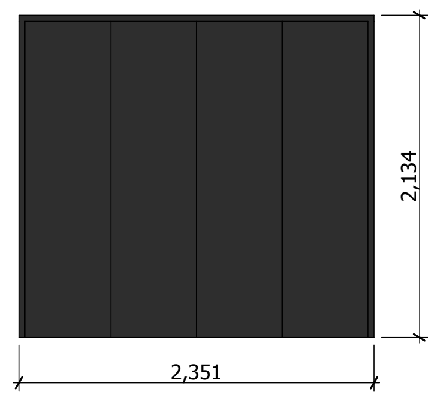
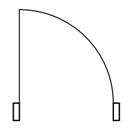
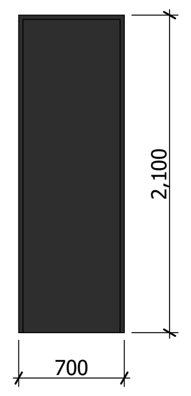
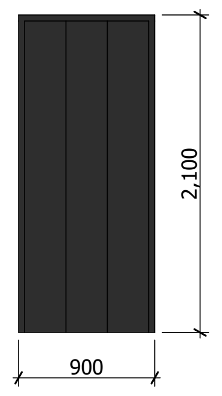
ROOM NUMBER	ROOM NAME	DOOR ID	LEAF WIDTH	STRUCTURAL OPENING WIDTH	STRUCTURAL OPENING HEIGHT	OPENING TYPE CODE	QUANTITY	SILL HEIGHT	HEAD HEIGHT	PLAN PREVIEW	ELEVATION FROM OPENING SIDE	FRAME WIDTH	FRAME THICKNESS	FRAME OUTSIDE MATERIAL	FRAME INSIDE MATERIAL	LEAF OUTSIDE MATERIAL	LEAF INSIDE MATERIAL	LEAF GLASS	LEAF THICKNESS	LEAF UNDERCUT	HANDLE HEIGHT	HANDLE OFFSET	NUMBER OF HINGES	HOLD OPEN DEVICE	FIRE EXIT	HARDWARE	LOCK	AUTO CLOSE	NOTES
---	---	D-1	844	900	2,100	<Undefined>	16	0	2,100			40	115	Paint - Anthracite	Paint - Anthracite	Paint - Anthracite	Paint - Anthracite	Glass - Clear	40	0	1,000	50		☐	☐			☐	<Undefined>
---	---	D-2	1,500	2,539	2,100	<Undefined>	12	0	2,100			40	115	Paint - Anthracite	Paint - Anthracite	Paint - Anthracite	Paint - Anthracite	Glass - Clear	40	0	1,000	50		☐	☐			☐	<Undefined>
---	---	D-3	---	1,860	2,100	<Undefined>	12	0	2,100			50	0	Timber - Pine Grained Horizontal	---	Timber - Pine Grained Horizontal	---	---	40	---	---	---	---	---	☐	---	---	☐	<Undefined>
---	---	D-4	2,271	2,351	2,134	<Undefined>	12	0	2,134			40	115	Paint - Anthracite	Paint - Anthracite	Paint - Anthracite	Paint - Anthracite	Glass - Clear	50	0	1,000	50		☐	☐			☐	<Undefined>
---	---	D-5	644	700	2,100	<Undefined>	32	0	2,100			40	115	Paint - Anthracite	Paint - Anthracite	Paint - Anthracite	Paint - Anthracite	Glass - Clear	40	0	1,000	50		☐	☐			☐	<Undefined>
---	---	D-6	820	900	2,100	<Undefined>	12	0	2,100			40	25	Paint - Anthracite	Paint - Anthracite	Paint - Anthracite	Paint - Anthracite	Glass - Clear	25	0	1,000	50		☐	☐			☐	<Undefined>

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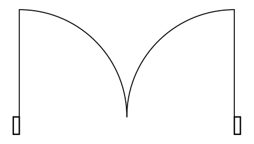
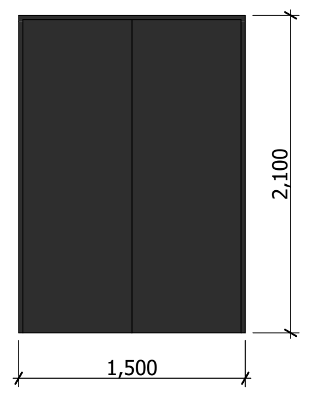
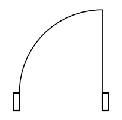
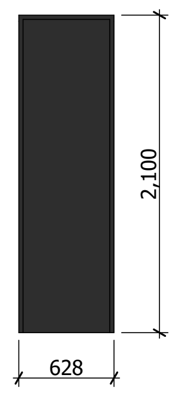
ROOM NUMBER	ROOM NAME	DOOR ID	LEAF WIDTH	STRUCTURAL OPENING WIDTH	STRUCTURAL OPENING HEIGHT	OPENING TYPE CODE	QUANTITY	SILL HEIGHT	HEAD HEIGHT	PLAN PREVIEW	ELEVATION FROM OPENING SIDE	FRAME WIDTH	FRAME THICKNESS	FRAME OUTSIDE MATERIAL	FRAME INSIDE MATERIAL	LEAF OUTSIDE MATERIAL	LEAF INSIDE MATERIAL	LEAF GLASS	LEAF THICKNESS	LEAF UNDERCUT	HANDLE HEIGHT	HANDLE OFFSET	NUMBER OF HINGES	HOLD OPEN DEVICE	FIRE EXIT	HARDWARE	LOCK	AUTO CLOSE	NOTES
---	---	D-7	1,444	1,500	2,100	<Undefined>	12	0	2,100			40	115	Paint - Anthracite	Paint - Anthracite	Paint - Anthracite	Paint - Anthracite	Glass - Clear	40	0	1,000	50		☐	☐			☐	<Undefined>
---	---	D-8	572	628	2,100	<Undefined>	12	0	2,100			40	115	Paint - Anthracite	Paint - Anthracite	Paint - Anthracite	Paint - Anthracite	Glass - Clear	40	0	1,000	50		☐	☐			☐	<Undefined>

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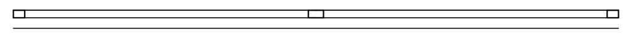
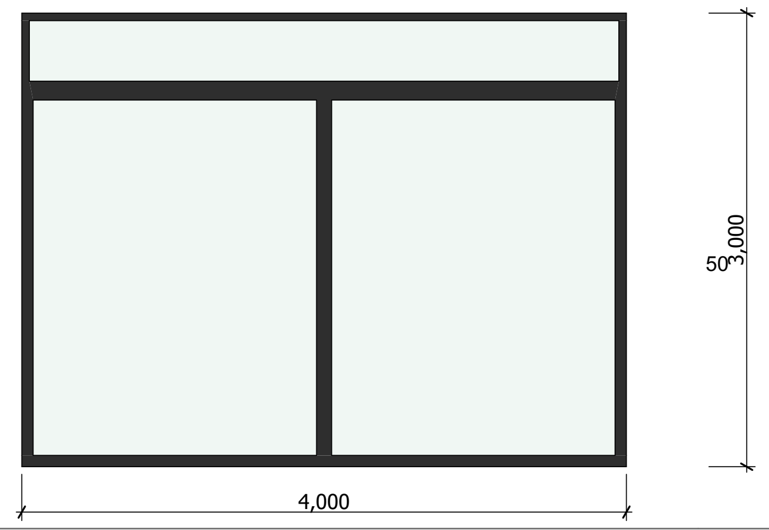
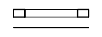
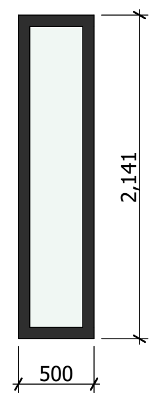
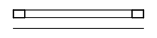
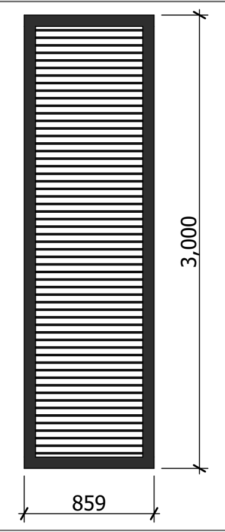
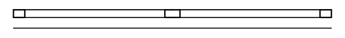
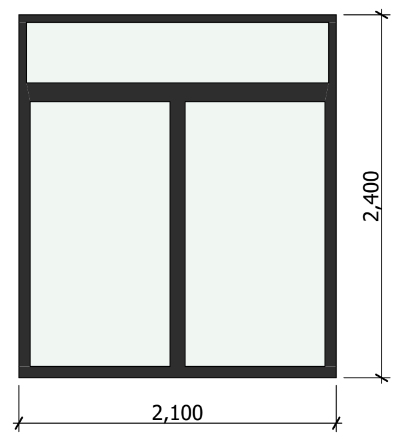
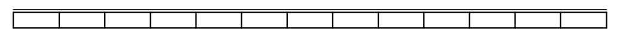
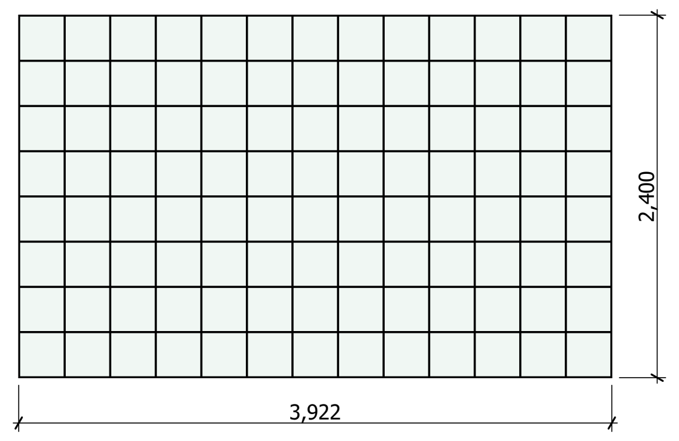
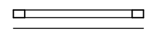
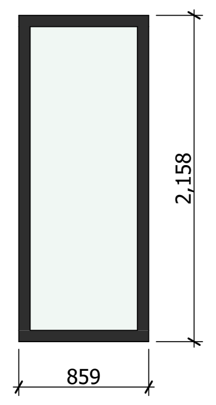
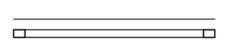
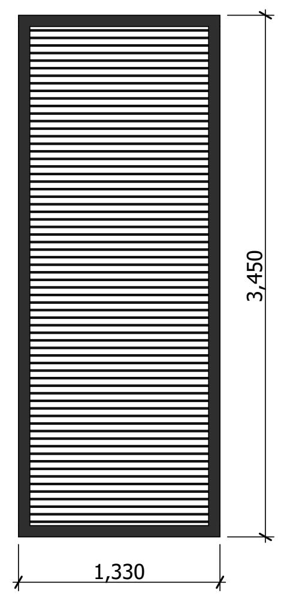
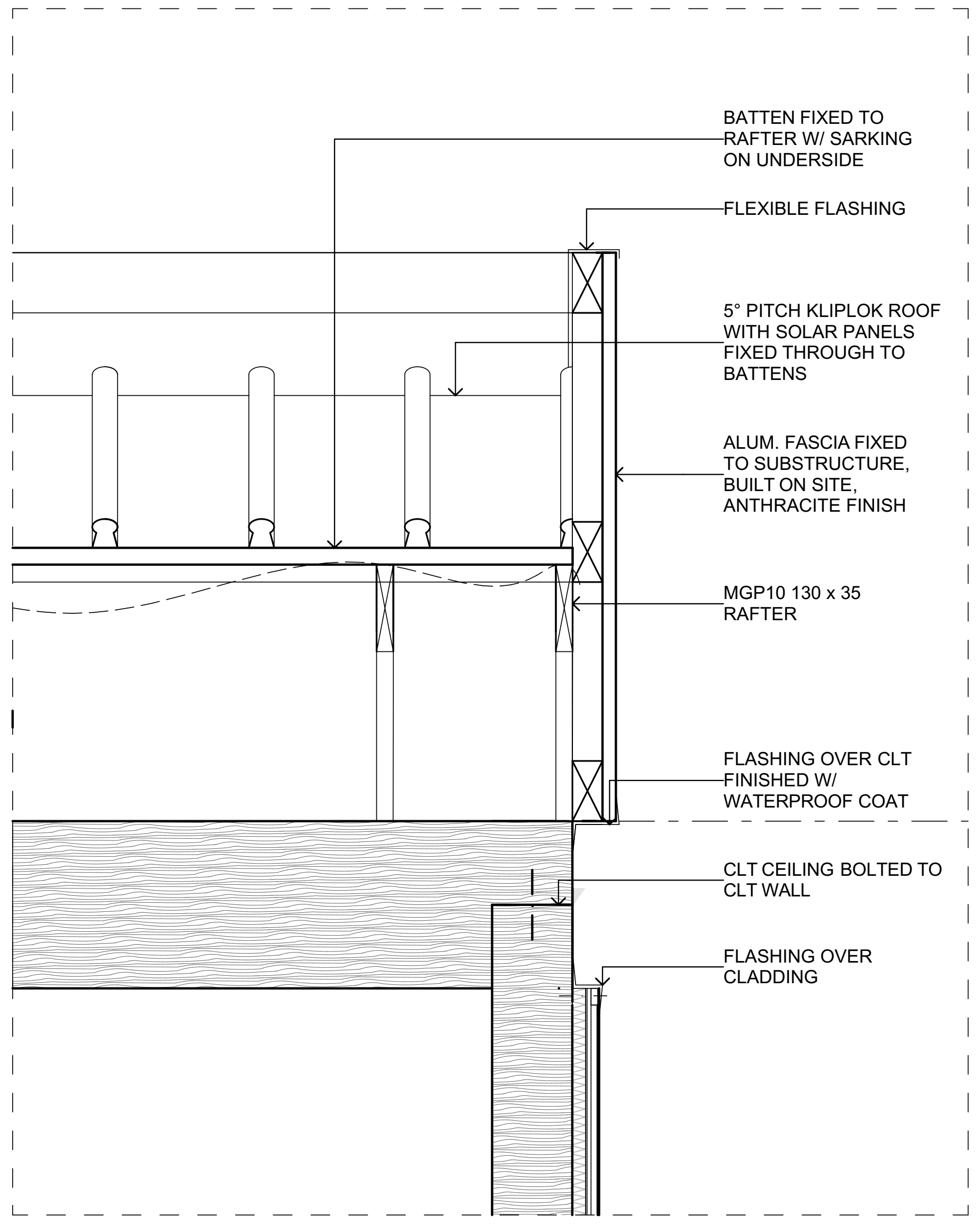
ROOM NUMBER	ROOM NAME	WINDOW ID	STRUCTURAL OPENING WIDTH	STRUCTURAL OPENING HEIGHT	OPENING TYPE CODE	QUANTITY	SILL HEIGHT	HEAD HEIGHT	PLAN PREVIEW	ELEVATION FROM OPENING SIDE	FRAME WIDTH	FRAME THICKNESS	FRAME OUTSIDE MATERIAL	FRAME INSIDE MATERIAL	GLASS MATERIAL	SASH WIDTH	SASH THICKNESS	SASH OUTSIDE MATERIAL	SASH INSIDE MATERIAL	NOTES
---	---	W-1	4,000	3,000	<Un...	12	0	3,000			50	50	Paint - Anthracite	Paint - Anthracite	Glass - Clear	50	50	Paint - Anthracite	Paint - Anthracite	<Undefined>
---	---	W-2	500	2,141	<Un...	12	0	2,141			50	50	Paint - Anthracite	Paint - Anthracite	Glass - Clear	50	50	Paint - Anthracite	Paint - Anthracite	<Undefined>
---	---	W-3	859	3,000	<Un...	12	250	3,250			50	50	Paint - Anthracite	Paint - Anthracite	Glass - Clear	50	50	Paint - Anthracite	Paint - Anthracite	<Undefined>
---	---	W-4	2,100	2,400	<Un...	20	600	3,000			50	50	Paint - Anthracite	Paint - Anthracite	Glass - Clear	50	50	Paint - Anthracite	Paint - Anthracite	<Undefined>
---	---	W-5	3,922	2,400	<Un...	12	600	3,000			70	50	Timber - Pine Grained H...	---	Glass - Clear	50	50	Timber - Pine Grained H...	---	<Undefined>
---	---	W-6	859	2,158	<Un...	12	0	2,158			50	50	Paint - Anthracite	Paint - Anthracite	Glass - Clear	50	50	Paint - Anthracite	Paint - Anthracite	<Undefined>

ROOM NUMBER	ROOM NAME	WINDOW ID	STRUCTURAL OPENING WIDTH	STRUCTURAL OPENING HEIGHT	OPENING TYPE CODE	QUANTITY	SILL HEIGHT	HEAD HEIGHT	PLAN PREVIEW	ELEVATION FROM OPENING SIDE	FRAME WIDTH	FRAME THICKNESS	FRAME OUTSIDE MATERIAL	FRAME INSIDE MATERIAL	GLASS MATERIAL	SASH WIDTH	SASH THICKNESS	SASH OUTSIDE MATERIAL	SASH INSIDE MATERIAL	NOTES
---	---	W-7	1,330	3,450	<Un...	8	0	3,450			50	50	Paint - Anthracite	Paint - Anthracite	Glass - Clear	50	50	Paint - Anthracite	Paint - Anthracite	<Undefined>



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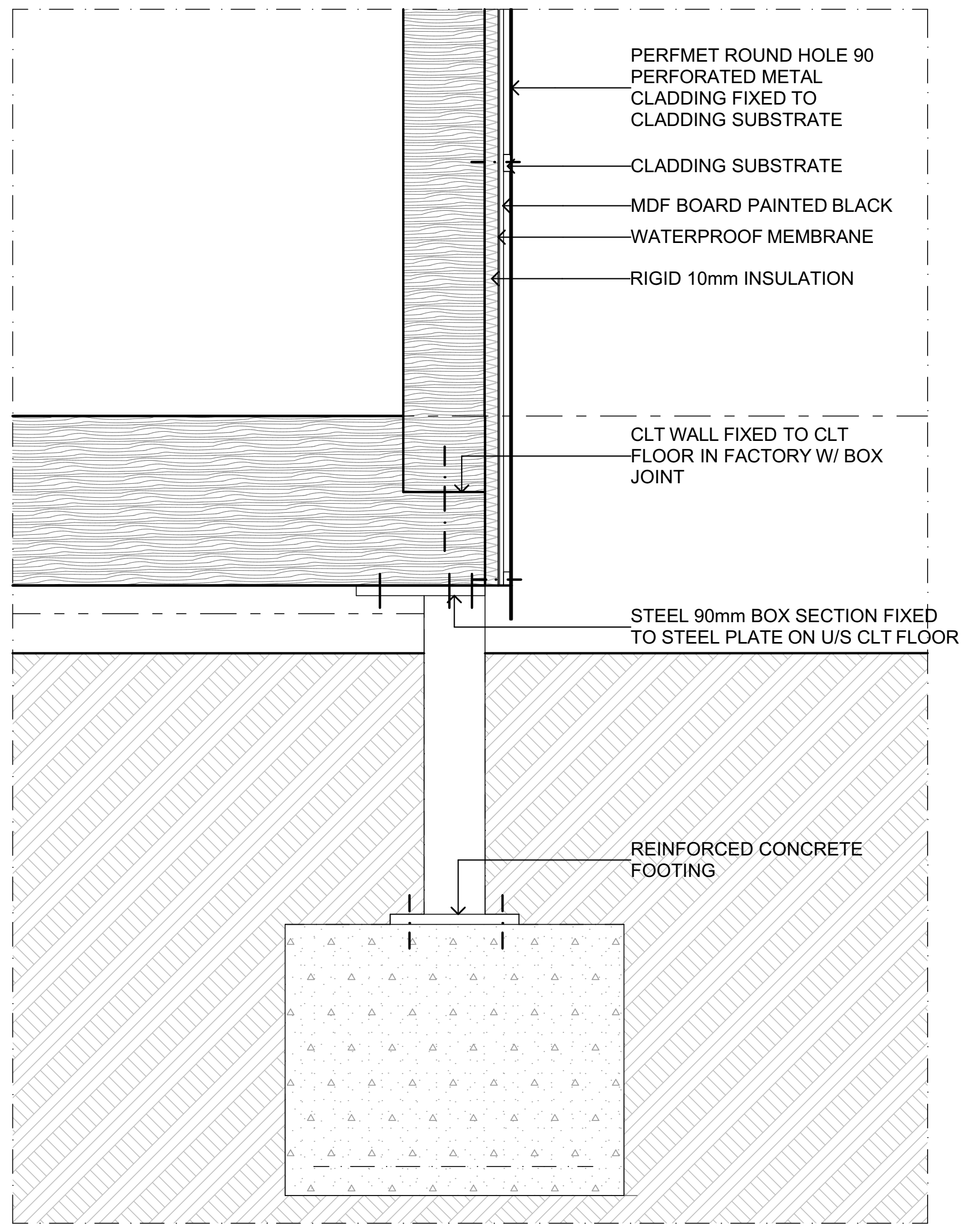

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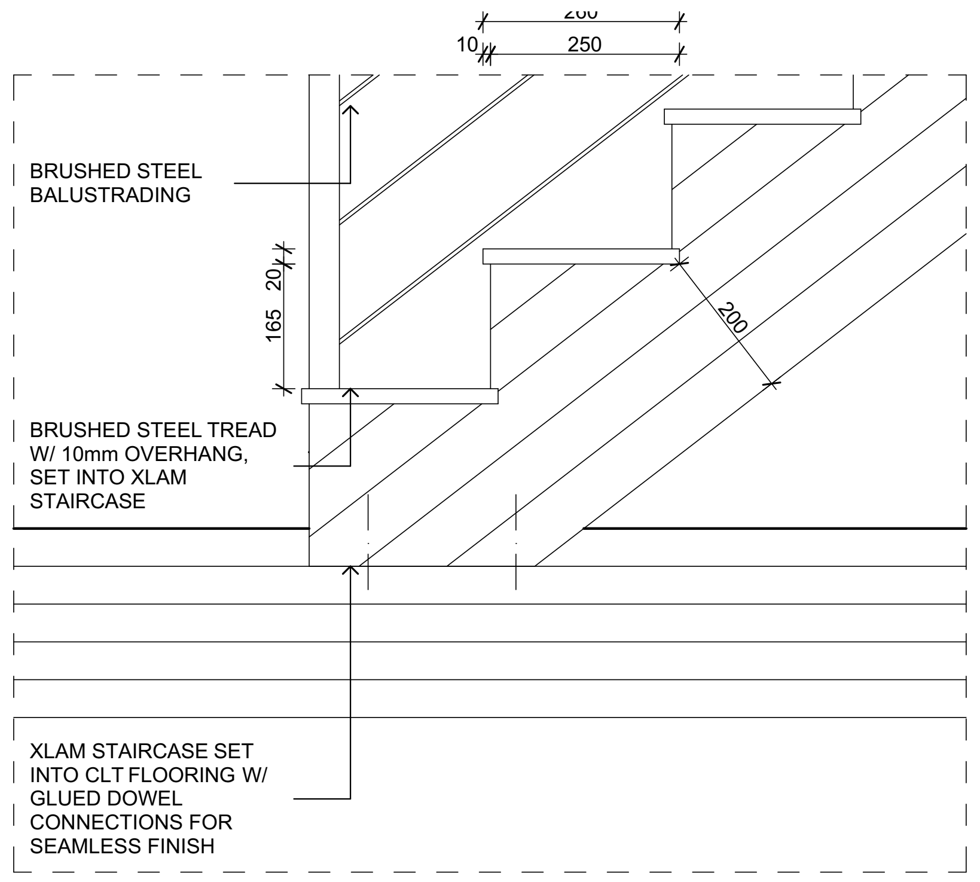

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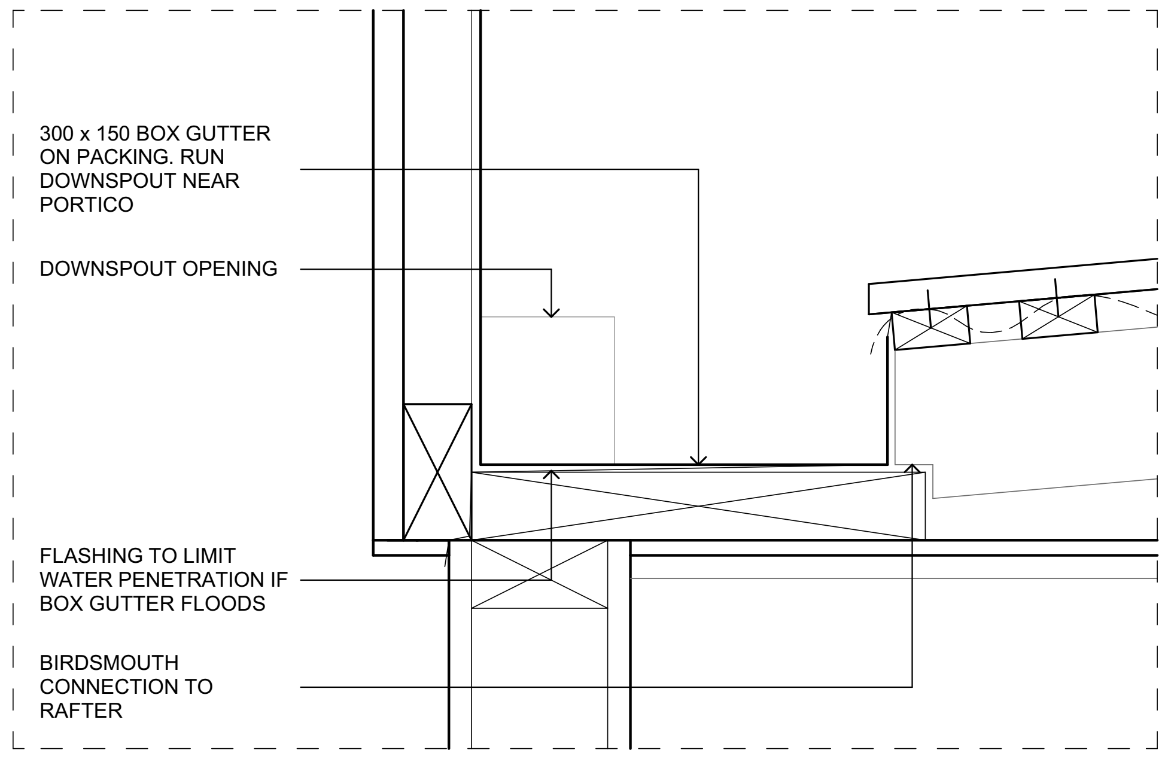

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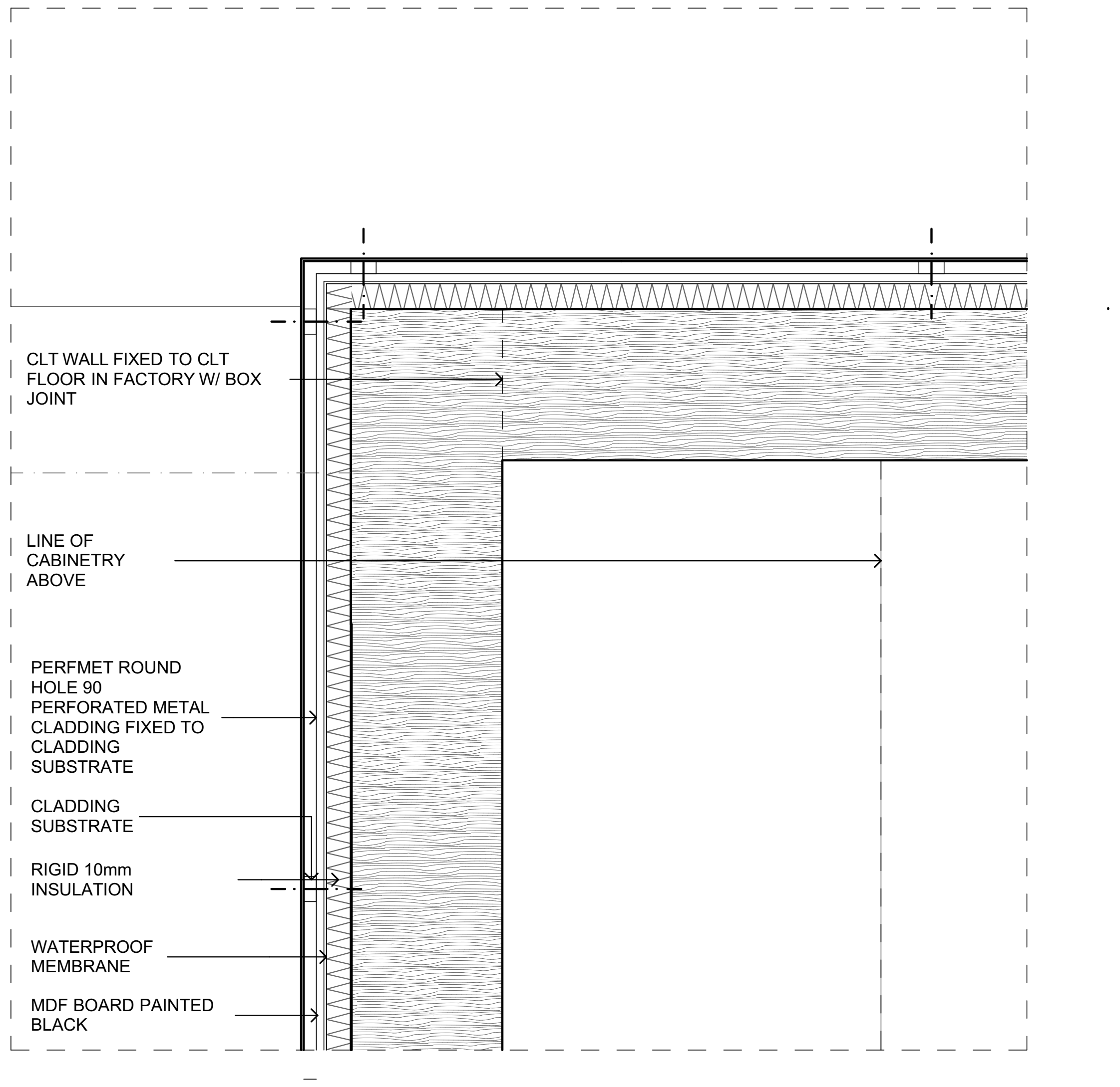

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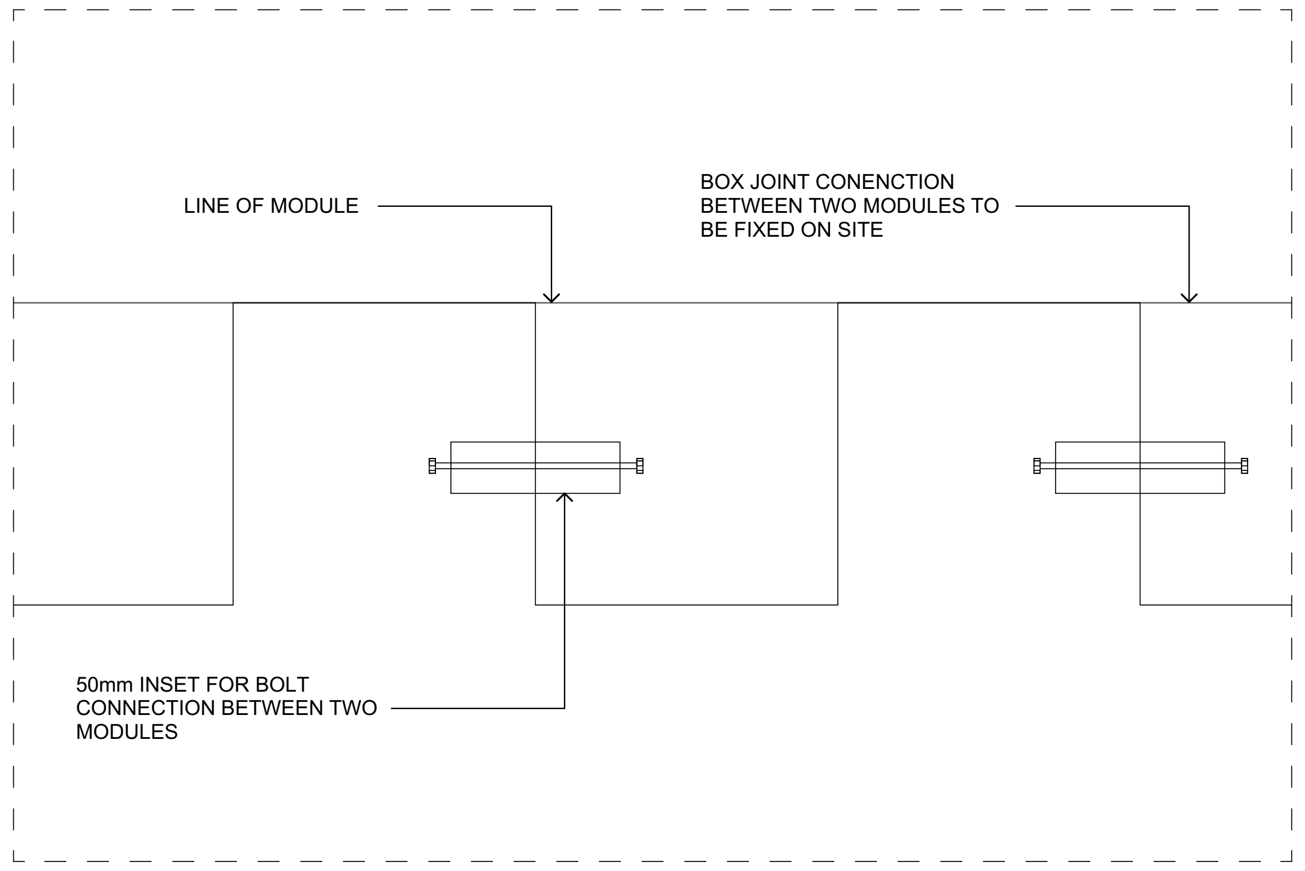

D-07
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Title:

Value Management Study

By submitting this assignment, I declare that I have retained a suitable copy of this assignment, have not previously submitted this work for assessment and have ensured that it complies with university and school regulations, especially concerning plagiarism and copyright.

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(Date/Signature)

Contents

1.0 EXECUTIVE SUMMARY

1.1 Project Brief

The proposed construction project is four residential buildings which are complex with the combination of two double-store blocks and two four-store blocks. According to the project plan, the project might be located in the CBD area. The project building complex is surrounded by existing buildings and a main entrance facing the roads. There is no ground surface car park area provided for the residents in the proposed project. The total development area of the building complex is 1000m^2. The estimated cost of the project is approximately $6.2 million.

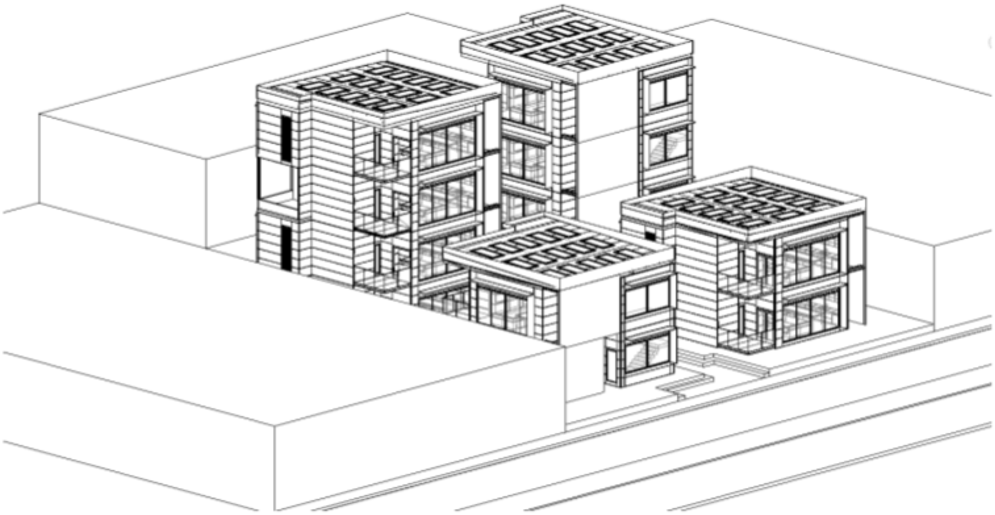


Figure 1: 3D View of Original Design

Each floor of the building layout is basically the same which consists of a living room, a kitchen, two bedrooms, a bathroom and toilet combination, a balcony and an extra empty customised area at the entry, as shown in Figure 2.

Figure 2: Floor Plan of Original Project

1.2 Summary of Problems

The project is currently in the early design stage, and there is still a lack of detailed information. The dimensions in drawing are not present properly, and some design may not be suitable to match the construction buildability. Moreover, materials for the elements used in this drawing are not reliable in building construction, they should be replaced by other alternative materials which can fulfill the long-term usage purpose.

In the process of taking off the quantities from the 3D model provided a number of issues were encountered. Firstly, there were two smaller buildings which seemed to be sketches or drafts that were very difficult to understand. These small buildings are not included in as part of our estimate and value management exercise and have been removed from the final model to be submitted.

The level of information within the objects in the model made it very difficult to 'import' the model quantities using CostX. It is unknown why this occurred, we tried using IFC and DWF files but the same issues occurred. We then attempted to use Navisworks manage to take-off the model quantities. We were more successful in doing so but unfortunately the model properties were not defined enough to separate the elements to the required level of detail. To separate all the items would have taken up a significant amount of time.

2.0 INTRODUCTION

2.1 The Purpose of Value Management Project

The objective of value management is to make a comparison between alternative materials in order to obtain the possible lowest cost with best function delivery. In other words, value management ensures the reduction of inefficient aspects to the project. As shown in figure 3 explains the purpose of value management should involve earlier in the project to create greater potential cost savings. This is because cost cutting can be easily achieved by modifying the design at the early stage of the project rather than the actual construction building.

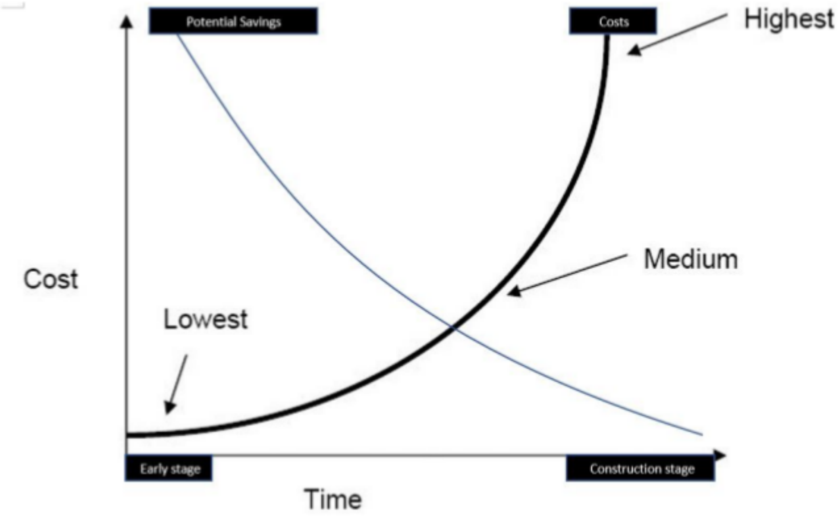


Figure 3: Matthewson, *Construction Cost Relationship*. 2019, Digital Image. Reproduced from: Foodability Co.

2.2 The Benefits of Value Management Project

Value management can help identify the use function and esteem function of the products or services. By combining the actual functional performance and value-added features can maximise the attractiveness of the project. In order to meet the expectations of different stakeholders including the clients and the end user, value management provides an optimum balance in terms of benefits, risk and costs. Value management study can minimise the unnecessary costs by selecting resources which are suitable for the project. In another word, value management can be defined as "Value for Money" approaches.

In addition to cost benefit, value management can also stimulate the competitiveness within the organisation to provide innovative and efficient resources. Effective communication and collaboration between disciplines help to improve the working relationships and organisational learning.

3.0 ORIGINAL PROJECT

3.1 Technical Specifications

The apartment is formed by 2 blocks of double-store and 2 blocks of four-store. The original design as below will be specified part by part. The first part will address the building structure elements and materials used in design, and follow by each room's proposed finish work and fitment.

3.1.1 Building Structures

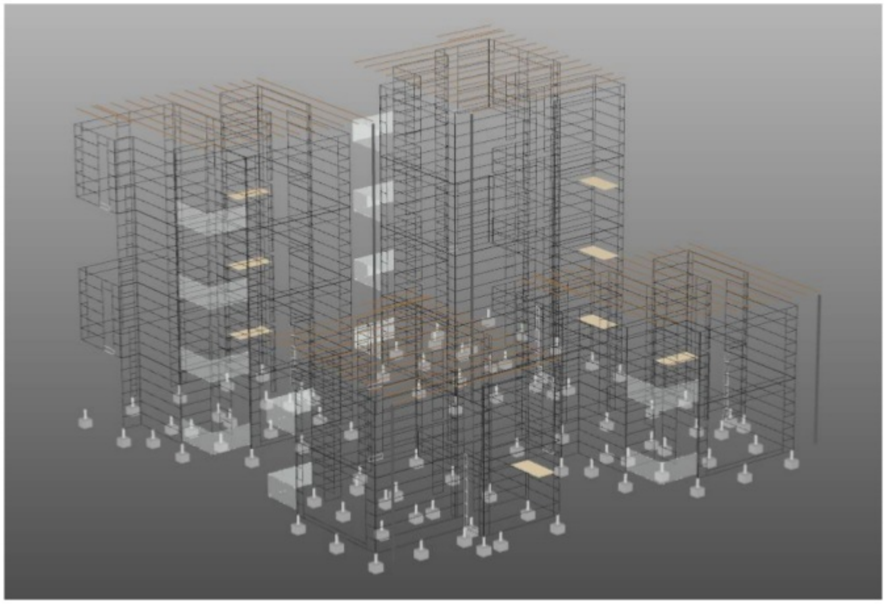


Figure 4: Foundation and Structural Frame

The design of the foundation is multiple concrete pad footings which will connect to the building steel frame, as shown in figure 4. Since this project is within the CBD area, pad footing is good for the short construction period and less distribution to the surrounding existing buildings. Because this footing system does not require much heavy machinery and open excavation work. Moreover, the stability and load bearing capacity are also strong enough to support the low-rise residential buildings in this project, which the maximum height is four stores.

The steel frame structure has been used for the main building structure. Since the slab and wall in design is mainly using timber, this type of structure will easily support the building. And the construction progress of steel frames is easy and does not require high level skill labour. It seems to be a cost efficiency option in this project.

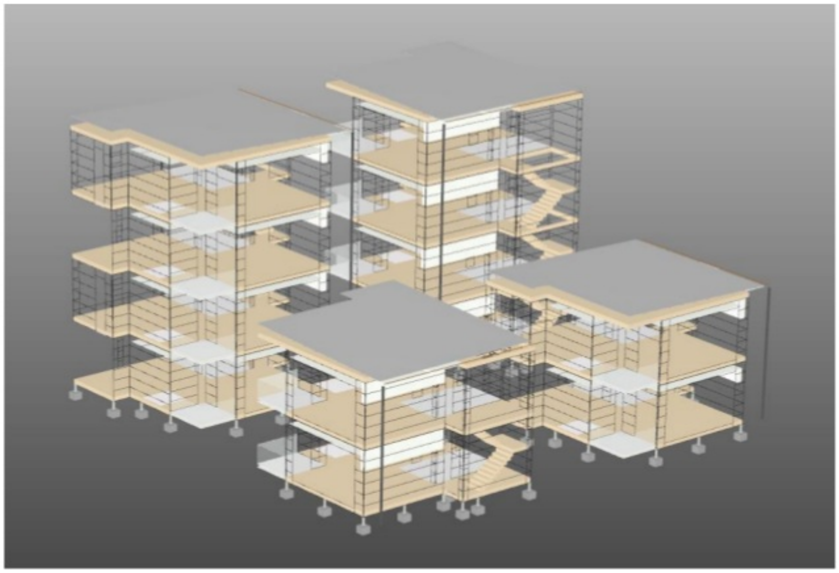


Figure 5: Ground Slab, Suspended Slab and Roof

Figure 5 shows the slab in design. The majority slab is using the timber material, which is the yellow colour in the drawing, and several parts which show in white are using stone material as floor slab. Timber slab is easy to install and eco-friendly construction material. Therefore, it is possible to shorten the construction period and reduce the noise, vibration and dust pollution from the construction works.

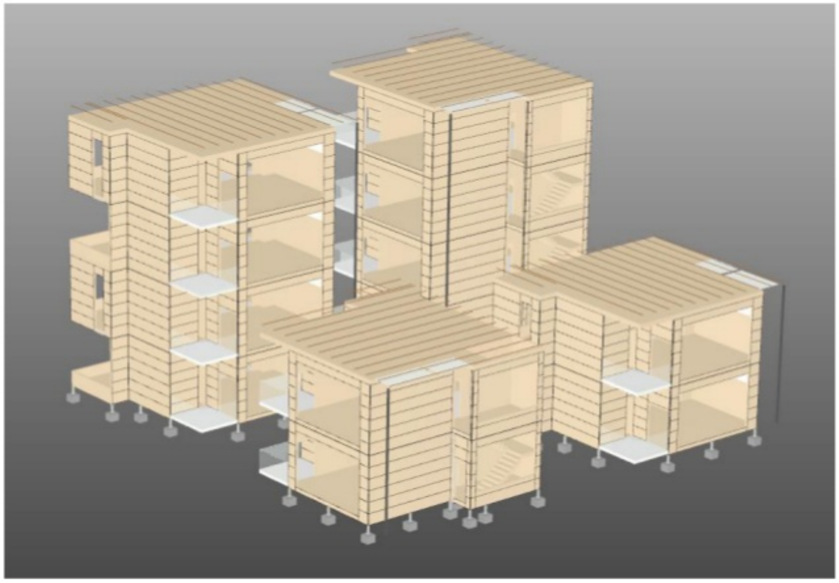


Figure 6: Inner Face of External Walls

The original design of the interior face of the external wall is fully timber wall, shown in figure 6. Timer wall is environmentally friendly construction material and also can provide a suitable living experience for the residents. Compared with the concrete wall, the difficulty of constructing a timber wall is much easier and faster, but the load bearing capacity may not be as good as concrete walls. Thus, timber walls are cost efficient and quick to construct, but may not be able to install too much wall fitments in the future development.

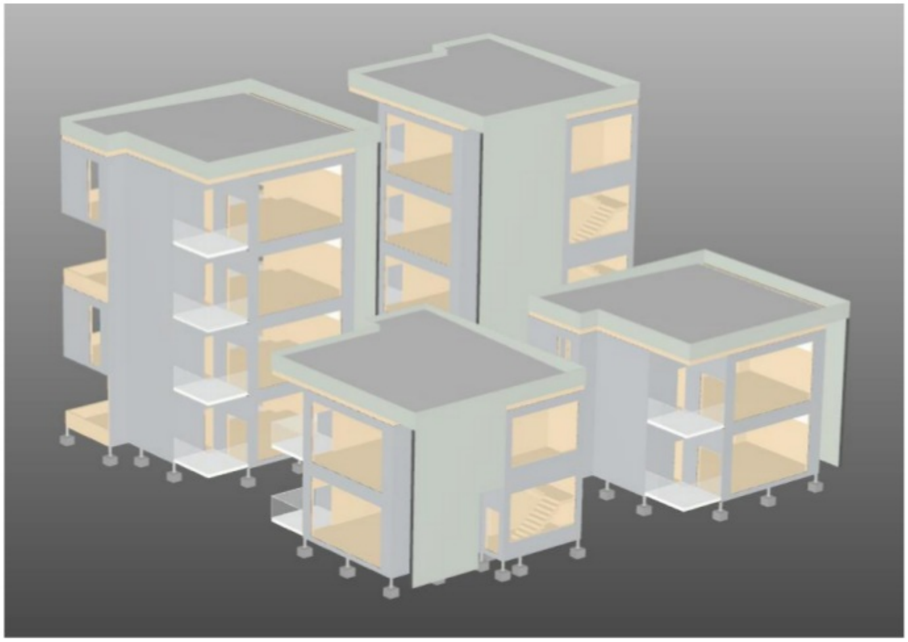


Figure 7: External Wall Finish

For the figure 7, it shows the outside wall finish of the buildings. The whole outside face of the external wall is using steel material, it may have a nice and modern appearance. And the steel surface can provide strong and stable protection to the inner timber structure, ensuring the safety level of the building.

3.1.2 Public Entrance Walkway

- The walkway is under the roof and a steel deck is installed as a separation wall with an opening to the main entrance door.
- The steel deck is supported by steel beams connected to the building and steel column connected to the roof structure.
- Door at the entrance is installed by a single swing timber door with lower cost compared with other material and easier to install and maintain.
- No special treatment upon the paving along the walkway.

3.1.3 Stair shuffle

- Louvered windows are installed at the external walls which facing the entrance walkway, it allows the air circulation around the areas
- Glazing windows are installed facing the outside, it allows sunlight at daytime that can reduce the use of lights
- Timber stairs

3.1.4 Apartment Entrance Spare Area

- A spare area for residents, can be shoes collection area, storage, build-in wardrobe etc.
- Double sliding doors accessing to living area and double swing door in between the bedroom and entrance spare area
- Floor finished by tiles

3.1.5 Living Room, Dining Area and Kitchen

- There is no partial wall between areas which provide more space and flexibility to the resident for their own interior design
- Save cost of installing partitions or internal walls

3.1.6 Bathroom

- A combination of bathroom and toilet
- 2 bedrooms sharing 1 bathroom
- Ceramic floor tiling which is water resistance, durable and easy to maintain

3.1.7 Bedrooms

- Timber wall between two bedrooms which is easy to install and cheaper
- Double sash window facing outside
- Built-in wardrobe
- Timber flooring without finish

3.1.8 Balcony

- Louvered window in between toilet and balcony wall
- Timber double door is installed to access balcony from the living area
- Stone slab supported by steel beams with plasterboard covered on sides
- Frameless glass fencing with aluminum top rail

3.1.9 Electrical Services

- Solar panel system installed on rooftop

3.2 Building Costs

3.2.1 Superficial Method

According to the GFA building estimation (refer to appendix), the measurement of building areas and building cost range as below:

Fully Enclosed Covered Area (F.E.C.A.) includes:

1. Double-store building: 182.4 m2/building
2. 4-storey building: 351.37 m2/building

Total F.E.C.A. (4 buildings) round up to 1070 m2

Unenclosed Covered Area (U.C.A.) includes:

1. Double-store building: 20.47 m2/building
2. 4-storey building: 45.78 m2/building

Total U.C.A. (4 buildings) round up to 133 m2

The total Gross Floor Area (G.F.A.) will be approximately 1210 m2.

According to the Australian Construction Building Cost Ranges by RBL Intelligence (reference), this project can be priced by using the "Residential Unit - Walk-up 85 to 120 m2/Unit" price range. The price range is about $1,460 - $2,900/m2, and assumed to price the complex at the price of $2,900/m2. The subtotal of estimated building cost will be $3.51 million.

The preliminary estimation is mainly to provide an overall cost of the building construction including the items that normally contained in a building contract for example the tax, professional fees, loose furniture and fittings, site works and drainage, tenancy works etc. The estimation is not taking the price of materials into account and the price would be changed later after the alteration on the design.

To make it more accurate to the estimation, the price of building services considering to mark up the price. The price range from above reference to the building services is $240 - $470. Considering the solar panel would increase the basic building services cost, the services for the complex will be priced at $500/m2. In results, the total cost of the building will be $605,000 + $3,510,000 = approximately $4.2 million.

3.2.2 Cost Plan (Inc. measurement)

According to the cost plan established for the original plan, the total cost of elements is approximately $4.7 million excluding preliminaries and contingencies. With the adding of preliminaries, contingency, allowance and inflation, the total cost for the project has rounded up to $6.2 million.

PROPOSED APPARTMENT BLOCKS

Cost Indication

Date : **(29.05.2020)**

Based on Drawings :
Ground Floor Plan
First Floor Plan
Second Floor Plan
Third Floor Plan
N, S, E, W Elevation Drawings
Roof Plan

Ref		Description	unit	qty	rate	total
	Substructure					
		Allow minor earthworks	m2	4000	$ 5.00	$ 20,000.00
A		Reinforced concrete column footings including excavation, backfilling and reinforcement - no formwork required poured in excavation				
		assume 1.2x1.2x0.4				
		count		92		
		volume	m3	53	$ 730.00	$ 38,690.00
B		ditto strip footing 1000x300				
		length		294		
		volume	m3	89	$ 730.00	$ 64,970.00
C		250 timber floor	m2	387	$ 250.00	$ 96,750.00
		Total Substructure				$ 220,410.00

	Superstructure					
D		250 suspended timber flooring				
		area	m2	581	$ 350.00	$ 203,350.00
E		Structural Steel Frame				
		610UB113 including suply and install of materials, connections, sundries, surface paint and protection				
		Columns				
		no (based on pad footing count)	no	92		
		length	m	1031		
		kg/m	kg/m	114		
		total weight (kg)		117191		
		total weight (t)	t	117	$ 6,000.00	$ 702,000.00
		Beams				
		location assumed to be connecting columns at all floor levels				
		no		48		
		length	m	585		
		kg/m	kg/m	114		
		total weight (kg)	kg	66438		
		total weight (t)	t	66	$ 6,000.00	$ 396,000.00
F		External Wall				
		Assumed stud wall with perforated iron sheeting externally taken from object properties including all materials, sundrie, framing and fixings				
		area	m2	2039	$ 200.00	$ 407,800.00
		external feature wall, cost saving option to remove this as it is an architectural feature only? Including all materials, sundrie, framing and fixings				
		area	m2	329	$ 250.00	$ 82,250.00

G				Internal wall				
				Assumed stud wall partition, including materials, framing and fixings				
				area	m2	1581	$ 150.00	$ 237,150.00
H				Windows				
				External glazed windows and doors				
				area	m2	459	$ 500.00	$ 229,500.00
I				Staircase				
				assumed concrete in-situ staircase including formwork, reinforcement and sundries				
				volume	m3	29	$ 650.00	$ 18,850.00
J				150mm thick In-situ reinforced concrete wall to lift shaft including reinforcement, formwork and sundries				
				length	m	60		
				Area	m2	828		
				Volume	m3	124	$ 580.00	$ 71,920.00
K				Passenger Lift				
				no	no	4	$ 100,000.00	$ 400,000.00
L				Ceilings				
				Suspended plasterboard ceiling including framing, fixings and all sundries				
				area	m2	968	$ 150.00	$ 145,200.00
M				Roof				
				Corrugated metal roof sheeting including all framing, insulation, sundries, downpipes and fixings				
				area	m2	406	$ 175.00	$ 71,050.00
N				Solar panels				
				Assume solar water heater system	item	1	$ 250,000.00	$ 250,000.00
P				Glass Balustrading including all materials and fixings	m	60	$ 600.00	$ 36,000.00
				Total Superstructure				$ 3,251,070.00

	ELEMENT - ND							
A				Single internal timber door, 920mm wide, including frame and hardware	No.	24	$ 573.00	$ 13,752.00
	24/	1.00						
			24					
B				Single internal timber door, 820mm wide, including frame and hardware	No.	12	$ 542.00	$ 6,504.00
	12/	1.00						
			12					
C				Single internal solid core door, 720mm wide, including frame and hardware	No.	12	$ 603.00	$ 7,236.00
	12/	1.00						
			12					
D				Single solid core fire rate timber door, including frame, hardware and fire rating plaque	No.	12	$ 1,380.00	$ 16,560.00
	12/	1.00						
			12					
E				Double stacker doors to assumed linen/ldry cupboard 720 wide, including frame and hardware	No.	12	$ 1,150.00	$ 13,800.00
	12/	1.00						
			12					
F				Double stacker doors to bedroom cupboard 920 wide, including frame and hardware	No.	12	$ 1,213.60	$ 14,563.20
	12/	1.00						
			12					
						TOTAL	(ND)	$ 72,415.20

	Finishes							
	ELEMENT - WF							
A				Internal wall finishes to units, including flushing, plaster and paint	m^2	1581	$ 39.50	$ 62,465.14
	6/	221.00		Floor design A				
	6/	226.00		Floor design B				
			2682.00					
		DDT		ddt internal doors & areas for wall tiling				
	48 /	0.82		Deduct 820mm wide				
		2.20						
	12 /	0.92		Deduct 920 solid core door				
		2.20						
	24 /	1.84		Deduct 920 Double stacker doors				
		2.20						
	12 /	1.44		Deduct 720 double stacker doors				
		2.20						
	12 /	1.84		Deduct 920 double doors				
		2.20						
	24 /	0.72		Deduct 720 door				
		2.20						
	1 /	308.96		Deduct tiling to bathrooms				
		459.00		Deduct external windows, measurement from superstructure item H				
			1100.60					
			1581.40	Total				
B				Wall finish to stairwell, including flushing, plaster and paint	m^2	421	$ 38.80	$ 16,332.63
	12 /	38.87						
			466.44					
		DDT						
	2 /	0.92						
		2.20						
	12 /	0.92						
		2.20						
	12 /	0.65						
		2.20	45.50					
			420.94	Total				
C				Wall tiling full height in bathrooms	m^2	309	$ 95.30	$ 29,444.27
	12 /	9.42						
		3.00						
			339.12					
		DDT						
	12 /	1.57		Deduct vanity bench				
		0.90						
	12 /	2.20		deduct bath				
		0.50	30.16					
			308.96	Total				
						TOTAL	(WF)	$ 108,242.04

	Finishes (Contd)							
	ELEMENT - FF							
				(Note: Finishes have been assumed)				
A				Timber floorboard finish tongue and groove including glues,nails and fixing to framed floor	m^2	595	$ 98.00	$ 58,341.36
	12 /	49.61						
			595.32					
B				Floor tiling including skirtings to unit entry, toilet and balcony 300 x 300 ceramic	m^2	252	$ 103.00	$ 25,956.00
	12 /	21.00						
			252.00					
C	12 /	7.00		Granolithic 25mm Concrete finish to stiarwell	m^2	84	$ 43.10	$ 3,620.40
			84.00					
					TOTAL	(FF)		$ 87,917.76
	ELEMENT - CF							
A				Plasterboard ceiling on and including timber joists including cornice and paint	m^2	173	$ 79.00	$ 13,633.03
	1/	172.57						
			172.57	*(Note : Timber supports have been assumed)*				
					TOTAL	(CF)		$ 13,633.03
	Fittings							
	ELEMENT - FT							
A				Vanity bench 900 length including quartz benchtop and cupboards	m2	3	$ 1,355.53	$ 4,256.36
	12 /	1.57 0.90						
			3.14					
B				Kitchen bench/cupboards	m2	30	$ 1,355.53	$ 40,828.56
	12 /	2.51						
			30.12					
C				Allow for sundry built-in furniture including mirrors, etc.	Item	12	$ 1,924.00	$ 23,088.00
	12 /	1.00						
			12.00					
					TOTAL	(FT)		$ 68,172.93

	Services							
	ELEMENT - SF,PD,WS							
A				Allow for sundry fittings:	Item	12	$ 895.00	$ 10,740.00
				- toilet roll holders				
				- soap dispensers, etc.				
	12 /	1.00						
			12.00					
				(Note: All sanitary fittings include supply, waste and vents (to face of external wall)				
B				WC Suite	No.	12	$ 2,150.00	$ 25,800.00
	12 /	1.00						
			12.00					
C				Wash hand basin	No.	12	$ 2,150.00	$ 25,800.00
	12 /	1.00						
			12.00					
D				Laundry wash trough	No.	12	$ 2,200.00	$ 26,400.00
	12 /	1.00						
			12.00					
E				Kitchen sink	No.	12	$ 2,950.00	$ 35,400.00
	12 /	1.00						
			12.00					
F				Bath unit	No.	12	$ 2,450.00	$ 29,400.00
	12 /	1.00						
			12.00					
						TOTAL (SF)		$ 153,540.00

	ELEMENT - VE,SH,EC							
				(Note: Mechanical services have been measured as an area and may belong to any one of three elements: Space Heating (SH), Ventilation (VE) or Evaporative cooling (EC))				
A				Mechanical ventilation to toilets	m^2	6	$ 51.00	$ 283.05
	12 /	5.55						
			66.60					
B				Mechanical ventilation to ldry cupboard	m2	10	$ 51.00	$ 514.08
	12 /	0.84						
			10.08					
						TOTAL	(VE)	$ 797.13
	ELEMENT - AC							
				(Assume air conditioning to internal of units)				
A				AC to internal areas as identified by measurement diagram ducted (includes heating)	m^2	881	$ 360.00	$ 317,260.80
	12 /	73.44						
			881.28					
						TOTAL	(AC)	$ 317,260.80
	ELEMENT - FP							
A				Allow for fire protection (including hosereels, fire extinguishers, etc 1 per level per building)	No	12	$ 5,905.00	$ 70,860.00
	12 /	1.00						
			12.00					
						TOTAL	(FP)	$ 70,860.00
	ELEMENT - LP **Electrical**							
A				To internal of units, including balcony	m^2	964	$ 133.75	$ 128,897.55
	12 /	80.31						
			963.72					
B				To stairwell area	m^2	111	$ 103.25	$ 11,448.36
	12 /	9.24						
			110.88					
						TOTAL	(LP)	$ 140,345.91

Cost Indication (Contd)								
External Works								
ELEMENT - XP								
A				Allow for site clearance (including trees, rubbish, old services, footings, etc.)	Item	999	$ 0.58	$ 579.63
	1 /	31.99						
		31.24						
			999.37					
					TOTAL (XP)			$ 579.63
ELEMENT - XF								
External Fittings								
				Disabled ramp to ground floor of each building	m2	96	$ 13.00	$ 1,248.00
	4 /	24.00						
			96.00					
					TOTAL (XF)			$ 1,248.00
External Services								
ELEMENT - XK								
				Rainwater drainage	No.	48	$ 1,110.00	$ 53,280.00
A				Assumed 4 soakwells due to roof drainage area per building				
	12 /	4.00						
			48.00					
					TOTAL (XK)			$ 53,280.00
ELEMENT - XD								
A				Sewer drain including excavation	m	129	$ 116.00	$ 14,996.48
		129.28		*(Note: assumed route to road)*				
			129.28					
B				Manhole complete	No.	4	$ 3,310.00	$ 13,240.00
	4 /	1.00						
			4.00					
C				Mains connection	Item			$ 5,800.00
					TOTAL (XD)			$ 34,036.48
ELEMENT - XW								
A				Water mains including excavation, etc.	m	129	$ 116.00	$ 14,996.48
				(Note: assumed from the road)				
		129.28						
			129.28					
B				Mains connection	Item			$ 5,800.00
					TOTAL (XW)			$ 20,796.48

	ELEMENT - XE								
A				Electrical mains including excavation, etc.	m	129	$ 200.00	$ 25,856.00	
				(Note: assumed from the road)					
		129.28							
			129.28						
B				Mains connection	Item			$ 5,800.00	
					TOTAL (XE)			$ 31,656.00	
	External Services								
					(All figures rounded to nearest $100)				
				Total cost of elements			$	$ 4,646,261.39	00
				Preliminaries %			8.00%	$ 371,700.91	00
							$	$ 5,017,962.30	00
				Design Contingency %			2.50%	$ 125,449.06	
							$	$ 5,143,411.36	
				Locality allowance			1.10	$ 514,341.14	
							$	$ 5,657,752.49	
					Inflation		5.00%	$ 282,887.62	
							$	$ 5,940,640.12	
				Construction Contingency %			3.00%	$ 178,219.20	
					TOTAL COST		**$**	$ 6,118,859.32	
					COST INDICATION within 15%		from	**$ 5,201,030.42**	
							to	**$ 7,036,688.22**	
				Excludes: - Fees, loose furniture and land costs, and connections to water, sewer and electrical					
							GFA =	**$ 1,168.32**	**m²**
					TOTAL COST PER M² GFA = $			$ 5,237.31	

3.3 Detected Errors, Incomplete Areas or Building Elements

The concrete pad footing system is good for the CBD area construction, but some design of the footing locations seems not arranged properly. Several pad footings located at the center of the slab, without any beam of steel frame structure. By considering the basic knowledge of construction, this design might be useless which will not provide any supporting purpose in future, but only increase the expenses of the construction.

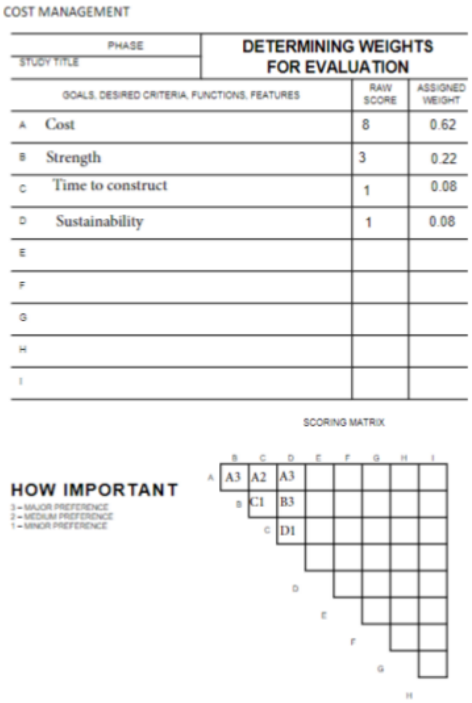
The overall building structures are built with steel frame and timber wall and slab. Therefore, in the short-term period, the structures of the building might not be strong enough to carry the live load from the building. For long term usage, the timber slab and wall may not be able to provide a stable living environment for the multi-store buildings, for example the termite issues and weather conditions will negatively affect the timber structures. In addition, timber walls and slabs have low sound isolation which will reduce the residence's quality of life.

Apart from that, with the unexpected design material of stonework on the entrance spare area and balcony. The stonework for each level is supported by the steel beam underneath and fixed to the timber wall. Although the design will provide a nice outlooking and high-quality finish for the apartment, the stability and load bearing capacity of this design should be taken into consideration.

Moreover, the steel surface of the external wall indeed will provide a strong protection to the inner timber structure, and also will enhance the stability of the building wall. On the other hand, this method of design may largely reduce the living quality of the resident. Because of the characteristics of the steel material, the internal temperature will be significantly high, especially in the heat weather. Moreover, the glazing windows are largely used in the design, which also will reduce the quality of thermal isolation. The energy loss for the air-condition is quite a serious problem in the future, even though the materials of the inner wall and slab are built with timber.

4.0 OUTCOME OF VALUE MANAGEMENT

4.1 Foundation



COST MANAGEMENT

PHASE	DETERMINING WEIGHTS FOR EVALUATION
STUDY TITLE	

	GOALS, DESIRED CRITERIA, FUNCTIONS, FEATURES	RAW SCORE	ASSIGNED WEIGHT
A	Cost	8	0.62
B	Strength	3	0.22
C	Time to construct	1	0.08
D	Sustainability	1	0.08
E			
F			
G			
H			
I			

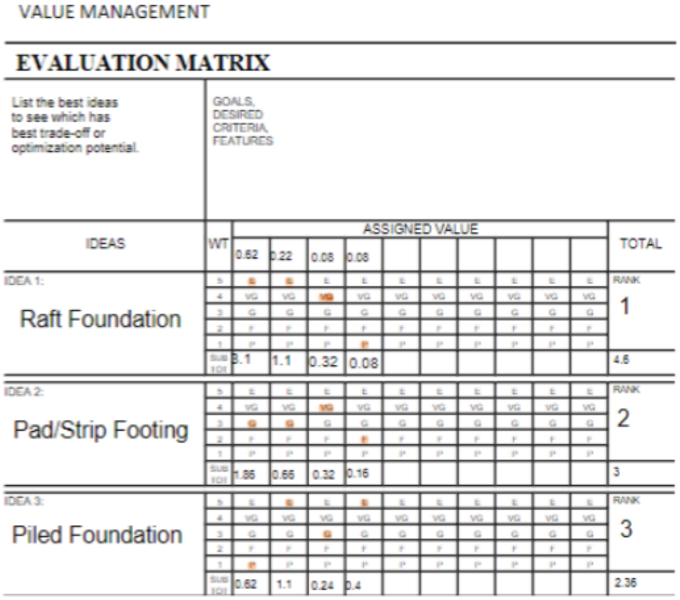
SCORING MATRIX

HOW IMPORTANT

3 – MAJOR PREFERENCE
2 – MEDIUM PREFERENCE
1 – MINOR PREFERENCE

	B	C	D	E	F	G	H	I
A	A3	A2	A3					
B		C1	B3					
C			D1					
D								
E								
F								
G								
H								

Figure 8: Foundation Evaluation Matrix



VALUE MANAGEMENT

EVALUATION MATRIX

List the best ideas to see which has best trade-off or optimization potential.	GOALS, DESIRED CRITERIA, FEATURES

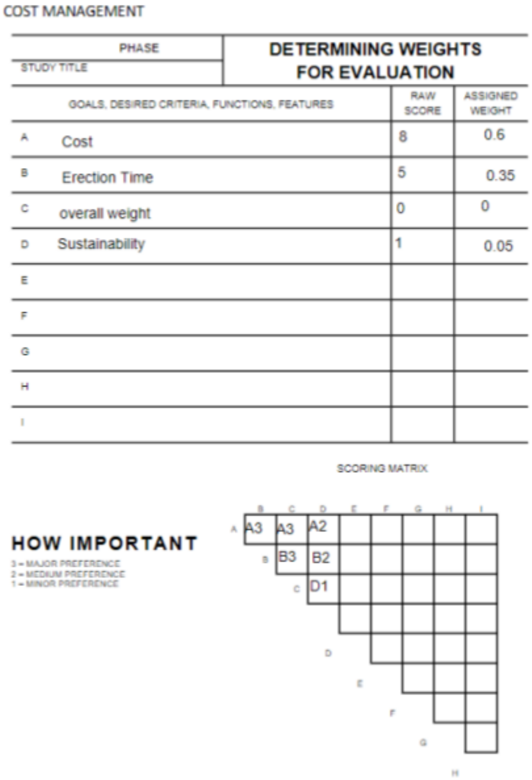
IDEAS	WT	ASSIGNED VALUE										TOTAL
		0.62	0.22	0.08	0.08							
IDEA 1:	5	**E**	**E**	E	E	E	E	E	E	E	E	RANK
Raft Foundation	4	VG	VG	**VG**	VG	VG	VG	VG	VG	VG	VG	1
	3	G	G	G	G	G	G	G	G	G	G	
	2	F	F	F	F	F	F	F	F	F	F	
	1	P	P	P	**P**	P	P	P	P	P	P	
	SUB TOT	3.1	1.1	0.32	0.08							4.6
IDEA 2:	5	E	E	E	E	E	E	E	E	E	E	RANK
Pad/Strip Footing	4	VG	VG	**VG**	VG	VG	VG	VG	VG	VG	VG	2
	3	**G**	**G**	G	G	G	G	G	G	G	G	
	2	F	F	F	**F**	F	F	F	F	F	F	
	1	P	P	P	P	P	P	P	P	P	P	
	SUB TOT	1.86	0.66	0.32	0.16							3
IDEA 3:	5	E	**E**	E	**E**	E	E	E	E	E	E	RANK
Piled Foundation	4	VG	VG	VG	VG	VG	VG	VG	VG	VG	VG	3
	3	G	G	**G**	G	G	G	G	G	G	G	
	2	F	F	F	F	F	F	F	F	F	F	
	1	**P**	P	P	P	P	P	P	P	P	P	
	SUB TOT	0.62	1.1	0.24	0.4							2.36

Figure 9: Foundation Evaluation Matrix

Based on the result from Foundation Evaluation Matrix, raft foundation is the best option while pad/strip footing take second place. Raft foundation obtained a significantly high score for cost and strength features as well as its construction time. Although piled foundation has a very high score for sustainability, sustainability features are not the main consideration to foundation selection. In the original design, the architect designed the foundation by using pad/strip footing. In fact, the pad/strip footing is not as cost effective as the raft foundation because it required more labour on fixing the formwork to construct the footing that is less needed for raft footing. By pouring the pad footing individually, the raft foundation concreted as one piece which eventually shortened the construction time and reduced the construction cost on ground slab.

Apart from that, the raft foundation required lesser excavation work than pad/strip footing. Therefore, lesser works and noise or dust pollution to surrounding areas. From the design we can notice that the project might be constructed in the CBD area which has limited access and space for stopping plant and materials storage, thus, raft foundation can easily cope with the situation during construction works.

4.2 Building frame



COST MANAGEMENT

PHASE

STUDY TITLE

DETERMINING WEIGHTS FOR EVALUATION

	GOALS, DESIRED CRITERIA, FUNCTIONS, FEATURES	RAW SCORE	ASSIGNED WEIGHT
A	Cost	8	0.6
B	Erection Time	5	0.35
C	overall weight	0	0
D	Sustainability	1	0.05
E			
F			
G			
H			
I			

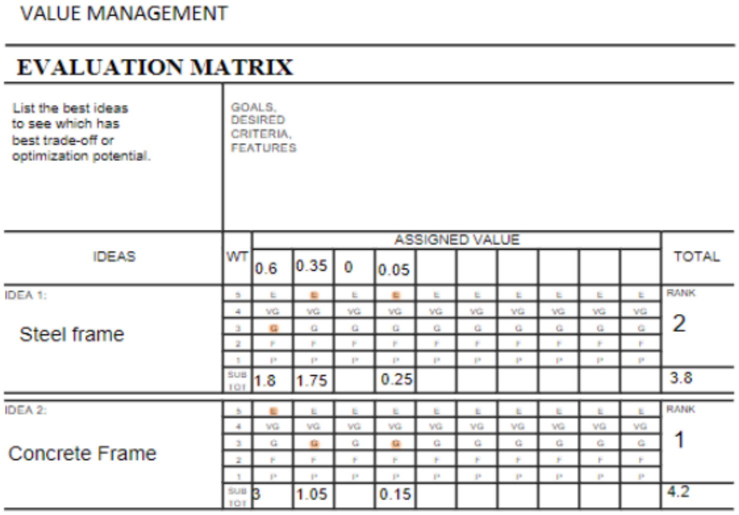
SCORING MATRIX

HOW IMPORTANT

3 – MAJOR PREFERENCE
2 – MEDIUM PREFERENCE
1 – MINOR PREFERENCE

	B	C	D	E	F	G	H	I
A	A3	A3	A2					
B		B3	B2					
C			D1					
D								
E								
F								
G								
H								

Figure 10: Frame Evaluation Matrix



VALUE MANAGEMENT

EVALUATION MATRIX

List the best ideas to see which has best trade-off or optimization potential.

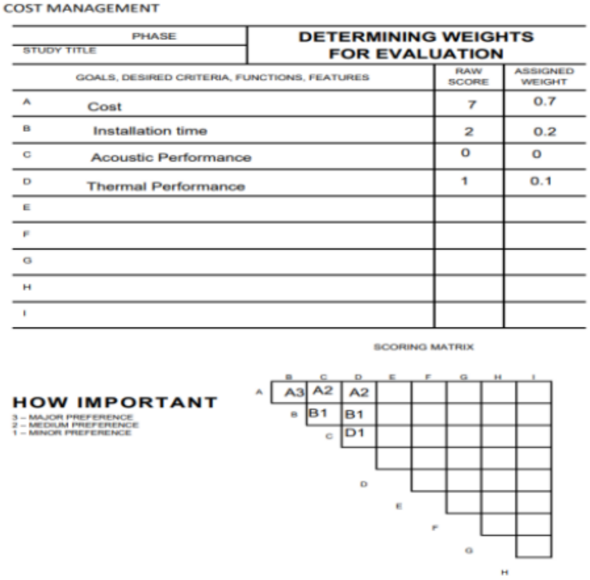
GOALS, DESIRED CRITERIA, FEATURES

IDEAS	WT	ASSIGNED VALUE										TOTAL
		0.6	0.35	0	0.05							
IDEA 1: Steel frame	5	E	[✓ E]	E	[✓ E]	E	E	E	E	E	E	RANK
	4	VG	VG	VG	VG	VG	VG	VG	VG	VG	VG	2
	3	[✓ G]	G	G	G	G	G	G	G	G	G	
	2	F	F	F	F	F	F	F	F	F	F	
	1	P	P	P	P	P	P	P	P	P	P	
	SUB TOT	1.8	1.75		0.25							3.8
IDEA 2: Concrete Frame	5	[✓ E]	E	E	E	E	E	E	E	E	E	RANK
	4	VG	VG	VG	VG	VG	VG	VG	VG	VG	VG	1
	3	G	[✓ G]	G	[✓ G]	G	G	G	G	G	G	
	2	F	F	F	F	F	F	F	F	F	F	
	1	P	P	P	P	P	P	P	P	P	P	
	SUB TOT	3	1.05		0.15							4.2

Figure 11: Frame Evaluation Matrix

Based on the result from Frame Evaluation Matrix, there are only two ideas to consider which are the original design of steel frame and the alternative proposed of concrete frame. Concrete frames scored highest for cost features that is the most important feature to consider. Even though steel frames scored highest in terms of erection time and sustainability features, concrete frames can perform pretty good to both features.

4.3 Floor slab



COST MANAGEMENT

PHASE

STUDY TITLE

DETERMINING WEIGHTS FOR EVALUATION

	GOALS, DESIRED CRITERIA, FUNCTIONS, FEATURES	RAW SCORE	ASSIGNED WEIGHT
A	Cost	7	0.7
B	Installation time	2	0.2
C	Acoustic Performance	0	0
D	Thermal Performance	1	0.1
E			
F			
G			
H			
I			

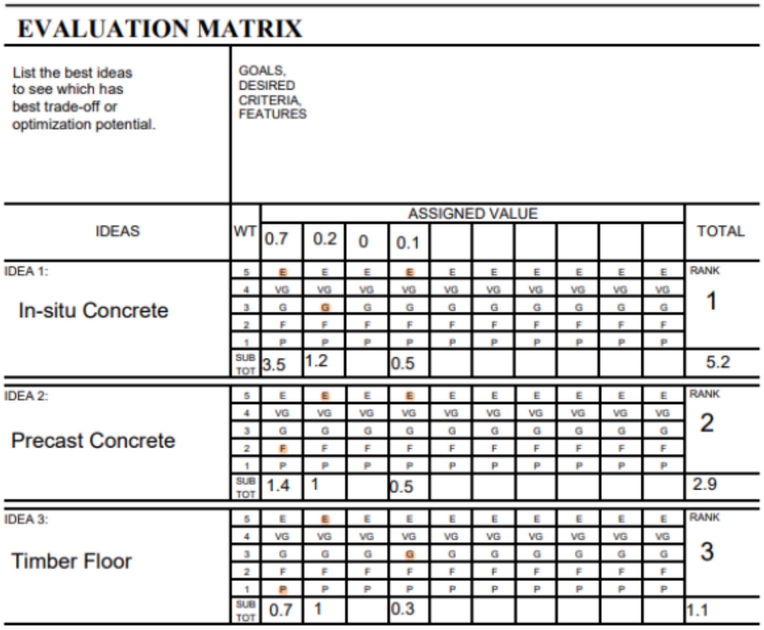
SCORING MATRIX

	B	C	D	E	F	G	H	I
A	A3	A2	A2					
B		B1	B1					
C			D1					
D								
E								
F								
G								
H								

HOW IMPORTANT

3 – MAJOR PREFERENCE
2 – MEDIUM PREFERENCE
1 – MINOR PREFERENCE

Figure 12 Floor Slab Evaluation Matrix



EVALUATION MATRIX

List the best ideas to see which has best trade-off or optimization potential.

GOALS, DESIRED CRITERIA, FEATURES

IDEAS	WT	ASSIGNED VALUE										TOTAL
		0.7	0.2	0	0.1							
IDEA 1: In-situ Concrete	5	**E**	E	E	**E**	E	E	E	E	E	E	RANK
	4	VG	VG	VG	VG	VG	VG	VG	VG	VG	VG	1
	3	G	**G**	G	G	G	G	G	G	G	G	
	2	F	F	F	F	F	F	F	F	F	F	
	1	P	P	P	P	P	P	P	P	P	P	
	SUB TOT	3.5	1.2		0.5							5.2
IDEA 2: Precast Concrete	5	E	**E**	E	**E**	E	E	E	E	E	E	RANK
	4	VG	VG	VG	VG	VG	VG	VG	VG	VG	VG	2
	3	G	G	G	G	G	G	G	G	G	G	
	2	**F**	F	F	F	F	F	F	F	F	F	
	1	P	P	P	P	P	P	P	P	P	P	
	SUB TOT	1.4	1		0.5							2.9
IDEA 3: Timber Floor	5	E	**E**	E	E	E	E	E	E	E	E	RANK
	4	VG	VG	VG	VG	VG	VG	VG	VG	VG	VG	3
	3	G	G	G	**G**	G	G	G	G	G	G	
	2	F	F	F	F	F	F	F	F	F	F	
	1	**P**	P	P	P	P	P	P	P	P	P	
	SUB TOT	0.7	1		0.3							1.1

Figure 13: Floor Slab Evaluation Matrix

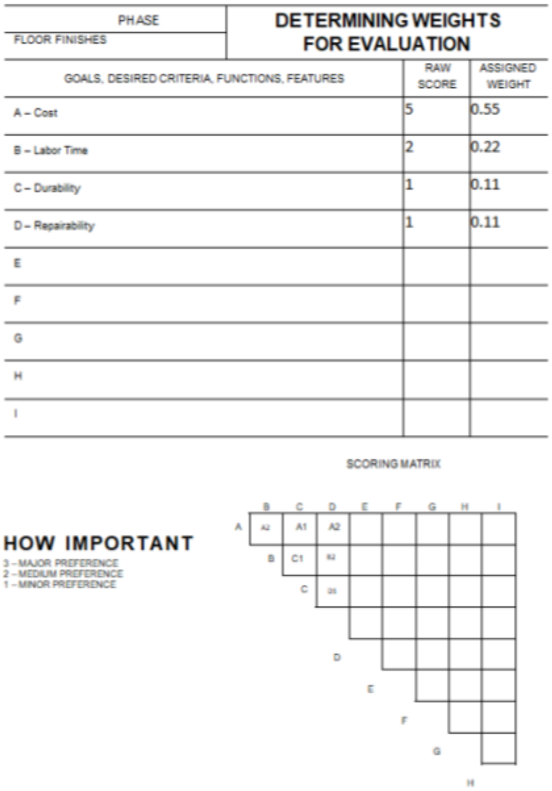
For the floor slab, by considering the pros and cons of the three types of building slab materials, which are in-situ concrete, precast concrete and timber. As shown in the matrix table, in-situ concrete will be the best choice for this project. Although the curing time of the concrete will be the drawback of this material which may pull long the total construction period, the outstanding benefits at the cost, acoustic and thermal performance are undefeatable by rest two materials in this project. For the in-situ concrete, the cost is cheaper than precast slab, and the acoustic and thermal performance is much better than the timber slab in original design.

Moreover, this construction project is within the CBD area, the possibility of transport and access will be considered. Since precast concrete slab is large size elements, it may cause traffic jams and potential hazard during the transport, and extra traffic managers should be hired for this activity. These all will directly lead to the increase of the project expense.

Due to this, sacrificing a few days curing time to gain a high standard quality and stable concrete slab is worth it. And in-situ concrete is easier for the raw material transport onto site. This will control the construction cost and significantly improve the building quality and residents' living quality in future.

4.4 Floor Finish

Floor Finish Matrix



PHASE	DETERMINING WEIGHTS FOR EVALUATION	
FLOOR FINISHES		
GOALS, DESIRED CRITERIA, FUNCTIONS, FEATURES	RAW SCORE	ASSIGNED WEIGHT
A – Cost	5	0.55
B – Labor Time	2	0.22
C – Durability	1	0.11
D – Repairability	1	0.11
E		
F		
G		
H		
I		

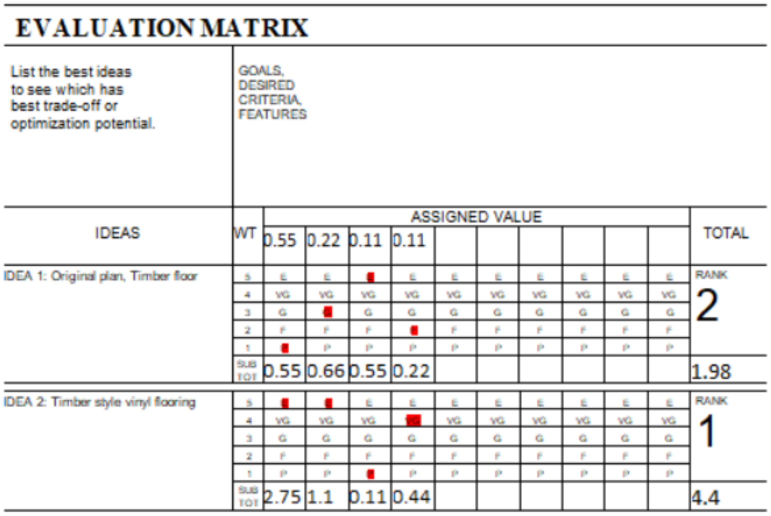
SCORING MATRIX

HOW IMPORTANT

3 – MAJOR PREFERENCE
2 – MEDIUM PREFERENCE
1 – MINOR PREFERENCE

	B	C	D	E	F	G	H	I
A	A2	A1	A2					
B		C1	B2					
C			D1					
D								
E								
F								
G								
H								

Figure 14: Floor Finish Evaluation Matrix



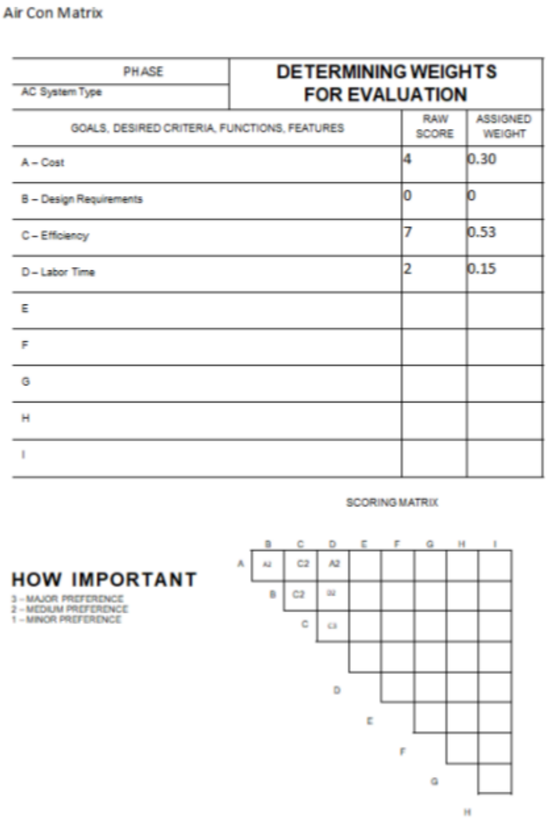
EVALUATION MATRIX

List the best ideas to see which has best trade-off or optimization potential.	GOALS, DESIRED CRITERIA, FEATURES											
IDEAS	WT	ASSIGNED VALUE										TOTAL
		0.55	0.22	0.11	0.11							
IDEA 1: Original plan, Timber floor	5	E	E	🟥	E	E	E	E	E	E	E	RANK
	4	VG	VG	VG	VG	VG	VG	VG	VG	VG	VG	2
	3	G	🟥	G	G	G	G	G	G	G	G	
	2	F	F	F	🟥	F	F	F	F	F	F	
	1	🟥	P	P	P	P	P	P	P	P	P	
	SUB TOT	0.55	0.66	0.55	0.22							1.98
IDEA 2: Timber style vinyl flooring	5	🟥	🟥	E	E	E	E	E	E	E	E	RANK
	4	VG	VG	VG	🟥	VG	VG	VG	VG	VG	VG	1
	3	G	G	G	G	G	G	G	G	G	G	
	2	F	F	F	F	F	F	F	F	F	F	
	1	P	P	🟥	P	P	P	P	P	P	P	
	SUB TOT	2.75	1.1	0.11	0.44							4.4

Figure 15: Floor Finish Evaluation Matrix

Timber style vinyl flooring will be recommended for the floor finish. Compared with the timber floor, this type of floor finish is more cost effective and shorter installation time. For the CBD area construction project, the shooter construction time is better for the project success. Although the price of the timber style vinyl flooring is cheaper than the original design, the appearance of the finished product will be similar. The durability of this material may not be as good as timber, but the repairability is strong. Vinyl floating can be easily replaced or repaired once it has damage during the using.

4.5 AC System



Air Con Matrix

PHASE AC System Type	DETERMINING WEIGHTS FOR EVALUATION	
GOALS, DESIRED CRITERIA, FUNCTIONS, FEATURES	RAW SCORE	ASSIGNED WEIGHT
A – Cost	4	0.30
B – Design Requirements	0	0
C – Efficiency	7	0.53
D – Labor Time	2	0.15
E		
F		
G		
H		
I		

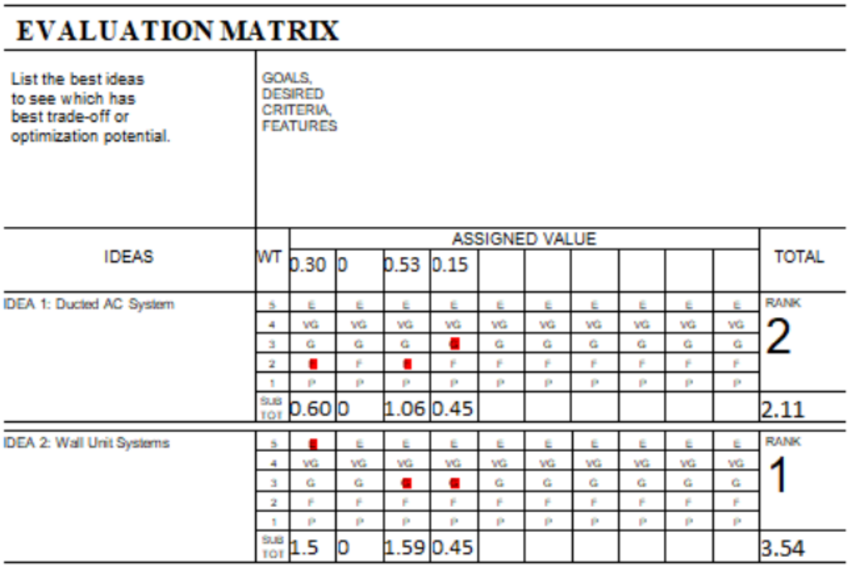
SCORING MATRIX

HOW IMPORTANT

3 – MAJOR PREFERENCE
2 – MEDIUM PREFERENCE
1 – MINOR PREFERENCE

	B	C	D	E	F	G	H	I
A	A2	C2	A2					
B		C2	D2					
C			C3					
D								
E								
F								
G								
H								

Figure 16: AC system Evaluation Matrix



EVALUATION MATRIX

List the best ideas to see which has best trade-off or optimization potential.

GOALS, DESIRED CRITERIA, FEATURES

IDEAS	WT	ASSIGNED VALUE										TOTAL
		0.30	0	0.53	0.15							
IDEA 1: Ducted AC System	5	E	E	E	E	E	E	E	E	E	E	RANK
	4	VG	VG	VG	VG	VG	VG	VG	VG	VG	VG	2
	3	G	G	G	■	G	G	G	G	G	G	
	2	■	F	■	F	F	F	F	F	F	F	
	1	P	P	P	P	P	P	P	P	P	P	
	SUB TOT	0.60	0	1.06	0.45							2.11
IDEA 2: Wall Unit Systems	5	■	E	E	E	E	E	E	E	E	E	RANK
	4	VG	VG	VG	VG	VG	VG	VG	VG	VG	VG	1
	3	G	G	■	■	G	G	G	G	G	G	
	2	F	F	F	F	F	F	F	F	F	F	
	1	P	P	P	P	P	P	P	P	P	P	
	SUB TOT	1.5	0	1.59	0.45							3.54

Figure 17: AC system Evaluation Matrix

Based on the result AC System Evaluation Matrix, there are only two selections to evaluate. The most important criteria are efficiency which wall mounted system scored higher than ducted system. Since a wall mounted system is a modern AC unit, it is more energy efficient that brings to lower running costs in the future. In contrast, a ducted system required a higher cost of installing ducts due to its complexity. Apart from that, a ducted system needs more space to accommodate which will reduce the usable space that decreases the selling price on client's point of view.

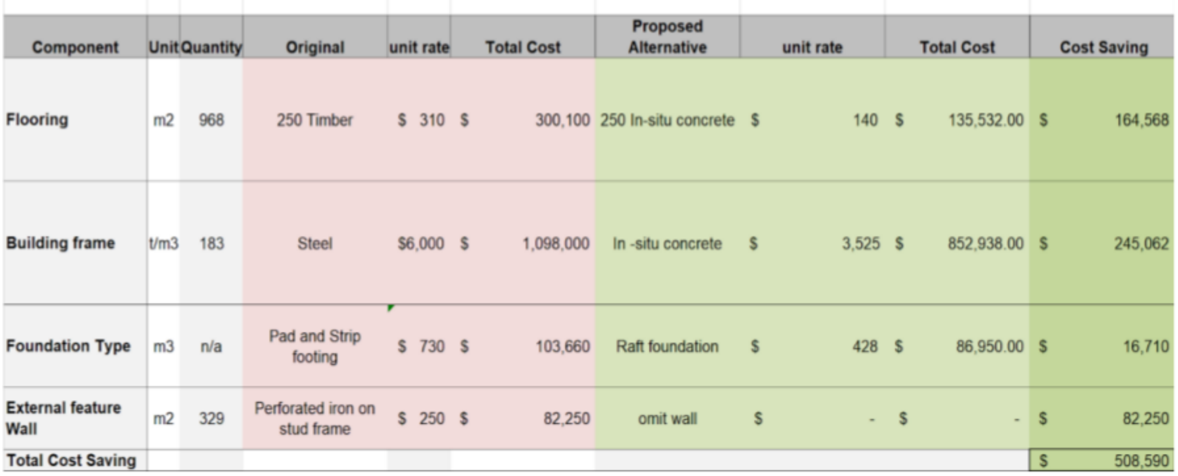
Considering the building complex is located in the CBD area, the selection of the AC system is critical for providing a maximum comfort to the resident. Therefore, a quieter AC system is important to minimise the noise for the residents or tenants during the time to rest.

4.6 Summary of Potential Improvements and Savings

The overall modification of element materials and methods have provided a better solution for greater performance. The basic method used for election is the Matrix table. The function of matric table is by examining each following criteria of the selection, the decision has been made from selecting the highest rank, but the final decision will be made according to the client's decision. Each alternative solution may have their drawbacks, but by comparing the majority desired criteria, features and function in matrix table, the best alternative choice will have the obvious strength and will potentially affect the construction project in a positive way. Moreover, these recommended alternative solutions will also provide a comfortable solution for the residents in future.

5.0 PROPOSED COST PLAN AFTER CHANGE IN DESIGN

5.1 Building Structures



Component	Unit	Quantity	Original	unit rate	Total Cost	Proposed Alternative	unit rate	Total Cost	Cost Saving
Flooring	m2	968	250 Timber	$ 310	$ 300,100	250 In-situ concrete	$ 140	$ 135,532.00	$ 164,568
Building frame	t/m3	183	Steel	$6,000	$ 1,098,000	In -situ concrete	$ 3,525	$ 852,938.00	$ 245,062
Foundation Type	m3	n/a	Pad and Strip footing	$ 730	$ 103,660	Raft foundation	$ 428	$ 86,950.00	$ 16,710
External feature Wall	m2	329	Perforated iron on stud frame	$ 250	$ 82,250	omit wall	$ -	$ -	$ 82,250
Total Cost Saving									$ 508,590

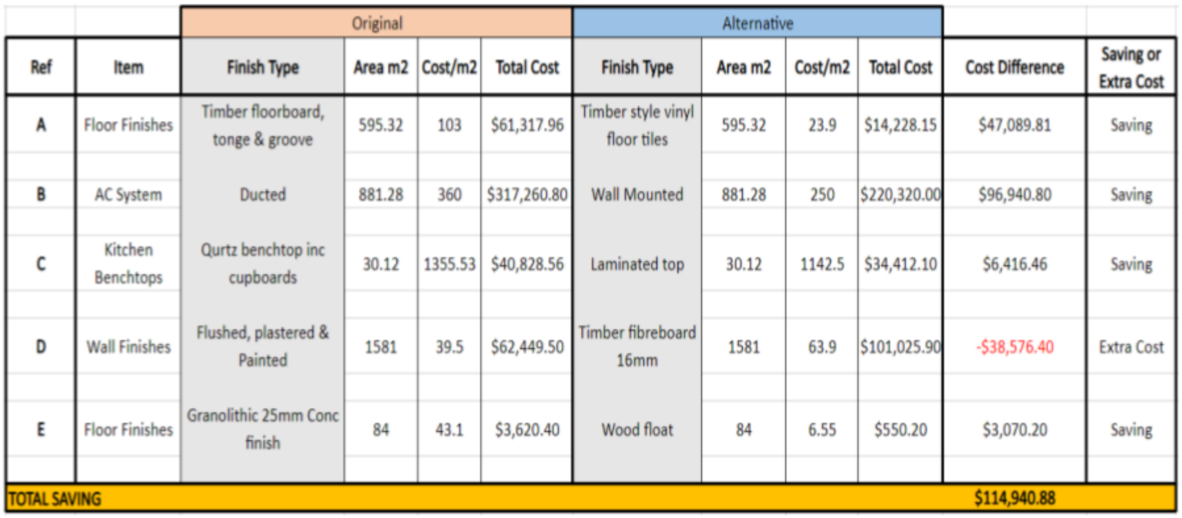
The potential saving cost of adapting concrete in-situ is $164,508 when compared to timber flooring. Timber flooring is considerably more expensive than traditional in-situ concrete. Although timber flooring is much more aesthetically pleasing, concrete has better thermal and acoustic performance. Besides that, in-situ concrete requires low maintenance and it is wind and water resistant. It provides better soundproofing than timber. The major downside of using a concrete alternative is the time taken to build it. Timber will be substantially faster.

The construction cost of steel is more expensive than concrete which cost an extra of $245,062. Although, these extra initial costs may be equaled out by the speed of construction as steel erection is significantly faster than in -situ concrete framing. However, steel frame needs to be covered in additional fire-resistant materials to improve its safety which concrete is naturally fire resistant according to the Building Codes. If the goal is to reduce capital cost then the concrete frame is advised.

The raft foundation is an alternative foundation type that offers greater stability if the ground is made up of unfavourable materials. The slab of the raft foundation will become the ground floor slab that can save the cost of constructing slab on pad footing. But both pad/strip footing and raft foundation are not having significant cost difference, the selection of either method would not impact the overall construction project and cost plan.

Cost saving available if the external feature wall at the walkway entrance is omitted as in appears to only serve an architectural purpose. The design of the wall might increase the heat to the building, if required any security to the walkway would recommend the extension of the rooftop for better appearance.

5.2 Building Finishes



		Original				Alternative					
Ref	Item	Finish Type	Area m2	Cost/m2	Total Cost	Finish Type	Area m2	Cost/m2	Total Cost	Cost Difference	Saving or Extra Cost
A	Floor Finishes	Timber floorboard, tonge & groove	595.32	103	$61,317.96	Timber style vinyl floor tiles	595.32	23.9	$14,228.15	$47,089.81	Saving
B	AC System	Ducted	881.28	360	$317,260.80	Wall Mounted	881.28	250	$220,320.00	$96,940.80	Saving
C	Kitchen Benchtops	Qurtz benchtop inc cupboards	30.12	1355.53	$40,828.56	Laminated top	30.12	1142.5	$34,412.10	$6,416.46	Saving
D	Wall Finishes	Flushed, plastered & Painted	1581	39.5	$62,449.50	Timber fibreboard 16mm	1581	63.9	$101,025.90	-$38,576.40	Extra Cost
E	Floor Finishes	Granolithic 25mm Conc finish	84	43.1	$3,620.40	Wood float	84	6.55	$550.20	$3,070.20	Saving
TOTAL SAVING										$114,940.88	

Floor Finishes: Simulation Table Ref A

The BIM model nominates a high level of floor finish, with timber floorboards, tongue and groove style throughout the apartment units (with the exception of the balcony and bathroom). The alternative which we have suggested is a "timber style" vinyl flooring. After a cost simulation the timber vinyl flooring was shown to produce a potential saving of $47,000.81 when compared to the hardwood floorboard finish.

Cost saving was not the only benefit which the simulation found. The following areas were also shown to be beneficial to the overall project:

- Labour time to install flooring decrease
- Transport and storage requirements
- Material availability
- Easily repairable

There is however a major downside when considering a vinyl type flooring and, in this scenario, compared to the hardwood timber floor, the vinyl flooring was not as durable in the long run, and may need refurbishment or replacing long before the hardwood floorboards.

Air Conditioning System: Simulation Table Ref B

The original plans and cost plan have nominated ducted air conditioning throughout each unit. Ducted air conditioning is a top end product providing easy zone control and great output in terms of cooling and heating; however, it is costly.

What we have nominated and simulated as an alternative is wall mounted AC systems to provide coverage of each unit. Based on the simulation the wall mounted systems would provide a staggering saving of $96,940.80. We see this as a huge saving for the client and hard to go past.

Putting the cost aspect aside, there are also other benefits of wall mounted systems for this project, these are:

· Less planning and design requirements at design and engineering phases of the project as there will be no requirements for ducting and mounting of ducted system units.

· Efficiency and running costs. Wall mounted systems can save a significant amount of money on energy bills, as an entire unit is not required to operate, a single smaller unit can operate for the area which the user wants to cool.

· Reduced labour time and cost.

· Easier maintenance than a ducted system.

Kitchen Benchtops: Simulation Table Ref C

Kitchen benchtops have been nominated by the architect to be of quartz stone, which is pleasing to the eye and durable.

What we have suggested in lieu of the stone tops is a laminated top finish. The laminated tops with cupboards included provided a cost saving of $6,416.46. Laminated finishes can come in a variety of styles giving the client a huge selection to choose from and a consistent finish.

When comparing the laminated top to the stone top there are some positives and negatives.

Positives:

· Cost saving

· Huge range of styles

· Easily replaceable if damaged.

· Quick installation time and labour on site

· Less lead time required than stone tops.

Negatives:

· Not as durable as stone,

· May not have the same luxury feel or be as aesthetically pleasing.

Wall Finishes: Simulation Table Ref D

The architect's drawings have nominated a standard flushed, plastered, and acrylic painted finish to the internal walls of the units. As the units appear to be marked to the higher end clientele, we have nominated an upgrade to the wall finishes.

What we have simulated is a 16mm timber fiberboard with acrylic paint, the cost increase of this method is $38,576.40, however it will provide the following benefits:

- Better durability
- Better acoustic rating
- More durability
- Similar labour to the original method and material.
- Less potential maintenance due to the increased durability.

Floor Finishes: Simulation Table Ref E

The stairwell area of the building is an area which will receive a lot of foot traffic from both tenants and visitors, for this reason a concrete flooring was decided on due to its durability.
The BIM model nominates a granolithic 25mm concrete finish which will be very pleasing to the eye and will likely bring character to the stairwell area.

The alternative option which we have suggested is a wood float finish. The simulation of the wood float finish provides a saving of $3,070.20. The saving was not the only factor in the suggestion of the wood float finish, however. The granolithic topping can sometimes deteriorate, and pieces can dislodge, which without repair can appear run down. A standard wood float will not only provide a minor cost saving but will also add extra durability and be more "bulletproof" over its years of use.

5.3 Summary of Potential Improvements and Savings

The final selection of the element materials and methods not only provided a better solution for greater performance, but also significantly reduced the construction cost. Apart from the wall finish element by selecting the greater value while increasing the element cost, other elements are mainly focusing on increasing or preserving the value while decreasing the final cost. The cost saving to building structures is $510,000 while finishes is $115,000 with a total of $625,000 to the final cost plan.

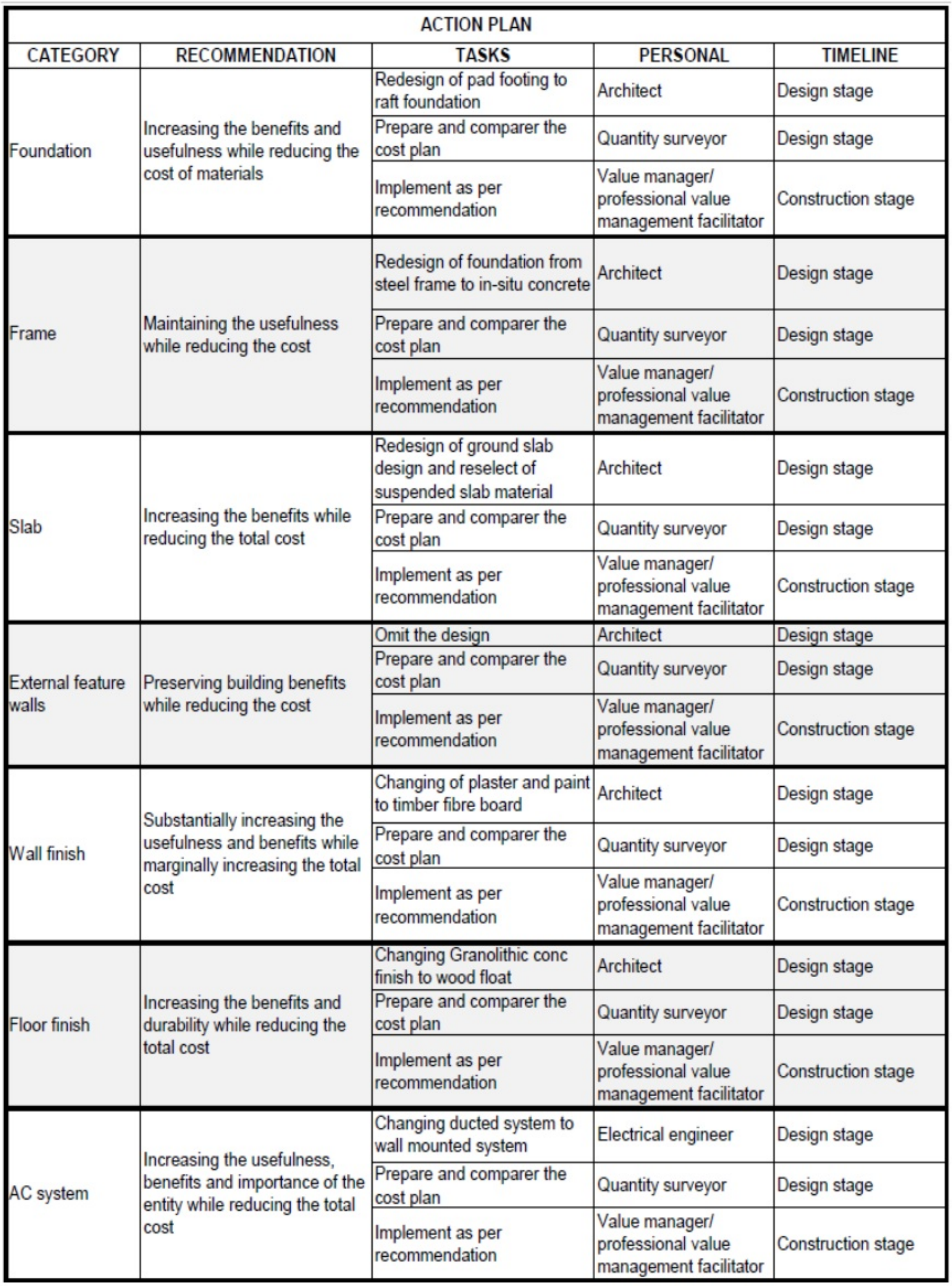
6.0 ACTION PLAN (Inc. PARTICIPANTS)

A useful action plan mainly aims to set up a detailed process sequence to successfully achieve a goal within a given time period. These plans will be the benchmark of the project, ensuring the construction process will go through in a well-planned flow and keep it on track all the time during construction. Because of this, the preparation work for the action plan is necessary before the project is processed. To set up the action plan, some basic questions should be carried out as the main idea, for example:

What kind of actions or changes will apply to the project?
Who will carry out those changes in the project?
When will they take place to apply the changes?
What resources should be carried out for those changes?
Communication before and during the project

Action plan will be clearly stating the involved objectives in an easy understandable and achievable schedule, and followed by the detailed steps and activities which will lead the process to the successful goal. This plan will aid the project step by step in a list and ensure the efficiency of the work finishes within the deadline.

By developing an action plan, it will bring many benefits to this construction project in further progress, for example avoid the details that may be overlooked; high efficiency for the time and resource management; reduce the cost in long term construction and so on. Action plan also can highlight the specific areas that require to assign professional labour or special materials to enhance the construction process within high quality standards.



ACTION PLAN				
CATEGORY	RECOMMENDATION	TASKS	PERSONAL	TIMELINE
Foundation	Increasing the benefits and usefulness while reducing the cost of materials	Redesign of pad footing to raft foundation	Architect	Design stage
		Prepare and comparer the cost plan	Quantity surveyor	Design stage
		Implement as per recommendation	Value manager/ professional value management facilitator	Construction stage
Frame	Maintaining the usefulness while reducing the cost	Redesign of foundation from steel frame to in-situ concrete	Architect	Design stage
		Prepare and comparer the cost plan	Quantity surveyor	Design stage
		Implement as per recommendation	Value manager/ professional value management facilitator	Construction stage
Slab	Increasing the benefits while reducing the total cost	Redesign of ground slab design and reselect of suspended slab material	Architect	Design stage
		Prepare and comparer the cost plan	Quantity surveyor	Design stage
		Implement as per recommendation	Value manager/ professional value management facilitator	Construction stage
External feature walls	Preserving building benefits while reducing the cost	Omit the design	Architect	Design stage
		Prepare and comparer the cost plan	Quantity surveyor	Design stage
		Implement as per recommendation	Value manager/ professional value management facilitator	Construction stage
Wall finish	Substantially increasing the usefulness and benefits while marginally increasing the total cost	Changing of plaster and paint to timber fibre board	Architect	Design stage
		Prepare and comparer the cost plan	Quantity surveyor	Design stage
		Implement as per recommendation	Value manager/ professional value management facilitator	Construction stage
Floor finish	Increasing the benefits and durability while reducing the total cost	Changing Granolithic conc finish to wood float	Architect	Design stage
		Prepare and comparer the cost plan	Quantity surveyor	Design stage
		Implement as per recommendation	Value manager/ professional value management facilitator	Construction stage
AC system	Increasing the usefulness, benefits and importance of the entity while reducing the total cost	Changing ducted system to wall mounted system	Electrical engineer	Design stage
		Prepare and comparer the cost plan	Quantity surveyor	Design stage
		Implement as per recommendation	Value manager/ professional value management facilitator	Construction stage

7.0 CONCLUSION

Value management to this residential complex is successfully completed by using an evaluation matrix and cost plan. The total saving cost for the building structures is nearly $510,000, and approximately $115,000 for the building finishes which eventually brings to $625,000 of cost saving to the project.

Original design element costs	$	4,700,000
ddt saving element cost after alteration	$	(625,000)
Amended element cost	$	4,075,000
Preliminaries %	8%	326,000
	$	4,401,000
Design Contingencies %	2.50%	110,025
	$	4,511,025
Localoty Allowance %	10%	451,103
	$	4,962,128
Inflation %	5%	248,106
	$	5,210,234
Constuction Contingengy	3%	156,307
	$	5,366,541

According to the final cost plan for original design, the total element cost is $4.7 million before adding the preliminaries and contingencies aspects. By using the amount to amend the total element cost the project total element cost was brought down to 4.1 million and eventually with the preliminaries and contingencies the total cost of the overall project after alteration is $5.4 million.

Additionally, the whole proposal is not just saving the construction cost, but also ensuring positive solutions for the building structure and construction process during the construction stage and securing the living comfort for the future residents. The change of building structure elements, such as footing system, supporting structures (columns, beams) and so on, will provide a stable and reliable final product. Moreover, the change of construction methods will also reduce the construction periods and reduce the distribution to the surrounding existing buildings within the CBD area. The alternative changes in building finishes and fittings, which the wall and floor finishes will provide a high-quality living environment and for the residents. The easy maintenance of the materials will also allow the residents to replace or repair the room fitment during usage in future.

In conclusion, the suggestions and cost plan in this report will significantly ensure the success of the project during the construction stage, even after the construction, to provide a high standard quality of life for residents in the future.

8.0 REFERENCE LIST

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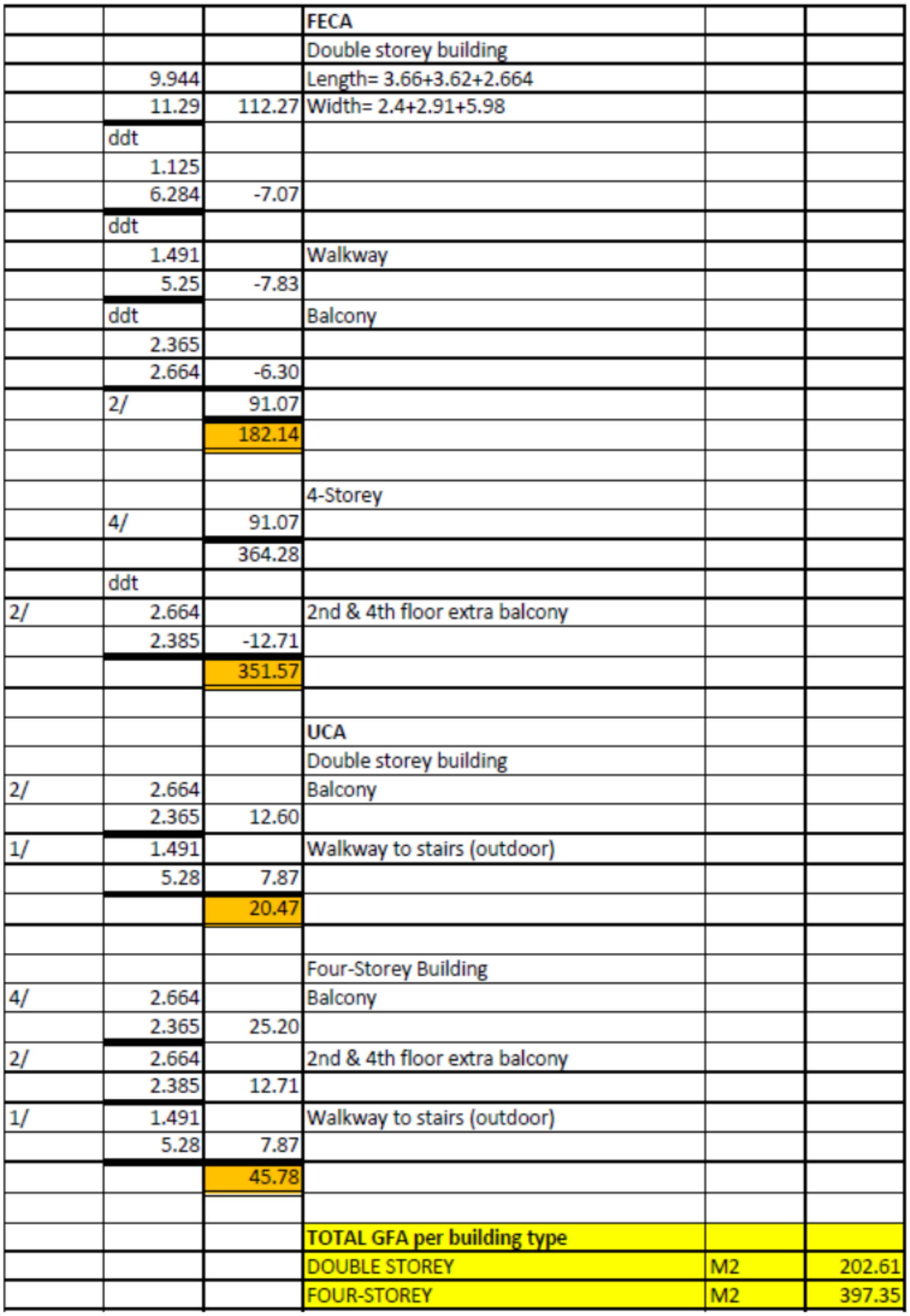
9.0 APPENDIX

9.1 Superficial Method



			FECA		
			Double storey building		
	9.944		Length= 3.66+3.62+2.664		
	11.29	112.27	Width= 2.4+2.91+5.98		
	ddt				
	1.125				
	6.284	-7.07			
	ddt				
	1.491		Walkway		
	5.25	-7.83			
	ddt		Balcony		
	2.365				
	2.664	-6.30			
	2/	91.07			
		182.14			
			4-Storey		
	4/	91.07			
		364.28			
	ddt				
2/	2.664		2nd & 4th floor extra balcony		
	2.385	-12.71			
		351.57			
			UCA		
			Double storey building		
2/	2.664		Balcony		
	2.365	12.60			
1/	1.491		Walkway to stairs (outdoor)		
	5.28	7.87			
		20.47			
			Four-Storey Building		
4/	2.664		Balcony		
	2.365	25.20			
2/	2.664		2nd & 4th floor extra balcony		
	2.385	12.71			
1/	1.491		Walkway to stairs (outdoor)		
	5.28	7.87			
		45.78			
			TOTAL GFA per building type		
			DOUBLE STOREY	M2	202.61
			FOUR-STOREY	M2	397.35