An Investigation of the Potential to Upgrade Existing Residential Apartment Blocks Using Prefabricated Retrofit Panels in Ireland

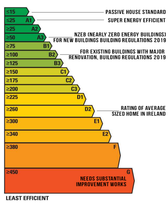
Introduction

Motivation

"In order to reduce emissions in line with national and international targets, Irelands building stock will need to be highly energy efficient and largely decarbonised by 2050"

"by **2030, 500,000 homes** will have been retrofit to a **BER level of B2** or cost optimal or carbon equivalent"

(Ireland's Long Term Renovation Strategy - Department of the Environment, 2020)



As part of Ireland's long term renovation strategy, **55,000** residential buildings are expected to be retrofitted to a **BER B2 every year** from **2024-2030**

However - "A total of 18,400 home retrofits were completed in 2020.

just **4,000** were to a **B2 standard** and 1,600 installed a heat pump.

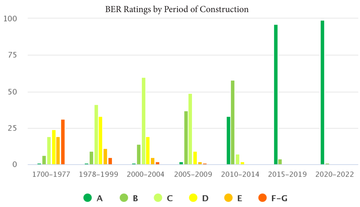
We need to **greatly increase the depth and volume of retrofits** as well as the number of heat pumps installed in order to deliver the required emissions reductions."

(Climate Action Plan 2021 - Department of the Environment, 2021)

These figures indicate that in order to reach the targets which have been set out, a major change is required. Hence the need for an investigation into potentially more efficient alternative methods to retrofitting.

Identifying a Typology

- Ireland's **1.7 million** dwelling stock is the **youngest** in the **EU**
- Approximately **16%** constructed **pre-1940** & an additional **15 %** from **1940 to 1970**
- Dwellings of this time were built with **little to no insulation**
- **Under 10%** of buildings from this time have a **BER Rating >C1**



3 in 10 Dwellings were built **Pre-1970**

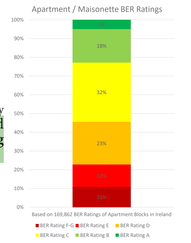
1.7 Million Irish Dwellings

Approximately **14%** of Irish dwellings are **Apartments / Multi-residential Homes**

This makes **203.720 Dwellings**

Of the Buildings which have been assessed for BER Ratings, **77%** are of **BER Rating C1 or lower**

This means that approximately **156,864 dwellings** could be **in need of retrofitting** to BER B2 or higher
- looking at apartment blocks alone



Aims

- Based on a case study of a suitable building typology in the Existing Irish Housing Stock, conduct an investigation into the feasibility of the use of Prefabricated Panels as a retrofitting strategy, ensuring it's capabilities through:
- Developing realistic, feasible, and efficient technical details
- Achieving the minimum required BER Rating of a B2
- Maintaining compliance with the relevant Irish building Regulations

Objectives

- Identify an appropriate dwelling typology in need of retrofitting across Ireland
- Investigate existing prefabricated retrofitting panel systems on the market and identify what makes a successful design
- Identify the most appropriate prefabricated panel system for apartment blocks in the Irish building stock
- Construct a BIM model of a chosen case study building which meets the most common characteristics of the building typology
- Carry out a detailed analysis of the building envelope with the panel system applied
- Perform thermal analysis on the building's critical junctions to verify the building's ability to reduce heat loss through the fabric
- conduct a DEAP calculation to identify if the panels can achieve a BER of at least B2
- Determine whether this method is feasible for the retrofitting of Irish apartment blocks on a larger scale

Methodology

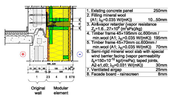
Material Assessment
- Research panel materials - Conductivity
- Ensure Compliance with TGD part L
- Minimum **nZEB** standards 0.18 W/(m2K)

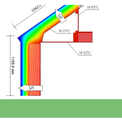
Panel Mass Calculations
- 3D BIM model
- Report volumes per material
- Multiply by Density to calculate **mass**

Case Study - Constitution Hill Flats
- **Revit Model** to be produced
- Prefabricated Modular Panels to be applied
- Critical thermal junctions examined and well developed

Thermal Bridge Analysis
- TRISCO
- In-depth heat flow analysis through **key junctions**
- Before / After

DEAP Analysis
- DEAP calculation
- Calculated both before and after retrofit
- Attempt to meet the requirements of a **BER of at least B2**





Case Study - Apartment Block

Why this Typology?

- Pre-1970s Construction
- BER Rating - Candidate for Retrofit
- Apartment Block - Proportion of Dwellings
- Uniform Building type - Compared to Detached Houses for example
- High level of vacancy
- Known for Social Issues - location

- To note: As exercise is technical in nature - issues regarding aesthestics and historical value are not being considered in the investigation

Building Context


Site Location within Dublin North Inner City

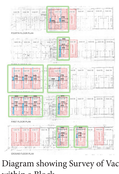
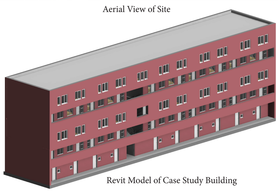
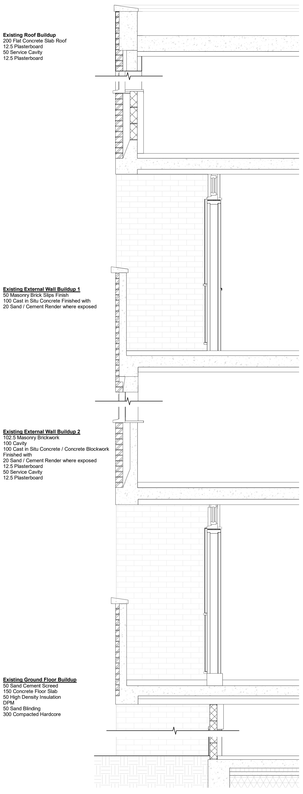


Diagram showing Survey of Vacant Units within a Block


Aerial View of Site


Revit Model of Case Study Building

Existing West Façade Section

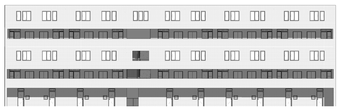


Constitution Hill Flats - Background

- Constructed in **1968**
- Comprised of 3 Apartment Blocks
- **5 Storeys** each
- Cavity Wall Construction
- Red Brick and Concrete Finish
- Irregular Façade featuring external wallways and stairwell
- Meets the most **common characteristics** of the building **typology**
- Is in need of **Retrofitting** in order to reach a **BER** level of **B2** or higher

Drawings of Existing

East
1 : 200



West
1 : 200

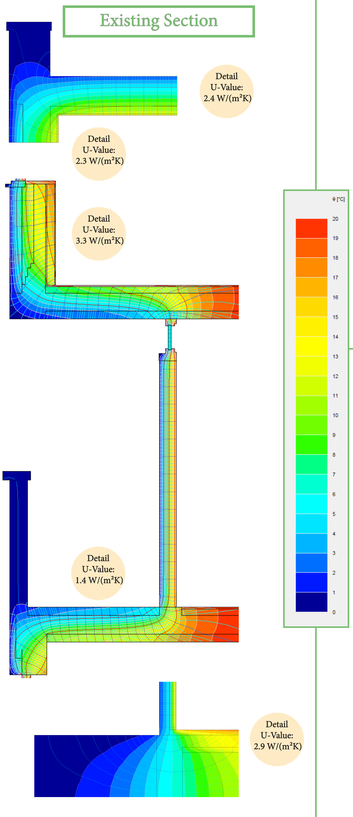
Real-Life Retrofit

- There is a **current real-life ongoing retrofit** of the Constitution Hill Flats
- Currently in **Planning Stage**
- Grafton Architects
- **Internally retrofitting** the thermal envelope
- Partial Demolition
- Additional storey to existing blocks
- 2 Additional blocks to the North and South
- Expected to reach a **BER Rating of B2**
- Can serve as an interesting baseline to compare results to

Table 7 DEAP Assessment Input Values, Nominated Apartments

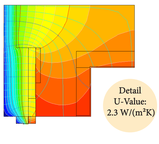
Input Parameter	Input Value
Roof U-Value	0.20 W/m²K
Walls U-Value	0.20 W/m²K
Ground / Exposed Floors U-Value	0.94 W/m²K (Existing slab) / 0.13 W/m²K (New slab)
External Doors U-Value	1.5 W/m²K
External Glazing U-Value	0.81 W/m²K
External Glazing g-value	0.64
Structural Air Permeability	1m³/m²hr at 50Pa
Thermal Bridging	0.15 W/m²K
Thermal Massing Category	Medium
Lighting	LED
Ventilation Method	Double Ducted Exhaust Air Heat Pump
Specific Fan Power	0.78 W/(L/s)
Heat Exchanger Efficiency	80%
Space Heating System	Double Ducted Exhaust Air Heat Pump
DHW System	Double Ducted Exhaust Air Heat Pump
DHW Storage Volume	180 L

Existing Section

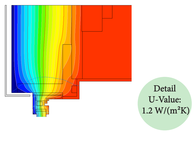


Opening Upgrades

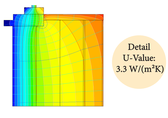
Existing Window Head



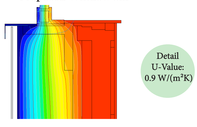
Proposed Window Head



Existing Window Sill

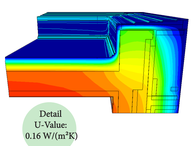


Proposed Window Sill

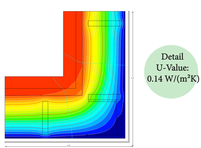


Panel Junctions

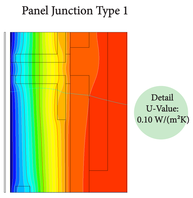
Panel Parapet Junction



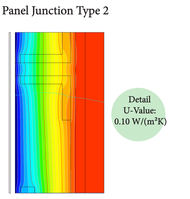
Plan Section Corner Junction



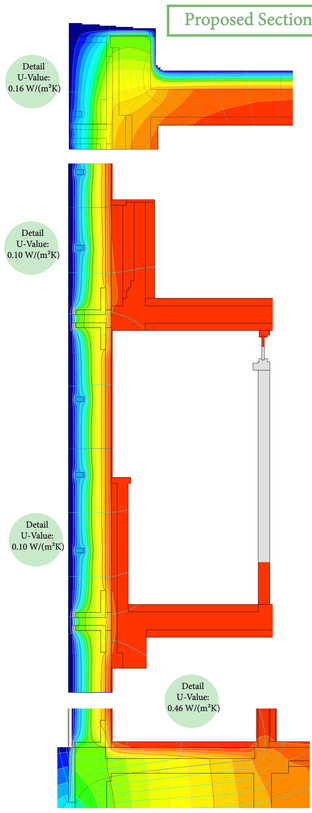
Panel Junction Type 1



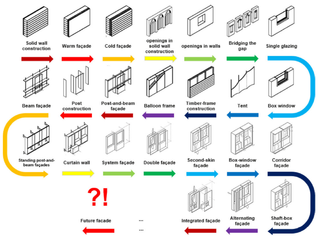
Panel Junction Type 2



Proposed Section



Prefabricated Modular Panels



Summarised History of Wall Construction

Overview

- The Modular Building Façade was first patented by American Lore Brown in 1974
- Recent drive for retrofits across EU has boosted development - **600m Euro** pre 2019
- Panels are manufactured **off site**, often based on drone surveys
- Different Panel structural types - **Timber, Concrete, Aluminium**
- Can be used in new builds and for retrofits

Why Prefabricated Modular Panels?

- Retrofit goals demand a **faster method** of thermally upgrading the housing stock
- Less work on site, less demolition, faster construction
- Decrease in material waste
- Savings on construction time - Less obstruction for tenants in apartment blocks
- Ri.Fa.Re System in Italy found a **time saving of 56%** at a **cost increase of 28%**

Manufacturing Process

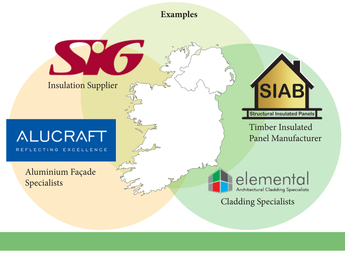
AUTODESK® AUTOCAD®

- Most Prefabricated Modular Panels follow a similar manufaturing process:

1. The Building in need of retrofit is scanned via laser or drone in order to get extremely accurate data for the existing structure
2. The scanned existing building is brought into BIM software which can then produce accurate CAD drawings
3. The CAD drawings are used on the manufacturing line in order to produce panels to the exact dimensions necessary
4. The panels are then made in the factory and transported to site ready to be installed
5. The panels can be quickly installed and provide the building with a new thermal envelope

Irish Context

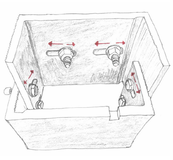
- Another potential upside to the use of these panels or similar designs in Ireland is the existence of manufacturers / suppliers of all of the required materials for these designs

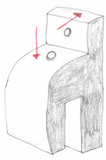


Fixing Methods

- There are various techniques for the fitting of panels back to the existing structure
- Most panel systems are either supported off the ground, hung from the wall, or a combination of both
- Due to the height of the average apartment block, a combination of both is most appropriate in this case

- Shown Above, are the fixings used in the Estonian nZEB case study
- They used Steel L brackets which were fixed through the joints between each panel
- Fixed at Top and Bottom
- No additional foundations used for ground support





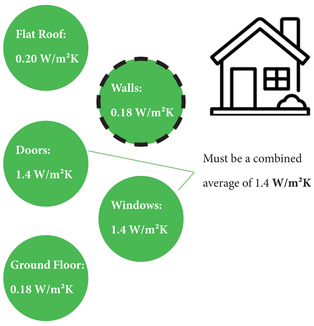
- Shown above is the Plug and Play system of anchorage used in their projects
- Shown on left - Anchor which is fixed to the wall
- Shown on right - Intermediate elementt which is fixed to panels and slots into the wall anchor
- The design is very flexible, with adjustable blots and serrated edges which allows for adjustment in the y axis and in the x azis while guaranteeing load transmission

Panel Choice / Application

The choice of Panel to be applied in this study is driven by the following factors:

- Thermal Performance
- Feasible application to the chosen building typology
- Sustainable Material Usage
- Producible within the Irish context
- Proven Real World Application

Irish TGD Part L Requirements:

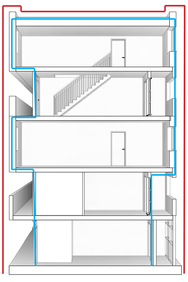


With the aforementioned factors in mind, the panel system which will be applied to the case study will be **Panel System 1**

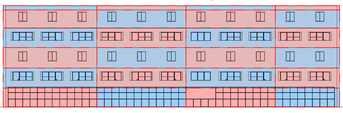
- The system has been used to reach nZEB levels previously
- It has been applied to the relevant building typology
- It is timber based
- Producible within Irish context
- Has previous Real World Application

Building Envelope

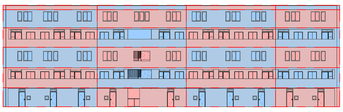
- When considering the application of prefabricated panels to the existing façade, key design choices must be made
- One such design choice involves deciding what thermal line the panels will follow
- The method being used in the real life retrofit by Grafton Architects involves following the existing thermal boundary of the building as shown in blue
- However, potentially a more efficient and effective solution when dealing with panels in particular is changing the thermal line as is shown in red
- This involves enclosing the external balconies, into enclosed corridors



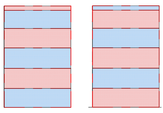
Panel Layout



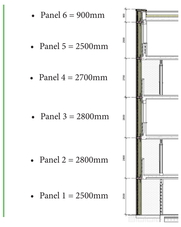
East 1:200



West 1:200



South 1:200 North 1:200

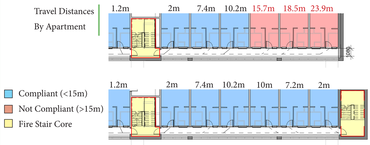


Panel Dimensions range from 2.8m to 2.5m in height and from 8m to 12m in length. Top parapet panels are 600mm in height.

Design Challenges

Fire

- Proposing to enclose the existing balconies has implications with regards to Fire Safety - Primarily, this is in regard to the creation of inner rooms and the creation of a new fire corridor
- The Technical Guidance Documents Part B: Fire Safety, defines inner rooms as the following: A room whose only escape route is through another room - and is at risk if a fire starts in that outer room.
- In order to comply with the necessary fire escape travel distances, sprinkler systems will be installed in every flat and hallway on the affected stories along with a Smoke Control System in the fire corridors / lobbies



Existing (Top) and Proposed (Bottom) Fire Corridor Layouts at First Floor Level 1:200

The Existing first / third floor layout will no longer be compliant with TGD B upon enclosing the external corridor, as the maximum permitted travel distance permitted in a fire corridor is 15m. As shown above, in order to comply with these guidelines, an additional fire escape route would be necessary. One such option would be the construction of an additional stair core, to the south of the block.

Ventilation

- Ventilation will be on important factor particularly in areas which are being enclosed
- Ventilation ducts can be embedded into the wall module between the 175x45mm Timber Frame
- A smoke control system is to be installed in the location of any new fire corridors
- A smoke control panel will open all windows in fire corridors using actuators to ventilate smoke
- Services hosting location within panels shown dotted in drawing below

Existing Building DEAP Analysis Results

BER E2

- Analysis conducted on an average mid terrace first floor Duplex apartment - Most common apartment type in blocks
- Far from meeting BER B2 Standard
- Third lowest possible BER Rating

360 kWh/m²/yr

CO2 3045 kg CO₂/yr

Existing Building With Prefabricated Retrofit Panel DEAP Analysis Results

BER C2

- Analysis based on existing building services with the application of prefabricated panel system & roof retrofit
- Approximately 50% reduction in energy usage and CO_2 emmisions

178 kWh/m²/yr

CO2 1502 kg CO₂/yr

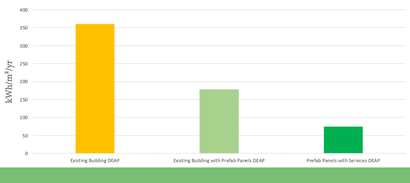
Prefabricated Retrofit Panel with Services Retrofit DEAP Analysis Results

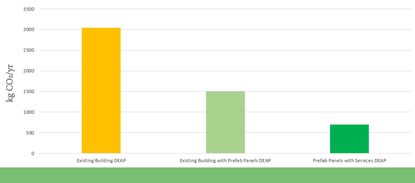
BER B2

- Analysis based on real life proposal of services with the application of prefabricated panel system & roof retrofit
- Approximately 80% reduction in energy usage and CO_2 emmisions from existing

75 kWh/m²/yr

CO2 694 kg CO₂/yr

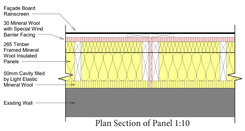




Adam O'Reilly
Architectural Technology

Panel System 1 - Estonian nZEB

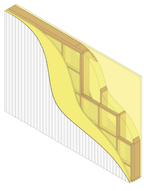
- Study was conducted on a typical 5 storey apartment block in Estonia constructed in 1986
- Existing walls consist of insulated concrete panels
- Irregular Façade shape - balconies
- Using a Timber based panel system



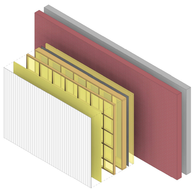
Plan Section of Panel 1:10

- Estimated approximately 60% time saving
- Cost for panel system was 180 euro/m2 compared to what would be 70 euro/m2 using alternative traditional methods
- Speculate that wider use of prefabrication would increase renovation volumes and decrease price
- Renovation was able to meet nZEB energy efficiency levels


Case Study Before and After


3D Cutaway showing wall buildup

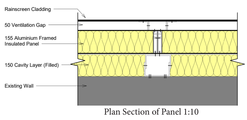
- **Panel Buildup From Interior to Exterior**
- 50mm Filling Mineral Wool
- Air & Vapour Membrane
- 45 X 195mm Timber Frame / Mineral Wool
- 45 X 70mm Timber Frame / Mineral Wool
- 30mm Semi-Rigid Mineral Wool Slab with Special Wind Barrier Facing
- 25 Ventilated Airgap
- 8 Façade Board - Rainscreen
- Overall Panel Thickness of 378mm



- **Capable of U- Values up to 0.11 W/(m 2K)**

Panel System 2 - Plug and Play

- The Plug and Play Modular Façade System was a design project conducted in Spain and Italy.
- The Case Study building used was a 1965 multi dwelling residential building in Durango, Spain.
- The façades consisted of a masonry brick cavity wall buildup
- The Building is 3 Storeys tall and has irregular façades featuring balconies and stairwells
- They opted to use an aluminium framed modular panel system



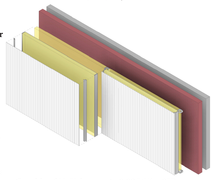
Plan Section of Panel 1:10

- Panels are floor to floor height
- System Concept is based on modular curtain wall systems - panels are fixed back to structure using 2 anchor points, and 4 anchor points for lower panels
- Assembly starts at the bottom and as rows are assembled and anchored to the structure above, while also being supported by the panels below
- Integrated solar thermal unit and photovoltaic panels as shown
- Integrated ventilation system through cavity
- They found savings of 50% in time, a 30% reduction in materials, and a 25% reduction in waste


Case Study Before


Case Study After

- **Panel Buildup From Interior to Exterior**
- 125mm Cavity - May accomodate any additional ducting or be filled with insulation in order to improve thermal performance
- Aluminium Framing hosting 155mm of insulation with various external finished possible for an overall panel thickness of 236mm
- Compatible with various insulation types

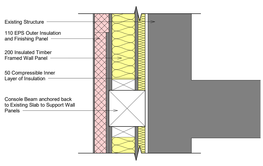


- **Capable of U- Values up to 0.09 W/(m 2K)**

Adam O'Reilly
Architectural Technology

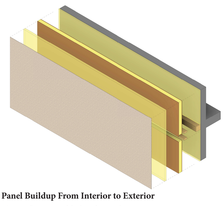
Panel System 3 - Ri.Fa.Re

- Ri. Fa. Re timber based solution, is an Italian based research group started in 2013
- Design geared towards energy refurbishment of the Italian pre 1976 building stock which contributes to 40% of the total energy consumed in Italy
- Not a case study approach - aims to develop a standardized but customizable prefabricated solution
- Timber based panel system, suitable for irregular façades, with multiple stories



Section of Panel 1:10

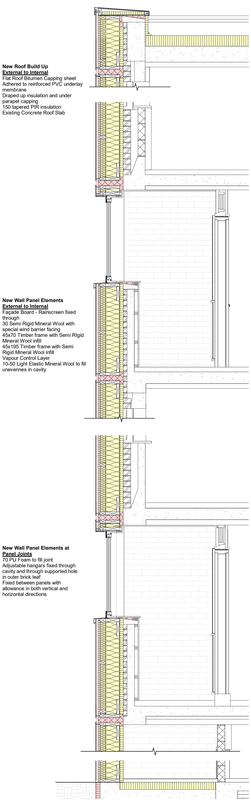
- Wall panels from 1.2m to 12m in length and 1.2m to 3.3m in height
- Compatable with different external finishes such as render, ventilated façade etc.
- Wall panels are placed on timber beams which are fixed back to the main existing structure
- In 3 Case studies of various scales the Ri. Fa. Re approach enabled on average, time savings of 60%, however at a cost increase of 20%



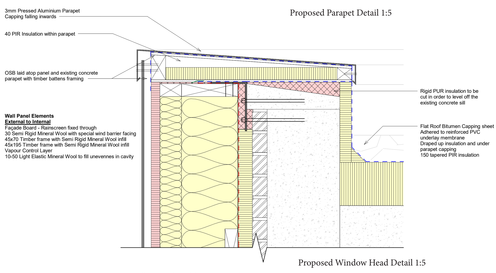
- **Panel Buildup From Interior to Exterior**
- 50mm Compressible Insulation Layer
- 200mm Prefabricated Insulated Timber Panel
- 110mm EPS Outer layer with selected finish to panel

Proposed Panel Application

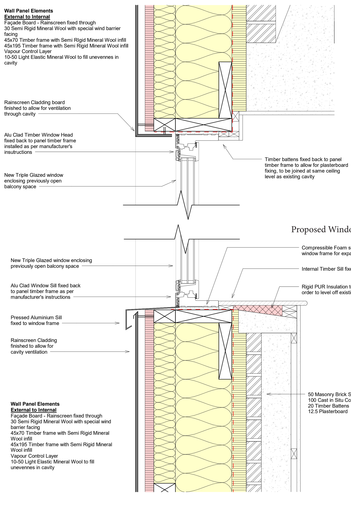
Section of Proposed Façade 1:20



Proposed Parapet Detail 1:5

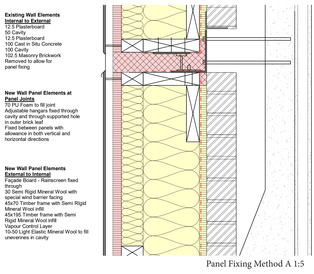


Proposed Window Head Detail 1:5

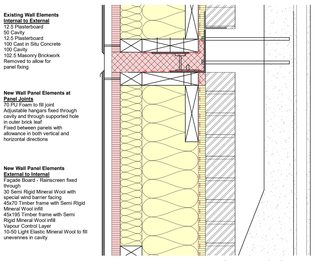


Proposed Window Sill Detail 1:5

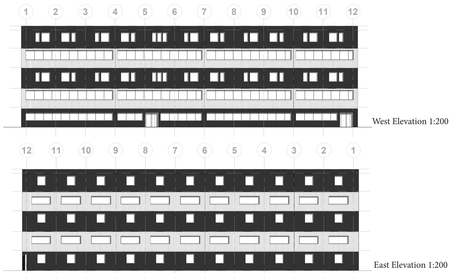
Panel Fixing Methods



Panel Fixing Method A 1:5



Panel Fixing Method B 1:5



Key Findings

Benefits of System

Faster Construction Time - Lower Skill Required

Timber Based - Flexible Finishings - More Sustainable

Thermal Performance - TGD L U Value Compliance

End of Life - High Potential for Removal and Recycling of Materials

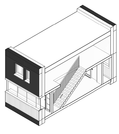
Uniformity of Building type - Faster Implementation of Standard Design

Barriers to Implementation

Price - In all previous Implementations - Initial Price has been higher than Traditional Retrofitting methods on the Market

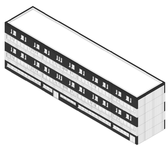
TGD B Fire Safety - Enclosure of External Walkways may require Construction of additional Stair Cores in Some Blocks

Building BER Conclusions



Existing **E2** → Existing w/ Panels **C2** → Panels w/ Services **B2**

23,786 kWh/y → 11,738 kWh/y, 12,048 kWh/y saved → **5,424 kWh/y**, **18,362 kWh/y** saved



Savings of 18,362 kWh/y = 1 Apartment

27 Apartments per Block

3 Blocks = 81 Apartments

Potential for Approximately **1,487,322 kWh/y** Saved

Potential Impact on wider Irish Building Stock

156,864 Apartment Dwellings rated C1 or lower

Approximately 75,000 Apartment Dwellings rated from D1 to G

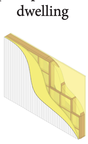
18,362 kWh/y X 75,000 Dwellings

1.37 Billion kWh/y Saved Across Ireland

2000 Panels Produced /Yr per Factory

1 Apartment Block with 27 Apartments required 60 Panels to retrofit to BER B2

Average of 2.2 Panels per Apartment dwelling



Approximately 350,000 Panels are required to retrofit the 156,864 Apartment Dwelling rated C1 or lower

29 Factories operating from 2024 would produce enough panels to retrofit every Apartment Block dwelling in need of Retrofit