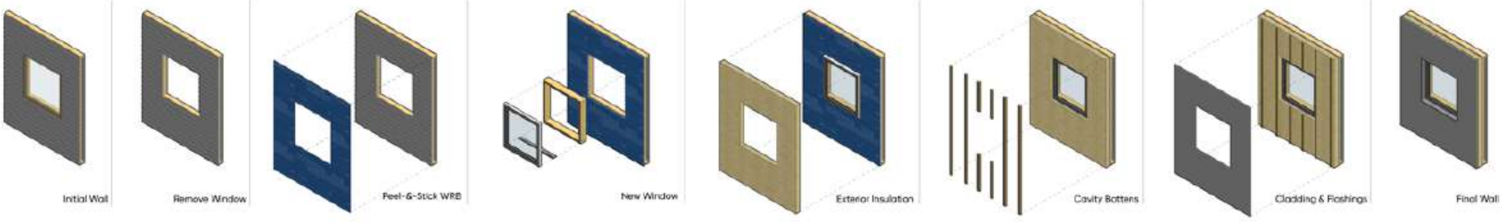

THE PARKA WRAP

RETROFITTING INSULATION ONTO EXISTING WALLS OF OCCUPIED HOMES

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RETROFITTING INSULATION ONTO EXISTING WALLS OF OCCUPIED HOMES

A THESIS

SUBMITTED IN FULFILMENT
OF THE REQUIREMENTS FOR THE DEGREE

OF

MASTER OF ARCHITECTURE
(BY PROJECT)

AT

UNITEC INSTITUTE OF TECHNOLOGY

BY

JON DAVIES
ID: 1209701

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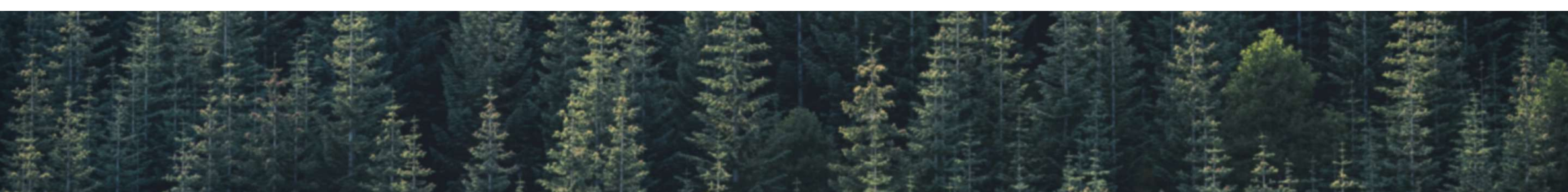


ABSTRACT

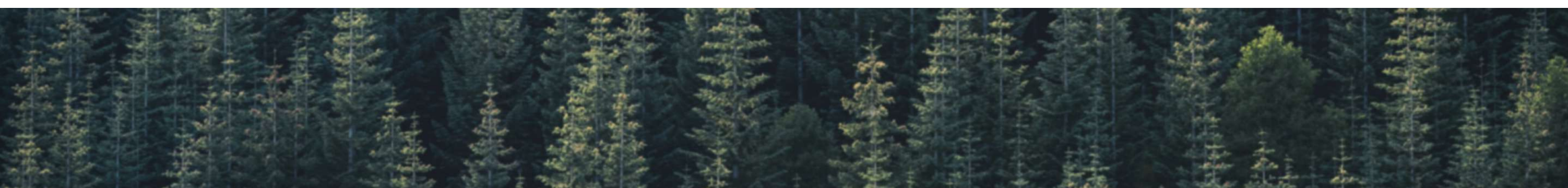
Currently, there is limited research to improve an estimated 830,000 homes in New Zealand that have no insulation within the external walls. Unfortunately, there is no comprehensive policy, standard or best practice guideline to housing providers and homeowners for retrofitting external walls that are not insulated. Therefore, this research aims to understand how practitioners can design and implement building interventions over existing wall claddings to increase thermal performance in existing occupied as-built homes.

While retrofitting homes have underlying barriers to implementation, the research will primarily focus on application technique and practical knowledge while considering thermal and hygrothermal performance. Aspects of construction and social costs will be acknowledged within the research but is out of scope.

The thesis is divided into seven chapters. Chapters one and two outline the research purpose and define the research question. They are followed by review of key background literature in chapter three and case studies within the subject field in chapter four. These lead to the evaluation of testing methodologies and the design of experiments in the fifth chapter which also describes the software simulations of proposed materials and assemblies.
Chapter six describes actively tested iterative scaled sections of building walls within a controlled environment. The knowledge gained from scaled testing is analysed and applied to a typical New Zealand bungalow wall and tested with wind, water and seismic pressures to provide insight into the process of retrofitting homes. The final chapter will review the value of the research and conclude with next steps.

International research and practice show an existing building's walls can be retrofitted externally. In New Zealand, cold houses cost New Zealand $7 Billion annually in respiratory healthcare, however there are major knowledge gaps in how to retrofit to create thermally efficient homes without causing harm to the building's durability. Case studies of attempted improvements using external insulation suggest it can easily result in a negative outcome with building damage (moisture entrapment) when available building science is ignored or misunderstood. Precedents internationally have suggested positive outcomes when the insulation has been applied as an external blanket; however, specific material combinations are critical to this success or failure.

Modelling the implementation of the proposed Parka Wrap system to existing buildings shows a 60% reduction of energy required to maintain 20 degrees inside a typical house where insulation already exists in floor and ceiling. Physically testing existing walls pre-retrofit shows they are leaky for both air and water as water is driven through existing cladding by wind pressure. The effects of wind alone contributes to cold internal environments. The addition of water requires either drainage and/or significant drying potential to avoid damage to structural framing.
The subsequent physical testing for water penetration in NZS4284:2008 test rig included seismic racking, and repeated water penetration testing has shown evidence of successful development of a robust weathertight assembly with predictable thermal performance. Further software based analysis of proposed design ensures avoidance of predictable moisture accumulation.



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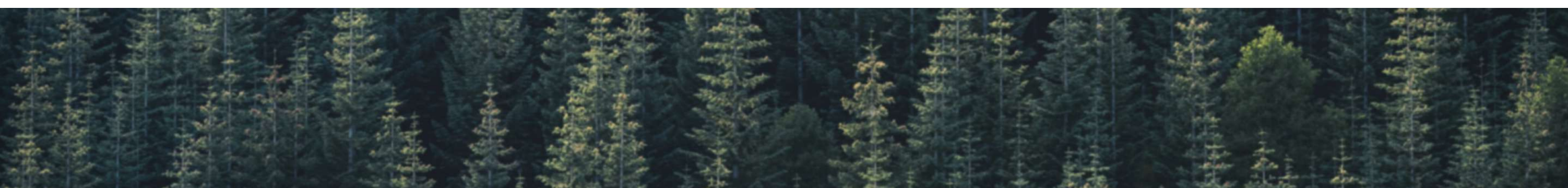

HE AHA TE MEA NUI O TE AO

WHAT IS THE MOST IMPORTANT THING IN THE WORLD?

HE TANGATA, HE TANGATA, HE TANGATA

IT IS THE PEOPLE, IT IS THE PEOPLE, IT IS THE PEOPLE

WORK FOR THE WELL-BEING OF THE CITY…
FOR YOUR WELFARE IS BOUND UP IN ITS WELFARE.

JEREMIAH 29:7

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1.0 INTRODUCTION

In the developed world, it is common practice to have a dwelling that is heated to a comfortable temperature of 20 degrees Celsius. This includes Northern and Western European countries such as Germany, Sweden and Switzerland, but also, former Soviet bloc countries, North America, and China. Required energy consumption to achieve healthy indoor temperatures is much too high for most people to afford within New Zealand. The problem is both an energy demand problem and a health outcome problem. Homes that are hard to heat are cold homes likely to result in damp and subsequent mould growth.

In New Zealand, statements about our 'warm' climate suggest we do not need to heat our homes as it is rarely cold enough to worry about. This perception held by many is dangerous and leads to heath issues of the New Zealand population (Ingham, 2019). Excess Winter Mortality statistics (Telfar-Barnard et al., 2010) clearly show we don't keep our houses warm enough - or can't keep our houses warm enough - to prevent people dying of cold-related illness every winter in New Zealand. Worldwide research confirms the higher likelihood of dying during winter occurs in mild climates rather than cold (WHO, 2018). Climate files from the National Institute for Water and Atmospheric Research (NIWA) confirm New Zealand is a heating-dominated climate where mean temperatures are below 18 degrees Celsius (NIWA, 2020). In this context, if New Zealand houses were maintained at 18+ degrees for comfort and health they would lose more heat than gain from the outside air temperature. This loss is based on the physics principle of heat energy naturally moving from warm toward cool to create equilibrium. In our buildings, to retain heat, there is a need to insulate walls, floors, ceilings, and windows to ensure they lose heat slowly.

Our housing stock in New Zealand performs very poorly thermally (Ingham, 2019). On average 53% of houses in New Zealand have no insulation in the walls. This was highlighted by Study Report 372 (BRANZ, 2017) where it was also estimated 66% of rented housing has no insulation in the walls. Houses were only required to have insulation installed in walls from 1978 (Standards New Zealand, 1977). Housing built pre-1978 makes up approximately 53% of our housing stock. There is a caveat here. Just because a house built after 1978 has insulation does not mean the insulation is performing optimally. Historically, we introduced upgrades to standard NZS4218 in 2000, 2004, and 2007 (Standards New Zealand, 2000, 2004, 2007) and there is currently another update in discussion. Therefore, a logical conclusion is most New Zealand homes would benefit from insulation improvement creating internal temperature increase and/or energy demand decrease.

The effect of adding wall insulation is a reduction in the amount of energy required to heat an uninsulated or poorly insulated home to a minimum of 18 degrees to meet World Health Organization guidelines (WHO, 2018). Due to the high energy demand of heating drafty uninsulated buildings to 18 degrees Celsius most homes are colder than WHO recommendations for health. The negative effects of cold housing on health are very well documented across decades of research (WHO, 2018) covering physiological, psychological, educational, and sociological outcomes. Health and housing research shows us what we need to fix, but they are not guidance pathways to show how we can fix the problem directly.

The 'what' (effect of cold on health) is documented, the 'action' (add heating and if possible insulation to homes) is clear as shown in WHO graphic below. In these research papers the 'how' (to install insulation) is not addressed.

Topic	Recommendation	Strength of recommendation
Indoor cold and insulation	Indoor housing temperatures should be high enough to protect residents from the harmful health effects of cold. For countries with temperate or colder climates, 18 °C has been proposed as a safe and well-balanced indoor temperature to protect the health of general populations during cold seasons.	Strong
	In climate zones with a cold season, efficient and safe thermal insulation should be installed in new housing and retrofitted in existing housing.	Conditional

FIGURE 1: THE WORLD HEALTH ORGANISATION IS CLEAR: HEAT HOMES FOR HEALTH THEN, IF POSSIBLE, INSULATE HOMES. IMAGE CREDIT WHO.

The purpose of this research is to provide a new method of retrofitting wall insulation. There are compelling reasons to insulate walls – reasonable expectations of comfort, health, mould-free homes, and efficiency of heating. Respiratory disease costs New Zealand $7 billion dollars annually in healthcare. In 2017 alone 3,243 deaths were attributed to respiratory disease (NZHIS, 2020) including a disproportionate number of Maori – more than double the rate of non-Maori. This gap has remained constant since 2013. University of Otago’s Asthma Research Group (2017) comparison of cold and mouldy houses’ effects on children’s health again highlighted this connection between housing and health. An online newspaper article promoting the findings at the time included this statement from Dr Caroline Shorter who conducted the research with others:

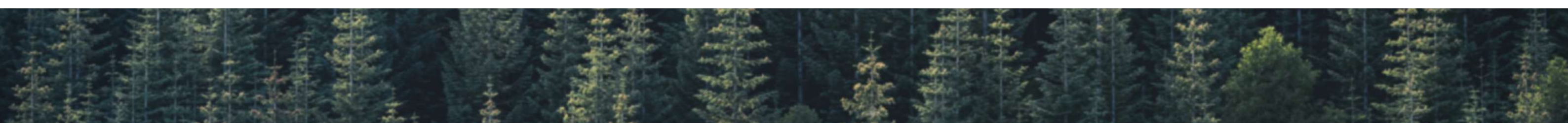
“There were a number of basic measures which could be taken to make homes drier, including having leaks repaired, installing good insulation and ensuring heating methods could warm the whole house, she said.”(RNZ, 2017)

The purpose of this research is to provide guidance for thermally improving the 830,000 homes with no insulation (Figure 2) in the walls (White and Jones, 2017) so warmth, comfort and health can be improved without requiring high or unaffordable energy demand.

Dr Shorter's comment above called the three suggested interventions 'basic measures' however, fixing leaks, installing insulation, and heating the whole house are not basic. This statement is well intentioned and correct but vastly underplays the challenges of insulating buildings using existing methods. The basic truth of the statement doesn't arrive at the practice of improving buildings. This is partly because there aren't basic and effective methods available.

In countries where heating to 20 degrees Celsius for comfort is already the norm, adding insulation will not make the house warmer, it just makes the existing heating system more efficient and/or makes the energy bills lower. It could be considered that if the occupants were not paying the bills, they may not notice any change. However, in New Zealand quickly losing heat through uninsulated walls results in cold homes. Because of this we are even encouraged to only attempt to heat one room – 'Only heat the space you're using.' (Genesis Energy, 2021) - in an attempt to lower energy consumption. Ministry of Social Development repeat this as a health message on their current website: "How to heat your house: Only heat the room that you are in". (MSD, 2008). Moreover, the Residential Tenancies Act only requires a heating appliance sufficient to heat the living room (NZ Government, 2019). Cold surfaces in a home result in condensation. Condensation results in mould. Mould results in illness.
While it is suggested retrofitting wall insulation is easy and effective the reality is different. Retrofitting wall insulation is hard, costly, disruptive and not particularly effective.

The Parka Wrap project – an investigation into the design and testing of a retrofit methodology where insulation is overlaid on an existing wall (Figure 3). The expected outcomes; reduce disturbance of building occupants, improve the thermal performance, minimize building material waste.



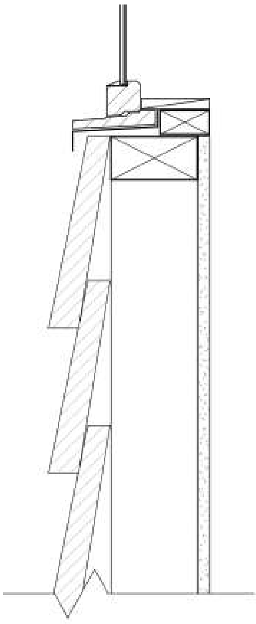


FIGURE 2. EXISTING WALL, NO INSULATION.

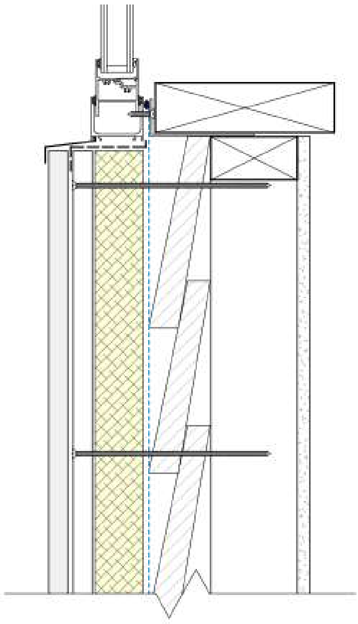
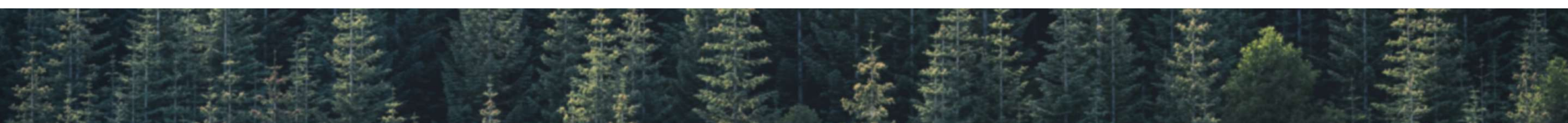


FIGURE 3. PARKA WRAP LAYERS ADDED OUTSIDE OLD.

If a parka is an insulated winter coat, the Parka Wrap is a winter coat for buildings - designed to protect families from frostbite, wind and cold.



1.3 THESIS STRUCTURE

Chapter 1 Outlines the purpose of the research and introduces the importance of the proposed outcome for New Zealand weatherboard houses. It allows the reader to understand the Parka Wrap concept and why insulation should be applied to existing house walls.

Chapter 2 Defines the research question and primary aims for the following chapters. This chapter also looks at the scope of the research and its limitations.

Chapter 3 Introduces the background information to better understand the research question. In this chapter the legislation and building codes are investigated and expert opinions are shared. The wider social implications of displacing occupants while renovations are happening is introduced. The need for efficient building structures, insulation and heating are explored. Finally in this chapter the building envelope is explored to explain where the research is targeted for this thesis.

Chapter 4 Shows the case studies where insulation is used, externally and internally. Of note is the common use of external insulation and its benefits in thermal performance for a given thickness.

Chapter 5 Explores the design method and framework for the proposed design. The Software modelling used is introduced and results explained.

Chapter 6 Explains the design iterations, physical testing sequences and findings.

Chapter 7 Concludes and explores future actions.

2.0 RESEARCH QUESTION, LIMITATION & SCOPE

Whole-house modelling of a new design incorporates every feature of the building enclosure and considers how this interacts with its environment – both inside and outside. The benefit of this approach to design is in the predictable outcome. While the focus of this thesis is old walls, the same rules of design apply - the science must be done before building starts. The envelope is designed, modelled, changed, modelled, and confirmed to ensure a successful long-term fight against the surroundings – wind, rain, sun, humidity. All of this to create a comfortable range of living temperature (18-25 degrees Celsius), and with some predictability of the costs to maintain that temperature.
The technological challenges to design healthy new buildings have already been overcome. What is needed are designers willing to take on a changing expectation of comfort for existing occupants of existing buildings, and landlords and owner occupiers willing to spend on improvements to the fabric of the building. Benefits that will actually affect occupants, rather than merely complying with current Residential Tenancies Act (RTA, 2019) legislation requiring expensive heaters.

2.1 RESEARCH QUESTION, AIMS & OBJECTIVES

This thesis is about retrofitting insulation to existing uninsulated walls. It is not about the whole house, but the whole house must be considered when applying changes to the thermal envelope to avoid unanticipated or unforeseen consequences. These consequences are clearly laid out in MBIE guidance 'Retrofitted Insulation' where it is stated, 'Retrofitted insulation could affect the structural performance of an existing house if moisture were to accumulate in a wall cavity and cause timber studs to rot and collapse.' (MBIE, 2020).

The research question is:
Are there safer, more effective ways of improving wall thermal performance while limiting occupant disruption?

The Primary research aim is to:
Design new retrofit methodology where insulation is overlaid on an existing wall.

To achieve this aim, the objectives are to:
- Understand current housing typology and existing retrofit methods and effectiveness
- Design a system where insulation is overlaid outside an existing wall
- Model the effects of proposed design

The Secondary research aim is to:
Test the physical design recommendation and develop an application methodology

To achieve this aim, the objectives are to:
- Develop details for specific wall to window connections
- Model connections for sequencing during application
- Build and Test the system to ensure weathertightness is improved
- Develop solutions and recommendations for retrofit methodology for occupied buildings, without removing occupants.

The focus of the research is the wall only. There are a multitude of elements, physical connections and practical interrelationships within a single wall build-up so it is only possible to focus on the design and testing of the wall and the window to wall junction. The following aspects are mentioned briefly below but full investigation and/or design are considered out of scope of the thesis:

1. Roof wall junctions
2. Engineering of primary structure
3. Other weathertightness and insulation systems
4. Window performance (glazing and frame)
5. Heritage protection

1. Roof wall junctions.
There are several options to maintain thermal continuity with the removal and replacement of soffit albeit with a smaller roof overhang due to the additional build-up of materials outboard of the framing line. This approach gives opportunity to improve envelope performance in both truss roof (insulation at ceiling level) and skillion roof scenarios where external insulation would be prevented from reaching the top of the wall without removal of the soffit. The other option with more work involved is the connection of wall insulation with a warm roof overlaid onto an existing roof such as Allco’s Allrite Re-cover roofing system currently in development. Connecting weathertightness, insulation layer and airtightness/vapour control are three areas needing development of details. A BRANZ research report SR233 into the application of injected insulation named this area of insulation as critical: “This wall top soffit area is a critical part of the thermal envelope and it appears that it is often missed during installation.”(BRANZ, 2010). See also Figure 2.2.

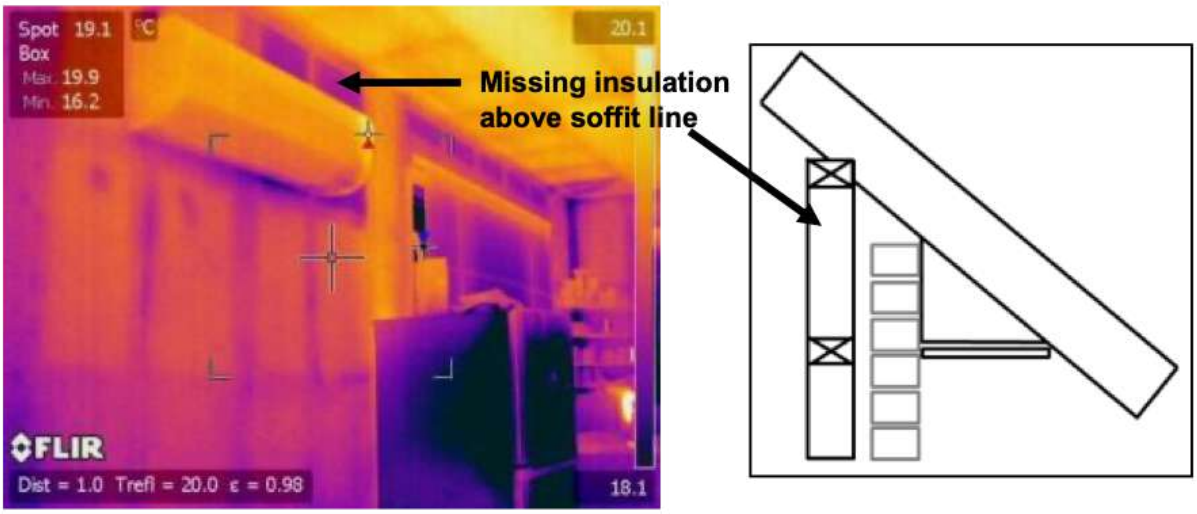


FIGURE 2.2 BRANZ SR233 SHOWED MISSING INSULATION WAS COMMON WITH INJECTED INSULATION.

2. Structural Engineering.

This thesis document does not investigate the engineering of the existing timber structure, only clearly pointing to the need to investigate and consider the integrity of an existing structure before attaching additional product to the outside. There are several things here; the integrity of the frame itself to ensure structural soundness (free from water damage causing rot), the ability for the frame to cope with additional dead loads applied (avoiding deflection of light-weight timber studs at wide centres if cladding loads are too high), and the ability of a sub-frame and/or primary structure to transfer these dead loads into the foundation (Figure 2.3). Where an existing timber frame and foundation is clearly in good condition – free from borer and/or moisture damage, there is little reason to doubt its ability to cope with an additional load of light-weight cladding as defined by NZS3604:2011.

FIGURE 2.3 INVESTIGATE STRUCTURE BEFORE ADDING TO IT.

3. Other weathertightness and insulation products.

With infinite combinations of products possible, research focusses on just a few to create a design solution.

Design solution uses SOLITEX ADHERO due to availability, performance, product support, weathertightness, and a much lower cost than main competitor Vaproshield. Rockwool insulation 100kg/m3 was used although there are several similar spun rock insulation products. All spun rock products are made from basalt and have similar properties. Other options are lower density glasswool products like Knauf 'Mineral Plus Rainscreen Insulation' and this was used in the initial mock-up because it was available, it has silicone treated fibres and a woven glass fibre facing that works as an additional water shedding surface. At 36kg/m3 product it's much higher density than traditional wall insulation but still does not have enough density to support cladding attachment with long screws as proposed. To counter this Technoform's Isolator Clip was used to provide structural stand-off for a cladding rail from the primary structure without compromising the thermal performance of the external insulation. The clips themselves are thermally broken and make up around 1% of a wall area. Proprietary clip and rail systems are available from other suppliers in the market but have not been investigated for performance, applicability or cost.

4. Window performance

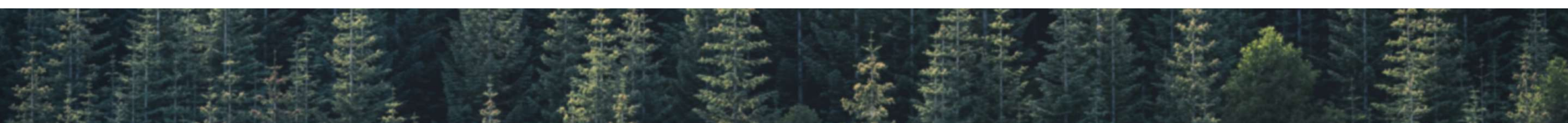
A significant portion of the practical (design, build, test) investigates the connection between the window and the wall. The focus is not on window performance itself. It is however anticipated the minimum acceptable frame type will be thermally broken aluminium with double glazing to avoid exacerbating the problem of moisture (condensation) accumulation on frames in insulated homes.

5. Heritage Protected buildings.

Heritage protection is out of scope due the nature of overlaying new materials onto existing walls and replacing poorly performing windows at scale and at reasonable cost. By definition heritage protection seeks to preserve original features, materials – 'Avoid work that will… obscure fabric of heritage value' (NZHPT, 2007).

3.0 BACKGROUND & LITERATURE

This chapter introduces the background information to better understand the research question. In this chapter the legislation, building codes and health implications are investigated and expert opinions are shared. The wider social implications of displacing occupants while renovations are happening is introduced. The need for efficient building structures, insulation and heating are explored. Finally in this chapter the building envelope is explored to explain where the research is targeted.



The New Zealand Building Code has been updated several times since the 1960's however our recent and ongoing (Thomas, 2019) leaky building crisis shows not all of the derived acceptable solutions have been good for buildings. It stands to reason the application of building technology must be done with caution and with the very best knowledge from building application technology from around the globe. Applied building science shows how the technological improvements (legislated use of insulation) introduced in 1978 began to degrade houses, along with other poor choices (Dyer, 2019). This knowledge should ensure we apply existing (better) knowledge to avoid respiratory illness prevalent in damp mouldy homes.

The New Zealand Building Code is performance-based, rather than prescribing how a building should be put together, or what it should be made of, it requires outcomes such as '...have a low probability...of...collapsing during construction or alteration and throughout their lives.' (NZBC Clause B1.3.1). This approach means we have a strong framework for building wonderful homes, schools, commercial spaces for office and industry.

The New Zealand Building Code's related clauses for this thesis could be summarised in this way:

1. Stand up and cope with seismic movement (B1 Structure).
2. Not degrade quickly (B2 Durability).
3. Keep water out – be dry resulting in durability (E2 External moisture).
4. Be comfortable for occupants - be easy to heat (H1 Energy Efficiency).
5. Not burn down quickly so occupants have time to leave (C clauses – Fire).

The problems begin when you cannot meet the functional requirements together. New Zealand has a very strong history of constructing leaky buildings (Dyer, 2019). New Zealand also has a strong history of constructing cold buildings that are not good for our health as evidenced by Lucy Telfar-Barnard's research into 'Excess Winter Mortality' (2010) and the types of homes most likely to contribute. It was discovered it made little difference what decade a house was built in and what condition it was in, our houses kill us more often than OECD averages. Our houses are in poor condition.

Close to 57% (1,040,000 dwelling units) of all residential building stock located in New Zealand were built before 1980 (Ryan, 2008). In his 2019 book Rottenomics, Peter Dyer describes that in the periods prior to the 1980's the building trade was made up of highly skilled workers that built homes that are now sought after. Those older homes are regarded as better than more recent builds which are known to have a tendency to leak. This means it's a knowledge problem - the knowledge used to successfully build those homes [pre-1980] has largely disappeared.

The Healthy Homes Guarantees Act 2019 (NZ Government, 2019) provides legislation to ensure homes are fitted with a heating appliance to be able to heat internal living spaces to 18 degrees Celsius. The legislation requires landlords to provide heating sources in all tenanted dwellings along with insulation in ceilings and floors where possible (MBIE, 2019). The problem is building occupants are unlikely to enjoy the temperature increases and expected result in improved health outcomes due to the cost of energy.

Heating appliance expenditure for landlords is understandable to avoid prosecution under the Residential Tenancies Act 2019 (NZ Government, 2019), but supplying a heater doesn't equal warm homes. This can be interpolated from Study Report SR372 'Warm, dry, healthy?' house condition survey data that included owner-occupiers (BRANZ 2015) and found homes to be underheated and damp.

The legislation change could also give an opportunity to improve a home's building fabric. Applying the outcomes of this study directly does not result in a warm house but is one element of the building's improvement requiring other products and systems (heating, ventilation) to be combined to reach an energy demand target.

Given extensive worldwide and local research over decades, knowledge of the benefits of warm and dry homes could reasonably have driven change in legislation to a much greater impact than it has.

Completely uninsulated buildings should now be relatively rare, but it is estimated across New Zealand's 1,800,000 homes there could be as many as 40% (720,000) yet to be improved from when they were built (Ministry of Housing and Urban Development, 2020).

These uninsulated homes consume more than twice as much energy to maintain 20 degrees than a similar pre-1978 house but RTA compliant (perfectly insulated ceiling and floor) – See Section 6.3. It is also estimated only 67% of tenanted buildings are insulated to required standards (White and Jones, 2017).

Insulation in houses has a health benefit and a social benefit. Phillipa Howden-Chapman's 2001/2 study on Housing, Insulation and Health found 'the benefits of insulation outweighed costs by almost two to one' (Figure 3.1). Interventions included ceiling and underfloor insulation which had a small effect on the internal temperature of the homes studied. The newspaper article highlights the realization that a benefit to an individual (a private benefit) ie. being warmer and healthier, is really a public benefit to our country in the reduction of healthcare costs, improved school and work attendance, and reduced energy consumption.

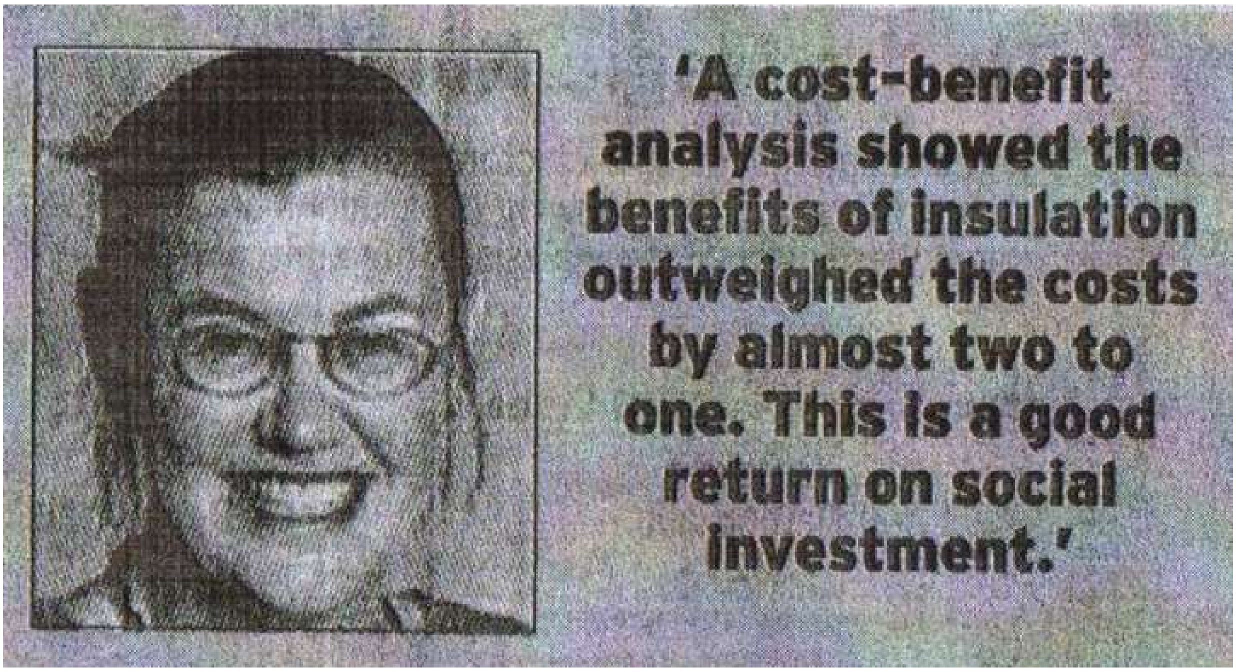


FIGURE 3.1 PHILLIPA HOWDEN-CHAPMAN. IMAGE CREDIT: DOMINION POST, NOVEMBER 4, 2008.

3.3 DISPLACEMENT OF OCCUPANTS: A SOCIAL ISSUE

Renovation is a rare opportunity to improve a building's performance (Davies, 2018). Improving the qualities of the building fabric is an infinitely better option than providing a heater occupants are unable to afford to use. Improving the thermal qualities of New Zealand's poorly insulated housing is for the social benefit of people. The nature of normal renovation – specifically pulling off internal linings to insert wall insulation – is very disruptive. In most cases occupants likely need to vacate the building for weeks or months in order for demolition work, reinstatement of linings, bathrooms, kitchens to occur. It is this disruption that can be avoided by applying external insulation rather than a 'linings off' insulation retrofit. The disruption is not just in the moving, but in the options occupants have – two thirds of these buildings are occupied by renters (White and Jones, 2017). The options available are conceivably going to move them from their immediate community, possibly away from children's schools, and access to work. Removing tenants is also a disincentive to landlords due to loss of rent.

3.4 PASSIVE HOUSE

Early in the research the target was to design for EnerPHit standard (passive house standard for retrofit projects), this target was superceded to focus on developing improvements for the walls only. This acknowledged the initial narrow focus on a single building and it's intricacies to bring it to EnerPHit standard, and instead develop a practical method of improving more than 900,000 homes across Aotearoa New Zealand.

This study uses the benchmark of 'Certified Passive House' as a comparison for energy demands using the software package PHPP (Passive House Planning Package) which has proven itself worldwide. For the purpose of this thesis using this software provides a sensible control and comparison for planned improvements to an existing building enclosure.

The target energy use for heating or cooling in a certified passive house is a maximum of 15kwh per square metre per year. This is a very low amount of energy to keep a house warm and means the thermal envelope (the insulated external part of a building) is very good at keeping warmth in. A new New Zealand house might have a demand of 120kwh, or 200kwh, or more and still not achieve what a carefully designed thermal envelope can with maintaining temperature. As shown in the modelling the heating energy demand for uninsulated and/or poorly insulated homes could be more than 400 kWh/m2/annum. It is difficult to compare all houses realistically, however the software gives some ability to show the differences between exactly the same building as shown in Section 6.3.

FIGURE 3.2 THE FIRST EUROPEAN WEATHERBOARD HOUSE BUILT FOR JAMES BUSBY IN 1834 AND NOW KNOWN NOW AS THE WAITANGI TREATY HOUSE.
IMAGE SOURCE: WWW.WAITANGI.ORG.NZ.

Weatherboard walls are found on New Zealand houses built across every decade since a timber framed European house was first erected in Waitangi in 1834. This wall type was chosen for the research and development of the Parka Wrap methodology due to the simple fact of the popularity, and how many walls are uninsulated.

A note on structural design.
Most of the buildings that will use Parka Wrap techniques and products as proposed are expected to be low level (<10m) housing built to NZS 3604 or older equivalent standards applicable at the time. It will be important to have a clear idea of what can be applied (additional weight) to existing frames – as guidance on Renovate.org points out: “All renovation work must begin with a detailed survey of the building structure.” There are specific issues with houses built in different time periods that must be considered, such as typical 1940’s framing sizes (therefore their capacity to bear additional load) for instance, “Structural problems in 1940s-60s houses may include undersized framing, inadequate bracing, and unsafe chimneys.” (Renovate, 2020)

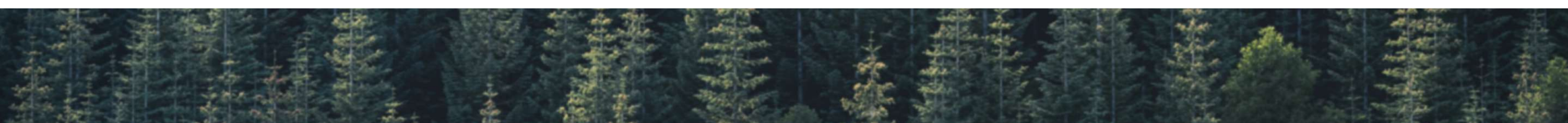
Moisture sensitive material.
New Zealand’s typical construction for residential construction is lightweight timber structures that are moisture sensitive, that is, when wet and maintained wet, timber framing is at high risk of decay. We have seen this play out in our leaky building crisis where a combination of materials, design and workmanship coupled with poor or no maintenance regimes have resulted in water ingress and significant levels of decay (Dyer, 2019). In some cases the moisture damage has been enough to warrant demolition rather than repair.
Finding damage is not always straightforward however a visual check for rotten weatherboards or stain lines and invasive checking may be required. The positive part here is, the over-cladding process will cover holes and even removed weatherboards, therefore making no difference to the finished wall. The ‘negative’ will be in the added cost of removing and replacing rotten framing if it is uncovered. Uncovering and repairing is undoubtedly safer (structurally and to avoid mould spores in the home) than leaving rotting timber inside the walls. The additional costs here must be put in two risk baskets. The risk of finding damage and degradation with a potential single cost to fix, versus the risk of not uncovering damage and degradation which is a potential ongoing health cost.

In New Zealand the need to heat may be considered relevant for a few winter months, yet this is inaccurate when recorded climate data is considered. NIWA's data sets from 1981-2010 shows we have a climate predominantly requiring heating (NIWA 2020). Only Kaitaia and Whangarei have a single month (February) where the average monthly temperature is above 20 degrees Celsius (20 and 20.2 degrees respectively). Insulation material slows down the movement of heat, so an adequately insulated house will prevent heat loss in winter and heat gain in summer through those insulated elements. An insulated wall will not stop heat pouring through plain glass facing east or west though, so these elements should be considered as part of holistic approach to building envelope improvement. Through understanding what we have (a climate needing heating for comfort) we can better plan for efficient use of heating.

A commonly heard catch-phrase in New Zealand is: 'warm up your home with insulation' - the intent may be right but it is not true. This promise is sometimes even stamped on the bags of insulation (see Figure 3.3) Insulation does not warm up a home. Heating warms a home, while insulation slows down heat loss in winter and heat gain in summer. It's a subtle message and could lead to a belief that houses don't need heating. If tenants/occupants cannot afford to heat, it is not reasonable to expect insulating alone will make a valuable difference unless Certified Passive House standard or better is achieved. Insulating will possibly make a home feel colder (if not heated) as it will then not experience the temperature fluctuations where sun on opaque (cladding) wall assemblies with no insulation allows heat transfer into the building quickly. Insulating slows down this heat flow.

FIGURE 3.3. 'WARMTH YOU CAN REALLY FEEL'? A MISLEADING MESSAGE. INSULATION DOES SLOW DOWN HEAT LOSS, BUT IT DOESN'T HEAT. IMAGE CREDIT GREENSTUF.

Heating is the one thing that reliably increases the temperature in a home either by heaters or the sun (when it's shining, and shining in the right direction, and preferably shining in the windows). This is true for an uninsulated home as much as it is for some of the best possible houses available - Certified Passive Houses. The only difference is the rate at which heat is lost. The uninsulated house loses heat very quickly and requires large energy input to maintain 20 degrees Celsius. The Certified Passive House might lose heat 10 times slower than an insulated house. An old uninsulated wall with single-glazed windows is going to be losing heat much faster – see modelling in Section 6.3.



Common strategies for new homes as well as renovations is to put insulation within the frame line. While there are some positive reasons for doing this – containment, and protection from elements - the performance of the insulation is significantly reduced when installed this way – see modelling in Section 6.1. This critique is not of the installers who have the potential to do perfect work, but against the industry expectation that the R-value stamped on the outside of the bale of insulation is going to result in that R-value installed.

Beacon Pathway, a New Zealand housing research group, recently released their study ER53 (2020) that surprised the industry somewhat – it was expected that timber made up approximately 18% of the wall, therefore the remaining available space was able to be insulated i.e. between timber framework of studs and nog/dwangs. The findings were quite different. They found on average 34% of the wall was framing. Timber is only 25% as effective at insulating when compared to air-filled fibrous insulation (fiberglass, polyester, cellulose or wool) so this 'additional' timber makes a big difference to overall wall performance. This means the wall's effective R-value - while always a lower than the R-value stamped on the insulation bag - is lower again than expected. To calculate this, every piece of timber frame was assigned a heat loss u-value, and the remaining insulation space is assigned its u-value. The more timber there is performing at a lower value, the lower the overall wall performance (Ryan, 2020).

Beacon Pathway's study ER64 points toward the effectiveness of external insulation – even though the study was about in-wall insulation effectiveness. They found the biggest change to an insulated wall was insulating outside the perimeter of the concrete slab: 'The largest single increase in wall construction R-value is attributed to insulating the floor slab edge on single level houses which improves the whole house wall construction R-value by around 40%' (Ryan, 2020). This is useful background information even though insulation connections at the base of the wall are outside the scope of this study. These effects are investigated further in Chapter 6 by software modelling.

External insulation by nature continuous - it sits external to the frame therefore unaffected by thermal bridging of that frame. There is need for attaching cladding through the insulation and there are many different solutions (Finch and Higgins, 2018) available in New Zealand and tested worldwide.

3.8 BUILDING ENCLOSURE ENGINEERING

Building Enclosure Engineering is a still a developing field within the New Zealand context. Enclosure engineering combines a knowledge of materials, design and physics to better anticipate building performance and consequence of poor planning and execution. Consequently, the industry is still largely required to employ expertise that has gained knowledge internationally. Unfortunately it is incorrect to expect a building will be warm simply because it has double glazed windows and partially insulated wall, floors, and ceilings. Basic elements of a building enclosure are continuous layers; of structure, of insulation, of weathertightness and of airtightness – all needed to ensure adequate building performance. These layers must work together in conjunction with other non-façade items – heating and ventilation. When buildings do not work as a system, we get designs that might have individual component's compliance with specific New Zealand Building Code clauses and relevant standards, but they can't work together as a system: "Supplementary to insulation [are] the services of a home. Mechanical systems… to regulate… air flow… to ensure there is no potential damage to the building fabric and is no discomfort to the inhabitants." (van Raamsdonk, 2011).

According to the Ministry for Business, Innovation and Employment (MBIE), the largest potential problem for retrofitted insulation in relation to NZBC Clause E2.3.2 is the bridging effect of the material, which they note in specific insulation retrofit guidance documentation, "… allows moisture on the inside of the cladding to penetrate further into the wall cavity, to framing and the lining" (MBIE, 2020).

There is a knowledge gap in the industry – a limited knowledge of building science and its application. As a generalization, this is coupled with low thermal performance expectations from designers and consultants. This means as a country neither designers nor homeowners know what to ask for or expect, and in the majority of cases the design community have not been taught new techniques. If they have, it may have been piecemeal from suppliers trying to influence buying/specification decisions whether the information is accurate or carrying bias.

Additionally, there is a 'common sense' approach New Zealanders are proud of, a do-it-yourself approach which doesn't always work. For instance, common sense tells us to paint weatherboards completely to seal out the weather. That sounds reasonable however testing shows this is not a good strategy for the wall's ability to dry out. BRANZ have provided guidance on this recently in Guideline: "Don't seal the board laps – this restricts drainage and drying. Some manufacturers (and BRANZ Appraisals) require a 2mm expansion gap at the overlap." (BRANZ, 2021).

As the New Zealand Building Code is not prescriptive, we have freedom to design high performance new homes and improve existing low-performance homes. The literature findings highlight the following points:

- 830,000 homes have uninsulated walls.
- Cold housing affects health.
- There is need to retrofit homes to lower the nation's rate of respiratory illness.
- Slowing down the heat loss by insulating a building still means heating is required.
- Slowing down the heat loss may mean a lower energy demand occurs.

In the author's opinion, New Zealand's building industry also needs to overcome an aversion to accepting advice that will improve the building stock through better use of building science, materials, and internationally accepted performance standards. Introducing and enforcing better standards has a demonstrable effect on internal temperatures in homes and a reduction in energy consumption to maintain those temperatures.

To achieve change, the design community needs guidance for new and retrofit design to meet targets for energy. The contractors need this guidance and the ability to create these designs. We need a new language and culture of performance in construction. The options are:

1. Continue to design and build legal housing that is not fit for purpose – not to the reasonable performance of liveability possible. This looks like meeting the legal minimums of insulation levels, ventilation of small areas of the house, and only considering a heat source for rental accommodation because it's now law. This does nothing for the health and wellbeing of the occupants and costs nothing except for the high cost of ongoing healthcare related to cold buildings.
2. Choose to improve the fabric of the building, conserve energy (retain energy in the building), and thereby improve the comfort and health of occupants. There is little doubt this is the most expensive (of these two options) by way of capital cost, however meeting very specific performance targets means ongoing heating costs are lowered. This low cost of maintaining heat is a critical factor in assisting low-income families to improve their economic situation. Instead of Government spending money on ongoing healthcare it could eventually be spent on supplying other low-performance buildings – building new homes. According to recently released analysis by Aecom, building new medium density housing to Passive House standard does not need to cost more than a Building-Code minimum with 'oversized' heatpump when this target is designed in from the beginning of a new-build process. (Mitsiakou and Cheshire, 2021).

4.0 CASE STUDIES

The following cases will be reviewed:

- The Zetland Passive House in Manchester, United Kingdom
- The Kainga Ora retrofit project in Wellington, New Zealand
- The Kurobe Passive House in Kurobe, Japan
- The generic ‘Leaky Building’ in New Zealand - a material review

The purpose for reviewing the three named projects is to understand the thermal performance improvements possible when retrofitting buildings with insulation. The differences in materials selection is highlighted and give guidance for what can work in New Zealand, and also based on the fourth case - the Leaky Building Crisis, what should be not be copied from international examples due to differences in building materials.

Two Certified Passive Houses have been included in this review because the modelling, planning and retrofitting to reach the energy demand requirements is extremely rigorous and comparable across the world with similar buildings using the same software. It is this software used within the New Zealand context to demonstrate the thermal performance gains using the Parka Wrap intervention and shown in Section 6.3.

ZETLAND PASSIVE HOUSE, UK.

FIGURE 4.1.1 ZETLAND PASSIVE HOUSE – RETROFIT ON INSIDE AND OUTSIDE – HERITAGE PROTECTION CHALLENGE. IMAGE CREDIT: PASSIVE HOUSE DATABASE.

Located in Manchester, England, the Zetland Passive House is a duplex dwelling and a double-brick heritage building. To retrofit the building, a combination of internal and external insulation was added to the walls. To ensure brick was visible on the street-facing side, it was insulated internally. On the remaining sides it was insulated on the inside and the outside. Zetland is an interesting project to understand the application of materials for the sake of performance in respect to moisture. Different products were used to cope with the differing risks of moisture accumulation, including the use of vapour control layers. Although the project was successful, it was far from cheap as the developer points out: “It was very uncompromising as a project,” Knowles says. “Although it’s not economic in its own right, it means that we’ve got the solutions moving forward.”(The deepest greenest retrofit ever? - passivehouseplus.ie, n.d.)

When considering improvements onto the outside surface of an existing façade it’s clear as noted in the limitations of research, that heritage protection requires a significantly different approach. What is also important when considering ‘similar’ performance in New Zealand dwellings, they do need thermal improvement to either improve comfort or reduce energy demand for heating, or both.

KAINGA ORA HOUSING IMPROVEMENTS, LOWER HUTT, NEW ZEALAND

FIGURE 4.1.2 TYPICAL KAINGA ORA SOCIAL HOUSING MULTI-UNIT TIMBER FRAME CONSTRUCTION. IMAGE CREDIT KAINGA ORA.

Kāinga Ora has recently (2018) upgraded a series of houses (approximately 60) in Lower Hutt using similar principles of envelope improvement, software modelling and includes ongoing monitoring. This has been achieved in conjunction with Jason Quinn from Sustainable Engineering Ltd. While it is not yet clear whether access to the project details and long-term data will be available, the decision-making process analysing the performance was undertaken using modelling software (hygrothermal) to guide the interventions which were; additional insulation, targeted airtightness, and providing heating. John Tocker from JTB Architects led the design challenge to achieve Kainga Ora's stated goal of 'warm, dry and healthy' homes. One of the biggest challenges encountered was in the expectation of very high occupant numbers and thereby overloading the structure with moisture. Due to this challenge a smart vapour control layer was used for the first time in Kainga Ora homes.

This improvement example of social houses in New Zealand is an important example of what can be achieved with careful planning. As this was a 'linings off' internal intervention, tenants were required to move during construction. This improvement with some modification is currently being rolled out across approximately 2500 Kainga Ora homes nationwide including a further 70 homes in Wellington. Intervention includes only 70mm of insulation installed between studs which leaves 20mm of drying space between insulation and cladding. While this may prevent water transfer into the wall cavity it lowers the potential thermal performance of the upgrade. To compare, insulation within a wall can only be installed into approximately 30% of the space due to framing (Beacon Pathway, 2021), while insulation installed as a blanket is close to 99% uninterrupted as calculated using a cladding support calculator developed for Technoform's Isolator Clip (Technoform, 2020).

KUROBE PASSIVE HOUSE, JAPAN

FIGURE 4.1.3, 4.1.4 KUROBE ENERPHIT (RETROFIT) PASSIVE HOUSE IN KUROBE, JAPAN.
BEFORE AND AFTER PHOTOS. IMAGE CREDIT PASSIVE HOUSE DATABASE.

The ‘Kurobe’ Enerphit (Passive House) project is a 27-unit apartment building in Kurobe, Japan, renovated using external insulation techniques and completed in 2017.

Over-cladding of the masonry walls used vapour-closed insulation (Extruded polystyrene). Expanded polystyrene was also used which is less vapour-tight than XPS but similarly decreases drying capacity of moisture sensitive walls. The use of XPS or foil-faced PIR on masonry buildings poses little risk of structural damage, and large benefits of energy/heat retention. Over-cladding of other sections of the building were undertaken using 125mm of Rockwool.

One of the considerations when retrofitting external insulation and new cladding is the weight increase. It is interesting to note in this project the overall weight was reduced where concrete balconies were removed and replaced with steel framed accessways. The improvements were in the continuity of external insulation and the weight reduction allowed for elevators to be installed within the new balcony/walkway structure. This example is of use as there are similarities in construction methods in New Zealand with a mix of wall (concrete, timber) and floor types to be considered for improvement.

ONGOING LEAKY BUILDING CRISIS, NEW ZEALAND.

FIGURE 4.1.5. LEAKING AND ABOUT TO BE DEMOLISHED. 17 TOWNHOUSES, GLENSIDE CRESCENT, EDEN TERRACE, AUCKLAND. 2014. IMAGE CREDIT AUTHOR.

Leaking buildings let water in, trap it and this results in decaying framing and structural degradation. Cladding, insulation material and cladding detail designs are the critical choices to keep water away from moisture sensitive framing materials (timber or steel).

Insulation material is only as good as the protection of that insulation from air movement (van Raamsdonk, 2011). The selection of a fibrous type of insulation (rather than closed sheet like XPS, PIR, foil faced PIR) is a safer option to achieve compliance with B2 Durability requirements as well as the performance objectives of E2 External Moisture (prevent accumulation of external moisture) and E3 Internal Moisture (prevent accumulation of internal moisture).

Insulation material that doesn't allow vapour to dry through itself such as extruded polystyrene (XPS) was considered, but its ability for entrapment of moisture against a timber frame wall does not make it a viable product for overlay. Similarly, the testing will avoid the use of injected formaldehyde foam insulation. Studies conducted by BRANZ highlight several ill effects on the structure (moisture entrapment), errors in workmanship resulting in building damage, and the difficulty in both installation into all cavities and subsequent quality checking. Shrinkage over time has been another concern of wet installed products (BRANZ, 2011). These reports (SR233 and SR234) are invaluable when considering similar blown-in applications of insulation as many of the same issues and challenges are present with dry products too.

External insulation has some clear thermal improvement benefits and is accepted and used over non moisture-sensitive materials in other markets successfully. However, the use of these systems in New Zealand has resulted in moisture damage from both internal and external sources. This has been highlighted by BRANZ study reports and the ongoing Leaky Building Crisis which has an estimated 'fix up' cost of $52.3 Billion dollars (Dyer, 2021). External insulation is not responsible for all of the related moisture issues in New Zealand buildings however, but the impact of any application of materials in a building envelope must be carefully considered. Specifically, the success of externally insulating structures world-wide can be seen predominantly in improvements to masonry buildings. Where timber or other structures are 'wrapped', the choice of materials and position is critical to prevent moisture accumulation.

The learnings from this chapter are

- the need for understanding material performance
- the importance of modelling likely effects using software tools available
- the significant improvements possible with retrofit insulation

5.0 DESIGN METHOD & FRAMEWORK

The design output of this research will look into prototyping wall assemblies using available materials in the New Zealand market.

The purpose is clear: the performance of insulation when installed in walls has been demonstrated to be lower than anticipated, and current retrofitting practices increase the risks of moisture entrapment.

Iterative Design

It has taken many hours of iterative design - testing, redesign and retesting to come to a solution for walls. Therefore, there is little doubt experienced designers will have difficulty coming up with all the details that can answer every high-level requirement of the building code. Success certainly requires trial and error and access to research, materials, experience, and expertise that have been available during this process. This then is an iterative design - a trial and error approach – where weaknesses are discovered, improvements are made, with a feedback loop directing redesign where required before retesting.

The realization designers are doing this in isolation again and again across the country for buildings of all scales and typologies means different levels of success will be occurring. Of course, some of these buildings are simple like-for-like renovations. The potential problem is, as an attempt to improve walls for thermal performance can have unintended consequences of moisture entrapment, IAQ degradation (where ventilation is not adequately addressed), or just simply giving a false expectation of comfort.

The tests through iterative design are described below.

1. Selection of suitable materials
2. Software modelling
3. Building and testing models
4. Testing large scale models

5.1 SELECTION MATERIAL FOR SOFTWARE MODELLING & TESTING

The planned build-up of materials for use in the common wall assembly has been refined to include (in order from the existing cladding outward):

- Weathertightness layer SOLITEX ADHERO
- ROCKWOOL insulation segments at 100kg/m2
- Tanfor Galvalume steel structural battens
- Cladding (lightweight, <30kg/m2)

SOLITEX ADHERO is a peel and stick membrane with well tested and proven weathertightness characteristics using a TEEE (Thermoplastic Elastomer Ether Ester) monolithic (non-porous) film. This film prevents liquid moisture from penetrating while allowing water vapour to pass through – allowing for drying of the structure. This product also fulfils the requirement of an air barrier to prevent water being driven through gaps/holes in the building fabric.

ROCKWOOL is a spun basalt rock. The 100kg/m3 insulation slabs used have a thermal conductivity of 0.034 W/mK at 20 degrees Celsius which is slightly better than lightweight fibrous insulation typically used in New Zealand construction within wall cavities (usually around 0.04 W/mK). Rockwool is unaffected by vermin (it’s rock), by sunlight/UV, by water although it must remain free-draining when in a position where it could be temporarily wetted - as discovered in my water testing with no cladding and an accidental water catch-tray at the base of the wall (see Section 6.5.9 images). It has high structural integrity meaning it will not slump, and with a density of 100kg/m3 can be used with battens resting directly onto the outer face. Using the density and structure of the insulation it provides support in a truss arrangement in conjunction with long screws through the batten and fixed into the underlying building structure.

TANFOR batten. 1.2mm BMT Steel batten with a Galvalume coating to prevent corrosion. Battens are structural which means they can transfer imposed loads from cladding weight and wind pressures from the cladding through to the underlying structure.

CLADDING. Selected cladding for water deflection and aesthetic purposes. The material and type of cladding is not critical, however the weight is. Any existing structure could be expected to carry some additional load unless it’s been designed and operating at 99% load capacity already – highly unlikely. This has been confirmed in principle by Oculus in-house engineers and John Chapman from the University of Auckland's Engineering Department (ret), with the caveat any structure including foundation should be carefully inspected and consideration given to accumulated weight ie. the difference in loading of foundation wall or piles/posts for a single storey vs two storey.

Software has been used to measure wall assembly and building envelope performance. The energy demand is directly related to the thermal performance of the building envelope, but the exercise is not simply a case of creating a thicker and thicker wall to make an improvement. The balance of insulation, airtightness, ventilation, and heating within a house must be understood. The three key software analysis tools used to plan for retrofit interventions are:

1. Single element heat transfer: 'Thermal Bridges' can be measured using a software package called THERM. The software allows the user to demonstrate the thermal performance of materials in three dimensions and allow targeted improvement of junctions. THERM modelling has been undertaken by Denise Martin from Oculus Architectural Engineering to inspect wall insulation performance where it is placed within framing (timber and steel) and external to the framing – Parka Wrap design. This then guides the design and also provides a method of fact-checking the automated inputs within PHPP modelling software.

2. Wall assembly: WUFI software is a hygrothermal modelling tool that firstly evaluates materials specification for their ability to slow down heat transfer in or out of the building. The software secondly assesses the ability to slow down, speed up or stop moisture transfer in and out of the building. The software takes in to account specific climate conditions outside (geographically based climate data from NIWA), and internal climate conditions based on heat, ventilating, number of occupants and other expected moisture loads. The simulations provide guidance to the modeller, assisting in the decision making process when trying to avoid interstitial condensation. In short, it predicts moisture accumulation and moisture loss over time, with a key piece of information shown in the amount of water in an assembly at the beginning and at the end of the simulation period. This is vital knowledge to the overall durability performance of a building.

3. Whole building: Understanding the full picture how a building performs within a site-specific geographical location. Architects use a calculation tool called 'Passive House Planning Package'. The software contains a large spreadsheet that accounts for the performance of individual components of the building and includes factors of size, orientation, materials of windows and even how they connect into the wall. The software aims to improve insulation design to predict the energy demand and energy source. The modelling software's primary purpose is for evaluation, as it enables designers to test hypothetical improvements and decisions. For instance, deciding on specific thickness of insulation onto existing walls. The software allows these things to be chosen with confidence in outcome.

The downside to relying on simulations is that they can assume perfect installation of insulation. In reality this in unlikely, and as is described in NZS 4246:2016 2.4, "Effect of poor insulation installation on thermal performance. Gaps, shrinkage, folds, tucking '…gaps as small as a few millimeters around the edges of insulation can halve the overall thermal resistance'." (Standards New Zealand, 2016).

5.3 PAPER DRAWING,FABRICATED DETAIL ASSEMBLIES

The use of drawings to formulate assembly concepts are important. It enables a range of ideas to be quickly tested within software as above, and peer-reviewed by colleagues. Once satisfied, the assembly detail is fabricated to 1:1 scale. The scale model enables the following:

1. Validating the design assembly
2. Allow for sequence of installation to be determined a success or failure

5.4 LARGE SCALE TESTING

Within this body of research, the author developed carefully planned intervention and external improvement strategies for uninsulated walls on common timber-framed buildings.

Building a full scale wall using demolition materials (weatherboards and window) typical of a 1940’s bungalow was planned to test the wind and watertightness of these common assemblies. Testing was planned using a test booth at Shelby Wright Test Labs that applies wind pressure, water coverage, and seismic racking to the wall specimen. This first test simulated the performance of an existing wall. The second test took place after the Parka Wrap intervention had been added. This showed the effectiveness of weathertightness strategies, drainage and drying capacity of the assembly. It did not show the thermal performance improvement of the wall. This thermal improvement can only be shown in this study by modelling the effects of continuous thermal insulation within a software package (PHPP).

The following will always need consideration when designing:

1. Moisture entrapment must be avoided through careful material selection and design. It is important to select materials that do not have the potential to trap or carry moisture when retrofitting a home resulting in mould, rot and structural damage.
2. Improving insulation performance thereby thermal comfort and energy consumption must be achieved without causing harm and disruption to building fabric or people from moisture entrapment.

6.0 DESIGN

This chapter develops the design elements. It establishes the basis of design through software simulations of proposed layers. This is followed by the iterations of physical mock-ups showing the competing challenges of keeping building elements attached, allowing for drainage, and maintaining drying capacity for both external and internal moisture. Finally the central element to work around is the new insulation in a different position to traditional construction.

The main performance considerations for proposed retrofit methodology are dealt with in this chapter using these software models:

1. THERM. Representative heat transfer through materials.
2. WUFI. Hygrothermal analysis simulates the heat and moisture transport.
3. PHPP. Passive House Planning Package is a whole-house energy demand calculation tool.

The software modelling is followed by physical mock-up and testing:

1. Window sill mock-up with externally insulated panel and terracotta tile.
2. Weatherboard wall full scale mock-up
3. Flashing detail mock-up
4. Weatherboard wall with Parka Wrap layers and a new window

This series of thermal simulations using Therm software was undertaken by Denise Martin from Oculus Architectural Engineering Ltd. The modelling shows the heat transfer that occurs via framing – effectively bypassing the insulation between the studs. There are 4 different wall assemblies modelled. Insulation between timber studs is modelled in Figure 6.1, between steel studs in Figure 6.2. Figure 6.3 shows the addition of an XPS thermal break. Finally, insulation outside the wall is shown in example Figure 6.4. This example represents the thermal performance improvement with external insulation.

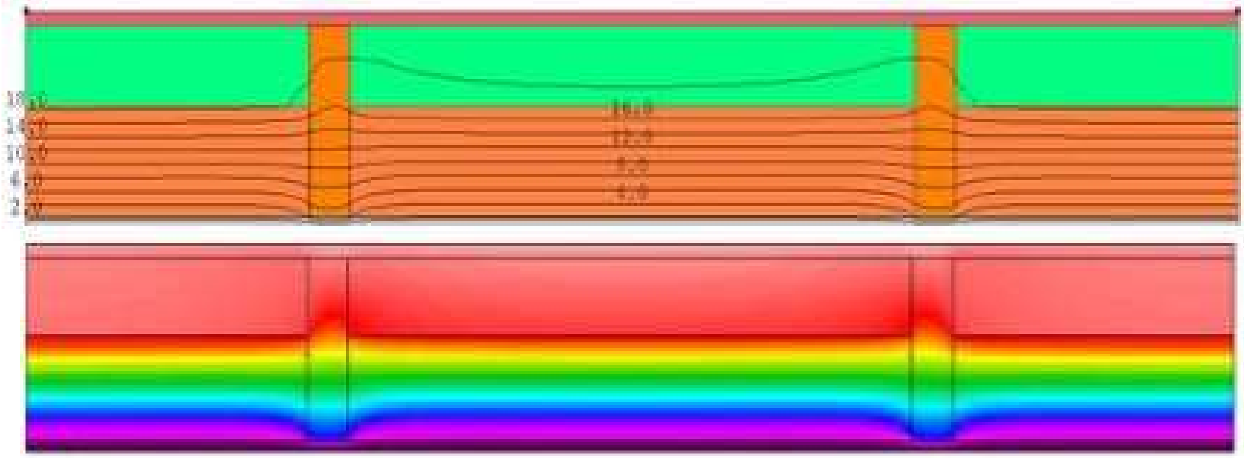


FIGURE 6.1.1. POOR OUTCOME. 140MM TIMBER @ 600 CTS 90MM FIBREGLASS INSULATION BETWEEN FRAMES.

The modelling shows external insulation is a better option than any type of insulation installed between any type of frame. In example four the result would be substantially similar if the steel frame was swapped to any frame/structure type such as block, precast concrete, timber frame or CLT. This is because the insulation is outside the framing line therefore keeping all of the frame on the warm side in winter conditions – there is no easy pathway for heat transfer. This does not suggest ‘internal’ insulation between frames is of no value, what it argues is the efficacy of external blanket insulation. There are instances where combining both will be of value.

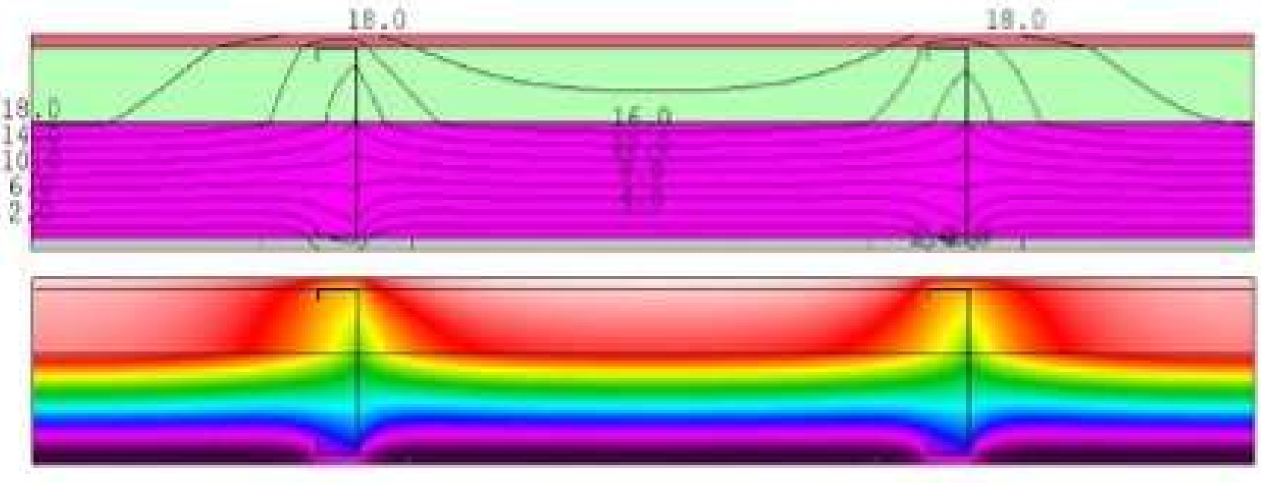


FIGURE 6.1.2. VERY POOR OUTCOME. 150MM 1MM BMT STEEL @ 600 CTS 90MM BULK INSULATION BETWEEN FRAMES.

The RAB (Fibre Cement) sheathing in every wall assembly modelled does not provide a thermal break, the steel stud is a thermal bridge conducting much more heat per square metre than a timber stud. This loss is not mitigated by the fact steel stud in Light Gauge Steel framing is only 1.15mm thick material compared to timber stud width of 42-45mm. This is because in this situation and thicknesses, the steel conducts heat through the wall 10X faster than the timber.

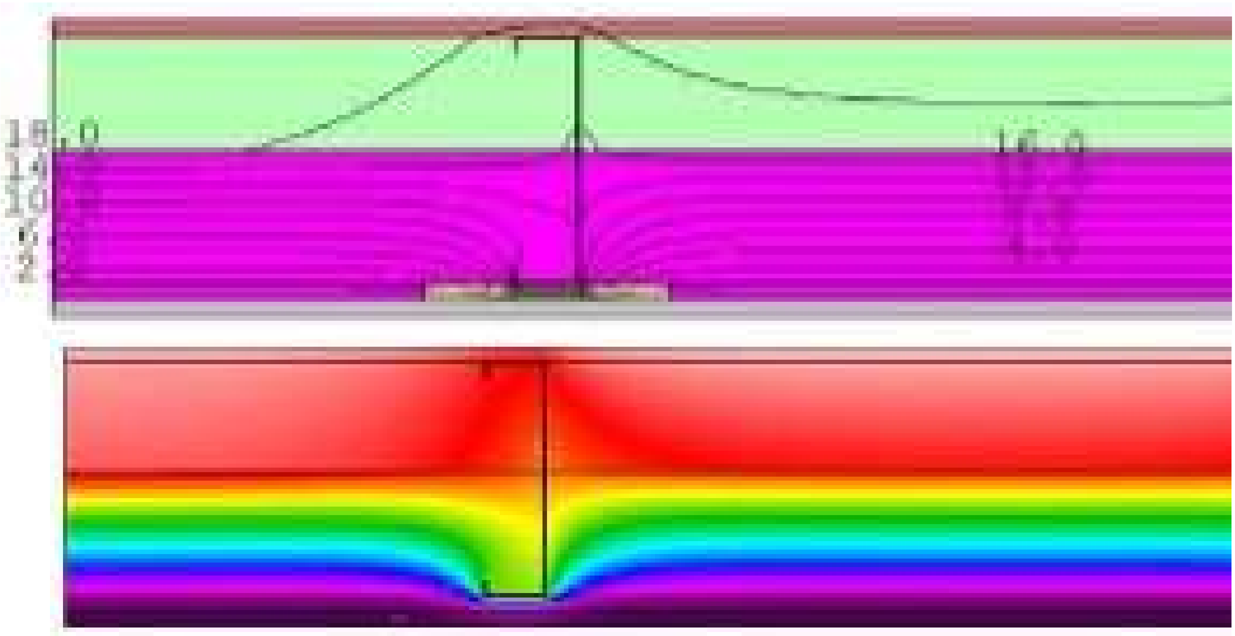


FIGURE 6.1.3. POOR OUTCOME. 140MM STEEL WITH XPS THERMAL BREAK (BULK INSULATION BETWEEN FRAMES).

Thermal energy is transferred 410 times faster through 1mm of steel than 1mm of timber. There are other factors here that affect insulation performance (radiation surface area, attached layers, still air layers). The solution is to ignore poorly performing elements and insulate continuously outside the line of the frame. This overcomes heat loss through framing members and eliminates the low performance outcomes of even the best segmented insulation ‘chop and stop’ between-frames install.

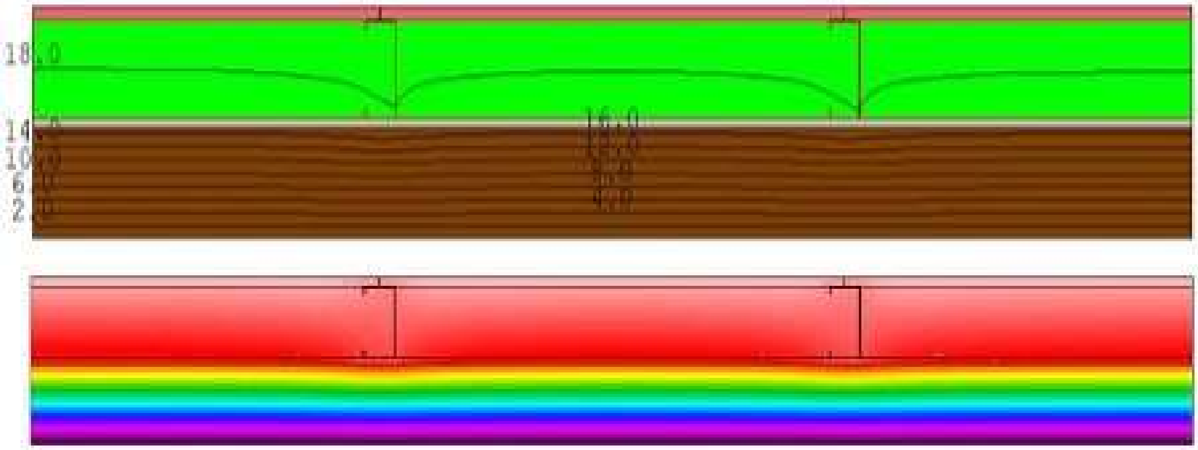


FIGURE 6.1.4. GOOD OUTCOME. 90MM STEEL WITH 100MM EXTERNAL INSULATION (OUTSIDE FRAME).

Summary of simulations.
Figures 6.1.1 and 6.1.2 show low overall performance of insulation when installed between frames and especially with steel frames. There is very little improvement using a wide thermal break in Figure 6.1.3, even though is accepted practice promoted by manufacturers. The step in performance improvement comes by putting the same insulation on the outside of the frame – see Figure 6.1.4. When insulation is moved to the outside of the frame line it is able to work with no thermal bridging to degrade the performance. It is important to note the frame material itself becomes irrelevant as thermal bridging through that material is eliminated.

Multiple WUFI software simulations were undertaken including modelling the old uninsulated wall, then in-wall insulation without smart vapour retarders, and finally the proposed wall assembly. A small selection is shown below. The climate area is Rotorua in the central North Island, and was selected because it is the author's current project in design. The purpose of modelling is to ensure no damage can be expected due to moisture entrapment within the layers (both old and new).
Weatherboard cladding on a cavity has been chosen to replicate a common typology that is likely to be replicated during Parka Wrap renovation and a southern wall orientation simulates the largest challenge for drying.
A single check was also performed using XPS polystyrene on a southern orientation in Rotorua to test this option. As predicted, XPS is not without risk of moisture entrapment and is not recommended over timber weatherboards in Parka Wrap assembly.

Figure 6.2.1 simulates an existing wall and shows some wetting of weatherboard occurs but drying (through air convection) overcomes any wetting event. Relative humidity is shown in green and stays below 80% across the uninsulated framing depth. In context, this outcome is already shown nationwide with every drafty, dry and durable 50+ year-old weatherboard building.

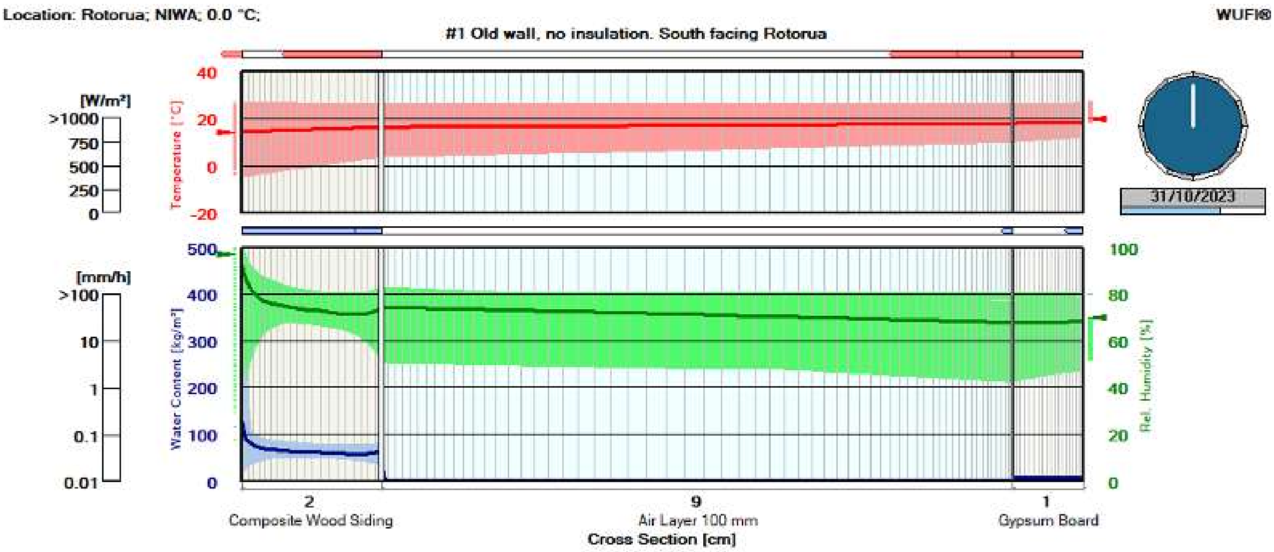


FIGURE 6.2.1. UNINSULATED WEATHERBOARD WALL, SOUTH FACING, ROTORUA.
HIGH POTENTIAL FOR DRYING DUE TO DRAFTY CONSTRUCTION.
WEATHERBOARD MOISTURE 75KG/M3 --> 68KG/M3. RESULT: SUCCESS.

The next simulation in Figure 6.2.2 held moisture in the insulation, preventing adequate drying. The simulation assumed insulation was installed directly against the weatherboards without any type of separation or drainage layer. MBIE strongly advises against this due to the 'effect on moisture transfer within walls' and BRANZ have changed their previous recommendation to now include drainage and drying pathways (Pringle 2016). Despite this, some material suppliers have certified methods of installing insulation to fill cavities. Based on simulations and later physical testing, this approach is not without risk of moisture entrapment. Elevated moisture levels above 80% in the framing and insulation space confirms this, as shown in green.

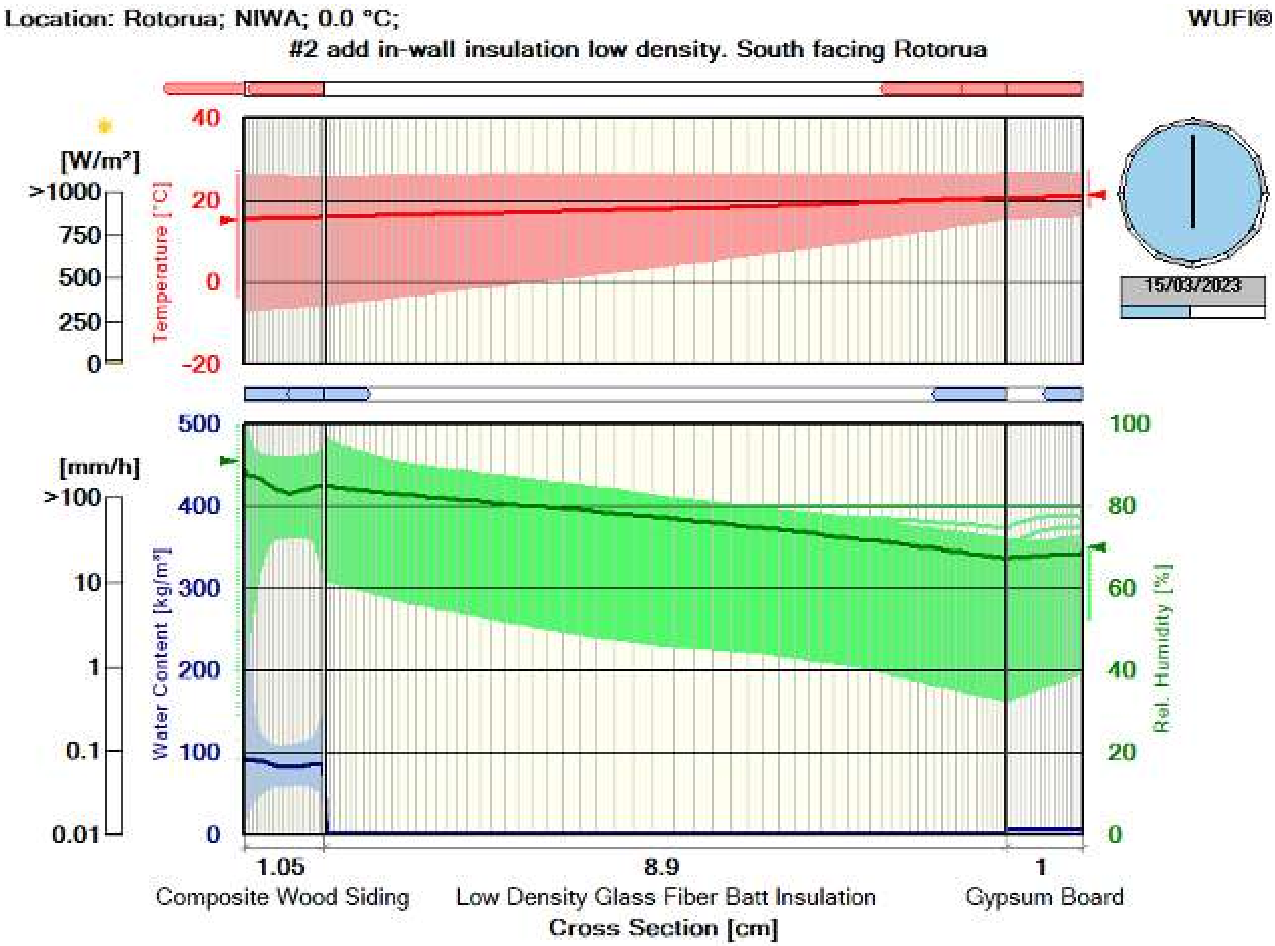


FIGURE 6.2.2, WEATHERBOARD WITH LOW DENSITY IN-WALL INSULATION INSTALLED WITHOUT WALL UNDERLAY. ELEVATED MOISTURE CONTENT IN ASSEMBLY OVER THREE YEARS: WEATHERBOARD 75KG/M3 --> 96KG/M3 RESULT: NOT SAFE, ELEVATED LEVELS (>80%) MOISTURE IN INSULATION.

Parka Wrap wall assemblies were modelled across 3 years of local weather for two wall orientations: South (Figure 6.2.3) and West (Figure 6.2.4). South is chosen because the dominant heat drive is outward, West is chosen because there is a combination of outward (cool conditions including overnight) and inward vapour drive (solar driven moisture) typically in the latter part of the day. Insulation is only placed on the outside of the existing walls, and subsequently the moisture levels within the timber framed space (named as 'air layer 100mm') are below 80% relative humidity. This means the likelihood of mould growth is very low. Moisture in the old timber weatherboards – mid-wall- see a decrease in moisture from the beginning of the simulation to the end.

East and North facing facades were also modelled and showed very similar results to South facing wall overlaid with insulation and new cladding.

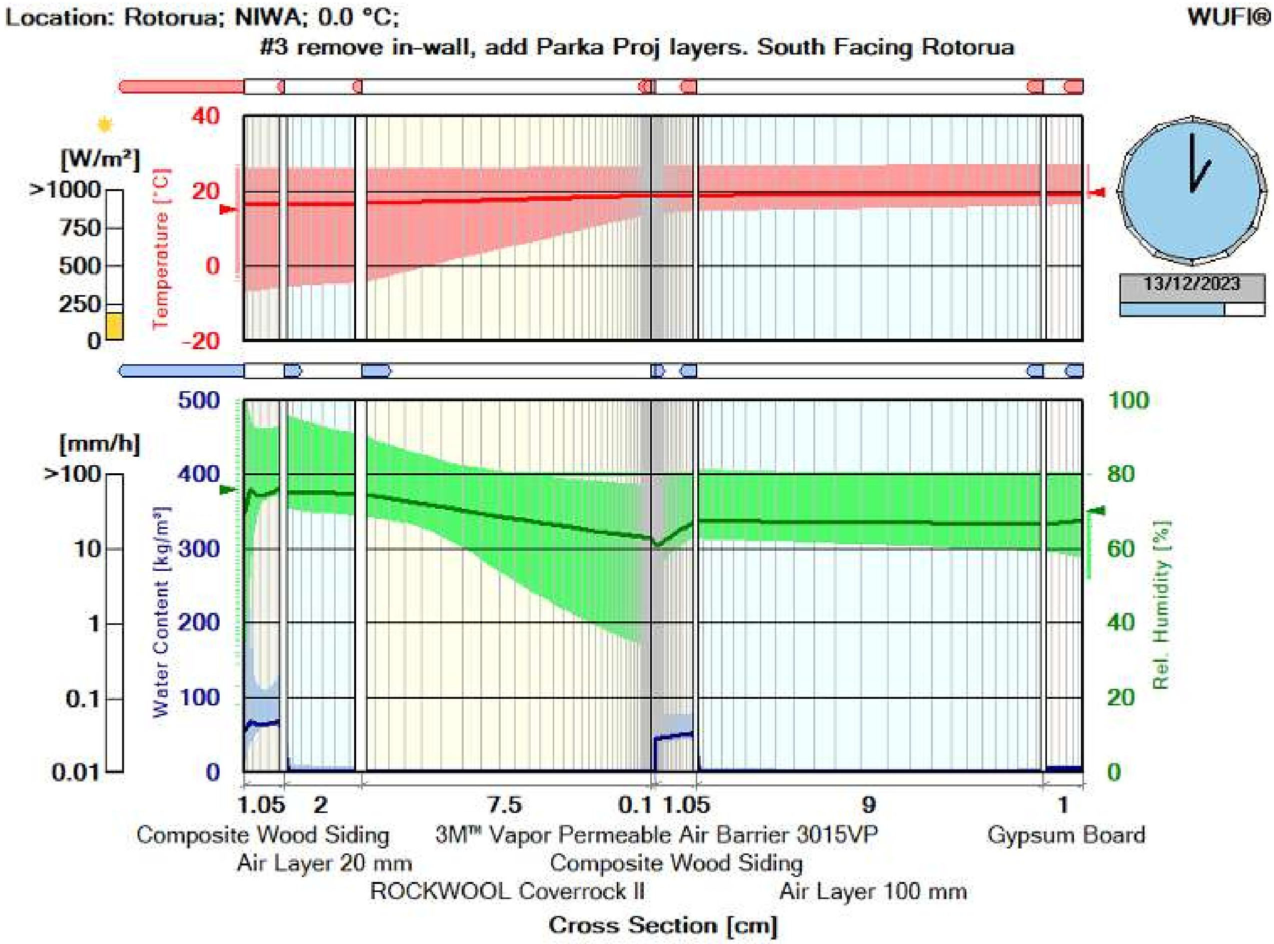


FIGURE 6.2.3, SOUTH FACING WEATHERBOARD WALL WITH PARKA WRAP LAYERS. REDUCTION OF MOISTURE LEVELS OVER TIME IN KEY LAYER OF OLD WEATHERBOARD (WOOD SIDING) 75KM/M3 --> 52KG/M3 OVER THREE YEARS. RESULT: SUCCESS.

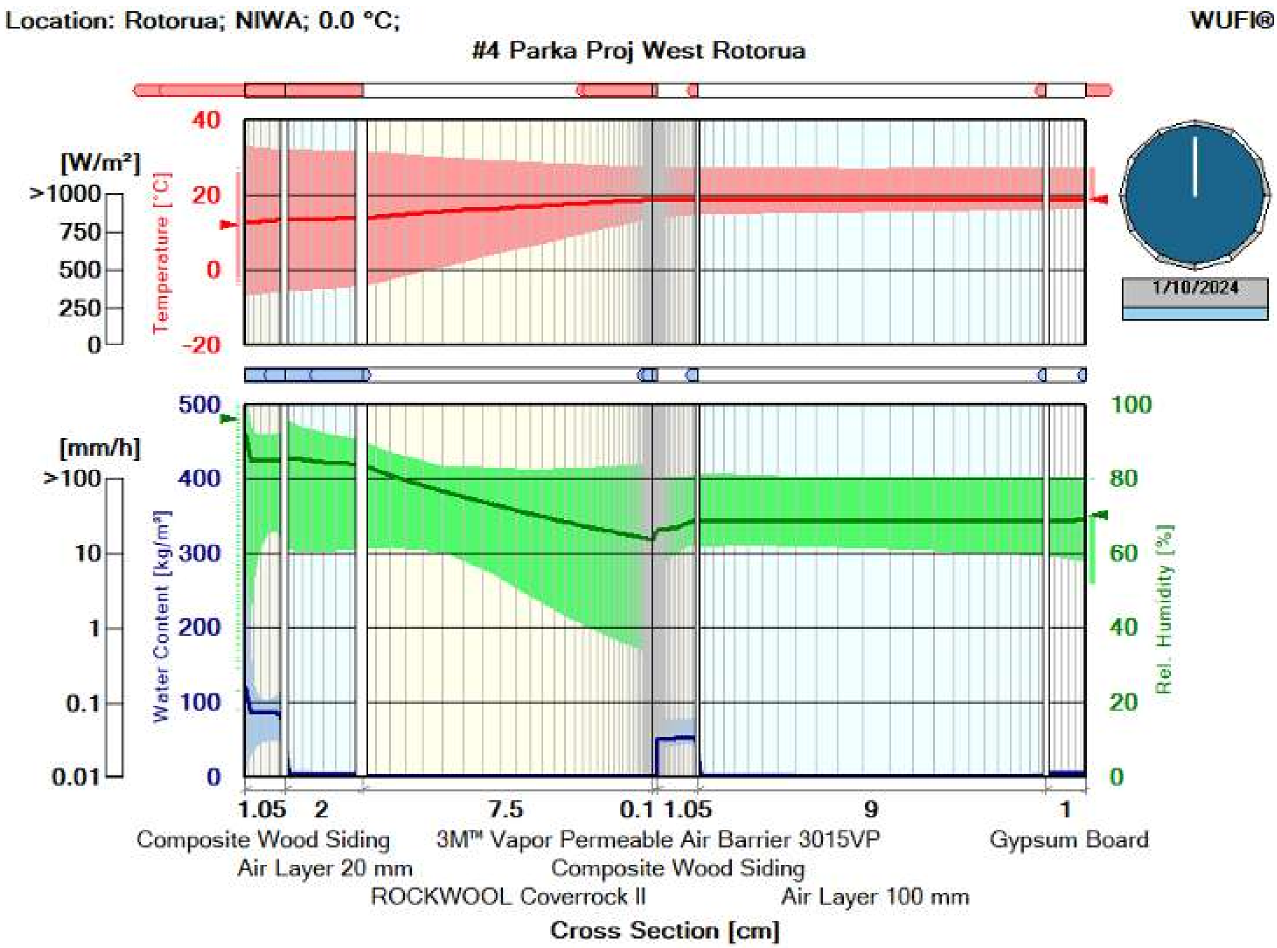


FIGURE 6.2.4, WEATHERBOARD WALL WITH PARKA WRAP LAYERS. WEST FACING WALL. SHOWS SLIGHTLY HIGHER RELATIVE HUMIDITY IN THE INSULATION LAYER DUE TO SOLAR DRIVEN MOISTURE HOWEVER THIS IS OUTSIDE THE WEATHERTIGHTNESS LAYER AND IS OF NO SIGNIFICANCE. OLD WEATHERBOARD 75KG/M3 --> 54KG/M3 OVER THREE YEARS. RESULT: SUCCESS.

The limited number of simulations begin to show the efficacy of the proposed additional layers. They also confirm BRANZ research warning of the dangers of moisture entrapment (Figure 6.2.2) in walls where insulation is installed without consideration of drying capacity and/or installing pockets of wall underlay between studs and nogs. It must be noted this is not a suggestion that wall underlay installed from the inside in small pieces between studs and nogs prior to insulation can actually assist in draining water out of a wall assembly.

Drying in the proposed externally insulated wall assembly is a combination of air movement around cladding, and diffusion through materials using heat flow. It is reasonable to expect the proposed assembly will avoid accumulation of moisture from internal and external sources.

FIGURE 6.3.1. CURRENT CERTIFIED PASSIVE HOUSE DESIGN IN ROTORUA.
IMAGE: 7D ARCHITECTURE. USED WITH OWNER'S PERMISSION.

Predicting the yearly energy demand for heating.

To determine the expected performance of the thermal envelope before and after Parka Wrap intervention, software simulation was undertaken using a single-family home in Rotorua currently in design.

Passive House Planning Package simulates heat loss and gain through a building envelope. Modelling is undertaken typically to influence the design decisions to achieve an energy target.

Modelling a single building is described below with specific changes introduced to create comparative data displayed as energy demand in kilowatt hours per square metre of usable space, per annum – kWh/(m2/a).

To create simplified comparisons, each modelled building (1-7) was maintained at an airtightness level of 0.6 ACHn50 (compliant Passive House target). This is because modelling does not allow selection of different levels of airtightness on different elements (roof, wall, floor, windows, penetrations). What must be assumed then is all data is moderately comparable on a very still day (and still ignoring air pressure derived from temperature differential). Wind pressure has a large effect on heat retention in a drafty home and almost no effect at all on an airtight home. Additional modelling (not shown) added a conservative 20 air changes per hour on the completely uninsulated house with a resulting energy demand of 557kWh/(m2a). The high energy demand is realistic when needing to replace heated air 20 times per hour. The less drafty a house is, the lower and more predictable heat loss becomes.

The results of the simulations are highlighted (Figure 6.3.2). The key step change created by introducing the Parka Wrap insulation happens between simulation 5 and 6, named as 'Compliant Tenanted' and 'Parka Project' in light blue and green respectively.

In total, 7 simulations of the same house were produced. Each simulation differed as follows:

Simulation 1: Passive house. Modelling a designed Certified Passive House in Rotorua (2-storey, 199m2 floor area) in Passive House Planning Package (PHPP) software shows an expected heating energy consumption of 15kWh/(m2a) – this means 15 kilowatts of energy is required for every square meter of floor area per year. The walls are 170mm thick including cladding (wall is still less than a concrete block thickness) and well insulated for Rotorua climate at R4.0. To reduce performance to the minimum 15kWh/(m2a) energy target, the original model was slightly modified from the actual planned building. This reduction was achieved by reducing the insulation thickness. This simulation then becomes the reference to compare following simulations.

Simulation 2: Identical building but all wall insulation removed. These walls still have approximately R0.5 due to timber materials and air cavity which is assumed to be still air which is not a good assumption of normal uninsulated walls with weatherboards. The heating energy consumption required to keep the same home at 20 degrees Celsius is shown by this modelling to be **108kWh/(m2a).** This means with very good insulation in the roof and floor, and high-performance windows, 7.2 times more energy is required to keep the building warm enough for comfort compared to the reference building.

Simulation 3: Wall insulation installed to code minimum (effective R-value). Comparison was made by insulating the same walls for Rotorua (currently climate Zone 2) which requires R1.9 minimum to comply. This took some trial and error to reach an equivalent u-value of 0.5263 across the wall components and was achieved by reducing the framing percentages to 20.7% of the total wall. This is much lower than the average 35% timber framing in walls that Beacon Pathway research found in 2021 so suggests the expected wall construction R value of 1.9 is significantly lower. The heating energy demand to maintain 20 degrees was **27 kWh/(m2a).** This simulation is only shown here to describe the simulation process and is not representative of a realistic construction.

Simulation 4: Insulation to code minimum, realistic timber percentages. Due to the artificially reduced nature of the timber percentages in simulation 3, an additional comparison used standard 90mm fluffy insulation within a 'standard' wall using the average 35% timber Beacon Pathway's 2021 study found. The modelled energy consumption rose to **32 kWh/(m2a).** This difference of 5kWh between simulation 3 and 4 highlights the impact of 'real' timber percentages in the walls against commonly expected 18%. (Beacon Pathway, 2021).

Simulation 5. Compliant tenanted home. Modelled the timber building as a pre-1978 but compliant tenanted home (as per 1 July 2019 Residential Tenancies Act) as if it had been insulated prior to 2016 in the floor and ceiling. This means using ceiling insulation of R1.9 and underfloor of R0.9. Double glazing was reduced to single glazing which retained reasonable performance of window profile to match timber (rather than thermal-zero unbroken aluminium extrusions). Heating energy demand rose to **186kWh/(m2a). This simulation is the closest approximation of the typical 1940's – 1960's timber framed building in this study.** Modelling assumes insulation in the floor although this is only required under the RTA 2019 'if possible' to retrofit. This means the simulated data is conservative.

Simulation 6. **Parka Wrap intervention applied.** To closely replicate the interventions planned on the building 'Simulation 5 Compliant tenanted home', 75mm of mineral wool and new weatherboard cladding were added to Model 5 on the outside of the existing. Timber window frames were left in this model due to the difficulty in getting good data for low-performance aluminium thermally-broken frames in New Zealand. Creating and inputting accurate data here is not worth doing simply because it would never be an acceptable choice for a house design targeting passive house certification. The resulting energy demand for the improved building using Parka Wrap intervention strategy was **59kWh/(m2a)**, a drop of 68% in energy demand to keep the building at 20 degrees.

Simulation 7. Pre-1978 timber building, no insulation, single glazing. A final comparison version of the building was modelled where no interventions had been made to a completely original uninsulated 1940's-1960's weatherboard building (but with concrete slab on grade). The energy required to maintain 20 degrees was 423kWh/(m2a). Represented as dark blue. There are an estimated 720,000 homes across New Zealand's differing climate zones in this scenario with no insulation. This means the energy consumption will be different, but the gains to be made are proportionally similar.

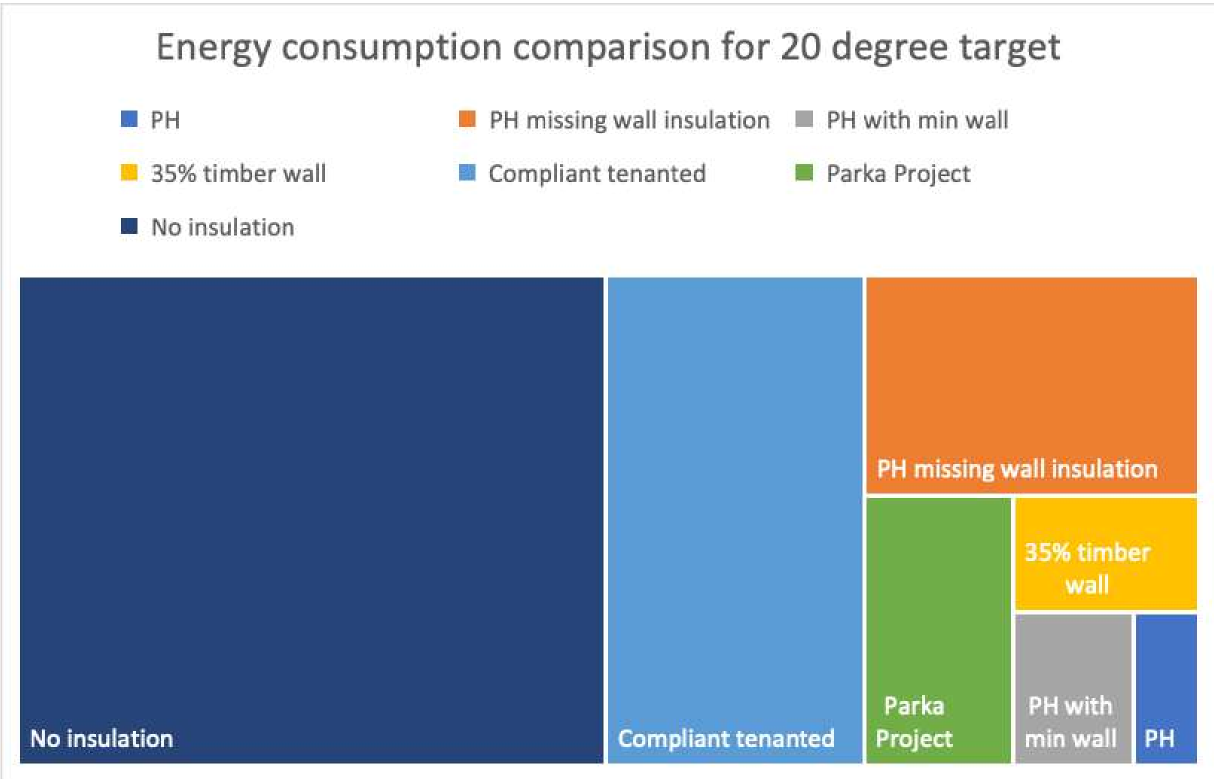


FIGURE 6.3.2 ENERGY DEMAND STEP CHANGE FROM 186KWH 'COMPLIANT TENANTED' (UNINSULATED WALLS) TO PARKA PROJECT 59KWH (INSULATION WRAPPED AND NEW WINDOWS).

Visual representation of the simulations can be summarized by Figure 6.3.2. It shows the target of this proposed methodology is to move ‘Compliant tenanted’ buildings with insulation in ceiling and floor (light blue) to ‘Parka Wrap’ (green). By making this intervention they will be consuming two thirds less energy again from their current position to maintain healthy temperatures. According to this modelling the last statement is true, however, it can be expected the proportion would not stay the same if it was windy. This is because the ‘Compliant tenanted’ building has no dedicated layer to prevent wind movement through the walls, whereas the ‘Parka Wrap’ building now has a dedicated wind-tight layer (to walls only), and draft-free window-to-wall connections. To simulate this ‘real-world’ environment which accounts for wind-pressure forcing air through the building envelope, the air leakage has been increased for the ‘Parka Wrap’ from 0.6 to 5ACH. This accounts for limited (still low) air leakage through the existing floor and ceiling – neither of which can be expected can be airtight due to the likelihood of timber strip flooring, and gaps, cracks, and deliberate holes (downlights) often made in ceilings.

Therefore, an air change of 20m3 per hour was assumed for the ‘Compliant tenanted’. The resulting comparative energy results are 319 kWh/(m2a) for ‘Compliant tenanted’, and 88 kWh/(m2a) for Parka Wrap - a 72% difference in energy consumption. Actual airtightness values of real houses pre and post Parka Wrap improvements would help to improve the accuracy of the argument here as a basis for calculating return on investment but would also have to factor in insulation performing worse than modelled for ceiling and floor. Regardless, the improvements made during Parka Wrap retrofit will be 3 or more times better thermal performance than existing buildings with only insulated in ceilings and floors, and single glazing.
Every building eventually loses 100% of energy that is put in. Well insulated buildings lose heat at a slower rate than poorly insulated buildings. By analysing the compliant tenanted building (model 5 - light blue) and comparing this with model 6 (Parka Wrap interventions, green) we can see the significant energy reduction by preventing the current heat loss through the walls. This will allow building occupants to retain expensive energy in the building for much longer, creating higher levels of comfort and with a broad expectation of lower respiratory stress due to cold temperatures in homes.

Summary of Passive House Performance Package Simulation Findings
This section and results has been the most significant but unexpected element of the research process and shows a significant performance gain for houses using the Parka Wrap intervention. Improvement using this approach was expected, the scale of improvement was surprising. Taking this 'existing' building with ‘sufficient’ insulation in the ceiling and floor and reducing the energy required by more than two thirds shows the impact this intervention could be expected to have.

Figures 6.4.1 (a, b, and c) below highlight development of the window still design using the back dam as a central/critical feature when creating structural, and weathertightness connections while maintaining high levels of insulation connection to window element.

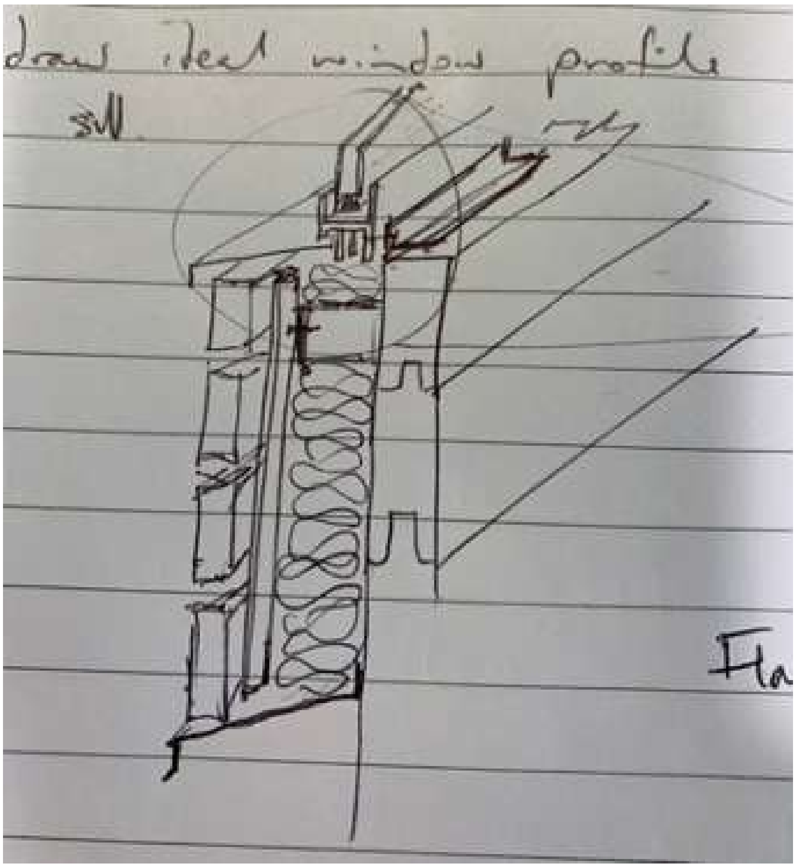


FIGURE 6.4.1A. CONCEPT SILL DETAIL, EXTERNAL INSULATION.

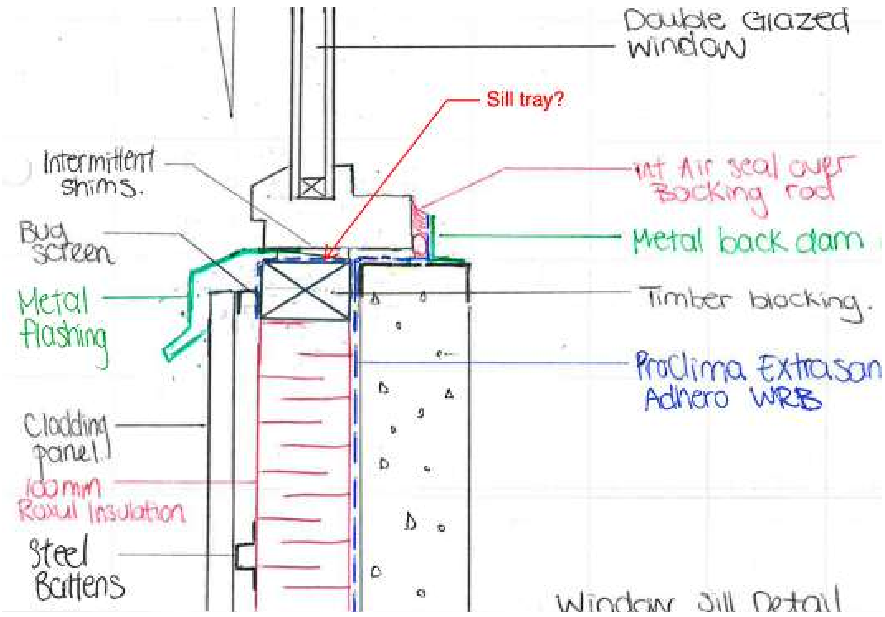


FIGURE 6.4.1B. DEVELOPING THE STRUCTURAL CONNECTION FURTHER USING DEEPER RECESS AND AN EXTERNAL PERIMETER TIMBER FRAME.

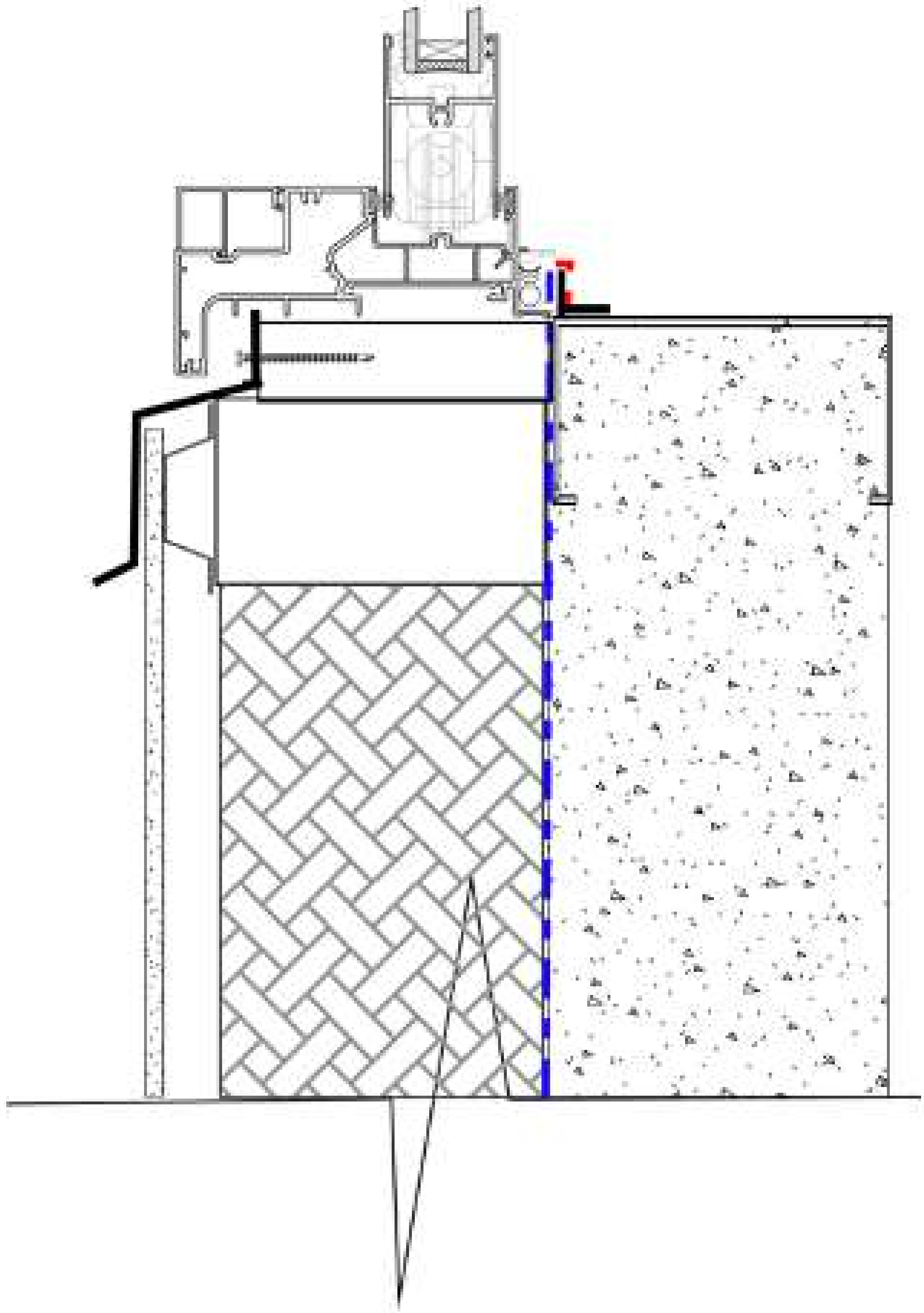


FIGURE 6.4.1C. DEVELOPMENT OF STRUCTURAL, THERMAL AND WEATHERTIGHT CONNECTIONS TO SCALE, USING PRODUCTS WITH LOW OR NO COMBUSITIBILITY IN THE INSULATION LINE.

Critique and development of an existing window position at the sill.

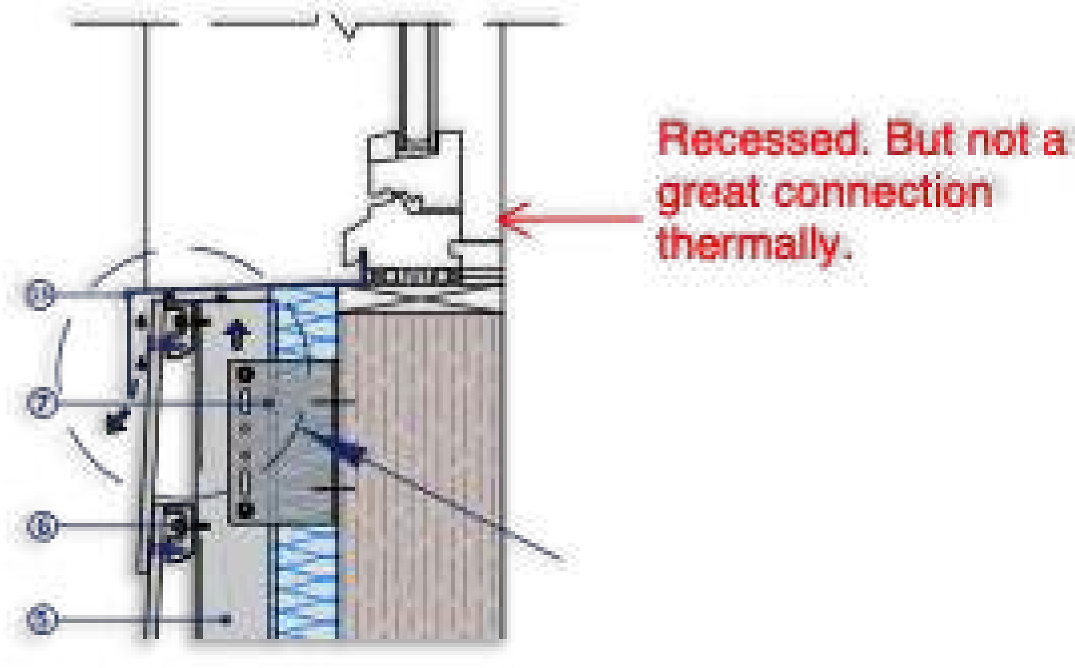


FIGURE 6.4.2A - STEP 1 - INITIAL RECESSED WINDOW CRITIQUE.

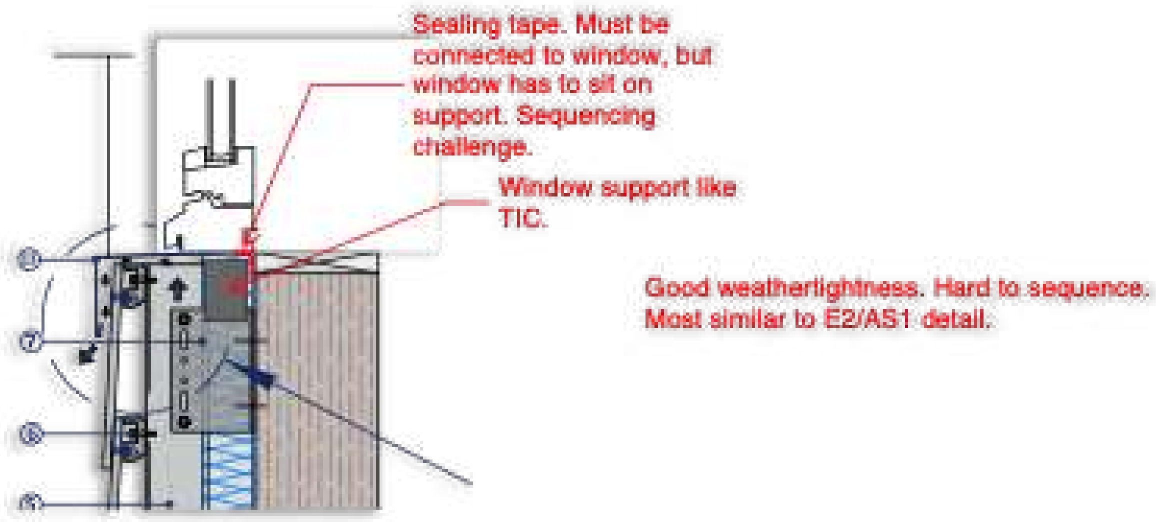


FIGURE 6.4.2B, INITIAL DESIGN POSITION AND WINDOW SUPPORT USING TIC – TECHNOFORM ISOLATOR CLIP.

Figure 6.4.2b is an improvement and critique on Figure 6.4.2a. This most closely matches the first built mock-up (shown below in Figure 6.4.2c) with Korok panels and terracotta tile vertical cladding.

FIGURE 6.4.2C - WINDOW SUPPORT BUT NO ABILITY TO FIX DOWN.

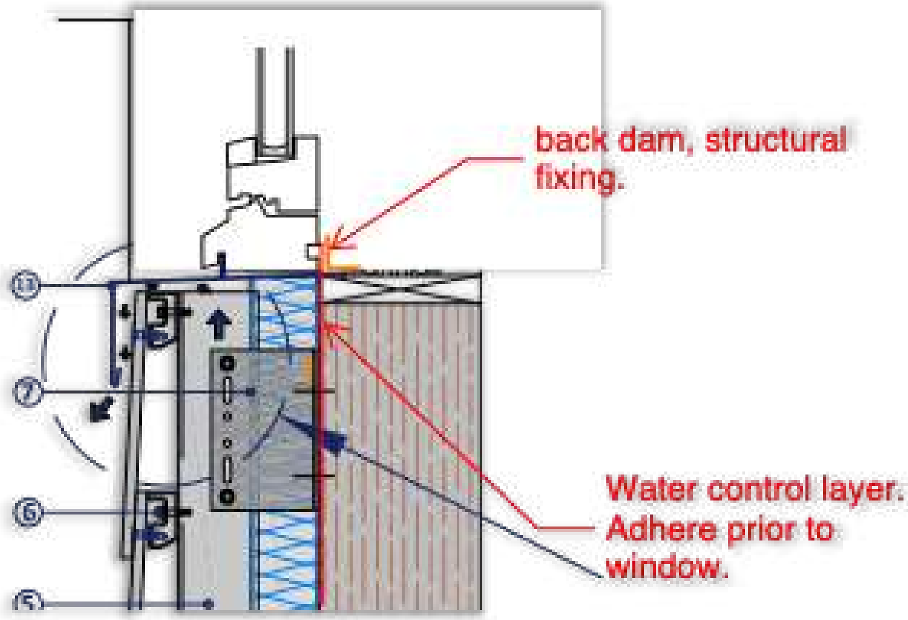


FIGURE 6.4.2D, BACK DAM FOR WEATHERTIGHTNESS LINE CONTINUITY, EASE OF BUILD, STRUCTURAL FIX OF WINDOW TO BACK-DAM.

Figure 6.4.2d above is a later improvement after rejecting the complexity in sequencing the construction of Figure 6.4.2c. The full findings are described in following test described in Section 6.5.

FIGURE 6.4.2E. POSITION OF BACK DAM FOR WINDOW FIXING AND SEALING. SUCCESSFULLY LINES WINDOW UP WITH INSULATION FOR HIGH PERFORMANCE.

Process in sequence
When the drawing was satisfactory, mocking up the details (Figure 6.4.1c and Figure 6.4.2d), served two purposes. It allowed for materials to be checked and the correct sequencing to also be checked.

Although the first detail design (Figure 6.4.1c) was good on paper, the planning of heights and the set-outs related to cladding type was difficult. Sequencing of materials during install proved to be labour intensive and slow. The results of the prototype required aspects of cladding, window fixing, and water deflection to be developed further. Exploring the concept further through iteration led to development and eventual use of the back dam connection method (Figure 6.4.2d). This is also shown during iteration in the third image below where the window is positioned ‘ready’ for fastening.

FIGURE 6.4.2F ,G, H. MATERIALS AND POSITIONING OF SUPPORT, REMOVAL OF SUPPORT AND BACK-DAM CONCEPT BEING EXPLORED.

By avoiding any direct sill support system for the window (Figure 6.4.2f and g) such as a WANZ support bar, the thermal performance is increased by decreasing thermal bridging. Ultimately removing thermal bridging altogether is the perfect solution. At this stage in the development using a structural back dam is looking likely.

Experimentation on the use of back-dams in the window opening within a timber frame had been undertaken earlier in 2020. The back-dam initially sat deep within the opening and provided the weathertight back-stop using a bead of sealant (compressed) between aluminium joinery (chair frame) and the upstand of a back-dam (L-angle). The sill tape was installed across the sill and up onto the back-dam providing a one-way exit for water at the sill – outward. This was making a significant step away from common New Zealand details found in E2/AS1 - the common detail of horizontal windowsill Figure 6.4.3 below and a reliance on PEF rod and foam as the last line of defence. Where water can drain to or be driven into the sill area it must be drained out again. This is not ideal for weathertightness and has no thermal performance due to the outside (cold) air moving through the area with highly heat-conductive aluminium.

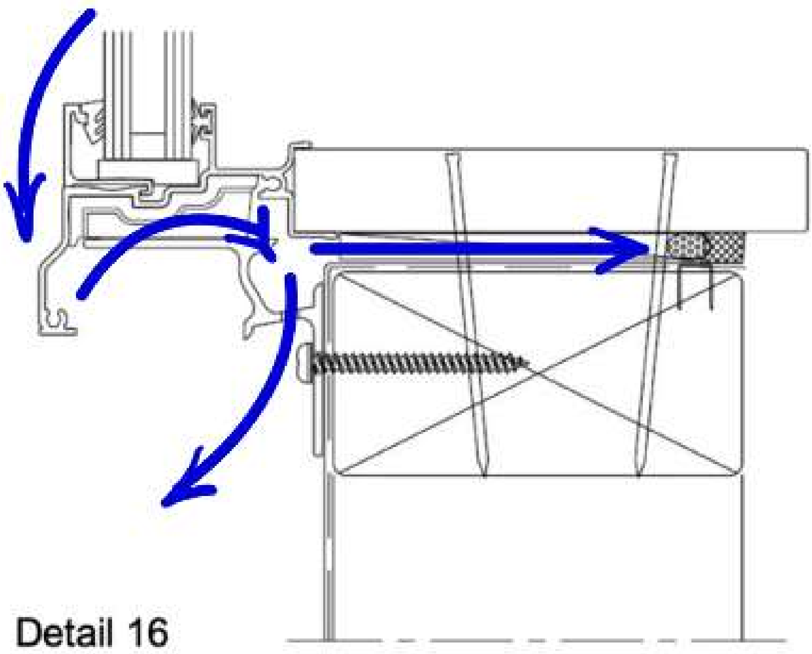


FIGURE 6.4.3 E2/AS1 RELIES ON PEF ROD AND FOAM/WETSEAL.
NO THERMAL PERFORMANCE.
IMAGE CREDIT: ACCEPTABLE SOLUTION E2/AS1. EXTERNAL MOISTURE ARROWS ADDED.

The structural connection improvement using a back-dam between window and wall was made (See Figure 6.4.4). This appears to be a significantly better attachment system than fixing through a timber liner as shown below in Figure 6.4.3 which is stapled onto aluminium joinery profiles.
Based on this approach and during these iterations, pulling the back-dam out to the face of the steel-skinned wall panel was experimented with. It was quickly apparent the weathertightness line was significantly improved by means of creating a straight vertical plane for the drainage pathway. This means the ability for water to be kept outside a defined line or layer on the building envelope was simplified – both in detailing and in practice. Figure 6.4.4 – the externally insulated detail - shows a straight line – even when water is flowing 'over' the window. Water can be deflected using head flashing and/or flashing tape and cannot move back behind the outer line of the substrate. The dotted blue line shows a continuous straight line of weather defence in contact with the window.

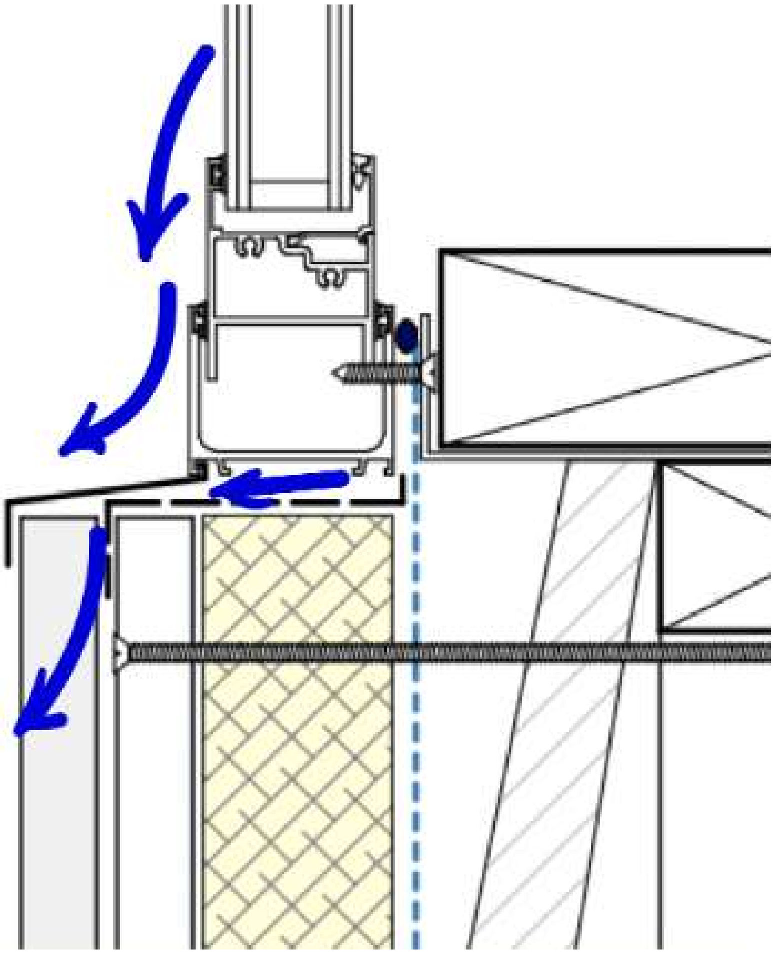


FIGURE 6.4.4 PROPOSED DETAIL RELIES ON SEALANT CONNECTION. WINDOW LEAKAGE DIRECTED OUTWARD PAST NON-MOISTURE-SENSITIVE MATERIALS. THERMAL PERFORMANCE IMPROVED BY LINING UP GLASS WITH ROCKWOOL. FURTHER IMPROVEMENTS COULD BE MADE WITH THERMALLY BROKEN ALUMINUM.

There were six remaining steps:
Step 1: Further Mock-up with Terracotta tiles investigating flashing approach and sequencing
Step 2: Software mock-ups in SketchUp for layer sequencing and product position.
Step 3: Replica 1940's weatherboard wall build and testing in NZS4284 Test rig
Step 4: Flashing check for window detailing with external insulation – a recessed window
Step 5: Parka Wrap prototype – Overlay old wall with intervention testing in NZS4284 Test rig
Step 6: Final design detailing and summary of design

FIGURE 6.5.1A. BUILDING MODEL ON STEEL SKINNED WALL PANEL (CLIENT PROJECT).

FIGURE 6.5.1B WINDOW SUPPORT SYSTEM USING TECHNOFORM ISOLATOR CLIP.

FIGURE 6.5.1C. WINDOW FIXED WITH BACK-DAM.

FIGURE 6.5.1D. CLADDING RETURN INTO WINDOW JAMB.

This mock-up proved to be successful in meeting required Code Clause performance elements but required complex sequencing, set out of heights, and creating the connections for weathertightness. It proved possible but not straightforward. The detail was then re-worked through iteration on wall to develop back-dam application – size, material, and position. It was discovered later during full scale mock-up intervention the sequencing still didn’t work.

SketchUp modelling was useful to communicate the process of proposed intervention before models had been built. This was most successful when using the animation feature. The expected build position and sequencing for the new layers were designed using the software tool SketchUp to highlight the position of new back-dam and window over existing weatherboard. The sequence was ultimately proved wrong as the removal of the old/existing window was not considered. The existing window prevented the installation of the back-dam at the planned time therefore a redesign was required.

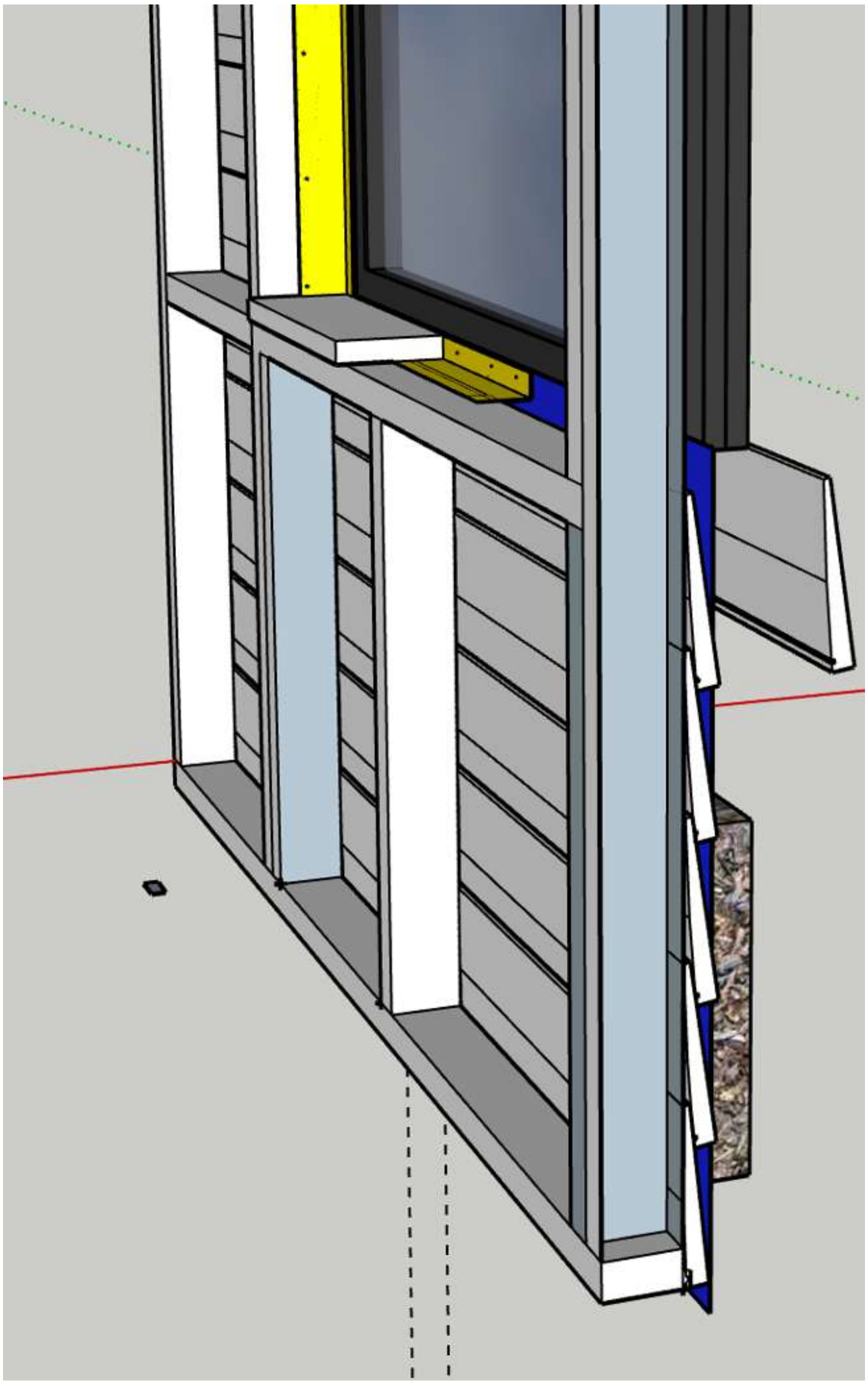


FIGURE 6.5.2A SKETCHUP MODEL LOOKING FROM INSIDE TOWARD OUTSIDE SHOWING PLANNED MATERIALS OVER ORIGINAL WEATHERBOARD (OLD WINDOW REMOVED). KEY ELEMENTS; WEATHERTIGHTNESS (BLUE) AND BACK-DAM STRUCTURAL FIXING (YELLOW).

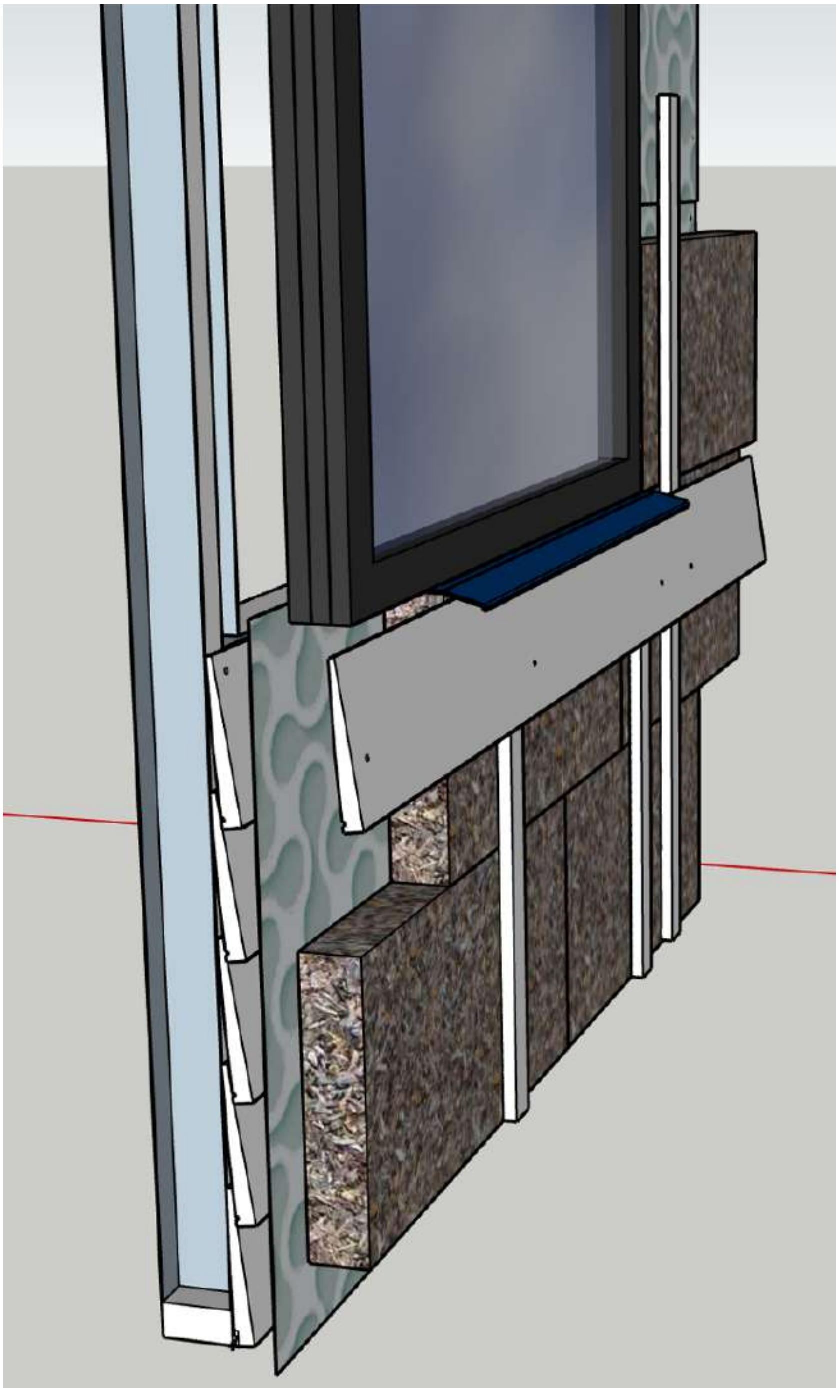


FIGURE 6.5.2B. SKETCHUP MODEL SHOWING PLANNED MATERIALS OVER ORIGINAL WEATHERBOARD. KEY ELEMENTS: CONTINUOUS INSULATION (BROWN), WEATHER DEFLECTION SILL FLASHING (BLUE) HOOKS ON TO OUTER EDGE OF WINDOW JOINERY TO AVOID THERMAL BRIDGING.

6.5.3 STEP 3: REPLICA 1940'S WEATHERBOARD WALL BUILDING & TESTING IN NZS4284 TEST RIG

Shelby Wright Test Labs made available the newly built NZS4284 test rig to run initial testing and plan the E2/VM1 testing required to prove efficacy of the Parka Wrap intervention.

Challenges to overcome.
Significant wind pressure created in the test booth will break windows and deflect walls out of plane. To allow for seismic movement and still measure deflection of specimen out of plane (wall moving in and out with wind pressure), bracing was required around the specimen to avoid out-of-plane loading of the seismic rail. Maintaining a weathertight connection between test specimen and test booth was achieved by developing a flexible connection using wide EPDM rubber stapled and taped to the specimen and then taped to the test booth surround.

Design and build replica weatherboard wall.
40 lineal metres of demolition Rimu weatherboards and a typical 1940's timber window with a casement and awning opening were purchased and installed on a 90 X 45 timber frame assembled with Spax screws. New timber was used for the structural framing because the framing was of low importance. It was the weather resistance of weatherboards that required testing. That said, the frames were screwed together so the planned seismic racking tests would not pull the frames apart and need repair before Parka Wrap interventions were made. This was a successful approach.

FIGURE 6.5.3A. INSTALLING AN OLD CASEMENT AND AWNING WINDOW INTO NEW TIMBER FRAME.

FIGURE 6.5.3B 'OLD' WEATHERBOARD WALL WITH WINDOW INSTALLED.

Installed weatherboards around the window used typical single fixing (jolt head nail) towards the top of the weatherboard at each stud. Sealant was used to plug large holes in each board, and around the jambs of the window. The reason for this approach was the expectation the window would leak, and a tightly fitting scriber outside the facing timber would achieve similar reasonable levels of water deflection. There was significant visible open space between the weatherboards due to their typical ill fitting. The same approach was taken with the head flashing - instead of the typical metal flashing, a length of rimu weatherboard ripped down and sealed above the window head provided water deflection.

FIGURE 6.5.3C. 'OLD' WEATHERBOARD WALL WITH EPDM RUBBER SKIRT ATTACHED, READY TO LIFT INTO THE TEST RIG BEHIND.

Building a 2.4m X 2.4m wall required the use of a quarter of the test rig opening, the rest of which is closed using connected shutters and weathertightness materials.

Test setup – existing old wall.
To seal the wall specimen into the test-rig, a small strip of peel and stick membrane behind the lowest weatherboard was installed to seal against the base of the booth. Around the head of the wall and the two sides a neoprene rubber strip 450 millimeters wide created a weathertight skirt and baffle to allow seismic movement between the wall and the test rig. The neoprene was attached to the wall sides, around the shape of the weatherboards - stapling and sealing it to the boards. A gantry hoist was used to move the wall into position. Sealing the skirt onto the test rig was achieved from the inside of the booth. From outside the structural connection was made to the seismic rail placed at the top of the wall.

Initial air test – existing old wall.
The initial air test was also the very first specimen in the new test-rig so the ring blowers were very slowly brought up to speed as the wall and the pressure gauges were observed. It quickly became apparent there were so many air leaks directly through the wall that we were in no danger of over pressurizing and breaking the glass. The test was paused while a theatrical smoke machine was placed inside the rig and the pressure brought up again.

Results Air Pressure only.
There was significant air leakage through window, window to wall junction and weatherboards themselves. This was recorded visually using smoke leakage, see Figure 6.5.3d. This would have been very slightly less leakage with plasterboard installed on the inside face where air leakage would have been seen through gaps and cracks in skirting boards, architraves, scotia, and holes in the plasterboard for power points, light switches, and other common penetrations.

FIGURE 6.5.3D. SMOKE POURING OUT THROUGH GAPS IN WEATHERBOARDS, WINDOW SURROUND, AND THROUGH WINDOW'S OPERABLE ELEMENTS.

Initial water test.
The water spray nozzles were placed to allow for the correct distance away from the test specimen according to the calibration. During the initial test water pressure was run mistakenly at 60 psi when it should have been 22 psi. This was not realized until approximately 10 minutes of wetting and observation time had occurred.

Results with water only.
During the time with higher water pressure, there was a very small amount of water leakage around the window, some of which could be attributed to workmanship. There was little or no leakage through the weatherboards themselves. This was despite visible water being present resting between weatherboards when looking from outside the test booth - looking from the back (inside) of the weatherboard wall. It was at this point it was realized that water pressure was running higher than required and it was dialed back to 22 psi.

Summary of water-only test results.
Interpretation of test results: the wall including window was deflecting water as weatherboards are expected to do. What was not expected was the wall to stay dry internally at this point with such large gaps between weatherboards.

Water and wind test.
At this point with water running at 22psi, air pressure was added by slowly ramping up the ring blower's speed to provide air pressure inside the test booth and against the outside of the weatherboard wall. Air pressure was 250Pa, equivalent to a 30 kilometer an hour wind on the outside of the wall in a continuous manner.

Results with wind and water pressure.
The first most noticeable leakage was immediate and through the window opening. Leakage was around the sealed awning window (sealed using sealant and glue prior to the house demolition), and around the casement window with water splashing 'inside' and onto the floor. Water was also leaking through the weatherboards with water being driven over the top of boards and mostly running down the back. Water was tracked back towards the outside in the majority of leakage areas (widespread across the wall). Overall, the wall was wet, and wetting the framing. Significant leakage created with higher wind pressure is shown in Figure 6.5.4.

Interpretation of test results.
Wind can drive water into a wall. Wind will also provide the primary drying mechanism of that bulk water - provided air can freely move through. A perceived failing of this (informal at this stage) test might be in the consistent wind pressure against the building not allowing water to drain off weatherboards easily, however, a consistent wind of 30 kilometers an hour with gusts significantly in excess would not be an uncommon scenario. In this case water is driven into the wall regardless.

Following this informal testing, the next step was to run the full sequence of NZS 4284 testing against this same wall, however, there seems to be little point in proving for a second time that the wall allows wind movement which drives water through toward the inside.

Weatherboards and window installed without tapes or wall underlays showed a surprising ability to resist water. On reflection, everything in the assembly is positively lapped (shedding water towards the outside), has positive slopes to also shed water, and around the window openings and operable window elements had weather-grooves preventing capillary action. This all leads to an assembly operating as expected when water is sprayed horizontally at the wall.

It's important to note again, weatherboard walls are ‘intended to leak’ because that’s also part of their drying mechanism as noted by BRANZ in their guidance: ‘Because they allow air to enter and water to drain or dry, bevel-back weatherboards are considered a robust cladding system with good weathertight performance. ‘ (BRANZ, 2014).

FIGURE 6.5.4 WATER SPRAY WITH WIND PRESSURE @250 PASCALS – A REAL STORM AGAINST WEATHERBOARD WALL

Wind pushes water, and gaps allowing air flow through a wall also allowed passage for water. Where water was held even temporarily between weatherboards and any other gap available, it was driven toward the inside. The nature of the test creates this leakage intentionally. Some water was pushed over the top of weatherboards and made its way down the back face of the boards and could make its way outside again. Due in part to the absence of an air barrier formed by sheet products on the inner face of normal walls (usually plasterboard), water was also thrown past the frame, landing on the floor ‘inside the building’ (onto the workshop floor). This action is due to wind driving water through and would also occur where significant gaps and cracks are present within internal linings, not least of which would be power points and light switches. This testing confirms the reason and requirement for wall underlay to be installed prior to insulation within a wall cavity as described here by MBIE Guidance on Building Code compliance for retrofitting insulation in external walls (Aug 2011): “Building paper, between the cladding and framing, will help to mitigate any moisture bridging by insulation as it will reduce the amount of moisture that comes into contact with the insulation.”

In the tested specimen water also had free pathways around the operable window elements and highlighted how air-leaky the windows of older buildings can be. Of interest, the demolition window that was bought for the test had the awning window screwed shut and mostly sealed with paint. The small gaps in the paint let in plenty of water which accumulated on the sill beneath the fixed portion of glazing.

This testing sequence was repeated multiple times over the following weeks to show visitors, clients and our team what effect air leakiness has on weathertightness, including introducing much higher wind pressures (see Figure 6.5.4).

Significant learnings for witnesses of these tests and demonstrations

- water deflection – effectiveness of existing walls and positive deflection laps
- significant air leakiness of weatherboard - and effective drying
- effect of wind pressure on water ingress – how water is held and driven through gaps
- effectiveness of weatherboard where no insulation exists (drying capacity, water shedding surfaces)
- recognising the reasons for not insulating in the cavity without significant use of water defence layers installed against the weatherboard

Risk in every wall assembly is moisture ingress within detailed junctions. Attempting to de-risk the proposed assembly has led to reducing the complexity of the details, therefore reducing the complexity of the installation. This risk of moisture accumulation within the assembly (possibly a failure of both Clause E2 External Moisture and E3 Internal Moisture) with resulting durability (rotting timber) issues and ultimately structural failure is mitigated in three ways. Firstly, when properly applied, the proposed wall layers will prevent water penetration through deflection and windtight backup layer. Secondly, moisture 'trapped' in the insulation is still outside the framing line and has drainage and drying pathways. Thirdly, moisture that may migrate through solar driven mechanism and/or diffusion is allowed to dry toward the inside of the building. There are no products which prevent or heavily restrict the passage of moisture vapour both inward or outward (internal moisture) which could otherwise result in damp and mould growth.

Most cladding materials available in the market can be considered to be leaky – that is, they are intended to be installed as part of a rain screen style cladding assembly where the panels form the outermost water shedding surface. They typically do not join perfectly to provide a perfect barrier to water (BC Housing, 2019). Should water bypass cladding through holes, gaps, cracks over overlaps, a large drainage cavity is created between the cladding and the rest of the wall assembly by the cladding rails and in some cases brackets supporting the rail.

Should water manage to cross the cavity, additional water shedding layers are provided by the ProClima Solitex Adhero underlay installed to the external side of the stud framing which is intended to prevent water penetrating further into the wall assembly. After the deflection characteristics of cladding as a water shedding surface, the peel and stick weathertightness layer is the main line of defence against wind and wind-driven moisture.

The rockwool insulation within the cavity provides a further obstacle to water ingress and will not be affected by small amounts of water within the cavity expected to occur behind a cladding system such as this.

Drainage/ventilation holes and vents at the soffit/cladding interface should be provided to create a drained and ventilated cavity that will assist in removing any bulk water and moisture from within this cavity.

6.5.6 STEP FOUR: FLASHING CHECK

In Chapter 3 the significant lack of knowledge to design for thermal performance was highlighted. Currently this is no more obvious than where windows are being recessed. Through experience this hesitancy appears to come from a national history of poor weathertightness performance of windows, and a reliance on E2/AS1 drag-and-drop detail solutions that can be relied on for weathertightness but typically have no useful thermal performance. (See Figure 6.4.3). Key elements to achieve here are a large part of this research – recessing windows but keeping water out, making the thermal connection work adequately and ensuring it can all be kept attached to a building. Recessed windows require consideration of flashings to deflect water, but without creating thermal bridging from the back to the front of the window opening.

Bending flashings for a window opening to find out how to do this in practice informs the drawing of those details. This process was undertaken with work colleagues to guide the final details required for this practical thesis.

FIGURE 6.5.6A. SILL FLASHING POSITIONING WITH THERMALLY BROKEN WINDOW.
6.5.6B. SILL AND JAMB FLASHING OVER EXTERNAL INSULATION.
6.5.6C. SILL AND JAMB FLASHING TUCKED INTO UPVC WINDOW.

FIGURE 6.5.6D AND 6.5.6E. FLASHING MOCK-UP. PLANNING CLADDING POSITION FOR FLASHING DEPTH.

6.5.7 STEP FIVE: PARKA WRAP PROTOTYPE INTERVENTION IN NZS4284 TEST RIG

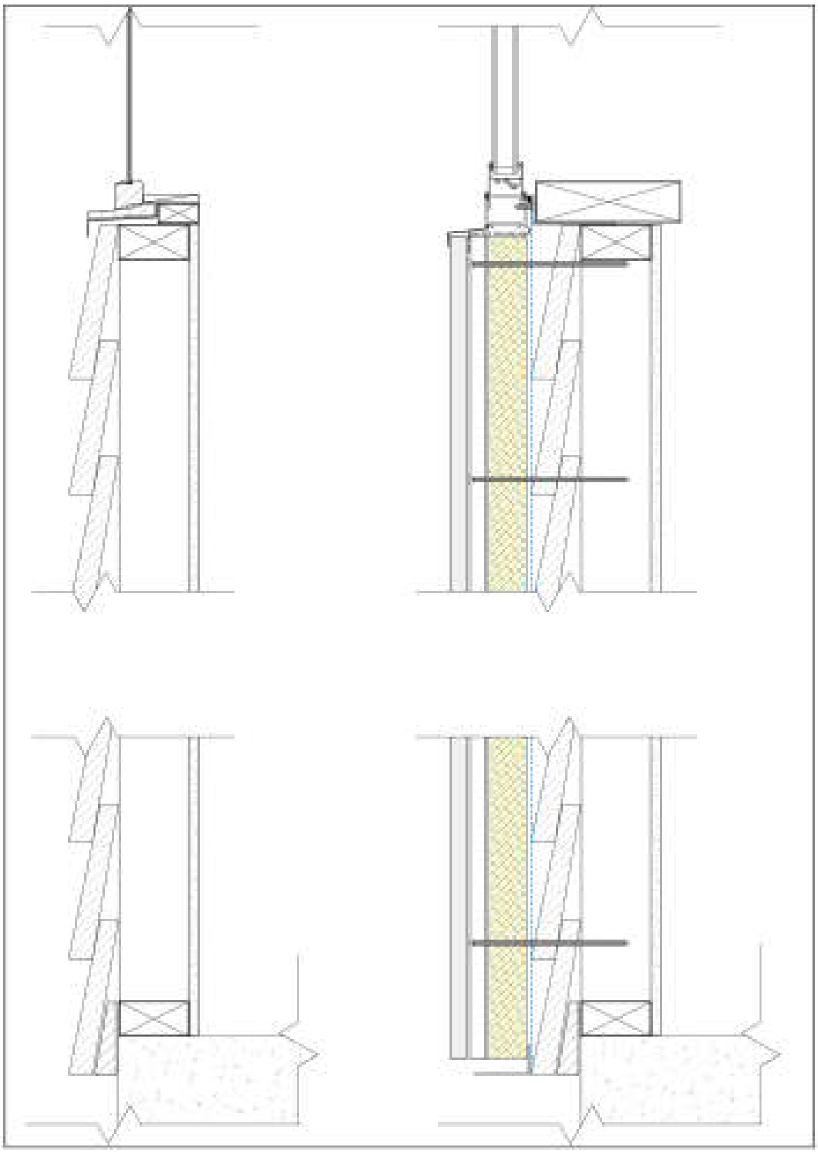


FIGURE 6.5.7A. OLD WALL (LEFT) RECEIVES NEW LAYERS OF WEATHERTIGHTNESS, INSULATION AND CLADDING ON CAVITY. REVIT MODEL CREDIT: ERIK TODOROV, OCULUS ARCHITECTURAL ENGINEERING.

Applying the Parka Wrap materials to the existing old weatherboard wall (Figure 6.5.7a) largely as planned as described in this section:

- Initial application findings – investigating the structure
- Sequencing challenge
- Application of new layers and window

Investigate structural soundness

The framing 'hidden' in the wall requires checking for rot and borer with the use of a wormhole camera inserted through multiple drilled holes (Figure 6.5.7b). Drilling holes through existing weatherboards makes no difference to the weathertightness of the wall once the peel and stick membrane is overlaid. Once this was complete, starting the application of the proposed method as described in the hypothesis immediately exposed a weakness in the planned sequencing.

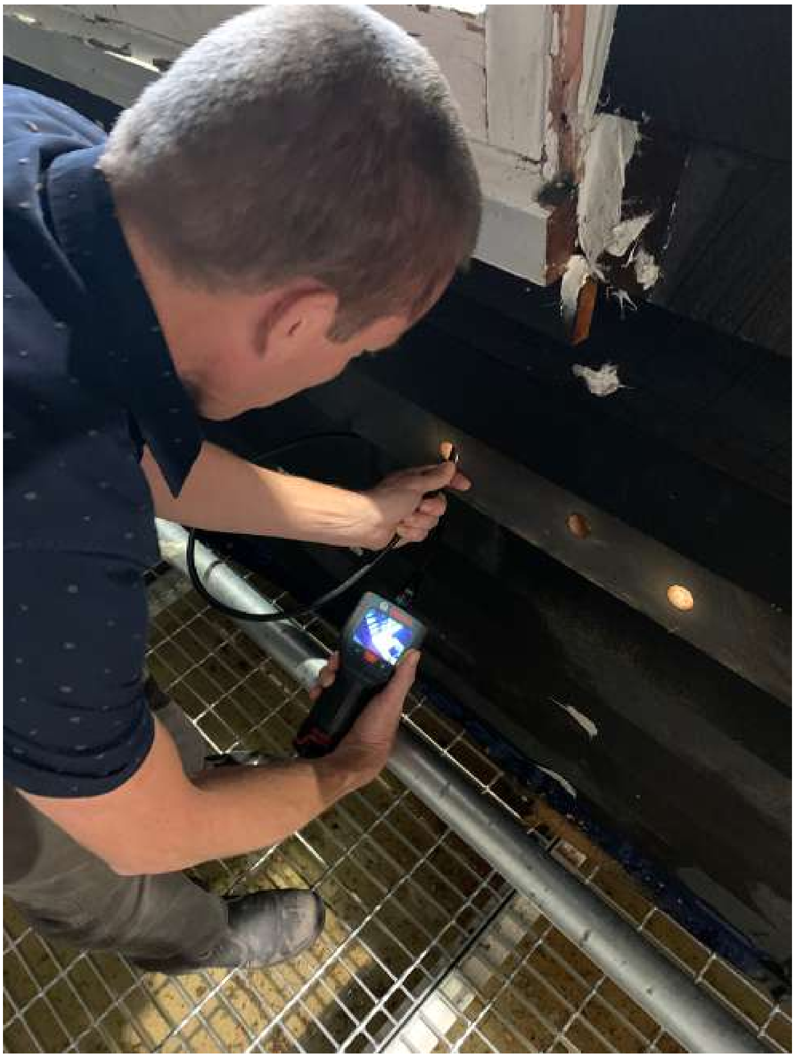


FIGURE 6.5.7B WORMHOLE CAMERA CHECKING FOR ROT AND BORER.

Sequencing challenge.

It was not possible to fix the aluminium back-dam while the existing window was still in place as it required fixings into the window opening (rather than onto the vertical face).

When the old timber was removed it became a simple process to install the aluminium back dam angle (Figure 6.5.7c). This was lined up with the outer corner of the existing weatherboards to ensure the weathertightness line remained in a single plane to the window opening.

FIGURE 6.5.7C. ALUMINIUM STRUCTURAL BACK DAM AROUND WINDOW OPENING.

FIGURE 6.5.7D. ADHERO PEEL AND STICK APPLIED OVER EXISTING WEATHERBOARDS.

Application of new layers and window.

This was followed by Proclima's Solitex Adhero peel and stick membrane (Figure 6.5.7d). This product was chosen because of its watertightness properties and its ability to allow moisture to move out of a wall cavity.

Window installation used sealant and horizontal fixings through the back-dam as detailed. A single strip of weathertight tape was also used across the window head to remove any direct water pressure from the sealant between window and back dam.

Rockwool insulation was installed as a continuous layer - pinned in place using vertical battens (non-combustible Tanfor metal battens) fixed through to the structural. These two products together form a cladding support by creating a truss action, transferring loads (gravity, wind and seismic) using the fixings and the density (100kg/m3) of the insulation. New cladding (charred black Abodo weatherboard) was installed followed by flashings around the new window.

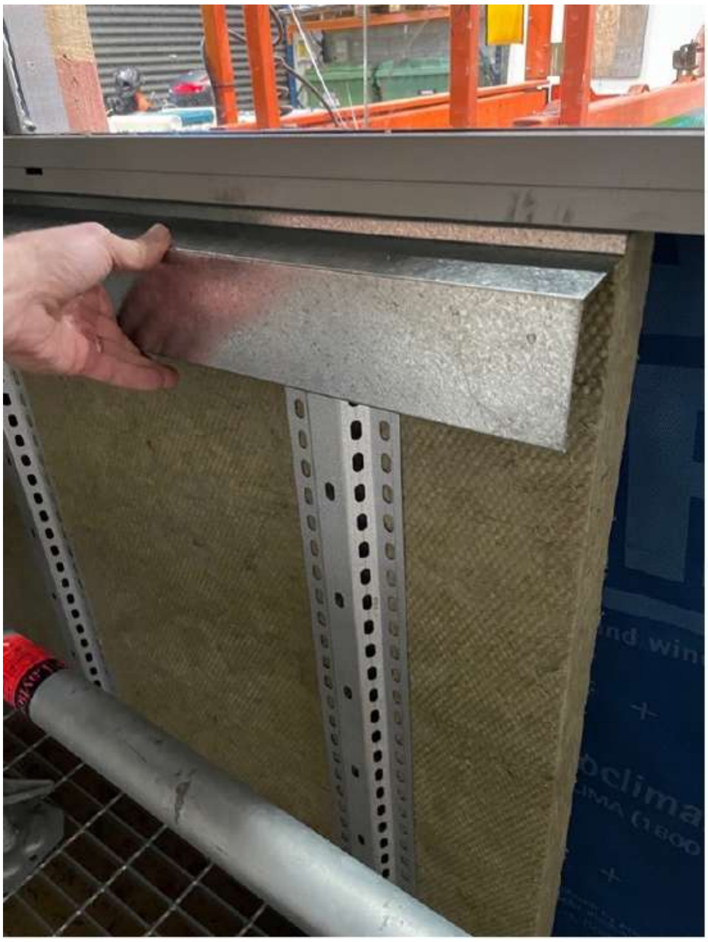


FIGURE 6.5.7E. SILL FLASHING TUCKED UNDER LIP OF WINDOW PROFILE

FIGURE 6.5.7F. INSULATION UP TO WINDOW PROFILE WITH TAPE DEFLECTION LAYER TO AVOID THERMAL BRIDGING.

FIGURE 6.5.7G. NEW WEATHERBOARDS OVER BATTEN, INSULATION, WALL UNDERLAY AND OLD WALL.

FIGURE 6.5.7H. NEW WEATHERBOARD OVER BATTEN, INSULATION AND WEATHERTIGHT WALL.

The purpose of testing this rainscreen cladding assembly is to show situations where external moisture is driven through the external cladding (the main line of defence against moisture). This water should drain down the back face of the cladding and out through the opening at the bottom of the cavity cladding system. In extreme weather situations moisture may be driven through the exterior cladding, through the exterior insulation andreach the wall underlay. In this unlikely (RDH 2014) instance the weathertight wall underlay acts as a secondary line of defence and effectively drains this moisture downwards and out through the opening at the bottom of the cavity cladding system (BC Housing, 2019).

The functional requirements of rainscreen cladding system are part of the building code and set out by clause E2.2: “Buildings must be constructed to provide adequate resistance to penetration by, and the accumulation of, moisture from the outside.” (NZBC Clause E2 External Moisture n.d.). Therefore, the watertightness strategy of the exterior wall assembly is comprised of three main components:

- A water shedding cladding at the exterior
- A batten/rail system for cladding attachment that allows for a drained cavity
- A weather-resistant barrier system

To test the points outlined above, any proposed design needs to consider the materials outlined below:

- There is a water shedding cladding at the exterior, the cladding forms the primary line of defence against moisture. In this application, the water shedding surface is the Abodo weatherboards.
- The cavity behind the cladding is a minimum of 20mm (the same as the E2/AS1 detail). This creates a drained cavity and also incorporates ventilation slots at floor lines to further promote drying of the cavity should exterior water or interior vapour accumulate in the cavity.
- The weather resistive barrier in this assembly is the Proclima Solitex Adhero which is a fully self-adhered vapour-permeable membrane in accordance with E2/AS1 Table 23. This weather resistive barrier is adhered to the existing weatherboard cladding and remains open to diffusion of internal vapour through the wall assembly.
- There are sloped through-wall drainage flashings from the weather resistive barrier to the exterior of the cladding – shown under window. This allows for any liquid water that accumulates behind the cladding to migrate outward.
- There should be a gap created at the top of the claddings below the soffit to allow airflow and pressure equalisation behind the cladding. Airflow provides a drying pathway, and the pressure equalisation of the cavity reduces the potential for water to bypass the water shedding cladding surface.

Physical testing with water was undertaken on a full scale wall assembly similar to external insulation testing by RDH in Canada (a building research company) in 2014. They measured drainage rate of a mineral wool assembly alongside a wall insulated externally with sheets of XPS.

Parka Wrap testing began prior to the new aluminium window install when just the peel and stick membrane was overlaid (across window opening) with standard water spray but high wind pressure. This was to prove the weathertightness of the peel and stick weathertightness wall underlay to a client concerned about water ingress possibilities in his current design. Holes and cuts were subsequently made to introduce leakage pathways during the high pressure test to simulate damage to wall underlay.

After the window was installed but prior to insulation, water testing occurred several more times and included violent (150mm/sec) seismic racking of the test specimen and checks for water leakage afterward.

Insulation was installed over the peel and stick membrane, pinned in place by vertical battens using long screws. Further testing took place to simulate drying potential of the wall assembly. The results were as expected and consistent with RDH testing summarised here: ‘7 hours after an intense simulated driving rain event [horizontal driving rain event 70 times higher than 90% of the rainfall events that occur in Toronto] on open-jointed cladding, one square meter of the Roxul-insulated wall assembly stores approximately half an ounce more water than the XPS wall assembly.’(Smegal and Straube, 2014). A key applicable finding in the study was (with partially removed open rainscreen) the 1% of water at the back of the insulation. This driven rain event is exceptionally unlikely to occur and would require significant amounts of missing cladding, however if it did, water can only get to the dedicated weathertightness line in front of the framing. As initially tested, water did not penetrate the Solitex Adhero wall underlay when fully exposed.

FIGURE 6.5.9A. WATER TESTING SEQUENCE
OF EXPOSED ROCKWOOL INSULATION.

FIGURE 6.5.9B. INFORMAL WATER SPRAY TEST OF EXPOSED ROCKWOOL. WATER WAS HELD TEMPORARILY IN THE LOWER SECTION AS THERE WAS NO DRAINAGE PATHWAY PROVIDED THROUGH THE WIDE UNPERFORATED CAVITY-CLOSER.

FIGURE 6.5.9C. PUSHING CAVITY CLOSER OUT OF CONTACT WITH ROCKWOOL TO PROVIDE DRAINAGE PATHWAY. PERFORATED CAVITY-CLOSER REQUIRED.

How did the assembly perform overall?
Structural framing was maintained dry under all testing scenarios. Solitex Adhero peel and stick weathertightness layer prevented any water from penetrating through to the old existing weatherboards and framing.

How did the new weatherboard assembly perform?
For the most part, successfully. It’s weatherboard and not expected to be 100% watertight (Elkink, 2007), so the assembly of products behind this rainscreen element works together to provide weather tightness (protection against water and wind ingress).

How well did the insulation maintain position during water and seismic testing?
The insulation stayed in position, dried relatively quickly. Ibest possible thermal performance. Yes, as close as possible to the windowsill without impeding drainage of water leakage through window frame and into drainage pathway.

Did water penetrate through to the back-up weathertightness layer under normal test conditions?
Testing has not been able to ascertain this yet. Further NZS4284 testing is required. In the interim, the previously discussed testing by RDH was sufficiently similar to this test requirement to give confidence water will be maintained outward of the primary weathertightness layer (Solitex Adhero fully adhered membrane).

6.5.11 WINDOW FINDINGS

How did the window perform? The window leaked around the rubber seals where wind driven moisture was able to move around the outside of the IGU and accumulate inside the frame.
Did the window-to-wall connection leak water?
Not significantly however water penetrated through a fastener hole that was an error during window installation.
Did the window and wall connections handle seismic movement and remain weathertight?
Yes. The wall was moved at high speed across 200mm travel at the top of the wall relative to the bottom. This is much larger movement than normally expected of a residential wall. Subsequent water testing showed no damage had occurred. Water still leaked around the IGU to approximately the same amount as previous tests even though the glazing unit had moved significantly within the frame during seismic movement.

In summary, the wall design will cope with limited unanticipated moisture intrusion. Water will not pass the primary line of defence (Solitex Adhero) and has drainage pathways down and out of the wall to the outside. Insulation material is itself not adversely affected by water however in an extreme weather event could temporarily hold some water at which point the water will temporarily decrease the thermal performance.

Testing on the Parka Wrap wall without cladding has shown drying potential to be high. This is assuming better building practice (using a perforated cavity-closer) than what is shown in Figure 6.5.7b and c where water was held for a time.

In conclusion, this proposed assembly can be a robust weathertight wall with predictable thermal performance.

An updated window profile has been added. This is shown in Figure 6.5.13 where a thermally broken suite from Starke Windows is used to further improve thermal performance of the interventions.

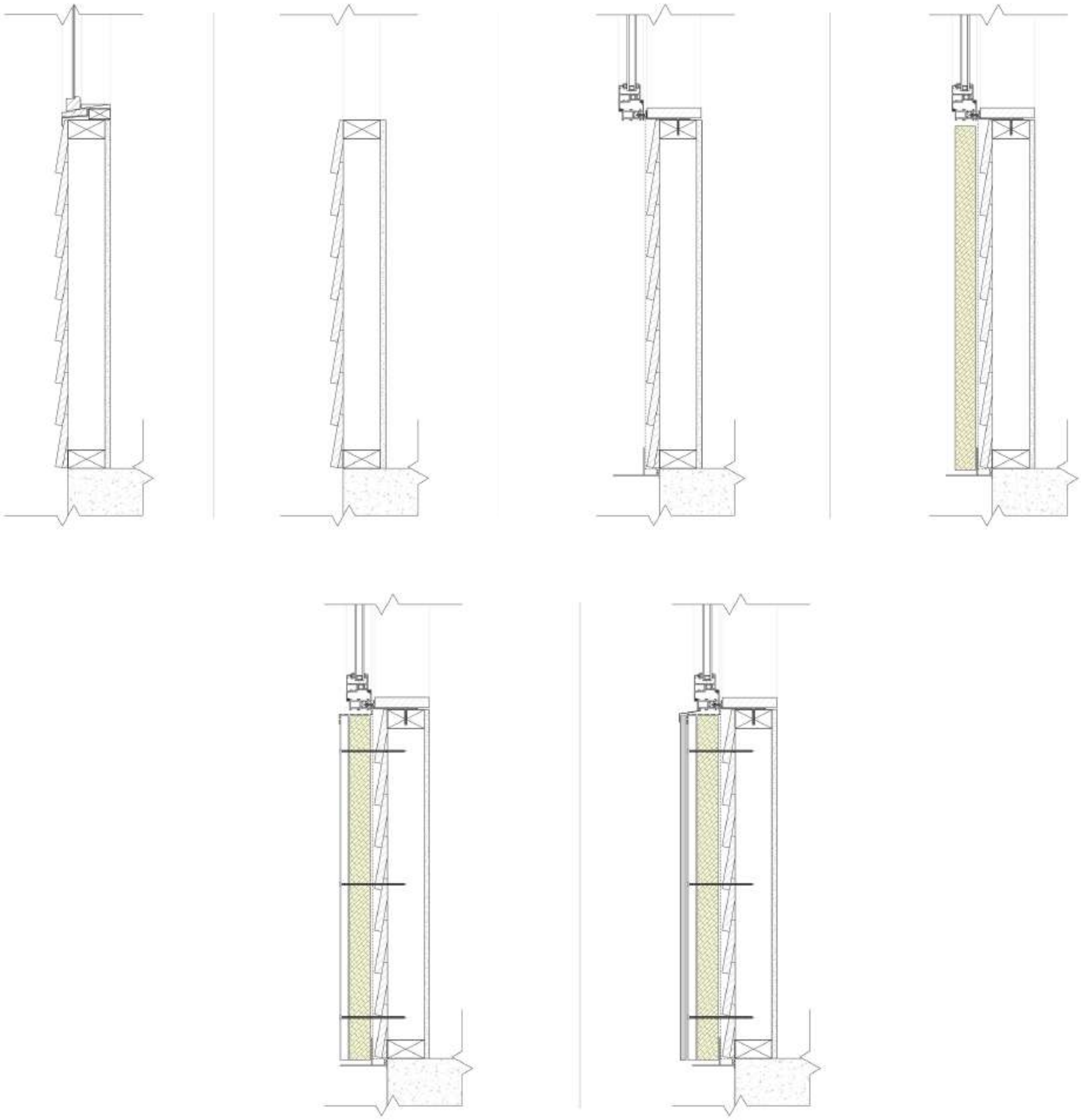


FIGURE 6.5.13. THE PARKA WRAP METHOD FROM EXISTING WEATHERBOARD WALL TO NEW LAYERS AND WINDOW. REVIT MODEL CREDIT: ERIK TODOROV, OCULUS.

Old method of insulating:
Standard NZS 4246:2016 ‘Energy Efficiency - Installing bulk thermal insulation in residential buildings’ serves to guide insulation application for both new and old construction. There are a significant number of steps to be taken before retrofitting insulation into existing walls. Section 5.2.2 describes checking cavities for moisture damage, for rot, for mould or borer. This check is easy if wall linings have been removed from the inside but is not the case with the Parka Wrap method.

Parka Wrap method of insulating:
The steps mentioned above are important so either drilling holes to insert inspection cameras or removing small sections of cladding must be part of the process. Where walls are found to be in reasonable condition by a suitably qualified person, installation of layers as proposed can be done with little or no additional preparation. The proposed method of installing external insulation over slightly damaged and/or missing weatherboards (and other cladding types) as demonstrated in the build-test sequence can be achieved. However, it cannot be done over a damaged structural framework. As Section NZS 4246:2016 section 5.2.2 states, where remediation is required, this should be undertaken prior to further work.

Sequencing for window and wall improvements are shown in Figure 6.5.14.

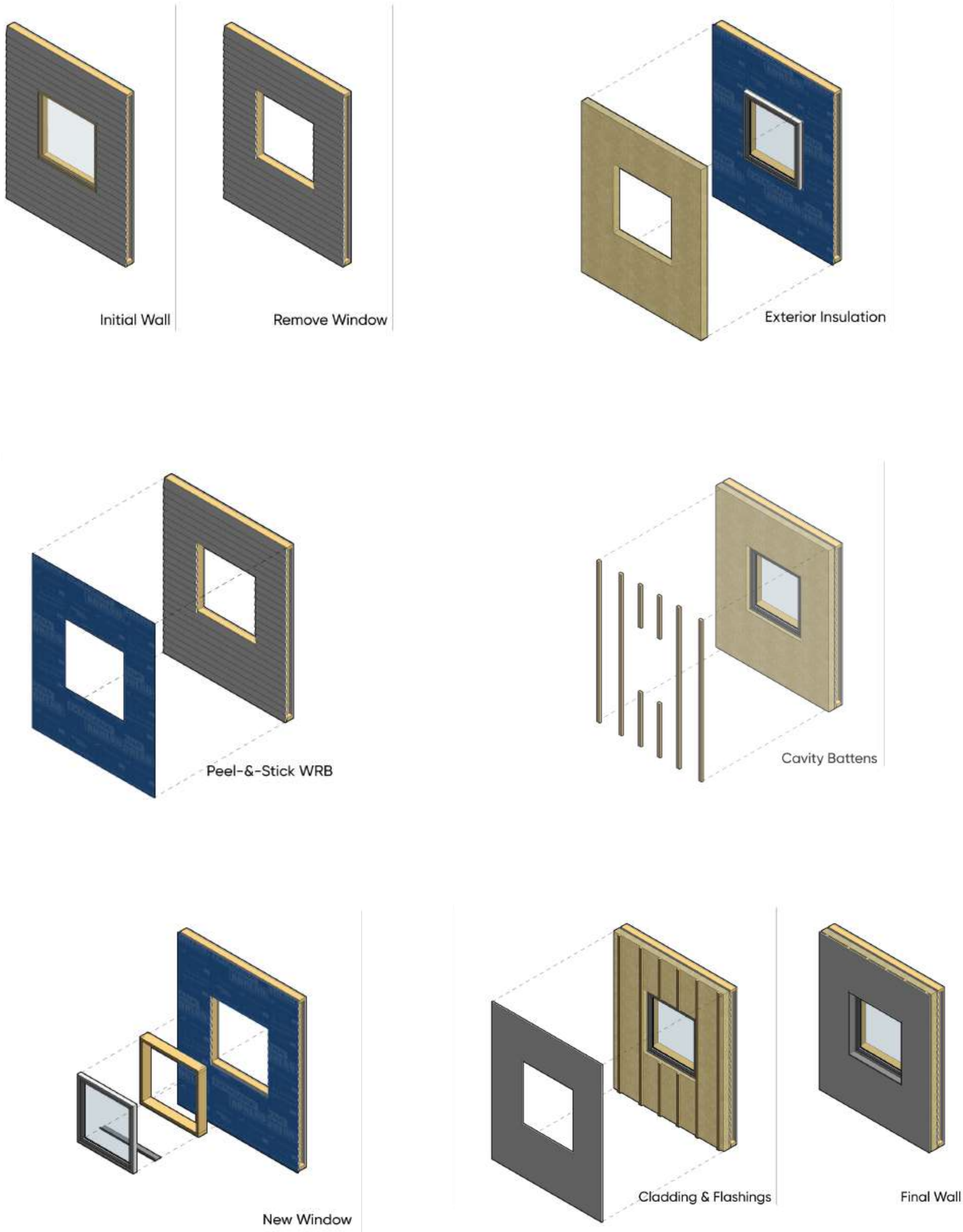


FIGURE 6.5.14. 3D PROCESS OF PARKA WRAP INTERVENTION. REVIT MODEL CREDIT: ERIK TODOROV, OCULUS ARCHITECTURAL ENGINEERING.

Proposed application of materials will plan for removal of window prior to application of back-dam, wall underlay and new window. It is therefore necessary to acknowledge disruption is increased beyond the time to remove existing windows from the inside. Now, the building will be open to the weather for the time taken to remove window, install back-dam, install wall underlay and install new window. This limited disruption is considered preferable to relocating occupants.

This methodology shows a simplified construction technique to improve current house thermal performance. External insulation applied over the existing façade doesn’t consider age of the interior or any internal aesthetic improvement. However, it does allow for thermal improvements to be made at much lower cost. This intervention does allow for a cladding and window replacement, therefore making it possible for tenants to heat their homes at far lower cost than previously. Perhaps the most significant gain when insulating from the outside, occupants can stay in their houses.

When adding material layers on to the outside, from the outside, it is possible without significant building change to install a wind, water, and air-tight layer (one single layer) followed by insulation, a cavity and new cladding. Replacing the window is the most disruptive element and does require a short period of time inside the building to remove and reinstate reveals and architraves.

Overall, confidence is now high in applying learnings gained from the current testing to inform designs now. Further testing planned will look to achieve broader Building Control Authority acceptance. This same methodology can then be applied consistently across many existing building's walls to improve thermal and weathertightness outcomes. It is this improved wall assembly pictured above that will undergo NZS4284 E2/VM1 and 2 testing to verify the procedure against the standard. If they pass the testing, the materials and procedure will become a verified method of construction that Building Control Authorities must accept when design is within the parameters of the tested specimen.

6.6 CAN RETROFIT WALL INSULATION BE APPLIED WITH LOW DISRUPTION?

The answer is yes! Renovation work to install external insulation on the outside from the outside to improve the thermal qualities of existing walls can be achieved without significant disruption to building occupants.
The design including learnings through the process can successfully be applied – specifically around the most difficult area of windows – while maintaining majority of the structure and existing cladding. This allows occupants to remain in the building to avoid significant upheaval caused by moving out for renovation as is typical when undertaking this type of work.

The next step in developing this methodology is to apply findings across more residential typologies. Prescribing pre-checks of structure, showing differences in detailing, guiding major differences in how to handle existing products that need some modification onsite ie. asbestos soffits, stucco, concrete.

Additionally, for newer buildings with existing wall insulation there is a need to run hygrothermal modelling to understand the potential impacts on overlaying new insulation on existing walls. Dwellings built post-1978 encompass more than 1 million New Zealand homes and there are a wide range of buildings and current performance in this category. It is a guess, albeit educated, to suggest most need improvement. Overlaying any insulation on existing insulated walls has potential to radically improve, and equally to cause significant moisture issues therefore further investigation is required for each building typology before a specific intervention is made. This will avoid additional leaky-building crises.

A significant area ripe for improvement is in developing a similar strategy for those buildings other than residential typologies such as schools, healthcare facilities and military buildings.

Other specific areas of further investigation have been highlighted in the 'Limitations of this research' section including development of specific guidance for installing insulation around the soffit area.

Parka Wrap design application has used a thermally broken box section window profile. In the initial mock-ups a uPVC window (with the terracotta tiles) was used, and a timber window while building up the old wall. There are many different window profiles and materials on offer, many can be used in conjunction with this method. Further work would be useful in developing the details required in conjunction with the Window and Glass Association of New Zealand so this approach can be implemented at scale and with simplicity across New Zealand.

7.0 CONCLUSION

Over and above the 720,000 uninsulated homes, New Zealand has another 830,000 households with no insulation in the walls. Being cold in homes is normal in winter. It's possible that total number is closer to 1,700,000 homes if we consider the World Health Organisation recommended temperatures begin at 18 degrees Celsius.

In the places we all call home, we breathe, cook, clean, shower, and exist. If doing these things in comfort is a target - in a 'warm, dry, healthy' home - how do we get there? One part of the answer is to improve the thermal performance of walls, focusing first on those buildings that have little or none, to keep warmth in.

Heating homes has beneficial health outcomes, but in common New Zealand homes this is very expensive due to the lack of insulation. The targeted opportunity proposed in this new methodology is to improve a building's ability to retain heat.

This research has found (modelled) an expected 66% drop in the energy required to heat a typical tenanted home in Rotorua (insulated ceiling and floor, single glazed) by adding insulation on the outside of the existing wall and replacing the single glazing with double-glazed thermally-broken joinery.

Beyond energy consumption, which is comparatively easy to measure, **improving the insulation values of existing walls from the outside and onto the outside suggests relatively low disturbance to the building's occupants –** either homeowners or tenants. Replacing windows creates some disruption while work is undertaken inside the dwelling, but this is demonstrably better than removing occupants.

This design proposal reduces the monetary costs of moving and rehousing people, and the demolition, waste removal, and waste transport.

Develop a new method of retrofitting wall insulation.

An effective methodology has been developed to wrap a building on the outside of the existing fabric to retain the warmth inside. This has been achieved through the process of designing, building and testing with readily available materials. To make this change without major disruption and/or dislocation of the occupants, most of the intervention is achieved from the outside.

The benefits are for people, for energy, and for building waste reduction. In the final design methodology, there is slightly more disruption to occupants than anticipated, however it is still possible for occupants to remain living in the home while work occurs.

It must be acknowledged there are limitations on how this methodology can be applied –

- it will not 'fix' damaged or decaying structures
- it will not overcome non-existent building maintenance practices
- insulation on its own does not create heated spaces
- it will not create ventilated spaces

But it can –

- prevent heat loss through otherwise uninsulated and drafty walls
- avoid significant building waste ending up in landfills during renovation
- reduce the energy demand to achieve 'warm, dry, comfortable' homes
- make buildings more comfortable for people
- reduce the incidence of cold and mould occurrence in homes
- reduce the rates of respiratory illness thereby reduce the costs of respiratory healthcare

The aim of the research was to investigate a practical, safe and effective method of improving the thermal performance of existing walls of residential buildings. The objective was to create a methodology of applying retrofit wall insulation to make this possible without the need for occupants to relocate.

Occupants
It was initially anticipated a very low amount of disruption would occur for occupants – requiring approximately a day to remove all old windows from the inside and restore internal window reveals/liners. This was ambitious and came undone only as the second mock-up wall was built – the main test wall. It was only at this point with an old timber window in place was the realisation it could not be sequenced as intended. The upshot of this 'error' was an opportunity to undertake a more careful check of the existing window rough opening (timber frame), and re-size that opening for the newer thermally broken window installed.

Industry knowledge
The benefits in producing mock-ups for proposed designs have been strongly highlighted within our engineering team who work with designers every day improving buildings. Translating designs into real-world objects during a mockup process forces thinking about that design – the materials, sequencing, and skills required – and exposes deficiencies of 2 dimensional drawings alone. It also highlighted the benefits and simplicity of being able to see how thermal and structural connections can be made, and in the examples, how water might be deflected, held, directed, and drained across three dimensions.

Energy demand reduction
Improving the thermal performance of the existing walls of a dwelling as described in the Parka Wrap method had a significant impact on the ability to heat for comfort. The modelled energy demand required was reduced by two thirds. This outcome alone could justify the implementation of the Parka Wrap methodology.

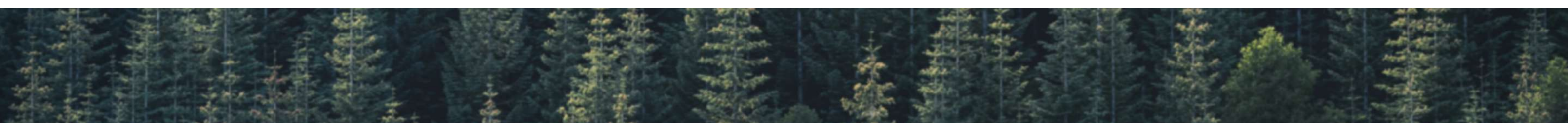
Health outcomes
Other significant outcomes relate to not just the health outcomes for people living in warm dwellings but the reduction in disruption – for continuity of social engagement with neighbours and neighbourhoods, schooling and work attendance, and stability.

Action
Well insulated homes are better for people. This research is intended to generate a trajectory toward better health outcomes based on the already-known effects of temperature and living conditions on health.
Why this method? Homes with ceiling and floor insulation and some draft-stopping measures have been shown to make a small difference (1 degree) on internal temperatures. Applying the retrofit methodology described here in practice for a weatherboard home, and in principle for most typologies, could be expected to improve internal temperatures further.

Research already shows that an increase in temperature sees a decrease in respiratory stress and illness, and, the cost of improvement is less than the cost of ongoing respiratory healthcare. The resulting improvement in health outcomes could be evidenced by further quantitative research into areas such as heating demand, temperature monitoring, school attendance and incidence of respiratory illness.

In the meantime, this method makes it possible to improve houses now, along with the comfort and health of the people who live in them.

He tangata, he tangata, he tangata.



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