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Medium-density housing construction quality survey

Matthew Curtis and Nick Brunsdon

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1222 Moonshine Rd, RD1, Porirua 5381
Private Bag 50 908, Porirua 5240
New Zealand
branz.nz

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Preface

This is the first of a series of reports into the construction quality of medium-density housing (MDH). This report sits within the BRANZ MDH research programme. It is designed to help answer the research question 'What are the technical issues that affect MDH?' taking a case study approach to determine what technical issues are occurring on site.

Acknowledgements

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Authors

Matthew Curtis and Nick Brunsdon

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Abstract

Medium-density housing (MDH) has been suggested as a solution to affordability and land availability issues in New Zealand. As New Zealand shifts away from stand-alone housing towards increased MDH developments, it is important to understand and overcome potential quality issues.

Problem areas that we found as part of this study included weathertightness risks, roof bracing, provisions for services and a lack of common design detailing for MDH. Many of these issues are shared with stand-alone housing. However, the risk of failure is potentially higher in MDH, as the construction is generally taller and utilises multiple claddings with complex wall junctions and narrow eaves.

This study also looks into learnings from the existing stock of MDH, particularly around the need for maintenance. We propose utilising cladding materials that have low life cycle costs, which are typically those with lower maintenance requirements.

Keywords

Medium-density housing, MDH, claddings, maintenance, life cycle costs, LCC, defects.

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Executive summary

As the construction industry moves further towards medium-density housing (MDH), it is important to understand potential construction quality issues and areas of concern. This report utilises several case studies of MDH developments to identify quality issues that are occurring now, the maintainability of these developments and the potential for alternative cladding materials.

Construction problem areas

Weathertightness seems to be a potential issue with MDH currently under construction. Issues were found across multiple developments relating to loose wall underlay and flashing tape during the post-wrap survey. This risks the transfer of moisture across the cavity, and therefore water ingress, if not identified during the council inspection as it would normally be.

This was also identified as an issue during our interviews with builders and designers. One builder reported seeing some poor installations of wall underlay, utilising off-cuts. Another considered that flashing details were sometimes not buildable.

There were also issues with the roof bracing on multiple developments. This could be due to the work being incomplete at the time of our survey, and bracing could have been added later.

The provision for services was often difficult, as it was felt to be not well provided for in MDH plans. Plumbers were said to be creating large holes in structural elements, leaving virtually no residual strength after cut-outs. This was not something that was within the scope of the survey, but some instances of large plumbing cut-outs were spotted during the surveys.

Common design detailing for MDH was thought to provide a solution for some of the buildability issues. Builders felt that designers were not taking buildability into account during the design of the building. A designer stated that there was a strong resistance from builders against non-standard details due to concerns over a lack of skills to carry out the work on site. However, designers did not think that they were able to offer standard details as contractors had individual supply agreements for materials so often wanted to substitute for cheaper products.

Evidence from existing MDH

Similar issues were found with surveys of the existing MDH stock, which ranged in age from the mid-2000s to the present. There were multiple examples of issues relating to poor flashing details. In one case study, there was found to be minimal clearance between the cladding and head flashings and the cladding and service penetration flashings. There was also minimal gap between the horizontal flashings and the cladding. In another, the vents had not been flashed to the cladding, and the clearance between the cladding and head flashings was also insufficient.

Staining was found on some internal walls, particularly around windows and exterior doors. The stains indicated that the developments may have issues with moisture ingress.

Maintenance issues

Some of the issues found in the existing MDH stock surveyed were related to a lack of maintenance. These issues included:

- cracks in timber weatherboards
- peeling paint
- vegetation too close to cladding
- fixings pulled or popped.

There were additional issues with external components requiring repair. Cracking was present between some window sills and frames, and painting was required to prevent moisture damage. There was evidence of damage, such as to the fascia board to the front of one of the units, that could be repaired or replaced.

Some fencing had been erected in close proximity to the exterior cladding. This does not provide sufficient clearance to be able to maintain the cladding.

There were also numerous cases of moisture damage internally caused by leaks in the plumbing and around the shower in the units inspected.

It is not clear from the case studies where the ultimate responsibility for the exterior maintenance of each of the units lies. In some cases, the responsibility may be with the individual owner. In others, a body corporate may be responsible. However, it is clear from the surveys of the existing MDH that maintenance is not always happening.

The maintenance of exterior claddings can be a significant cost over and above the initial purchase price, which may be part of the reason for the maintenance not being undertaken.

Life cycle costs

Life cycle cost analysis was used to compare the claddings used in the inspected MDH development with lower maintenance alternatives. This revealed that low-maintenance claddings may save building owners money in the long run through reduced maintenance requirements, offsetting higher upfront costs. This was particularly the case where the cladding is located at higher levels, which requires control systems for working at height each time that maintenance is performed.

1. Introduction

Medium-density housing (MDH) has been proposed as a solution to New Zealand's affordability and land availability issues. As the supply of MDH increases, it is important to understand whether construction quality issues are arising and where improvements can be made.

This report focuses on the quality of construction of MDH. It reports on 18 case studies – 10 focus on new MDH and eight on existing MDH.

The study forms the basis for further investigation of potential for issues in the construction of MDH and acts as a preliminary study into the quality of construction. It investigates the construction quality of new MDH during various stages of construction and identifies any problems and/or challenges.

In addition, it will estimate the likely maintenance life cycle cost of exterior claddings and evaluate other choices of material that would be possible and compare their life cycle cost. It also looks at existing MDH to determine the exterior envelope performance and ease (or otherwise) of maintenance.

For the purposes of BRANZ work in this area, the following definition of MDH has been adopted: multi-unit dwellings (up to 6-storeys) (Bryson & Allen, 2017).

This project builds on previous BRANZ work on new stand-alone house construction quality. Page (2015) found that most houses that were inspected had at least one compliance defect and one quality (appearance) defect. On average, there were over four quality defects per house.

2. Literature review

Plenty of research has been undertaken to better understand building at density (see Bryson & Allen, 2017). However, very little exists on the causes of defects and the common types of defects. The following sections detail some of the existing literature in the areas.

2.1 Causes of defects

The house building process can be fraught with difficulties. It relies on "organising a series of sequential, interrelated and standardised activities" (Georgiou, Love & Smith, 1999). The authors also suggest that subcontractors, irrespective of the builder, are left to self-manage.

Cooper and Brown (2014) suggest that there are several reasons why defects may occur. The authors state that reasons include complexity of solutions, incorrectly specified materials, substitution of materials, incorrect installation, damage caused by subcontractors and defects in component parts before they are brought onto site.

Ong (1997) suggests that it is when developers shirk from taking the required care that building defects over and above what is normal become an issue. Shirking can happen when developers pre-sell properties before completion, as developers have less incentive to provide quality workmanship. The author states that "building defects are often caused by poor workmanship or shoddy construction practices".

Hall and Tomkins (2000) found that most incidents were attributable to errors and mistakes by specific individuals or supplier errors. It was also common for incidents to be caused by management and communication problems.

The low-bid award procurement system for contracting likely produces "low-quality work, adversarial working conditions, a high incidence of contractor-generated change orders, claims, litigation, and increased project management costs" (Kashiwagi & Byfield, 2002). It forces contractors to increase volume, with lower profit margins, bringing higher risks and lower levels of quality.

BRANZ surveys of new homeowners found that 34% of defects that were present upon handover could be attributed to damaged/faulty work, usually caused by a subtrade. Incomplete or incorrect work accounted for 13% of defects (Curtis, 2013). More recent surveys have found that the majority of defects in detached housing required a plumber, electrician or painter to be called back (Curtis, 2017).

To complement the BRANZ new homeowners surveys, BRANZ undertook some new-build housing inspections. Page (2015) found that approximately 8% of new houses surveyed had compliance defects causing serious concerns. In addition, the "incidence of quality defects averaged over four per house" (p. 1).

As part of this work, a postal survey was sent out to a sample of builders to ascertain what issues they typically have whilst constructing a house. The main problem was found to be inadequate detailing, particularly around roof and wall flashings and structural connections. The second most commonly identified issue was difficulty obtaining workers with adequate skill levels.

Building inspectors do not – and cannot – check the quality of every piece of construction work and every material on site. The builder is responsible for supervision, along with other building professionals (Cooper & Brown, 2014). BRANZ research suggests that inspectors in high-demand areas, such as Auckland, have limited time to carry out their inspections. Therefore, on occasion, there may be limited time to ensure that all details have been built to specifications (Page, 2015).

2.2 Common defect types

Abdul-Rahman, Wang, Wood and Khoo (2014) created a table detailing defects in buildings and housing from various sources. It shows that there are a number of studies that have found defects in the several aspects of new-build construction.

Table 1. Defects summary.

Type of defects	Authors
Foundation and floor structure	
Distortion and cracking of ground floors	Olubodun and Mole (1999); Georgiou et al. (1999); Olubodun (2000); Garrand (2001); Ilozor et al. (2004); Lourenco et al. (2006); Georgiou (2010)
External walls	
Cracking in external wall	Olubodun and Mole (1999); Georgiou et al. (1999); Olubodun (2000); Garrand (2001); Ilozor et al. (2004); Kazaz and Birgonul (2005); Lourenco et al. (2006); Georgiou (2010)
Internal staining; mold growth and fungal decay	Garrand (2001); Chew (2005); Lourenco et al. (2006)
Roof	
Water staining, mold growth and fungal decay	Ilozor et al. (2004); Garrand (2001); Chew (2005)
Deterioration of coverings	Olubodun and Mole (1999); Olubodun (2000); Garrand (2001); Ilozor et al. (2004); Lourenco et al. (2006)
Deformation or displacement of roof	Olubodun and Mole (1999); Olubodun (2000); Garrand (2001); Ilozor et al. (2004)
Internal walls and floors	
Inadequate resistance to the passage of sound	Watt (1999); Garrand (2001); Olubodun and Mole (1999); Olubodun (2000); Garrand (2001);
Distortion and cracking of partition	Ilozor et al. (2004); Kazaz and Birgonul (2005); Lourenco et al. (2006); Georgiou (2010)
Above ground service	
Failure of water supply system	Garrand (2001); Ilozor et al. (2004); Kazaz and Birgonul (2005); Georgiou (2010)
Poor ventilation system	Watt (1999); Garrand (2001)
Below ground drainage and external works	
Surcharge of drains and flooring	Olubodun and Mole (1999); Olubodun (2000); Garrand (2001); Kazaz and Birgonul (2005);
Fracture and displacement of drains	Georgiou (2010)
Wall and floor finishes	
Uneven floor finishes	Georgiou et al. (1999); Chew (2005)
Uneven wall plaster	Georgiou et al. (1999); Kazaz and Birgonul (2005)
Broken floor tiles	Kazaz and Birgonul (2005); Chew (2005)
Broken wall tiles	Olubodun and Mole (1999); Olubodun (2000); Kazaz and Birgonul (2005); Chew (2005)
Damp proof course	
Dampness to concrete wall	Watt (1999); Olubodun (2000); Georgiou (2010)
Floor dampness	Olubodun and Mole (1999); Olubodun (2000); Georgiou (2010)
Door and window fixings	
Faulty door knobs	Olubodun (2000); Kazaz and Birgonul (2005)
Broken window knobs	Olubodun and Mole (1999); Olubodun (2000); Kazaz and Birgonul (2005)
Sanitary installation	
Faulty sanitary installation	Kazaz and Birgonul (2005)
Electrical installation	
Exposed wires	Georgiou et al. (1999)
Faulty electrical fittings	Olubodun and Mole (1999); Georgiou et al. (1999); Olubodun (2000); Ilozor et al. (2004); Kazaz and Birgonul (2005)
Piping work	
Leakage of pipe	Olubodun and Mole (1999); Georgiou et al. (1999); Olubodun (2000)

Source: Abdul-Rahman et al., 2014. Reproduced with permission of American Society of Civil Engineers via Copyright Clearance Center.

Further sources of defect information, focusing in particular on MDH and high-density housing. can be found in Cooper and Brown (2014). They identify that waterproofing is a particular problem in high-rise residential development. They found internal water leaks, cracking to internal or external structures and water penetration from the exterior of the building. In addition, the authors noted issues with poorly located services, noise transfer and car parking.

Earlier work by BRE (1988) found that most faults could be attributed to either the external walls, roofs, and windows and doors. Further research identified the main types of defects, which were mostly rain penetration, condensation, cracking or detachment (Trotman, 1994).

A study into the poor quality of high-rise and medium-rise housing in Turkey found that the quality performance of medium-rise housing units was worse than for high-rise housing units. Doors, windows and their accessories were found to be the main components in poor quality (Kazaz & Birgonul, 2005).

A final study from Spain found that most defects were from a missing item or task, surface appearance or inappropriate installation (Forcada, Macarulla & Love, 2013). The most common defective construction elements were found to be fixtures and fittings, doors and windows, internal walls or doors. The authors also analysed the defects by subcontractor type. They found that the most common trades in which defects arose were painting, door and window closures, and services.

3. Methodology

Realsure was commissioned to inspect 10 MDH sites during construction and eight existing MDH sites for exterior envelope performance and assessment of ease or otherwise of maintenance. Realsure offered two services that provide the information we were seeking as part of this project:

- Pre-purchase visual inspections of new houses to NZS 4306:2005 *Residential property inspection.*
- Realsure Quality Tracker – a quality assurance programme for new construction, culminating in an NZS 4306:2005 report.

The report provided to BRANZ includes a complete breakdown of building materials (including visible insulation, heating and security systems). Realsure also undertook a basic operational test of plumbing and electrical systems, with a primary purpose of identifying significant issues or urgent maintenance. Three types of inspection were undertaken on each new MDH development surveyed. The first was a post-wall underlay inspection, the second was at the pre-lining stage and the third was on completion of the unit. As with the previous inspections undertaken on behalf of BRANZ, the post-underlay inspection focused on framing, joinery and wall underlay. There was also an opportunity to inspect the roof, providing it was accessible. The pre-line inspection focused on the insulation, cladding and plumbing. The final inspection focused on poor or incomplete building work, poor workmanship or incomplete finishing work and weathertightness risks.

The post-wall underlay inspection included matters such as:

- poor or incomplete workmanship
- design details causing issues
- weathertightness risk detailing
- building materials and appropriateness for ease of maintenance
- review of plans where a detail found has triggered a plan review
- site workflow
- site condition.

The pre-line inspection included matters such as:

- poor or incomplete workmanship
- design details causing issues
- weathertightness risk detailing
- building materials and appropriateness for ease of maintenance
- review of plans where a detail found has triggered a plan review
- site workflow
- site condition.

The final inspection included such matters as:

- poor or incomplete workmanship
- design details causing issues
- heating and the presence of double glazing
- weathertightness risk detailing
- building type and materials
- opinion of ease of maintenance of external envelope.

Realsure were also able to assess the weathertightness risk of the exterior envelope and ease (or otherwise) of maintenance of existing MDH. The inspections were conducted using an adapted version of the inspection standard NZS 4306:2005, which in turn is based on the weathertightness risk criteria of ES/AS1. However, the assessment deviates from E2/AS1 with respect to cladding cavities and decks. The presence of a cavity behind the cladding is considered as a factor mitigating weathertightness risk rather than as a consequence of the risk assessment. No comment is made on the deck design due to insufficient information.

Exterior inspections of MDH were limited to safe height access. For the purposes of this work, no height access equipment was used. Inspections were limited to what was in a clear line of sight of the survey from the ground or from the top of a ladder.

The inspections and access to sites were organised by Realsure through an approved party or parties. Contractors were given minimum notice to prevent any prejudice to the findings. The information provided to BRANZ was non-identifying as part of the agreement with the contractors to allow Realsure access on site.

After the information was collected, we were able to undertake the life cycle costing section of this report. Cost data from *QV costbuilder*[1] was used to identify the cost of various materials. QV did not have any information on the cost of scaffolding, so quotes from various scaffolding providers were used to estimate scaffolding costs.

Maintenance requirements were provided by BRANZ Maintenance Schedules.[2] The schedules provide generic maintenance requirements, maintenance periods and replacement periods.

Interviews were arranged to coincide with the case studies, which allowed us to corroborate early findings and identify additional issues that were not picked up during the inspections. The interviews also provided a platform to understand the circumstances and frequency of these issues.

Letters were sent out to developers, builders and designers (including architects) listed as being involved in the construction of MDH in New Zealand to invite them to take part in this research. Interviews were loosely structured around a set of interview questions (see Appendix A). However, interviewees were largely encouraged to talk about the issues that were concerning them within MDH.

Notes were taken during the interview, and interview summaries were provided to the interviewees to ensure they were an accurate reflection of the points they made. Once we had completed all of the interviews, we looked to find commonalities between the interviews.

[1] www.qvcostbuilder.co.nz
[2] www.maintenanceschedules.co.nz

4. Case studies

The MDH developments inspected by Realsure on behalf of BRANZ are reported in this section as case studies. No attempt has been made to obtain a representative sample of MDH in New Zealand. Instead, the case studies represent those developments that we could get access to and that would be completed in a timely manner to meet project deadlines.

Results presented under sections headed as a case study apply only to those case studies and are not necessarily prevalent in any other MDH units.

4.1 New MDH developments

A summary of the results from the inspections is presented in Table 2 and Table 3 below. It shows that, when analysed by element, there do not appear to be many issues that are consistent across multiple developments. However, there were some issues that were picked up on multiple developments that may require further investigation or oversight:

- Roof frame not adequately braced.
- Wall underlay incorrectly fitted/sealed.
- Wall underlay not between flashing and timber framing.
- Joinery flashing tape not installed.
- Flashing not installed on all internal and external corners.

Table 2. Post-wall underlay inspection summary.

Item	Comment
Wall framing	
Top plates straight	Good
Bottom plates straight	Issue present on single unit
Walls straight and plumb	Issue present on block of units
Blocking flush and secure	Good
Inter-floor blocking	Good
Framing connections	Good
Inter-floor connections	Generally unable to be inspected
Factory-manufactured flooring components	Good
Top plate connections	Generally unable to be inspected
Bottom plate connections	Generally unable to be inspected
Bottom plate hold-down bolts	Good
Bracing elements and connections	Good
Roof framing	
Top plate hold-down connections	Generally unable to be inspected
Roof frame bracing	Issue present on multiple sites
Fixings	Good
Joinery	
Joinery (windows and doors) installed	Good
Joinery secured	Good
Air seal backer rod fitted	Generally unable to be inspected until pre-line

Item	Comment
Expanding foam applied	Generally unable to be inspected until pre-line
Sill and jamb tape applied	Issue present on block of units
Joinery head and sill flashings installed and taped	Issue present on block of units
Sill bars present where required	Good
Wall underlay	
Wall underlay as specified	Good
Correctly fitted and secured	Issue present on multiple sites
Wall underlay continuous between timber framing and back of flashing	Issue present on multiple sites
Joinery (windows and doors) flashing tape installed	Issue present on multiple sites
Penetrations taped and sealed correctly	Issue present on block of houses
Bevel-back weatherboard cant strip fitted correctly	Issue present on block of houses
Cavity closer inset at base and above joinery	Good
Battens installed correctly with staggered nailing pattern	Issue present on block of units
Flashing internal and external corners	Issue present on multiple sites
Bricks	
Ties sloped, free of mortar	Good
Cavity clear	Good
Roof	
Material as specified	Issue present on block of units
Roof underlay as specified	Good
Roof underlay lapped correctly	Good
Netting support installed correctly	Generally unable to be inspected
Fixing adequate for roofing type	Good
Flashing correct size for wind zone, eave flashing installed	Good
Kick-outs on apron flashings correct type	Good
Gutters have adequate clips	Generally unable to be inspected
Rainhead drip edges formed	Generally unable to be inspected
Gutter material as specified	Issue present on block of houses
Roof cladding overhang to gutters	Issue present on block of houses
Penetrations vermin caps	Generally unable to be inspected
Ventilation/heating/solar systems adequately fixed	Generally unable to be inspected

Table 3. Pre-line inspection summary.

Item	Comment
Wall framing and inter-floor	
Bottom plates straight	Issue present on block of units
Top plates straight	Good
Walls straight and plumb	Issue present on block of units
Blocking flush and secure	Issue present on single unit
Blocking (bathroom, toilet, curtain rails)	Issue present on single unit
Inter-floor sound proofing	Generally not installed
Joinery	
Joinery installed	Good

Item	Comment
Joinery secured	Good
Air seal backer rod fitted	Good
Air seal expanding foam applied	Good
Sill and jamb tape applied	Good
Joinery head and sill flashings installed and taped	Good
Sill bars present where required	Good
Reveals correctly sized and straight	Good
Insulation	
Ceiling	Issue present on single unit
Walls	Good
Staircase	
Blocking (handrails)	Issue present on block of units
Staircase to framing connections	Good
Cladding	
Cladding fixings type	Generally unable to be inspected
Cladding fixing placements	Generally unable to be inspected
Plumbing	
Plumbing waste set outs	Good
Plumbing mixer set outs	Good

An issue for further investigation is those items that were unable to be inspected during this research. This can either be looked at through having surveyors on site more regularly during the build process or changing when the inspections take place.

The timing of inspections may not have coincided with similar inspections from council inspectors. Therefore, the issues found within this section should have been picked up by the council, and inspections should have failed where appropriate. Outstanding issues during our final inspection may have been in the process of being completed.

The ability to reconcile this information with council inspection records would likely prove valuable. The datasets were deliberately kept completely separate as part of the agreement with contractors to enable site access for Realsure. As a result, no attempt has been made to understand whether those issues found had been spotted by council inspectors nor whether they had been fixed upon returning to the site for a later inspection.

4.1.1 Case study 1 – new MDH

Case study 1 is a two-unit, 3-storey duplex. It was constructed using timber framing with some steel portals and vertical cedar weatherboard. The surveyor's general assessment of the site was that it was accessible, had evident health and safety procedures and was reasonably clean and tidy during the construction of the units. The consented building plans were not on site at the post-underlay inspection carried out by the surveyor.

Comments from the builders during the build included that, prior to the sheet bracing being installed, the 3-storey building tended to move due to only having temporary bracing. At times, the builders had to restraighten and rebrace some walls. The project was said to have had delays due to issues with supply of materials and labour.

The post-wall underlay inspection found that the general workmanship on the wall framing, roof framing and joinery was good on both sites. One of the sites was noted to have some bottom plates that had been cut out to run services and required repairs or replacement. However, no further defects were found at the post-underlay inspection.

No poor or incomplete building work was identified during the final inspection. However, poor workmanship and incomplete workmanship was found throughout both units. Internal doors in some bedrooms and a bathroom were found to be poorly installed. Cupboard doors in the bedroom of one of the units were twisted and needed refitting. A strip of daylight could be seen at a roof to fascia junction. However, there were no evident issues from the external inspection. Finally, the inspector found that some of the lower edges of the cladding required sealing to prevent moisture damage from occurring.

The surveyor's opinion on the weathertightness risk details of the units was as follows:

> The design being three levels with oblique soffits or no soffits in some areas in a high wind zone makes it a higher risk for weathertightness.
>
> However, the simple design with few junctions, the use of junction and joinery flashings and a cavity cladding system would in our opinion help manage this risk, making the unit overall a **medium** risk for weathertightness.
>
> The moisture meter **did not** indicate high moisture readings to the unit.

4.1.2 Case study 2 – new MDH

Case study 2 is a 10-unit, 3-storey row of townhouses. It was constructed using timber framing with aluminium joinery and clad with clay brick to the lower level and vertical cedar shiplap weatherboard to the upper two levels. The surveyor's general assessment of the site was that it was accessible, had evident health and safety procedures and was mostly clean and tidy. However, one of the four units inspected required some tidying up of the site. The consented building plans had been placed on all four sites and appeared to have been followed. The only comment heard on site regarded the delays that they were facing due to material supply issues.

At the post-wall underlay inspection, the inspector found that the general workmanship on the wall framing, roof framing and joinery were good on all four sites. No defects were found on any of the four sites at this stage. At the pre-line inspection, general workmanship on the wall framing and inter-floor, insulation and staircase was also found to be good. The inspector found that there was no inter-floor soundproofing. However, the wastepipes had been soundproofed.

There was no poor or incomplete work on any of the four sites during the final inspection. However, there was some level of poor workmanship or incomplete finishing work present across the units. A consistent finding was that there were marks on walls that needed to be cleaned to provide an acceptable level of finish. In addition, there was some impact damage to the internal wall linings that should be repaired.

In addition to the above, two of the units were found to have some areas of the bricks inside the foundation line. The inspector thought that trimming here would give a cleaner finish. However, they did not believe that it would cause any issues from trapped moisture at the base of the cavity. Another of the units was found to have some unsealed cut edges to the lower level of the vertical cedar weatherboards. These could be sealed to prevent moisture being soaked into the timber and causing damage. A final unit was found to have some split weatherboards that may need to be sealed or replaced.

The surveyor's opinion on the weathertightness risk details of the units was as follows:

> The design being three levels with oblique or minimal soffits in some areas in a high wind zone makes it a higher risk for weathertightness.
>
> However, the simple design with few junctions, the use of junction and joinery flashings and a cavity cladding system would in our opinion help manage this risk, making the unit overall a **medium** risk for weathertightness.
>
> The moisture meter **did not** indicate high moisture readings to the unit.

4.1.3 Case study 3 – new MDH

Case study 3 is a seven-unit, 2-storey row of townhouses. It was constructed using timber framing, Speedwall and concrete blocks and clad with timber horizontal bevel-back weatherboards. The surveyor's general assessment of the site was that it was accessible, had evident health and safety procedures and was in good overall condition. The building plans had been placed on all four sites and appeared to have been followed.

General workmanship at the post-wall underlay inspection across the majority of the four sites inspected was found to be good. However, workmanship on one of the sites was found to be average at the post-wall underlay inspection.

There was no poor or incomplete building work found on three of the four units surveyed. On the fourth unit, the metal capping to the fire wall between units was found to be poorly installed and required some reworking.

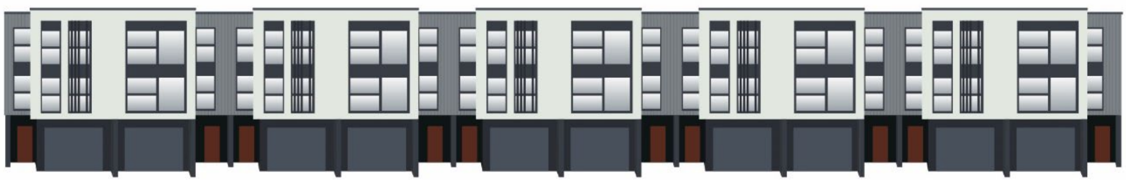
The builders and subtrades on site mentioned that the project had faced several delays due to poor weather.

The surveyor's opinion on the weathertightness risk details of the units was as follows:

The design being more than a single-level dwelling with minimal roof overhangs, complex junctions on the front elevation, in a high wind zone, on a cavity cladding system would in our opinion put it at a **medium** risk for weathertightness.

The moisture meter **did not** indicate high moisture readings to the unit.

4.1.4 Case study 4 – new MDH



Case study 4 is a 10-unit 3-storey row of townhouses. It was constructed using concrete blocks and timber framing and clad with vertical aluminium planks, fibre-cement bevel-back weatherboards and fibre-cement sheet. The surveyor's general assessment of the site was that it was accessible, had evident health and safety procedures and was in good overall condition. The building plans were placed on all four sites and appeared to have been followed.

In general, workmanship was found to be good on the majority of the sites. However, on a couple of the sites, the surveyor felt that the joinery was average. On one of those sites, flashing tape appeared to have been missed on the top corner of the sill and jamb and to the joinery head of a couple of windows.

No inter-floor soundproofing was present on two of the four units surveyed. Also, the cladding had been fixed using finishing pins and construction adhesive but the plans showed the fixings should be stainless steel screws. The fixing placements were not as per the plan on one of the units. The other three units had been painted, and it could not be ascertained whether the issue was present on the other units.

On one of the units, there was found to be some poor or incomplete building work at the final inspection stage. There was some splitting to the sealant at the sheet joins of the cladding that required repair to prevent future moisture issues. The lack of flashings noted at the pre-line stage also presented a weathertightness risk.

Poor workmanship was present in all four units. In the first unit inspected, an internal door was damaged and needed to be repaired or replaced. Due to an internal corner not being square, the cladding was approximately 10–15 mm clear of the cavity batten in some areas. The cladding was also found to not be straight in some areas, likely due to a bow in the framing that had not been checked before installing the cladding. Finally, the front of a two-piece plastic moulding on a section of the cladding was poorly fitted and required reworking.

On the second unit, there was no stop-end to the flashing at the end of some of the set-in window areas. The flashing abutted the cavity batten, which was also exposed to the weather. It appeared to our inspector that the cavity batten was not in the right place. The cladding was also damaged at this junction. Our inspector felt that it did not match the detailing of other similar windows, which would indicate that these windows had been incorrectly flashed, which is a weathertightness risk. There were also issues with a door striker plate requiring adjustment. Marks on the walls of one of the bedrooms also needed to be cleaned to provide an acceptable level of finish.

In the third unit, there were some popped nails on the wall lining of the living area. In the fourth unit, there was some cracked glazing in the windows that could be replaced. Also, there were some poorly sealed joins to some areas of the external corners that would require repair to prevent moisture issues.

The surveyor's opinion on the weathertightness risk details of the units was as follows:

> The design being a three-level dwelling with inter-storey cladding junctions, no soffits, on a cavity cladding system would in our opinion put it at a **medium** risk for weathertightness.
>
> The moisture meter **did not** indicate high moisture readings to the unit.

4.1.5 Case study 5 – new MDH

Case study 5 is a four-unit 2-storey row of townhouses. It was constructed using steel framing and clad with brick and fibre-cement bevel-back weatherboards. The surveyor's general assessment of the site was that it was accessible, had evident health and safety procedures and was generally tidy. The building plans were available for all four units. However, they did not appear to have be followed in all respects, particularly the cladding.

The general workmanship of the wall framing was found to be average at the post-wall underlay inspection. Framing and inter-floor connections were incomplete. Bottom plate connections and hold-down bolts were also incomplete. The builders had started installing the roof and cladding despite the structural work not being complete.

The roof framing had not been completed, despite the roof being installed. The top plate hold-down connections had not been completed, saddle truss braces had not been installed and fixings were incomplete.

The joinery had not been installed at the time of the survey. However, the sill bars had insufficient fixings and were too long.

The wall underlay was not correctly secured. The fixings should have been at 300 mm centres to each stud, as per the manufacturer's specifications. However, they were only held in place by the cavity battens, some screws and tape. The joinery flashing tape was not installed right over the sill, although it was not required to be according to the consent documents. The penetrations were not taped and sealed, nor were the head flashings. The battens were not installed correctly. They were fixed at 1200 mm centres, and some were loose. The builder advised that they do this as the cladding fixings provide the necessary fixings.

The roof material was as specified. However, the detail was not consistent with the material specified. This meant that the installation detail for structural ties between units did not work at the roof level. The gutter material was not as specified. It was also split in the centre and had minimal turn-down, which could allow water to track back along under the flashing. Some valleys only overhung the gutter by 5 mm.

At the final inspection, the surveyor found a number of items that were classed as poor or incomplete building work. They found a screw head on the exterior cladding that had not been filled. This could be repaired to prevent damage to the fixing. The pipes and cables penetrating the exterior cladding were not sealed around to prevent moisture getting in behind the cladding.

The bottom edge of some of the weatherboard cladding had split, which required repairs or replacement to prevent moisture ingress. There was also a gap down the side of some scribers, which required repair to prevent moisture getting in behind the cladding. The bottom edge of the weatherboard had not been painted, although they had the factory seal. The weatherboards were also out of alignment at the join, indicating incorrect installation.

There were also a number of items of poor workmanship or incomplete finishing work found at the final inspection. There were boxes, tools and dust to be cleared away and professional cleaning required. The stairs of one townhouse had not had the handrail fitted yet. The extractor fans in one of the townhouses did not operate and may have required repair or replacement. The ensuite in the second townhouse had a tear in the flooring that required repair.

There was paint splatter on the brick cladding, which is not good trade practice and could be removed. The bricks were inside the foundation line in some areas, which can allow water to wick back in behind the bricks. This may also have affected the width of the cavity at these points. There was a large gap in the cladding where the head flashing penetrated above the front exterior door. It was not known by the surveyor if there was a concealed flashing behind this. There were some gaps down the side of the facing boards that could be sealed to prevent moisture getting in behind the cladding. The cladding joins were visible, indicating they had not been correctly prepared. The bottom edge of the box corners had not been sealed and required painting to prevent moisture soaking up the end grain. The join in the scribers was out of alignment.

The original building contractor was unable to assemble the light steel frame construction in an orderly method that would have enabled the construction to flow. The workmanship of the standing of the frames and portals was inadequate, and the flow-on affected the quality of the build. This impacted on the installation of bracing, firewalls and other related fixings and fittings for other contactors engaged at a later stage to remedy the work.

The construction required a planned methodology from the outset, which did not occur. This resulted in time delays, a change of contractors and ultimately a poor level of workmanship across the build. Accordingly, the inspections could not be completed in the three proposed stages of construction, as they varied significantly across the units at any given time.

The surveyor’s opinion on the weathertightness risk details of the units was as follows:

> The design being a two-level dwelling with inter-storey cladding junctions and relatively complex design would in our opinion put it at a **medium** risk for weathertightness.
>
> The moisture meter **did not** indicate high moisture readings to the units.

4.1.6 Case study 6 – new MDH

Case study 6 is a six-unit 2-storey row of townhouses. It was constructed using timber framing with clay brick and horizontal fibre-cement weatherboard cladding. The surveyor's general assessment of the site was that it was accessible, had evident health and safety procedures and was in good overall condition. The consented building plans were placed on all four sites and appeared to have been followed.

In general, workmanship was found to be good on the four sites surveyed. However, during the post-wall underlay inspection of one of the sites, the wall wrap had been cut out and required repairs.

At the final inspection stage, the surveyor did not find any poor or incomplete building work. However, there were some areas of poor workmanship or incomplete finishing work.

In the first unit, there was some cracking in the ceiling lining to wall junction that needed to be repaired. The stairs to the attic were found to be incomplete, requiring the lower section to be cut to allow the stairs to be a straight flight and the spring system to be installed.

The second unit had some incomplete work in the kitchen, master bedroom, ensuite and roof cavity. The external door from the kitchen required a trim across the bottom of the frame as the expanding foam was still visible. The bedroom still required the floor covering to be installed. The door frame to the ensuite needed to be repainted. Finally, as with the first unit, the stairs to the attic were incomplete.

The third unit only had some minor repairs needed to the bedroom doors and door frames. In the master bedroom, the repairs to the door frame were in progress. Repairs were yet to commence to the striker plate in the second bedroom, which required adjustment to prevent the door from catching.

In the final unit inspected, there was found to be no seal between the vanity and the adjoining wall. This would have allowed moisture to get behind the vanity. It was also found that the insulation had been disturbed in places and required relaying.

The surveyor's opinion on the weathertightness risk details of the units was as follows:

> The design being a two-level dwelling, with minimal soffits, roof to wall junctions and relatively complex design on a cavity cladding system would in our opinion put it at a **medium** risk for weathertightness.
>
> The moisture meter **did not** indicate high moisture readings to the unit.

4.1.7 Case study 7 – new MDH

Case study 7 is a five-unit 3-storey row of townhouses. It was constructed using concrete and timber framing and clad in fibre-cement bevel-back weatherboard and aluminium planks. The surveyor's general assessment of the site was that it was accessible, had evident health and safety procedures and was in a good overall condition. The building plans were placed on all four sites and appeared to have been followed.

The post-wall underlay and pre-line inspections did not find anything of concern. The general workmanship was found to be good across all four units surveyed.

At the final inspection stage, the surveyor found some scratch damage to the surface of the aluminium cladding. The cladding would require replacement. No further poor or incomplete building work was found on any of the sites.

Two of the four units were found to have poor workmanship or incomplete finishing work. However, the other two units were in the process of having paint touch-ups at the time of inspection. One of these units had some minor damage to the painted surface of the living area that required repair and a repaint. The other unit had plastering marks showing through the painted surface of the wall that could be sanded and repainted, and the carpet required refixing adjacent to the joinery.

The surveyor's opinion on the weathertightness risk details of the units was as follows:

> The design being a three-level dwelling with minimal soffits, complex wall junctions, inter-cladding junctions on a cavity cladding system would in our opinion put it at a **medium** risk for weathertightness.
>
> The moisture meter **did not** indicate high moisture readings to the unit.

4.1.8 Case study 8 – new MDH

Case study 8 is a three-unit 2-storey row of townhouses. It was constructed using concrete tilt slabs and timber framing and clad in bevel-back timber weatherboard and vertical shiplap cedar weatherboard. The site was found to be accessible but was untidy. No health and safety procedures were evident on any of the sites. The overall condition of the site was found to be poor. The consented building plans were not on site.

The general workmanship on the wall framing was found to be average or below average. The wall framing was found to not be straight on any of the sites, off by 10 mm over 2.4 m on one unit and 5 mm over 2.4 m on another. The bottom plates on all three units were found to have unacceptable cut-outs in bracing walls. There was also no blocking provided for the bathroom toilet, curtain rails or handrails for the staircase.

The roof framing was generally found to have average workmanship. On one of the units, some of the strapping did not have tensioners installed. Joinery was found to be installed well and with good workmanship. However, due to the slab being out of level, some of the joinery was not level.

General workmanship on the wall underlay was found to be average. On two units, the wall underlay was not correctly fitted and secured and required refixing. On the third unit, the penetrations were not adequately taped and sealed and required reworking.

The surveyor also found wastepipes had been installed through plywood bracing, a stud in the bracing wall had been cut out for a waste pipe and no cap flashing had been installed to the exterior of the tilt slab. This meant that water was running down the inside of the interior of the tilt slab causing the insulation to get wet.

Poor or incomplete building work was found on each of the units. On one unit, the pipes and cables penetrating the exterior cladding needed to be sealed around to prevent moisture getting behind the cladding. In the other two units, the foundations were found to be out of level. The tilt slab and bracket were packed up due to the foundations being out of level.

Poor workmanship or incomplete finishing work was also prevalent across all three units. In the first unit, scuff marks were found on the walls of the living area and one of the bedrooms that needed to be cleaned to provide an acceptable level of finish. There was also some minor damage to the painted surface that could be repaired and repainted. Some of the weatherboards had been double nailed, which is not good industry practice as it can lead to splitting or bowing. There were damaged flashings that required repair or replacement and a large amount of surface damage to the roofing material that required repair or replacement.

In the second unit, there was some minor damage to the painted surface of the master bedroom that could be repaired and repainted. Some scribers of the cladding required reworking as they were not installed tight to the joinery and could allow moisture to access behind the joinery. A cap flashing had also been surface mounted and fixed through the top, which is not good trade practice. There was surface rust and surface damage to the roofing material that would require repair or replacement. There had also been a rebate cut in the concrete slab for the garage door after construction that had exposed the reinforcing mesh.

The final unit had fewer issues than the previous two units surveyed. The surveyor found holes in the cladding that required repair to prevent moisture getting behind the cladding. There was also some exposed reinforcing in some areas as the slab had been cut back.

The surveyor's opinion on the weathertightness risk details of the units was as follows:

> The design being two levels with complex roof-to-wall junctions on a cavity cladding would in our opinion put it at a **medium** risk for weathertightness.
>
> The moisture meter **did not** indicate high moisture readings to the unit.

4.1.9 Case study 9 – new MDH

Case study 9 is a seven-unit 3-storey row of townhouses. It was constructed using timber and concrete block framing and clad with fibre-cement bevel-back weatherboards. The surveyor's general assessment of the site was that it was accessible and had evident health and safety procedures but was generally untidy. The consented plans were available on all four sites and appeared to have been followed.

The post-wall underlay and pre-line inspections did not identify anything of concern, and all of the workmanship was found to be good across all four units surveyed.

At the final inspection stage, three units had no poor or incomplete building work identified. The fourth unit had some pipes and cables penetrating the exterior cladding that required sealing around to prevent moisture getting in behind the cladding.

All of the units exhibited poor workmanship or incomplete finishing work. The shower doors were yet to be installed in three of the four units at the time of inspection. The insulation had been disturbed in the roof cavity of all four units and required relaying. One unit was also found to have cladding that curved out in some areas. This may have been an indication that some areas of the framing required restraightening.

The surveyor's opinion on the weathertightness risk details of the units was as follows:

> The design being more than a three-level dwelling, relatively complex, with a reasonable roof overhang and cladding cavity and its location would in our opinion put it at a **medium** risk for weathertightness.
>
> The moisture meter **did not** indicate high moisture readings to the units.

4.1.10 Case study 10 – new MDH

Case study 10 is a five-unit 2-storey row of townhouses. It was constructed using timber framing and clad with brick and fibre-cement bevel-back weatherboard. The surveyor's general assessment of the site was that it was accessible, had evident health and safety procedures and was in good overall condition. The plans were available on all four sites and appeared to have been followed.

The general workmanship across all four units was found to be good during both the post-wrap and pre-line inspections. However, one of the units had ceiling insulation that required replacing in some areas.

At the final inspection, there was no poor or incomplete building work identified on any of the four units surveyed. However, some areas of poor workmanship or incomplete finishing work were found on three of the units. There were marks/damage to some of the linings that needed to be removed and/or repaired. Some insulation had also been disturbed in the roof cavity and required relaying. There were also some bricks overhanging the foundations, which were within acceptable tolerances. The inter-storey flashing required ends to be sealed to prevent moisture ingress.

The surveyor's opinion on the weathertightness risk details of the units was as follows:

> The design being a two-level dwelling with minimal soffits and horizontal cladding junction on a brick and weatherboard cavity system would in our opinion put it at a **medium** risk for weathertightness.
>
> The moisture meter **did not** indicate high moisture readings to the unit.

4.2 Existing MDH developments

This section describes eight case studies of MDH constructed since 2005. This time period has been determined as it aligns with changes to the Building Code post leaky buildings and the introduction of the risk matrix and Acceptable Solution E2/AS1.

The main purpose of this section is to analyse the weathertightness risk of some of the existing MDH stock. This includes specifying which weathertightness risks are present in the case studies and how well the case study building exteriors have been maintained. Given the working at heights restrictions, the survey did not extend beyond what could be seen from a ladder. Therefore, the roof cladding was not surveyed other than what could be seen from the ground.

While the units were being surveyed, we used the opportunities to also survey the interior. These units were typically furnished at the time of the survey, and therefore it was not always possible to visually inspect all of the flooring or wall linings.

Table 4 summarises the weathertightness risk details for each case study. The table is loosely based on the building envelope risk scores from E2/AS1. However, it deviates from E2/AS1 with respect to cavities and decks. The presence of a cavity behind the cladding is considered as a factor mitigating weathertightness risk rather than as a consequence of the risk assessment. No comment is made on the deck design due to insufficient information.

Table 4. Weathertightness risk details for existing MDH.

Case study	Wind zone	Levels	Building type	Wall junctions	Eaves	Cavity	Risk
11	Medium	1	Apartment	Complex	450 mm	N/A	Medium
12	Medium	3	Townhouse	Inter-cladding	200 mm	Yes	Medium
13	High	3	Townhouse	Inter-cladding	300 mm	Some	Medium
14	High	3	Apartment	Complex	None	Some	Medium
15	High	2	Townhouse	Inter-cladding	300 mm	N/A	Lower-medium
16	Medium	3	Townhouse	Inter-cladding	300 mm	N/A	Medium
17	Very high	3	Apartment	Complex	750 mm*	Yes	High
18	Very high	3	Apartment	Complex	Flush	Yes	Medium

* Rear of apartment. Flush eaves to front and sides.

For the majority of the sites surveyed, surveyors deemed the weathertightness risk to be medium. Previous work looking at risk scores for new-build detached houses in 2012 found that the majority of new houses had a low risk score (Page & Curtis, 2013). For those territorial authorities most likely to have MDH, risk scores tend to be higher. However, given that our case studies are generally taller and have complex wall junctions/inter-cladding details, it is not surprising they have higher risk scores.

Some of the case studies appear to have construction-related issues, many relating to poor flashing details. Flashings were also an issue on many new MDH sites inspected.

Some of the issues found related to lack of maintenance to the cladding. Cracks were found in some timber weatherboards, paint was peeling, vegetation was not being cleared and fixings had pulled or popped.

Staining was found on the internal lining below windows and around some external doors. Previous work by BRANZ (Curtis & Gordon, 2018) found that inappropriate use of sealant was common within the industry, which could be the cause of moisture ingress in these case studies.

There were also numerous cases of moisture damage or higher than normal moisture readings caused by internal issues. There was evidence of leaks in the plumbing and around the shower panel/screen and wall.

4.2.1 Case study 11 – existing MDH

Case study 11 is a four-unit 2-storey townhouse. It was found to be in average condition for its age. We were able to survey two of the units within the block of townhouses.

In one of the units, the living area recorded higher than normal moisture readings on the external walls below the joinery. The condition of any internal timber is not known. There was also moisture damage to the cabinetry that was wet, indicating a possible leak in the plumbing. The bathroom also had a higher than normal moisture reading on the external walls below the joinery. This may have been due to condensation or the window leaking. There was also a leak around the bathroom waste that required repair.

There were cracks to the cladding, which would require monitoring for a few months for any signs of movement. There was paint bubbling to the plastered concrete wall below the joinery, which could be an indication of moisture behind the plasterboard linings.

There were two areas requiring maintenance in the second unit. The first was that it appeared that probes had been installed in some areas of the external walls. The second was that an internal PVC corner was damaged and required replacement.

The surveyor’s opinion on the weathertightness risk details of the units was as follows:

> The design being more than a single-level dwelling with complex wall junctions and having had required remedial work around the joinery shortly after construction and the location of this home would in our opinion put it at a **medium** risk for weathertightness.
>
> The moisture meter **did** indicate high moisture readings to the units around the joinery.

4.2.2 Case study 12 – existing MDH

Case study 12 is a four-unit, 3-storey townhouse. It was found to be in average condition for its age. Only one of the four units was able to be surveyed.

The exterior cladding was due to be cleaned back and painted to protect the timber from moisture. The paint was peeling in places and should have been sanded back and repainted. Some weatherboards were split and needed replacing. Some fixings had pulled or popped in the weatherboards, which could be refixed or replaced and sealed.

There was cracking between the window sills and frames that should be resealed or painted to protect the timber from moisture damage. Some rubber window seals were damaged and could be replaced with new seals.

The tiles in the ensuite were cracked and would need to be replaced. The door striker plate in the ensuite door required adjustment. A handrail had been installed with fixings through the cladding. This is a weathertightness risk and should be modified.

The surveyor's opinion on the weathertightness risk details of the unit was as follows:

> The design being more than a single-level dwelling with inter-cladding junctions, balcony over an interior space and the location of the home would in our opinion put it at a **medium** risk for weathertightness.
>
> The moisture meter **did not** indicate high moisture readings to the unit.

4.2.3 Case study 13 – existing MDH

Case study 13 is a three-unit, 3-storey townhouse. It was found to be in average condition for its age. One of the three units was able to be surveyed.

The surveyor found stains on the ceiling. The stains were dry at the time but indicated past or occasional leaking. Repairs had been made to the ceiling but could have been tidied up. The stains were directly below the bathroom, which had recently had repairs undertaken to the shower.

Despite the repairs that had recently been undertaken to the shower, the shower was leaking between the shower panel and wall. This required sealing on the exterior of the junction to prevent the leak from occurring.

Further signs of past or occasional leaks were evident in one of the bedrooms. Some of the ceiling paint was peeling, although the ceiling was dry at the time. It was directly below another set of repairs that had been recently undertaken to the vent pipe.

In another bedroom, the skirting adjacent to the ensuite was swelling. This tested dry at the time of the survey but may be an indication of past or occasional leaking. The ensuite door frame was moisture damaged. This may be due to the lack of seals around the shower door.

The surveyor's opinion on the weathertightness risk details of the unit was as follows:

> The design being more than a single-level dwelling with some directly fixed cladding, minimal overhangs and the location of this home would in our opinion put it at a **medium** risk for weathertightness.
>
> The moisture meter **did not** indicate high moisture readings to the unit.

4.2.4 Case study 14 – existing MDH

Case study 14 is a three-unit, 3-storey apartment. It was found to be in average condition for its age. We were able to survey two of the three units.

Paint was found to be peeling to the wall beside the shower in the ensuite of one of the units. The surveyor found higher than normal moisture readings, and further investigation would be necessary to locate the source of the moisture and repair as necessary. The survey suggested that the shower screen may have been leaking.

Service penetrations had not been flashed to the cladding, fixing plates were hard to the cladding and there were no signs of compression washers, all of which are weathertightness risks. The surveyor also could not confirm the presence of the flashing at the inter-cladding junction. The junction is a weathertightness risk.

The clearance between the cladding and the head flashings was insufficient, which could cause moisture issues. Vegetation was growing against the exterior of the home. This should be cleared away to prevent dampness and the risk of damage. Further to these issues, the property has a concealed gutter system. The gutter sits directly on top of the interior and blockages or leaks could channel water directly into the interior.

The skirting had pulled away near one of the windows. This tested dry at the time of the survey but may be an indication of past or occasional leaking. Some of the walls had popped nails on the wall linings and some impact damage to the wall linings.

There was also a slightly higher than normal moisture reading to the external door. The surveyor suggested that it might have been due to condensation or the joinery leaking.

In the second unit surveyed, there was found to be some damage to the cladding that required repair or replacement. Nails from the rear deck had pierced the exterior cladding through the deck framing, posing a weathertightness risk. The decking framing was hard against the exterior cladding. There should be a gap at this junction to allow water to drain freely and to prevent damage to the cladding.

A saddle flashing should have been installed where the parapet joins the exterior of the house. There is also a gap in the cladding where the balustrade meets the house cladding. These present moisture risks.

Two further minor issues were found by the surveyor. There was also a bent flashing above the garage door that could be repaired, and the seal around the shower had deteriorated and should be replaced.

The surveyor’s opinion on the weathertightness risk details of the units was as follows:

> The design being a 3-storey townhouse with no eaves on a texture coat polystyrene cladding and a fibre-cement sheet cladding on a cavity system, concealed gutter and the location of this home would in our opinion put it at a **medium** risk for weathertightness.
>
> The moisture meter **did** indicate slightly high moisture readings to the dining area (external door).

4.2.5 Case study 15 – existing MDH

Case study 15 is a two-unit, 2-storey townhouse. It was found to be in a good condition, and the workmanship was deemed to be average where visible. We were able to survey one of the two units.

There were a few minor maintenance or finishing items required during the survey. An internal door striker plate required adjustment, some corner soakers were damaged and could be replaced and the fascia board to the front of the house was damaged and could be repaired or replaced.

The surveyor's opinion on the weathertightness risk details of the unit was as follows:

> The design and location of this home would in our opinion put it at a **lower-medium** risk for weathertightness.
>
> The moisture meter **did not** indicate any high moisture readings to the unit.

4.2.6 Case study 16 – existing MDH

Case study 16 is a five unit, 3-storey townhouse. It was found to be in a good condition, and the workmanship was deemed to be average where visible. We were able to survey one of the five units.

The living area was found to have marks to the paintwork on the walls. These marks could be cleaned off and the area redecorated. There was also some paint splatter on the timber window jamb that could be tidied up.

Paint runs or marks to the paintwork were common throughout the house, particularly within the bedrooms. Cracking between the plaster cornice and the plasterboard linings required repairs in one bedroom. Skirting boards also required additional fixings as they were loose to some of the walls.

The master bedroom required handles to the sliding doors as they were missing. The main bathroom's striker plate to the internal door was loose and required refitting, and the toilet seat was loose and the fixings required tightening or replacing.

The surveyor's opinion on the weathertightness risk details of the unit was as follows:

> The design and location of this home would in our opinion put it at a **medium** risk for weathertightness.
>
> The moisture meter **did not** indicate any high moisture readings to the unit.

4.2.7 Case study 17 – existing MDH

Case study 17 is an eight-unit, 3-storey apartment. It was found to be in new-build condition for its age and had not yet been maintained. We were able to survey one of the eight units.

The end grain of the vertical weatherboards had not been adequately sealed to prevent moisture ingress into the board. Some weatherboards were also found to be cupping, and if they could not be pulled back into place, they would need to be replaced to ensure weathertightness.

The timber fencing had also been fixed in close proximity to the cladding, which is a weathertightness risk. This may need to be modified to allow sufficient clearance to be able to maintain the cladding.

Some further minor touch-ups were required around the house, but these were all relatively minor.

The surveyor's opinion on the weathertightness risk details of the unit was as follows:

> The design being multi-storey with complex wall cladding junctions, minimal roof overhang and the location of the home would in our opinion put it at a **higher** risk for weathertightness.
>
> The moisture meter **did not** indicate any high moisture readings to the unit.

4.2.8 Case study 18 – existing MDH

Case study 18 is an eight-unit, 3-storey apartment. It was found to be in as-new condition, and the workmanship was of reasonable standard where visible. Two units were inspected as part of this case study.

On one of the units, the membrane on the roof was found to be loose on the corners and the substrate could be seen. This would require repair as water can wick into the substrate and cause moisture damage.

The second unit had some minor maintenance issues. There were marks to the paintwork in the kitchen/dining area and the garage walls.

The units had minimal clearance between the cladding and head flashings. Also, there was minimal clearance between the cladding and vent flashings. This could cause moisture issues. The cladding had been brought hard down onto the rubber membrane flashings and sealant applied to the junction of the roof and cladding. This could allow water to be wicked up as there was no capillary gap separating the cladding from the flashing.

There was a minimal gap between the horizontal flashings and the cladding, which could prevent the cavity from adequately ventilating and draining. This is a weathertightness risk.

The surveyor's opinion on the weathertightness risk details of the units was as follows:

> The design being more than a single level, complex roof/wall junction, cladding on a cavity system and location of this home would in our opinion put it at a **medium** risk for weathertightness.
>
> The moisture meter **did not** indicate any high moisture readings to the units.

5. Life cycle costing

The objective of the life cycle costing is to evaluate other choices of cladding materials in MDH. This is to determine whether there is an economic argument to be made to use materials that are easier to maintain over the lifetime of the dwelling. In addition to cost savings that may be made over the life cycle of a building, there may also be health and safety benefits (not analysed within this study). WorkSafe's best-practice guidelines for working at height in New Zealand (WorkSafe, 2017) present a range of methods for elimination for height hazards. This includes the "use of low-maintenance building materials" to help eliminate the potential of a fall.

Scope of analysis

This analysis focuses on cladding materials used in the recent construction of 10 MDH developments surveyed as part of this research. The authors have not seen the developments as part of the agreement with builders on site. Therefore, we have used a range of dollar per square metre rates ($/sqm) to take account of differing assumptions.

Period of analysis

The period of analysis is chosen to be the average normal life of the New Zealand housing stock. Johnstone (1994) found that "the period over which 50% of dwellings are lost from each dwelling cohort, is estimated to be about 90 years" (p. 184). Therefore, for the purposes of this study, 90 years is used. It is worth noting that the required service life of a building is not less than 50 years as defined as the minimum in New Zealand Building Code clause B2 *Durability*.

Method of economic evaluation

The assessment of the life cycle costing (LCC) will be through net present value (NPV) of the costs. The net present value is defined as "the sum of the discounted future cash flows, both costs and benefits/revenues" in IS EN 16627:2015 *Sustainability of construction works – Assessment of economic performance of buildings – Calculation methods*. Given that we are only looking at the costs, the analysis may instead be termed net present cost (NPC). IS EN 16627:2015 also states that it is "a standard measure in LCC analyses, used to determine and compare the cost effectiveness of proposed options".

Discount rate

The discount rate is an analysis to determine the present value of future cash flows. It takes into account the risk or uncertainty of future cash flows, with greater uncertainty resulting in higher discount rates.[3] IS EN 16627:2015 states: "The higher the selected discount rate, the less influence costs later in the required service life have on the calculation of NPV (cost). Higher discount rates tend to favour lower initial cost solutions which can have higher operating costs." For the purposes of this study, the current discount rates section of The Treasury website[4] recommends that, for general-purpose office and accommodation buildings, a real pre-tax discount rate of 4% p.a. is used.

[3] www.investopedia.com/terms/d/discountrate.asp
[4] www.treasury.govt.nz/information-and-services/state-sector-leadership/guidance/financial-reporting-policies-and-guidance/discount-rates

Risk/uncertainty

Materials may be chosen for numerous reasons. Therefore, it is important to consider factors other than the cost of the material, installation and maintenance when performing this analysis. However, these factors can be difficult to estimate.

One such factor is that these materials may be considered as more desirable to clients, resulting in a shorter timeframe to sell each unit. Also, it is assumed that there is no difference in how the cladding affects the performance of the building, particularly regarding the running costs or internal comfort for the occupant.

In addition, we assume that there is no difference in the profit margin for the contractor and/or client in choosing a different cladding option. However, there may be strong incentives for designers, developers and/or builders to use certain cladding options, despite the life cycle costs.

The analysis considers the life cycle costs for claddings in a moderate environment. More harsh environments are likely to require more frequent maintenance than we have accounted for. The exposure conditions are likely to be spread over a wide range of conditions, which will influence the need for maintenance.

There is also an assumption with the costings that the maintenance is undertaken as stipulated by product documentation and by someone qualified to do so. Maintenance may be undertaken less (or more) regularly with materials other than those specified, or the homeowner could undertake the maintenance themselves.

Sensitivity analysis

We did not perform a sensitivity analysis on the life cycle costs provided. We have instead opted to provide ranges for the life cycle cost of each material to better reflect how dependent the cost is on the situation. For example, the life cycle cost of a material that requires regular maintenance is likely to be significantly different if it is installed on the third-storey than it would be if it was used on the ground floor.

Options to be considered

Through evaluation of the case studies from the inspections, the first set of wall claddings to be examined are:

- vertical stained cedar weatherboard – moderate initial cost, high maintenance requirements
- vertical painted pine weatherboard – moderate initial cost, moderate maintenance requirements
- clay brick – moderate initial cost, low maintenance requirements
- fibre-cement weatherboard – moderate initial cost, moderate maintenance requirements
- fibre-cement sheet – moderate initial cost, moderate maintenance requirements.

Alternatives have been selected through analysis of BRANZ Maintenance Schedules and cost information being available from *QV costbuilder*. The selected alternatives are:

- stone veneer – high initial cost, low maintenance requirements
- concrete block – low initial cost, regular maintenance requirements
- PVC weatherboard – moderate initial cost, low maintenance requirements.

We have selected only a small sample of cladding types to be used for the analysis as we are interested in the higher than usual maintenance cost for MDH dwellings. Maintenance costs are higher due to the need for scaffolding for maintaining multi-storey MDH dwellings. Therefore, for this analysis, we have looked to select materials with differing installation and maintenance costs and timeframes. This allows us to test the effect of maintenance on the life cycle cost of different cladding types to determine the role maintenance requirements play in the cost-effectiveness of each cladding.

Cost of materials and installation

Cost data has been obtained from *QV costbuilder* – a subscription-based online platform that provides access to building cost data for those in the building trade industry and property professionals. It provides a comprehensive reference to New Zealand building costs and other related information. The costs are $/sqm rates and are for the material and installation. All costs exclude GST.

These costs encompass the product stage (cradle to gate) through to the practical completion of all construction work as defined by IS EN 16627:2015. This would include direct costs of equipment related to the construction, such as site accommodation, access equipment, contractors transport and cranes. There is an assumption in the costings that changing the cladding material would not affect the cost of other building components.

Note that the costs used are those provided by *QV costbuilder*. They may not represent those paid by builders, merchant prices or the price that the manufacturer expects the material to be sold for. The costs shown in Table 5 are our best estimates given the information that we have available from a neutral source at a particular point in time. Cost ranges take into account regional cost differences, differences in costs of coatings or different coating options.

Table 5. Wall cladding material costs.

Material	Cost
Cedar weatherboard	$178–208/sqm
Clay brick	$162–181/sqm
Pine weatherboard	$128–168/sqm
PVC weatherboard	$168–183/sqm
Stone veneer	$388/sqm
Concrete block	$101–116/sqm
Fibre-cement weatherboard	$145–193/sqm
Fibre-cement sheet	$135–155/sqm

Maintenance requirements

Most claddings have similar maintenance requirements. All claddings need to be washed yearly, for example. Those claddings that have a paint finish are likely to need repainting every 7–10 years. Some claddings may have a service life less than the required service life of a building, which will require a reclad.

A key consideration of this research is that MDH is likely to be multi-level. This considers that MDH is likely to encompass many 2-storey flats, terraced housing of up to 3-storeys and apartments up to 6-storeys. The maintenance for these multi-level houses will require some form of control to "isolate or minimise the potential for harm resulting from a fall" (WorkSafe, 2017).

The control system used will depend on the scale of maintenance undertaken and the type of maintenance required. For example, repainting the wall cladding of a 4-storey apartment block is likely to require a different control system than washing the wall cladding of a 2-storey unit.

For the purposes of this analysis, the washing of wall cladding is not going to be costed. Any cladding material should be washed annually, and therefore there should not be a significantly different washing cost for different cladding options.

Generic maintenance requirements and replacement periods shown in Table 6 were taken from BRANZ Maintenance Schedules.

Table 6. Wall cladding maintenance requirements.

Material	Maintenance requirement	Maintenance cost	Anticipated serviceable life
Cedar weatherboard	Wash cladding yearly. Restain cladding every 3–5 years. Replace damaged boards as required.	$26/sqm	45 years
Clay brick	Wash cladding yearly. Clean weepholes as required. Repoint mortar joins as required.	$0/sqm	90 years
Pine weatherboard	Wash cladding yearly. Sand, remove all loose and flaking paint and repaint every 5–7 years. Replace damaged boards as required.	$46/sqm	55–80 years
PVC weatherboard	Wash cladding yearly. Replace damaged boards as required.	$0/sqm	30 years
Concrete block	Wash cladding yearly. Clean weepholes as required. Repoint mortar joins as required. Reapply sealer every 5–10 years.	$7.40/sqm	90 years
Stone veneer	Stiff brush clean. Repoint mortar. Replace damaged stones. Obtain specialist advice when cracking occurs or a leak is suspected.	$7.40/sqm	80 years
Fibre-cement weatherboard	Wash cladding yearly. Repaint every 5–10 years.	$31.75/sqm	50 years
Fibre cement sheet	Wash cladding yearly. Repaint and reseal joints every 5–10 years.	$47.50/sqm	35–50 years

IS EN 16627:2015 defines the boundary of maintenance to include the costs of:

- all components and ancillary products used for maintenance
- all cleaning processes
- all processes for maintaining the functional and technical performance of the building fabric as well as aesthetic qualities of the building's exterior components.

Where maintenance requirements have a range of timeframes (i.e. every 5–7 years), estimates for both extremes in the range are used. This is part of the reason for the range of costs for each cladding type provided in the following sections.

Cost of control systems for working at height

An estimate of the cost of control systems for working at height was produced from quotes from several suppliers of control systems. Suppliers were approached with two representative floor plans – a 3-storey townhouse development and 4-storey apartment development. Across both developments, quotes converged on an average rate of $15.78 per m^2 of wall area to be scaffolded. This included erection, hire for a period of 4 weeks and dismantling in an Auckland suburban centre. These parameters were intended to reflect a typical MDH development.

Within the LCC analysis, scaffolding costs were only incurred when maintenance or replacement took place but not for initial installation of the cladding. It is assumed that scaffolding will be required for other building elements in the initial construction phase.

Salvage and disposal costs

These costs have been estimated using *Rawlinsons New Zealand Construction Handbook 2013/14* (now out of print)[5] and the *QV costbuilder* website.

These two estimates from Rawlinsons form the basis of our demolition costs:

- 100 mm concrete masonry wall – $37.40/sqm.
- Timber-framed, partly glazed partitions – $16.10/sqm.

To estimate how these costs may have changed over time, we compare it to the *QV costbuilder* estimate. Table 7 shows that there has been little change in the cost of demolition.

Table 7. Demolition cost comparison.

	Rawlinsons 2013/14	*QV costbuilder*
House, reinforced concrete floor slab, brick veneer cladding and tile roof, 2-storey, concrete block basement, 600 kg per m^2	$126/sqm	$130/sqm

Adjusting for today's demolition costs, we use $38.60 per square metre for heavy claddings (clay brick, concrete block and stone veneer) and $16.60 per square metre for light claddings (weatherboards of all types and fibre-cement panel).

5.1 Life cycle cost of cladding materials

The costs shown previously form the basis of the life cycle cost of the different cladding options that follow. These costs are shown as a range for each of the cladding options. The ranges illustrate the uncertainty in cost of materials, installation costs, maintenance costs and demolition costs.

Figure 1 shows the life cycle cost of those cladding materials analysed as part of this work. The bottom of the range represents the costs for materials that are:

- brought and installed at the bottom of the given cost range
- maintained at the end of the maintenance period range
- installed at a level where no scaffolding is required for maintenance.

[5] www.rawlinsons.co.nz/construction-handbooks/

The high end of the cost range illustrates the opposite assumptions to the above.

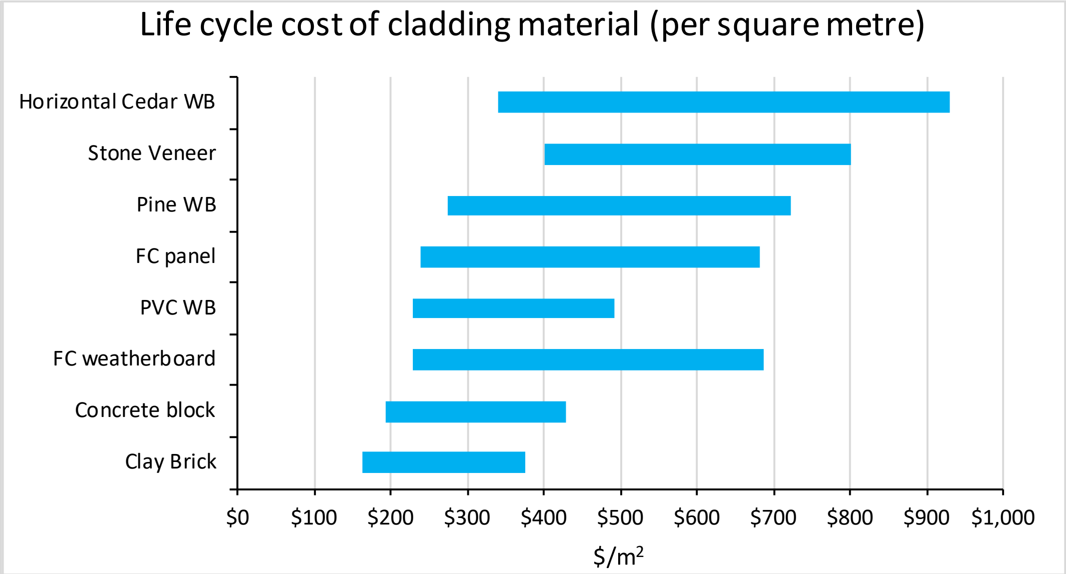


Figure 1. Life cycle cost of cladding materials.

Delving beyond the total LCC of claddings into the elements of installation and maintenance reveals the trade-off to be made in specifying claddings. Figure 2 illustrates the widely ranging make-up of cladding LCC costs based on the high end of the cost range. Clay brick and horizontal cedar weatherboards offer a comparable installation cost. However the much higher maintenance requirements of cedar lead to a total LCC of nearly three times clay brick. Similarly, the installation cost of stone veneer is very high – nearly double the other seven claddings. However, the low maintenance cost for stone veneer contributes to a total LCC that is lower than four other claddings. While not all clients will consider the 90-year lifetime cost for their cladding, it is important to consider the likely maintenance costs based on the environment and height of the cladding.

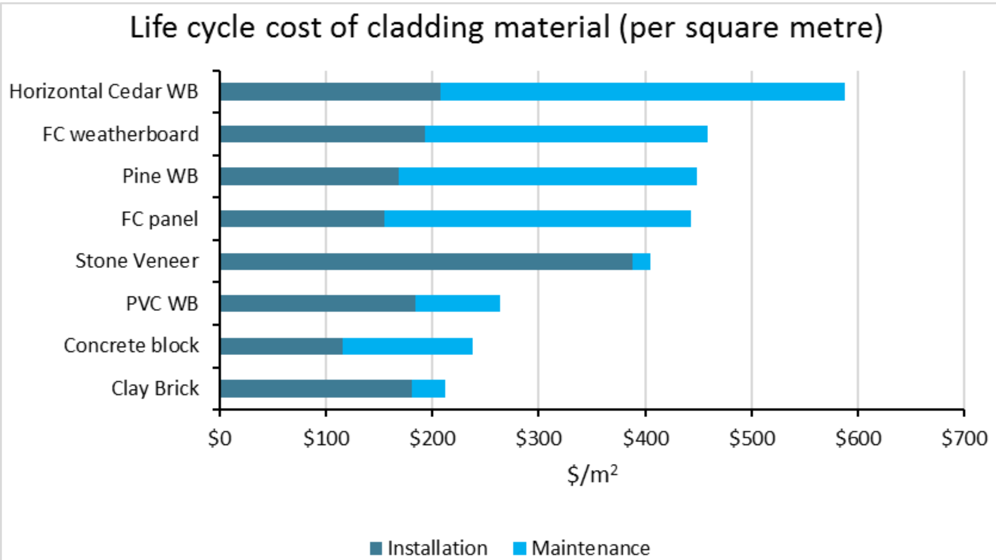


Figure 2. Life cycle cost of cladding installation and maintenance (based on the high end of the cladding cost range).

5.2 Evaluation

Maintenance and replacement costs can make up a significant proportion of the life cycle cost of cladding materials. These costs can be as high as 58–65% for some of those high-maintenance/low-serviceable life claddings, particularly when installed at higher levels.

This illustrates the importance of looking beyond the initial cost as the ultimate determinant of the materials being used in construction. Where a similar aesthetic can be achieved using lower-maintenance materials, these can provide a lower life cycle cost over the lifetime of the building. This is particularly the case if the material is going to be difficult to maintain. It is also likely to offer higher quality over the lifetime of the building, as maintenance will be cheaper to undertake and the material will not need maintenance as regularly as some alternatives.

6. Interview summary

Interviews with builders, designers and developers were undertaken to coincide with the surveys. The aim was to determine what they perceive the construction issues to be and to verify the findings from the on-site surveys.

Working on MDH

The interviewees generally felt that the industry was struggling to adapt to the move to MDH. It was noted that sites were generally messier (Interview 5) and that experience in stand-alone did not translate to MDH (Interview 6). One designer felt that there were not many changes in design for MDH compared to stand-alone (Interview 7). Another felt that design quality was good – the problem was the quality of the workmanship (Interview 10).

Scheduling

MDH construction is more difficult to schedule than stand-alone dwellings. A group builder that had moved into MDH had found that their typical group home builder pricing and scheduling software was not suitable for MDH (Interview 1). A larger more experienced builder noted that MDH typically has more complicated and intensive coordination, as timeframes are compressed and more trades are involved (Interview 3). Council inspectors were also said to make scheduling difficult, as uncertainty of inspector opinions made it difficult to schedule construction (Interview 2).

Subcontractors

The industry is currently facing a labour shortage. MDH is no exception, with shortages reported for bricklayers (Interview 5) and the finishing trades (Interview 6). Shortages meant that head contractors could no longer draw from a known or preferred pool of subcontractors (Interview 10). Many firms are operating gangs of unqualified builders led by a single LBP (Interview 5).

One designer felt that it was difficult to find builders with experience in innovative construction materials. Contractors often wanted to substitute for cheaper products, and this was dependent on each individual contractor's supplier relationships and discounts (Interview 9).

Framing

Framing hold-down bolts were mentioned by two interviewees as being difficult to install correctly. This was said to be due to having uneducated builders on site (Interview 1) or some systems make it difficult to maintain the distance between the hold-down bolt and slab edge (Interview 5). Another issue identified was the lack of a solution for reducing the moisture content in timber during winter. The framing can get very wet just over the time that it takes to stand the framing (Interview 2).

Windows

Window fixings were said to still be challenging for some (Interview 1). There was also a lack of good fixing details, particularly for sill bars into concrete (Interview 5). The same builder noted that there was still a lack of knowledge around sealing window jambs, with builders pushing backer rods for the sealing of window jambs in too far. Mounting windows with unequal space between the jamb and framing also made it challenging to effectively seal window jambs (Interview 5). It was also noted that flashing stop-ends could be easily knocked out, particularly as only a small amount of silicon is used to hold them in place (Interview 5).

Balcony detailing

Balconies were among a list of areas that could benefit from standardised detailing (Interview 2). This builder stated that they were finding different balcony details on every project. Waterproofing of balconies was also said to be challenging (Interview 6, 10).

Standard detailing/buildability

A key limitation the industry is facing is the resistance from designers for developing common detailing for MDH construction where the design is beyond the scope of Acceptable Solutions. It was felt that the designer wanted to "make their mark" with each development (Interview 2). Designs were not felt to be satisfactory and lacked buildability, and build-only contracts typically required lots of variations for buildability once on site (Interview 3). Designers with no practical experience were thought to be copying and pasting details without understanding buildability (Interview 5). A designer stated that there was strong resistance from builders against non-standard details due to concerns over lack of skills to carry out specific details on site. It was felt that contractors were not looking far enough ahead to work around predictable issues (Interview 9).

Provision for services

It was felt that MDH plans did not provide for services particularly well (Interview 5), and this can cause issues for the running of plumbing (Interview 4). Plumbers are creating large holes in structural elements (Interview 5, 9), leaving virtually no residual strength after cut-outs (Interview 2). Where services are being planned for, changes in spec can render this planning useless (Interview 2).

Wall underlays and flashings

One builder interviewed stated that they had seen some ropey installations of wall underlays, typically utilising off-cuts (Interview 2). Flashing details typically came from the cladding manufacturers (Interview 8). However, flashings were felt to sometimes not be buildable within the constraints of the detailed design, and units tended to have more complex roofs than stand-alone houses (Interview 4).

Maintenance

Many builds tend to be cost-driven, which can lead to compromises over maintenance (Interview 5). Bodies corporate were felt to be taking an increasing interest in maintenance (Interview 10), but developers were said to not be as interested (Interview 2, 4). Where builders and designers were able to specify, they tried to use low-maintenance materials, particularly claddings (Interviews 1, 6, 10). However, their input can often be limited by the client (Interview 2) or the type of contract (Interview 3).

7. Conclusions

Overall, the issues picked up as part of the MDH construction quality survey were similar to those picked up in the survey of stand-alone new homes. Weathertightness remains the highest concern in the construction of new dwellings. Given the higher weathertightness risks in MDH and the increasing proportion of MDH being constructed, this is a pressing issue that requires greater information and resources for designers and builders.

The provision of services seems to become a larger issue as the size and complexity of construction increases. On-site issues with installation of HVAC and plumbing services across both residential and commercial construction has shown the importance of proper provision for services. Ensuring that designs have fully considered the needs of the different services and that services within the design are the services being installed should help overcome some issues in this area.

Some areas, such as acoustics and passive fire, were not picked up as part of this survey. Further work is required to better understand how well these areas are being specified and their construction quality. Other areas such as top plate and bottom plate connections were generally unable to be seen while the surveyors were on site. Further work to cover these unseen items could prove beneficial.

Maintenance seems to be increasingly looked at by building stakeholders. The key driver still appears to be initial cost, particularly where developers are driving the design and material selection decisions. However, bodies corporates were taking an interest in maintenance and can help drive a move towards lower-maintenance materials.

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Appendix A: Interview details

Interviewees were sourced in two groups – builders (including developers) and designers – and were presented with the following introduction and interview questions.

Introduction

This is part of programme to support the construction industry to provide medium-density housing that meets the needs of New Zealanders

When we talk about MDH, we generally mean multi-unit dwellings up to 6 storeys. This excludes stand-alone houses and includes semi-detached/duplex, terraced housing and mid-rise apartments.

Ultimately, we want to support the building industry to meet the growing demand for this type of housing, particularly in Auckland.

The purpose of this project and focus group is to ascertain problem areas in MDH design and construction.

Therefore, the focus is on identifying issues and the factors that contribute to or cause issues.

Interview questions

What is the extent of your involvement in construction of medium-density housing?

Overall, how do you think the building industry is doing to adapt from construction of stand-alone houses to MDH? Specifically, builders? Designers? Why do you think that is? Is this improving with time?

What elements of MDH construction are challenging the building industry? Is this problem widely recognised? What is the consequence of these problems? How frequently are these problems occurring in your experience?

Building on the challenging building elements that we have identified, let's think about what **causes** these issues and how these **causes** are common across **issues**. What is causing these issues identified?

Beyond Code compliance, can you think of any areas where MDH construction could be improved for occupants and/or owners?

Interview responses

Interview 1 (Builder, 10–20 MDH units per year)

The building company has extensive experience in stand-alone housing and has now moved into a "moderate scale" of development of 2-storey townhouses with staggered construction. They found that the typical group home builder pricing and scheduling software was not suitable for MDH, and as a result, they had to change their approach part-way through development.

Existing subcontractor relationships have been able to be used for the construction of MDH developments. This has meant that the builder has been able to retain subcontractors for subsequent units on the same development site. The builder is seeing improvements in construction efficiency as the site develops and workers become familiar with the design. This has led to the building company completing three units per month.

Further efficiencies have been achieved through revisions during the process. The builder discovered some buildability issues during construction. However, the designs of the subsequent units were able to be revised to incorporate this understanding. They tend to go for simpler designs and detailing to reduce the cost and improve the speed of construction.

The proprietary system that they typically use for inter-tenancy walls had an as-constructed sound test that was very positive. They use light inter-tenancy systems as brick/block trades and tilt slab supply is very tight.

Overall, it was felt that the industry was doing well. However, the builder still saw issues with inexperienced or uneducated builders. They pointed out that some gangs of migrant workers were relying on one LBP builder across the gang. There were also some issues with health and safety compliance with these gangs. Another issue was framing hold-down bolts. The builder noted that these were generally done well, but some uneducated builders still did not understand.

Window jamb sealing was said to have improved across the industry. However, fixings are still challenging for some. Screws were found to be a better solution, as they have greater pull on the window and can be adjusted more easily. However, stainless steel is required for screws, which may make them cost prohibitive. Nails are being used most commonly.

Cut-outs of framing are still an issue, particularly where 3x2" framing is used for internal walls, as there is virtually no residual strength after plumbing waste cut-outs. As a result, the builder has had to change to 4x2" walls in these situations. Services were being planned for, but changes in spec (such as a different shower tray) during construction can render this pre-planning useless.

The builder felt that the sealing of penetrations had come a long way. It was common for trades to make their own seals using flashing tape. However, pre-formed boots are universal now and are done well.

As a building company, they consider maintenance in their material specification. They use low-maintenance claddings, such as Linea weatherboards.

Interview 2 (Builder, 50–100 MDH units per year)

This builder has been heavily involved in MDH for the past 7 years, including both residential and retirement villages. The MDH was typically 4–5 storeys, ranging from townhouses to multi-storey apartments. The builder tended to up-spec their acoustic design as they felt the Building Code requirements were very low for acoustics. They have not built using lightweight timber floors in MDH for this reason.

The builder uses 140 mm deep exterior wall framing on a third of their jobs, so cut-outs for plumbing are generally not as much of an issue as they would be with 90 mm framing. They suggested that plumbers were generally pretty good at allowing for sheet-metal brackets around cut-outs in their quotes. Any excessive cut-outs were being picked up during the council plumbing/pre-lining inspection. Internal vacuum systems used to cause significant problems with framing cut-outs but are not very common now.

They perceived the industry to be struggling with the shift to MDH. A key limitation was the resistance from designers for universal detailing for MDH. The builder finds that designers want to "make their mark", leading to new detailing with each development. This takes time for builders to become familiar with. It would be preferable for architects to make incremental improvements instead, supporting consistency, quality and volume of MDH construction.

The builder considers NZS 3604:2011 to not be relevant to MDH, as much of what they build is outside its scope. Some engineers were trying to apply NZS 3604:2011 solutions where they weren't suitable. Even 2-storey designs with large windows and open interior spaces often offer insufficient bracing for NZS 3604:2011.

The builder would like to build more standardised designs and NZS 3604:2011 structures. They consider standard detailing for MDH a "mountain to move" but as being essential for building more MDH. They suggested that balconies, fire and acoustic were the most deserving areas.

MDH design was deemed to be expensive, as it requires a range of consultants – fire, acoustic, mechanical engineer, CPTED, Homestar, façade etc. This applies to 3–4-storey MDH and sometimes 2-storey MDH. They felt that there was more risk aversion in the design profession than 10–15 years ago. Architects used to perform many of these functions themselves.

It was felt that it was difficult to meet all of the requirements for balcony details (i.e. aesthetically slim, fire resistant, 150 mm step down from interior). The builder finds different balcony details on every project. They can effectively build anything, but many balcony designs are expensive to build. Standardised balcony details would greatly assist MDH construction.

A limited range of claddings were said to be suitable for 3–4-storey buildings. The builder had a preference for low-maintenance weatherboards on a rigid air barrier. However, clients often preferred a monolithic appearance, which is expensive (especially with concrete panels). Cladding installation is on the critical path for interior works, so it is valuable to complete exterior cladding as quickly as possible.

Only some council inspectors accepted sealed rigid air barriers as sufficient to begin interior lining. The uncertainty of inspector opinions makes it difficult to schedule construction.

Rainscreen type claddings were deemed by the builder as challenging from a liability point of view. They typically required a large number of penetrations through the wrap shield and rigid air barrier. Rainscreen systems tended to not offer a weathertightness warranty. The wrap shield warranty is typically voided by a large number of penetrations for fixing the rainscreen. Ultimately, the builder takes on all long-term liability for performance of the exterior rather than installers or manufacturers. This was said to be an area that could benefit from further testing.

The builder felt that there was no solution for reducing moisture content in timber during winter. Sometimes, they used H3.1 treated timber as it has a waxier finish that water beads off. This area was also said to need further research, as a timber coating that encourages water to bead off and breathe could be beneficial to the industry.

Framing can get very wet in winter, just over the time that framing is being stood. There are some proprietary solutions that enable some components, such as the bottom plate, to dry out. However, it was said to not be accepted by engineers or consenting officials for fire/acoustic resistance and bracing. These solutions also need to be incorporated into system manuals for more commonly used construction materials.

Internal gutters were felt to be an issue too. They are effectively enclosed by the roof cladding. However, they are only subject to a short warranty, much less than that of the roof cladding. It was felt that this was a high-risk detail that relies on good workmanship for sustained performance. They also felt that UV exposure was a concern. Internal gutters and parapets are very common as a solution for maximising economic return while complying with recession planes in infill housing.

Brick parapets were also said to need better details. Currently, builders wait until brick cladding is built to full height and flashed before beginning lining inside due to inconsistency between council inspectors. They felt that an interim flashing for rigid air barrier boards that is then covered or replaced with a final parapet flashing could be a solution.

Slab edge insulation was said to be difficult to do right, as this reduced the area for framing hold-down bolts to anchor the framing. Some proprietary products were said to be good but expensive and still somewhat difficult to build, and they require a protective membrane. The existing BRANZ detailing (with additional H3 treated 90x45 mm strip) was felt to not be suitable as engineers don't like the separation of floor slab and footer. It also requires cast-in anchors, which were said to be difficult to work with. The builder suggested that we need a better solution, particularly one that provides a rebate for brick cladding.

Window head flashings, sill support bars and jamb sealing all tended to be built very well and are thoroughly inspected. The builder had seen some ropey installations of building paper/wrap, typically using cut-offs etc. Designs in general were said to be more reliant on the cladding cavity, with features such as a lack of eaves or multi-storey brick cladding.

Achieving higher mandated Homestar ratings (e.g. 6+) is very expensive, such as for the inclusion of water heating and edge insulation. The builder suggested that, if anything, buildings are too airtight today. This is good for energy savings but it means any moisture is trapped.

Internal heat pump hot water cylinders are a good solution but difficult to design for. They require free air flow but there is no specification for ducting, and they need to be installed within a conditioned space of the dwelling. This requires specification from the manufacturers. Split-system heat pump hot water is not suitable for MDH as this would require a high density of outside units, which is visually unattractive.

Consideration of maintenance depends on the client. Retirement village operators are very conscious, typically requiring access for cherry pickers and abseil anchor points in the design. The builder felt that developers do not care for maintenance. One such example was the specification of black cedar up to 3 storeys – a cladding that requires regular inspection and staining.

Interview 3 (Builder, 100–200 MDH units per year)

The project manager/builder predominantly builds low to mid-rise apartments and commercial buildings. The builder uses MDH as a training ground for younger project managers and prefers to use steel or concrete for the structure for 3-storey and above MDH.

There has been a big shift into commercial and MDH work, and the builder felt that the industry is struggling to adapt, particularly for the first 6 months. MDH has more compressed timeframes, more trades involved and more complicated and intensive coordination. Time to enclosure and getting watertight takes longer, which means that scaffolding is needed for much longer.

The builder has experienced large cost increases across a range of materials and trades. There seems to be insufficient labour, and some trades are more of an issue than others. Prices for carpentry and finishing trades have gone up, reflecting lack of resources, and service trades are also in short supply and prices are increasing. Façade consultants were especially hard to get but were essential for peer reviewing façade designs.

Longer timeframes for various trades leads to more time waiting. Consultants were generally understaffed and overcommitted, leading to a decrease in the quality of design. Design and build or early contractor involvement mitigates this somewhat. The builder felt that designs were never satisfactory and lack buildability. Build-only contracts typically required lots of variations for buildability once on site. Consultants generally seemed to have an underappreciation of trade availability and were generally behind that of builders. Therefore, builders had a better overview and value to add at the design stage when the construction methodology is being selected.

Precast concrete prices and lead times had increased, and capacity of concrete plants is constrained. Pours cannot be delayed by a day or two, and they must be rescheduled a few weeks later if the booked day cannot be achieved. The reinforcing trade is also under great pressure. Bricklayers and blocklayers are also under pressure. The builder has responded to these pressures by changing their construction methodology, particularly by moving to more in situ concrete work for walls and floors.

Fireproofing and passive fire protection were found to be an issue by the builder. There was resistance in getting details designed beforehand. However, they cannot get fixed-price contractors without the details. There was felt to be too few fire consultants. The builder now ensures that passive fire design is done upfront to smooth the process with the passive fire contractor later. The services trades are well trained around running services through structural elements, but they do not want to be involved in passive fire.

Intumescent paints were often applied to structural steel without sufficient regard for preparation. Intumescent paint applied to wet steel will likely fail several years down the track and may then be hidden by linings. The builder felt that there was insufficient testing or quality assurance on intumescent paint application. Therefore, the builder tended to design out intumescent paint by oversizing steel elements, encasing or using concrete instead.

The builder had noticed far more reinforcing was being required for seismic resistance, and there was an increasing strictness around external cladding for weathertightness. Both were adding complexity and time to building. Designs generally were taking 6–10 months or longer to get to the buildable point. In addition, there were often problems with consenting that caused delays.

Price was the main focus in the current market, which led to compromises over specifications (e.g. vinyl flooring instead of tiles). Often this is at the expense of more expensive products being more cost-effective over the long-term when considering the longer lifespan due to durability. However, the builder does provide input into the maintenance with design and build contracts (e.g. cleaning, access, and safety). However, it was felt that consultants can sometimes forget these aspects. Recent law changes bring an obligation to consider safety in design, so the builder now faces more questions from designers.

Interview 4 (Builder, 20–50 MDH units per year)

The builder works on 1–2-storey MDH, which generally are horizontally attached. Therefore, the builder was unlikely to face issues with sound/fire in inter-tenancy floors. The builder has moved to Auckland from Christchurch and has found that the weather in Auckland is much worse than in Christchurch. This leads to delays, as the Auckland workforce was felt to be less likely to work in inclement weather and less willing to travel across the city to sites.

A rigid air barrier is used to prevent racking of framing before interior lining. To prevent noise transfer through inter-tenancy walls, a proprietary concrete system is used.

The builder has found that the running of plumbing can be an issue, particularly when it is not considered during the design stage. Hiding wastewater stacks can be particularly challenging when it has not been practically designed for.

Flashings were also found to be more challenging in MDH, as the units tended to have more complex roofs. The builder felt that designers were providing too much information in some cases, and flashings were sometimes not buildable within the constraints of the detailed but impractical design. This was compounded by designers rarely going on site during construction.

Delays in processing consent amendments could take up to 4 weeks. This constrains the ability to make changes once construction is under way.

The builder has found that institutional clients cared more about maintenance than developers, as designing for maintenance and/or access can be difficult. Energy efficiency was also something that was often overlooked beyond the basics, such as LED lighting.

Interview 5 (Builder, 20–50 MDH units per year)

The group builder has recently taken up MDH development and predominantly builds townhouses. They typically utilise subcontracted builders and are currently facing a shortage of good, qualified builders that can work within their timeframes. MDH sites could be messier and faced additional complications with setting out infrastructure and managing supplies.

The builder was facing price increases from material suppliers and subcontractors. Some subcontractors were particularly hard to find, such as bricklayers. They also found health and safety compliance onerous, particularly with downtime for toolbox talks.

They felt that leaky home type issues were still arising from designs that did not consider buildability. The trend for multiple claddings leads to many cladding junctions, which are vulnerabilities. Houses are still being designed without soffits or with narrow soffits, despite learnings from the leaky home crisis. There were also issues resulting from builders using unfamiliar products from unknown sources.

Designers with no practical experience were thought to be copying and pasting details without understanding buildability. This meant that they were leaving too many things up to the builder's judgement.

Hold-down bolts were felt to generally be done well now, with sufficient spacing from the slab edge. However, it could be difficult to maintain the distance between the hold-down bolt and slab edge when using some proprietary edge products.

Flashings were also felt to be done well. However, stop-ends could be easily knocked out, particularly as only a small amount of silicon adhesive is used to hold them in place. Council inspectors generally picked this up when they had been knocked out of place. They had found that some brands of flashing tapes did not stick very well and could require techniques such as using a heat gun to ensure adhesion. The builder tends to avoid these brands of tape.

Sill support bars were felt to be used appropriately these days. However, the builder questioned the wisdom of standard designs using multiple short pieces that do not pick up the main weight loads. There was also felt to be a lack of good fixing details for sill bars into concrete.

The builders felt that there was still a lack of knowledge around sealing window jambs. Some builders continued to push backer rods for the sealing of window jambs in too far or design/mount windows with unequal space between the jamb and framing. This made sealing difficult. Good products are now available for sealing penetrations, so generally there are no issues.

There were difficulties with plumbers creating large holes in structural elements. This suggested that plumbers were not overly aware of the requirements of NZS 3604:2011. Sheet metal brackets were used to supplement structural elements that had been penetrated or notched but were often insufficient. Electricians also created holes, but they do not tend to cause problems as the holes were not particularly big. Running ducting for wet area ventilation could be challenging, particularly through bracing walls, as the duct diameter requires larger holes than would be allowed for. Ultimately, services were not particularly well provided for in MDH plans. Often these were rough schematics that often did not consider how they will traverse structural elements.

The builder thought that the requirements for overlap between flexible wraps were too relaxed. The current requirement for 200 mm lap between studs was felt to be insufficient and that they should be stud-to-stud overlap instead. The builder stated that they always tape flexible underlay joints.

The builder questioned why flashings by LBP builders on walls were thoroughly inspected by council. However, flashings by LBP roofers were not subject to the same council inspection, despite equal or greater importance to maintaining the building's weathertightness.

Across the industry, skill level was felt to be the core issue. Many firms were operating gangs of unqualified builders led by a single LBP. Many builders do not read NZS

3604:2011, instead believing that they "just know" what to do. The builder stated that they use an electronic copy of NZS 3604:2011 on site.

Inspectors cannot comment on bad workmanship, only on whether what they see on site meets Code. The builder felt that inspectors were often only sampling one element (e.g. one window rather than all windows in a house).

The builder suggested that extra bulk insulation in mid-floors and interior walls within each tenancy improves liveability in MDH. They also suggested pipe insulation, particularly of waste stacks, for the same reason.

They chose low-maintenance materials in their designs wherever possible, but often they have to work within the constraints of the design that had been submitted for resource consent. Cost-driven builds inevitably led to compromise.

Interview 6 (Developer, 20–50 MDH units per year)

The developer works on staged, mixed-typology development and largely utilises commercial builders and commercial structures/materials for their MDH. The developer felt that the industry is generally much better at MDH than 5 years ago. However, stand-alone experience does not translate to MDH experience, as there are different details and materials and planning is more important.

MDH often involves large concrete pours, which can be more difficult to achieve a crack-free slab, avoiding the need for a waterproof membrane. Stand-alone builders may not have the pulling power to get large concrete delivery on favourable terms.

The developer typically uses rigid air barriers for builds at all times of the year, and follows a thorough quality assurance process for all builds. However, the developer perceived that the quality of MDH construction across the industry is highly variable. Buyers of apartments are now doing thorough due diligence and are asking a lot of questions.

Finishing trades caused a particular issue for the developer. They were difficult to find, and there were challenges around ensuring the quality of their work, particularly stoppers and painters.

Waterproofing was a particular challenge. This was partially due to finding an appropriate specification for the substrate and product, but mainly it was around designing for subsequent maintenance. This was particularly challenging with tanking membranes on balconies where a deck is installed on top. The developer has changed to torch-on membranes with artificial turf to achieve a maintenance-free waterproofing system.

Acoustics were specifically designed, and cork underlay was used beneath tiles in habitable spaces to prevent transfer of impact noises. However, the Building Code was said to not require as much mitigation of noise travelling between non-habitable spaces (e.g. bathrooms), and perhaps this should be improved.

Fire engineers were found to be hard to source, and professional advice appeared to be subjective and variable. There was strong risk aversion across all consultants, often adding a personal factor of safety to what was required by the Code, leading to overly conservative designs.

The developer noted that their appeared to be misalignment between the Building Code and fire regulations since the 2015 changes and with the Health and Safety at Work Act. Some options in the 2015 fire regulation changes were felt to be impossible to test/comply with.

Buildings were handed over to bodies corporate with thorough maintenance schedules, including annual washing, to ensure longevity of materials. The developer selected low-maintenance wall claddings.

Interview 7 (Designer, 5–20 MDH units per year)

The designer stated that the Auckland Unitary Plan had enabled more opportunity for MDH in urban areas. The Unitary Plan enabled lots of 600 m^2 to be split into three dwellings, which greatly increases the potential for MDH. The designer is currently working on duplex development, and prior to the Unitary Plan, the designer was only working on stand-alone houses. Technical issues of fire, acoustic and emergency lighting design are dealt with by specialist engineers. However, the designer felt that there were not many changes in design for MDH compared to stand-alone, just slightly smaller spaces.

Weathertightness was said to be challenging. This was particularly the case for junctions between claddings, such as between brick and weatherboards. The designer uses BRANZ junction details to ensure compliance. When designers do slip up on these details, the designer felt that council often identified deficiencies. Council inspectors were said to be quite strict in general and especially with regards to flashings.

Dodgy builders can be the cause of quality issues, which comes about through a busy industry bringing in uneducated builders. One example was when the designer specified a proprietary firewall system but the builder missed it on the plans.

The designer now only works with selected builders with a good track record, and the designer feels that these builders do a good job. Gangs of migrant workers are more common now and typically deliver good-quality work. They typically involve an English-speaking and qualified builder supported by non-English speaking workers.

Interview 8 (Designer, 50–100 MDH units per year)

The designer has worked for a long time on MDH. They are currently designing for commercial conversions, infill social housing, terraced housing, low-rise apartments and one mixed-use apartment build. The designer likes to think about lifetime use/suitability of buildings.

They felt that it was difficult to encourage developers to design well. Developers were only concerned about yield through units per section and take the cost of a standard specification as standard. Designers rather than architects are more often involved in the development.

In addition, there was felt to be a lot of amateur developers in Auckland who had often enjoyed the benefit of upzoning through circumstance (the Unitary Plan changes) or bringing overseas wealth. They perceived development as an easy way to make money.

Local property owners were struggling with the concept of MDH too. Many own properties with significant potential for MDH. However, they still wish to add single dwellings onto vacant land instead of fully redeveloping. This fails to achieve good design outcomes for the city.

There is potential for a greater use of prefabrication, which was felt to be important for achieving higher quality and better outcomes. However, the importance of considering the life cycle of materials and the building is not considered much in New Zealand. The challenge for MDH is to bring in better quality systems, and affordability should include quality. The designer felt that we should be increasing standards (e.g. H1 *Energy efficiency*) incrementally over time.

More repeat houses with similar designs are needed, not bespoke designs. Given that we cannot standardise housing outcomes, we need to standardise systems and designs. The designer stated that the government is already doing this through Housing New Zealand. They have the best opportunity to take their time with design and refine, particularly compared to commercial developers with holding costs. This creates an opportunity to work to different objectives such as health.

The designer felt that any designs that were stretching the limits of the scope of NZS 3604:2011 were being picked up by council consent processing. Façade engineers are required for buildings taller than 10 metres, and acoustic engineers are used for most MDH developments. Acoustic requirements are increasing. However, the industry persists with light timber framing, which was felt to be increasingly difficult for meeting acoustic requirements.

Flashing details generally came from the cladding manufacturers. Therefore, most of the designer’s time is taken up getting producer statements from consultants to satisfy council consenting officers. The designer believes that builders/roofers should be responsible for detailing flashings as they have buildability knowledge. The builders would just need to obtain approval from the cladding supplier that the product is appropriate in the given context. The designer’s job should be to make sure a building is buildable but not specify the finer details of that buildability. This requires communication between the designer and suppliers/contractors.

Product suppliers were felt to be adequately skilled and provide sufficient information for designers, although there could be a delay in accessing their support services. In addition, some detailing is available from specialist associations, such as the WANZ standard for window detailing.

Basic design was seen to be done poorly across the industry. To achieve better design outcomes, we need more input from the design panel upfront. Research from Western Australia indicates that this leads to faster resource consent processing.

Maintenance is not often considered nor followed through on. Housing New Zealand has a maintenance matrix that covers the cost and frequency of maintenance on different building elements. This should be shared across the industry.

Interview 9 (Designer, 100–200 MDH units per year)

The designer works largely on standardised MDH with innovative materials and methods of construction.

The designer noted the difficulty in finding builders with experience in innovative construction materials. This has forced them to go back to standard NZS 3604:2011 construction. The contractors did not understand other methodologies of construction. Site access and crane access limited the use of prefabricated components. They found that they required a large labour pool on standby for when crane and prefabricated components arrived.

Contractors did not look far enough ahead to work around predictable issues. Similarly, product manufacturers did not foresee issues. There was a lack of standard delineation between contractor and manufacturer for prefabricated component delivery. This led to a misunderstanding on site about whether components should be delivered to the front of the site or lifted into final position.

Problems occurred on site due to plumbers drilling large holes in joists. However, areas such as fire and acoustics required engineers, so the designer did not have any issues.

The designer tried to develop standard specifications. However, contractors often wanted to substitute for cheaper products, and what was cheaper was dependent on each individual contractor's supplier relationships and discounts.

Durability and maintainability considerations were usually brought into flashing design. However, the designer faced strong resistance from builders who were against non-standard details due to concerns with lack of skills to carry out specific details on site. Buildability and durability could sometimes be at odds with one another.

Interview 10 (Designer, 100–200 MDH units per year)

The designer has experience in larger MDH developments from concept/resource consent stage through to detailed drawings and construction observation. They were involved long before the current boom period. They typically work on apartment buildings. The designer's firm is never retained for construction supervision – just observation or regular site meetings and clarifications as required.

They felt that the industry overall was struggling. The quality of design was said to be good. However, the quality of workmanship is a big issue. The lack of workers meant that the head contractor was no longer able to draw from a pool of known/preferred subcontractors. Instead, the head contractor had to bring in more unknown and potentially inexperienced subcontractors. Achieving quality requires active supervision from the head contractor.

The designer thought that the council was likely to pick up any designs applying NZS 3604:2011 solutions that fell outside the scope of NZS 3604:2011 during the consenting process. However, they felt that the council was largely focused on paperwork and responsibility, not overseeing designs themselves. The council relied completely on peer review from consultants and/or producer statements. The council-industry relationship does not involve working through solutions together.

Flashing detailing was felt to be much better than in the past. However, some contractors were still applying incorrect practices from 15 years ago. Waterproof tanking of balconies were said to be challenging, as this is very dependent on the quality of subcontractors, especially as products in the market continued to change.

The designer thought that early on-site testing would help for acoustics. Commercial tilers were felt to be good at complying with acoustic requirements around detailing. However, tilers coming from the stand-alone residential sector could cause problems by not isolating tiles from intertenancy floors.

There were some issues around the application of intumescent paints, which can often be required in terraced typologies for portal frames (in predominantly light timber-framed structures). The industry was felt to be aware of this issue and working on improvements around this.

However, a recent development has been council concern over flammability of cavity battens. This has required a move away from timber cavity battens and testing for non-timber products.

Quality of documentation for contractors in MDH is important, as time for clarification can cause more delays than with stand-alone construction. Busy consultants cannot always clarify/redesign immediately.

Some contractors were engaging in a clerk of works type role, which is distinct from the site manager type role. The typical background for this role includes building surveyors from the United Kingdom or experienced subcontractors. This requires a detailed understanding of plans.

The designer, through working largely on apartment buildings, has seen bodies corporate increasingly taking an interest in maintenance. Bodies corporate were ensuring that they had product information/documentation from the builder. Typically, the designers used concrete exterior walls, which were felt to be inherently low maintenance.