



Lessons from the Netherlands' Retrofit Catalogue for Securing Facades of New Zealand's Low Rise Unreinforced Masonry Buildings

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ABSTRACT

New Zealand has hundreds of 1-2 storey unreinforced masonry buildings that are earthquake-prone. Proposed changes to legislation suggest that many of these buildings will require a seismic upgrade consisting only of façade securing. As many of these unreinforced masonry buildings have construction detailing comparable to the masonry buildings in the Netherlands, this paper evaluates whether lessons from the Groninger Maatregelen Catalogus (Groningen Measures Catalogue), used in the Netherlands for seismic retrofitting buildings, can be applied in the New Zealand context.

1 INTRODUCTION

In the northern region of the Netherlands, natural gas extraction-induced earthquakes associated with the Groningen gas field (closed in 2023) have exposed the seismic vulnerability of a predominantly unreinforced masonry (URM) building stock. Much of this stock is pre-1945 and, given northern Europe's historically low seismicity, was not designed to resist earthquake forces. To date, approximately 27,792 buildings have been assessed: 6,517 (23%) have construction works completed, 11,669 (42%) require no intervention, and about 7,559 addresses await retrofit [1]. To manage the scale of works and deliver consistent outcomes, the Groningen Measures Catalogue (hereafter GMC catalogue) was developed to provide standardised retrofit solutions, support contractors, architects, and engineers, and streamline documentation and coordination among stakeholders. The GMC, the building works, and the assessment and design processes are funded by the Dutch state, which as a major stakeholder in the extraction process accepted responsibility for carrying out repairs and strengthening in 2015 (Sterling, 2015). This acceptance has led to the creation of an extensive social and

technical programme, requiring significant engineering resource, which has included contributions from New Zealand engineers (including the authors of this paper among many others).

Although Groningen's hazard is anthropogenic, its impact on vulnerable URM buildings and the need for programme-wide consistency in retrofit are directly relevant to New Zealand. New Zealand is a seismically active country and is currently reviewing its approach to strengthening vulnerable URM buildings and finding more efficient ways to secure façades. Approximately 2,900 URM buildings are listed on the earthquake-prone building (EPB) register, representing most of the EPB stock. Recent reforms to EPB legislation propose a risk-based framework that seeks a balanced approach between life safety and cost-effective strengthening. Under the proposed new regime, about 1,220 URM buildings will require façade securing works (refer Table 1). This paper examines whether some of the standardised details from the GMC catalogue could be considered within New Zealand's URM strengthening programme.

Table 1: Summary of earthquake-prone URM buildings in New Zealand

Earthquake-prone URM buildings	Current EPB register	Proposed new EPB regime			
		Removed (low zone)	Risk Register only	"Full Retrofit to EPB threshold"	Facade Securing
1-2 storey URM	2,672	701 Removed	824	-	1211
3+ storey URM	245	68 Removed	-	104	9

2 COMPARISON OF NL AND NZ URM CONSTRUCTION

2.1 Netherlands URM construction

Unreinforced masonry housing has been the predominant typology in the Groningen region since at least the 18th century, typically comprising two-storey buildings with attics. Construction up to the early 20th century used solid clay bricks bonded with lime mortar, featuring thick inner walls and freestanding URM chimneys (Messali et al 2018). Floors had suspended timber joists providing flexible diaphragm action, while shallow strip foundations led to high differential settlement risks, causing widespread cracking and structural vulnerability.

From the 1930s to around 1980, residential construction shifted to cavity walls with narrow cavities and galvanised mild-steel ties connecting inner and outer leaves. Corrosion of these ties in pre-1980 buildings has been recognized as a seismic safety concern, especially for façades over public spaces. Floor systems evolved to stiffer precast concrete from the mid-1960s, replacing timber joists. Foundations progressed from concrete strip footings to piles on weaker soils to reduce settlement and enhance load-bearing capacity.

Since the 1980s, URM housing in Groningen features more robust structural systems, including rigid concrete floor diaphragms, improved or stainless wall ties, standard cavity insulation, and more frequent use of piling. Concurrently, alternative masonry materials gained popularity: calcium silicate blocks, prized for strength and durability, became common for inner leaves and partitions, while lightweight aerated concrete blocks are widely used for non-loadbearing internal partitions due to their fire resistance, thermal insulation, and ease of installation.

2.2 New Zealand URM construction

The bulk of NZ's URM population was constructed between 1890 and the mid-1930s (Russel and Ingham, 2010). The result of this relatively short window of construction (in comparison to the span of building history

in other countries) is that NZ's URM buildings are relatively homogeneous in their typologies, detailing, scale and materials. In the context of considering standardised detailing and prescriptive approaches to seismic retrofit, this homogeneity presents an advantage, where a one-size-fits-many program becomes more achievable.

NZ's URM buildings are predominantly 1-2 storey standalone and row buildings. These buildings will be familiar to readers who have visited the business centres of most of NZ's towns and cities, or suburban shopping centres established in the first quarter of the 20th century. The buildings are modest in scale, and often feature open shopfronts, with little or no discernible lateral stability mechanism on the street-facing side of the lower floor. As in the Netherlands, clay brick construction dominates, albeit with a brick module with a slightly taller squatter proportion than the typical Netherlands brick. New Zealand brick units tend to have compressive strength in the range 10-15MPa, on the lower end of global masonry strength (Almfeser et al, 2014). Mortars were often originally lime-based, but bricks may have been subsequently repointed with cementitious mortar. Wall thicknesses vary, with taller buildings of three or more storeys sometimes having walls up to 600mm thick at the base, stepping inwards and reducing in thickness up the height of the building. Walls are a mix of solid and cavity construction, with cavities used for moisture ingress control. The majority of these buildings have lightweight timber floors and roofs, which may be capable of acting as flexible diaphragms.

3 GMC AND RELEVANCE FOR NEW ZEALAND

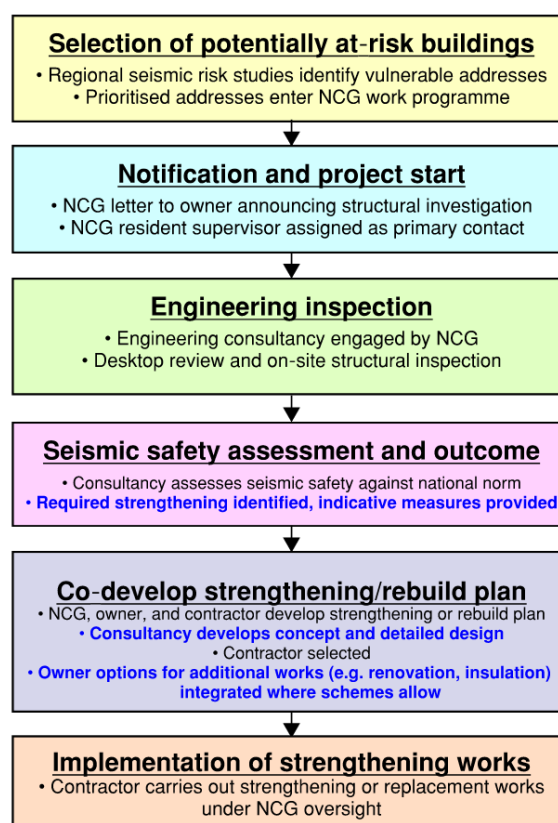
3.1 State-funded seismic upgrade of NL buildings

As noted in Section 1, the Netherlands Government has accepted a role as the funder of seismic upgrades for vulnerable buildings in the Groningen region. Figure 1 gives an overview of the process. As can be seen in the figure, the state-funded seismic programme includes processes for selection, triage, assessment, design and construction of strengthening measures (NCG, 2026). One element of the process is the creation of a catalogue of standard details (with attendant capacities and costs) which engineers are mandated to use for the design of upgrades. The catalogue is termed the Groninger Maatregelen Catalogus (hereafter the "GMC catalogue"). It is noted that the GMC is used in a number of the steps within the process shown in the chart, and that there are also additional steps required in addition to the GMC.

3.2 GMC catalogue

The GMC catalogue organises strengthening measures by hierarchical levels (for example, connections, diaphragms, walls out-of-plane, walls in-plane), which are then divided into individual measures.

The measures target the 'Near Collapse' (NC) limit state per NPR 9998:2020 C1 2.2.1.2, which permits significant damage and low residual lateral strength and stiffness, provided that primary gravity support is maintained. Each GMC measure is a pre-engineered, standardised "plug and play" solution intended for application in defined scenarios. Where applicable, the measures include load capacities supported by pre-packaged engineering calculations, drawings, and clearly stated assumptions. Additional practical information,



Blue colour indicates steps involving use of the GMC

Figure 1: Seismic assessment and strengthening process in Groningen, The Netherlands

such as cost estimates and coordination with architectural build-ups, is also provided where relevant. The measures are summarised in a catalogue and documented in further detail on an online platform.

GMC measure L4-K is shown in Figure 2 shows an example, representing index K for out-of-plane wall strengthening solutions. The retrofit solution consists of an internal timber-framed supplementary wall that provides out-of-plane strengthening to an existing masonry wall. Options for 600 mm and 400 mm stud spacings deliver a design capacity of 3.3 and 4.7 kNm/m respectively as prescribed by the GMC. Insulation is commonly added as a "coupling opportunity" (meaning an ancillary or add-on works opportunity).

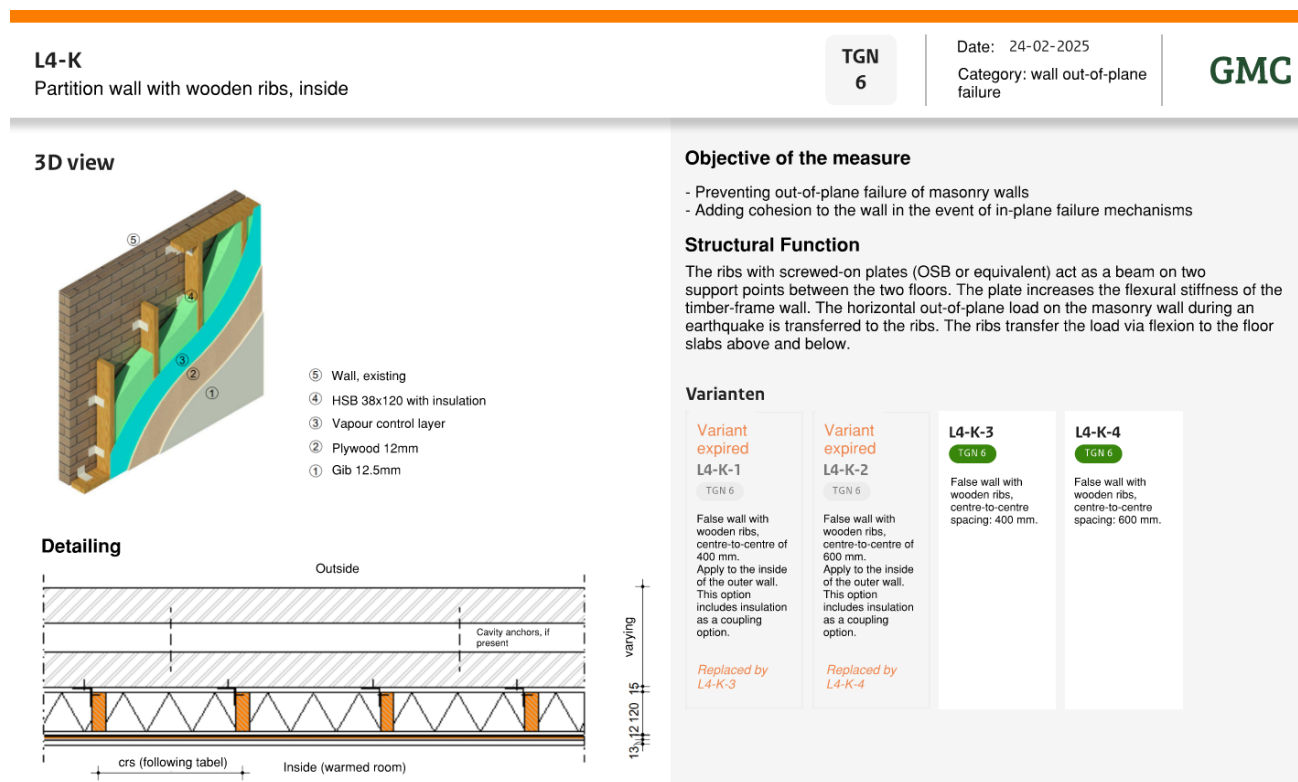


Figure 2: Measure L4-K, GMC catalogue

The measure is clearly defined in terms of its structural purpose and design philosophy. A 3D view and 2D drawing are provided for clarity, illustrating the wall build-up and its coordination with insulation, moisture control, and internal finishes. Variants of the measure are specified to address different structural demands, for example by varying the spacing of timber studs to suit the required out-of-plane wall capacity. Load capacities and cost estimates are provided for each variant.

Within the online portal, the measure is supported by a detailed work description and video guidance, intended both to assist the contractor and to facilitate communication with the building owner and wider project team. Structural calculations, material and product specifications, scope of application, health and safety aspects, cost breakdown, and thermal and acoustic considerations are set out in further detail.

While the design of an individual strengthening programme is carried out by an engineer, the practical application of the selected measures is typically led and coordinated by a *bouwkundige* (construction engineer), a role that sits between structural engineer and architect. The *bouwkundige* is familiar with structural build-ups and compliance documentation and coordinates the strengthening details with related works and constraints, including architectural and heritage requirements and sustainability measures.

The measures are designed to be combined in a "plug and play" manner. For example, measure L4-K, which provides out-of-plane strengthening and optional insulation to a wall, can be coupled with measure L5-A for in-

plane strengthening of the same wall via jacketing, measure L2-053 for tying the wall to the timber floor diaphragm, and measure L4-D for connecting the wall with new cavity ties to the adjacent leaf of the cavity wall. The GMC provides design variations (roughly equivalent to a Developed Design level) matching their provided design capacity. These need to be reviewed against the design assumptions and drafted to suit the as-built scenario. The details may also be modified to suit the desired design capacity.

In this way, the GMC measures provide clear, standardised, and accepted solutions for all parties involved (engineers, architects, technicians, contractors, and authorities). This streamlines the building consent process, reduces resource requirements, and lowers both engineering effort and inter-disciplinary coordination. The simple, modular, and well-coordinated nature of the GMC measures is central to their success in practice.

3.3 Relevance to NZ

Recently announced changes to the Earthquake-prone Buildings regime in New Zealand appear set to reduce mandatory minimum requirements for strengthening of URM buildings. For the majority of eligible buildings, there is anticipated to be a scope reduction (for mandatory works), such that URM buildings will require only “façade securing” – the details of which have not yet been announced. It seems likely that mandatory works schemes will move away from defining %NBS (percentage of New Building Standard) as per the current regime, towards focusing on risk reduction to pedestrians outside of the building—and accepting the residual risk to occupants. The URM typology appears to be a good candidate for the development and implementation of standardised measures like the GMC, as a way of achieving the mandatory façade securing outcome for a reduced cost.

New Zealand has experience with mandatory limited-scope securing. Following the Kaikōura earthquakes in November 2016, due to heightened risk of aftershocks the Hurunui/ Kaikōura Earthquake Recovery (URM buildings) Order 2017 (NZ Gov’t, 2017) was implemented to secure parapets and façades of 118 buildings in Wellington, Lower Hutt, Hurunui and Marlborough (MBIE, 2020). During the façade-securing process, Wellington City Council effectively acted as mentor and programme manager across numerous projects, with clear benefits. A key insight from MBIE’s post-implementation review was that individual building owners are often ill-prepared to carry out building works. The review noted that to complete seismic upgrade projects, owners of smaller buildings needed intensive support. Small building “owners lacked the knowledge, capacity and capability to manage the securing work on their own” (MBIE, 2020). For many owners, mandatory seismic upgrades may be the first and only construction project they attempt to commission, fund, manage, and carry out. Finding an NZ equivalent to the role of the *bouwkundige* (refer Section 3.2) who can assist building owners and act as an intermediary between owners, consultants and contractors, would appear all but essential.

A critical difference between New Zealand and Netherlands is the absence of centralised state funding. In the Netherlands, the Nationaal Coördinator Groningen (NCG) serves as project coordinator and invests in owner consultation—visiting communities, meeting individual owners, providing support, and accommodating owner-initiated additional scope while accounting for site-specific context. Owners of earthquake-prone New Zealand URMs are required to fund their own seismic improvement schemes. This paper notes the different economic and liability context in the Netherlands and NZ without further comment. Research has shown that many NZ building owners struggle to finance seismic upgrade, suggesting that many would welcome the potential for reduced cost via standardisation (see for example Aigwi et al 2019, Filippova and Noy 2020, Nakhies 2014, MBIE EPB system and seismic risk management review, 2025).

Much of New Zealand’s URM building stock is in need of maintenance. Condition issues create a challenge for standardised systems which are benchmarked against an assumed minimum performance of masonry, assumptions which depend on the presence of mortar in the joints, diaphragms which are not rotten, etc. The move to a more standardised mandatory strengthening allows for the integration of maintenance into the seismic

upgrade. For example, the GMC system includes opportunity for maintenance, alongside integration of architectural concerns, improvement of insulation and weather-tightness, and the acknowledgement that the building project is a financial, social and emotional journey for owners. While the authors of this paper are not advocating for a direct lift-and-shift of the Netherlands detailing into New Zealand's buildings, New Zealand's EPB new system may benefit from recognising the holistic nature of owner and building needs.

3.4 Hazard and Earthquake characteristics Netherlands vs New Zealand

Earthquake ground motions in Groningen Netherlands, driven by induced events, are generally much lower than New Zealand's tectonic shaking. PGAs are a small fraction of New Zealand levels, and assessment return periods differ (Netherlands 2,475-year; New Zealand 500-year for normal structures). For instance, spectral accelerations for existing buildings in Dunedin NZ and Groningen NL are similar at $T = 0.4$ s ($\sim 0.4g$), but diverge at $T = 1.5$ s by roughly a factor of four (0.05 vs 0.2g).

3.5 Philosophy of retrofit – Netherlands vs New Zealand

The philosophies surrounding seismic improvement in the Netherlands and New Zealand indicate differences in the seismic and economic context. In the Netherlands, seismic activity is smaller in magnitude, has mostly resulted in damage and not in deaths, and is expected to diminish or cease in the medium term, as gas extraction is managed and the geophysical system tends towards equilibrium. Nevertheless, seismic assessments in the Netherlands consider the entire building, and review in-plane and out-of-plane capacity, diaphragm connections, etc in a fashion that would broadly be familiar to New Zealand engineers. Less familiar is the widespread use of more sophisticated analysis methods such as Non-Linear Time History for modest residential buildings, the determination of small global deflections measured in no more than a few tens of millimetres, and the reliance on and calculation of the frictional capacity of critical connections.

Proposed changes to the New Zealand system indicate a move away from full review of the global response of a structure for common URM buildings. In New Zealand the risk settings are proposed to be adjusted to balance life-safety benefits against affordability. Mandatory compliance would prioritise strengthening of the most vulnerable external elements (e.g. facades, parapets) to maximize the cost-effectiveness of compulsory private spending, while more intrusive interior works for risk reductions to occupants —being higher cost—are to be left to voluntary investment.

3.6 Quality Assurance

A key challenge with moving to a standardised system of seismic upgrade is the maintenance of quality assurance through the process from design to implementation.

Under the Groningen seismic strengthening programme led by NCG, engineering consultants prepare structural calculations and strengthening designs in accordance with the Dutch Practice Guideline NPR 9998 for induced earthquakes. NCG subsequently determines whether the proposed measures satisfy the applicable safety standard. Strengthening works are executed under contract in accordance with the approved engineering design.

The design and construction documentation generated through this process is retained by NCG as part of the programme's records. This documentation may include confirmation of completed works jointly provided by the contractor and the engineering firm, based on on-site verification of the implemented strengthening measures and typically supported by photographic evidence. The approach hereby serves a similar assurance function to New Zealand's Producer Statement system, but with a reliance on QA records rather than on professional declarations.

Devising a system to implement façade securing in NZ will require consideration of design and construction review processes (via Peer Review, Building Consent, building inspections, etc) and their implication for

assigned liability. Furthermore, it should be acknowledged that despite the overall typological similarity of New Zealand's URM buildings, no set of "standard" detailing will fit all cases. Designers, builders and those responsible for inspection will require a conceptual understanding of the intent of detailing, to ensure that in-flight modifications are able to be effective. The trade-off proposed is that while some projects may be less well-implemented, but the reduced cost of securing through standardisation should result in a greater number of physical upgrades being affected nationwide.

4 REVIEW OF GMC DETAILS IN NZ CONTEXT

4.1 Detailing overlap between the GMC catalogue and typical NZ URM buildings

The suite of details in the GMC catalogue broadly overlaps with typical detailing requirements for New Zealand buildings, likely due to the broad global similarity of URM construction. Floor- and roof-wall connections, in-plane and out-of-plane capacity enhancements, foundation improvements, and support to chimneys are included and could provide a basis for a future NZ suite of standard details.

It is noted that differences between the building elements prevalent in common typologies in NL vs NZ mean that the GMC does not contain details for masonry cantilevers – parapets, pediments etc – which would be required for NZ purposes (with the minor exception of GMC measure L1-B, a post-tensioned detail for chimney support). While NL URM buildings do have parapets, these are more commonly decorative gables than cantilevers sitting above a hip roof. Roof detailing in the GMC reflects differences between typical NL (residential) and typical NZ (commercial) construction. The GMC details are designed for configurations where the roof plane connects directly to the wall, whereas in NZ buildings, internal gutters are common and often require specific detailing approaches to ensure diaphragm continuity. The GMC provides shear-only connections between hip roofs and walls, such that a separate horizontal ceiling diaphragm is required for restraint of OOP (out-of-plane) loads from the wall.

In the following sections, the capacities of two typical GMC connections are checked against NZ conditions. As shown, the stock GMC details are on the lower end of capacities required for NZ applications (as could be expected given the countries' relative seismicity). However, GMC connection capacities could be increased for NZ purposes with detailing changes.

4.2 Analysis

Two common details from the GMC were reviewed for their applicability in the NZ context. The details chosen were floor-to-wall connections and timber strongbacks for out-of-plane capacity. The selected details were considered relevant for review against NZ URM building configurations, as strengthening schemes typically include remediation of these two elements.

As noted in the following sections, the design capacity given in the GMC was applied to a range of probable NZ design demands. Design capacities are given in the GMC catalogue at www.maatregelencatalogus.nl (NCG, 2026) and have been used as presented in the catalogue without further factoring.

4.2.1 Wall-to-floor connection capacity

Wall-to-floor tension connections for out-of-plane restraint are provided in the GMC via measures L2-053 (joists parallel to wall) and L2-054 (joists perpendicular to wall, shown in Figure 3). The connection detail provides a stated capacity of 3.6 kN/m in tension for both joist orientations. The capacity of L2-053 and L2-054 was reviewed against typical wall types and calculated demands in the NZ context using the Engineering Assessment Guidelines Part C8 Cl. 8.8.5.2 Step 13, where connection demand is given as the lesser of C_m (the acceleration required to induce rocking), $C_p(0.75)$ (the short-period parts acceleration in Chapter 8 of NZS1170.5:2004) and an upper limit of 3.6g [Joint Committee for Seismic Assessment and Retrofit of Existing Buildings, 2025]. In accordance with the notes in C8 counselling caution at the application of C_m due to overcoming mortar tensile strength, an overstrength factor of 1.2 was applied to C_m .

Walls analysed were assumed to be one-, two- or three wythes thick. The assumed location of the connection was at the floor level for the upper of three or middle of three levels. In keeping with common NZ construction practice, walls were assumed to be one wythe thicker below the point of connection (e.g., demand on a floor-to-wall connection at the base of a 230mm thick wall was assumed to be from the lower half of a 230mm thick wall above the connection and the upper half of a 350mm thick wall below the connection).

Noting that C_m generally governs connection demand and is a function of wall geometry rather than Z factor, gross differences in calculated demand within the geometric range analysed generally come from a change in wall thickness. Connection capacity/demand ratios using the 3.6kN/m capacity given in the GMC catalogue were generally above 100% ULS demand for 110mm thick walls (an uncommon wall type in NZ but more common in NL), around 50% ULS demand for 230thk walls (common in upper floors), and 27-35% ULS demand for 350mm thick walls, meaning that the GMC detail would likely be suitable for providing a minimum-capacity connection for some NZ walls, but would require additional capacity for thicker walls. Further details are provided in the Appendix. Engineers who have designed these connections in NZ will be aware that connections located nearer the base of walls (with greater top load present) will require greater capacity to meet the C_m demand, meaning that the GMC connections would probably need to be modified to suit lower floors in NZ buildings.

The in-plane capacity of L2-053 and L2-054 connections, given as 6.4kN/m, is more difficult to evaluate against NZ conditions as shear demands vary greatly. However, given that a common value for the shear capacity of timber diaphragms is 4kN/m (refer Table C9.3 of the Engineering Assessment Guidelines (MBIE, 2017), at face value this capacity should be adequate for simple situations.

It is noted that the detailing of the GMC catalogue requires closely-spaced wall anchors (M12 epoxy anchors at 220mm centres, or essentially one anchor per brick) to achieve its stated capacity. The out-of-plane capacity of 3.6kN/m is governed by an assumed anchor capacity of 0.8kN – a low capacity by NZ standards, which results from the 1-wythe walls common in NL but uncommon in NZ. Various connection failure mechanisms are reviewed and checked in the calculated capacity including anchor failure and brick withdrawal. The authors noted that some additional potential failure mechanisms present within typical wall-floor connections are not

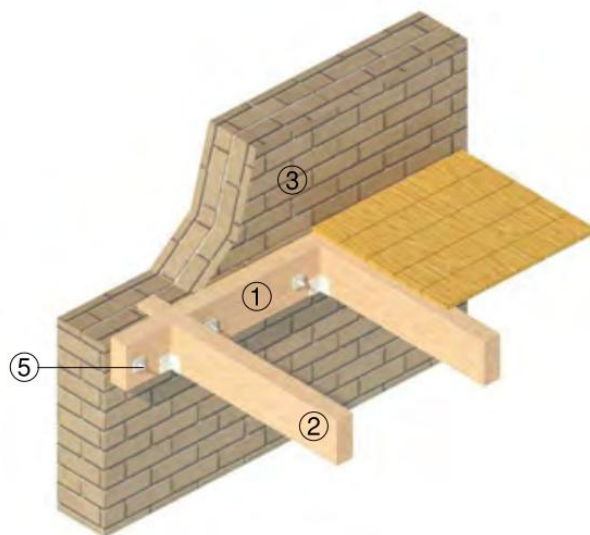


Figure 3: L2-054 (joists perpendicular to wall)

explicitly checked by the GMC (for example, moment from vertical eccentricity between the diaphragm and the connections), and the calculated load path terminates at the connection to the timber joist, meaning that aspects of the connection system like joist out-of-plane bending or joist-diaphragm nailing are not included in the capacity analysis. This observation speaks to the modularity of the GMC measures, but also to the potential for any standardised system to experience challenges at the interfaces between standard components – which will generally require engineering expertise to recognise and to resolve.

4.2.2 Out-of-plane wall strengthening

A typical out-of-plane wall strengthening detail in the GMC catalogue is L4-K (refer Section 3.2). The detail is a timber-framed supplementary wall in which the joists act as strongbacks and provide flexural capacity to restrain the masonry. The stated capacity of the detail in the GMC catalogue is 3.3kNm/m with strongbacks at 600mm centres, and 4.7kNm/m with strongbacks at 400mm centres.

The GMC capacities were reviewed against demand for a range of typical NZ wall types in different geographic locations. In accordance with common design practice, the retrofitted walls were assumed to respond flexurally, with rocking behaviour suppressed by the strongbacks, and with no flexural capacity contributed by the masonry, meaning that the strongbacks were considered to carry the accelerated mass of the bricks in bending. Demand loading used parts accelerations and the period was assumed to be less than 0.75s. Wall heights from 2.7m-3.7m (9'-12') were checked, using soil class C, for a range of Z factors. Walls checked were assumed to be the upper of two or three storeys.

In general, the stated capacity of the GMC detail L4-K was inadequate for 100%ULS-level demand. However, when compared to demand at 34%ULS, the stated capacity was adequate for a range of wall heights and wall locations, mostly for buildings within the “Medium” seismic zone ($0.15 \leq Z < 0.3$). For 3-wythe walls, or walls within the “High” seismic zone ($Z \geq 0.3$), GMC detail L4-K was usually inadequate at 34%ULS demand. Further details are provided in the Appendix.

5 CONCLUSIONS AND RECOMMENDATIONS

With the proposed EPB changes moving toward targeted retrofit for hundreds of URM buildings in New Zealand, this paper takes the opportunity to review an international large-scale retrofit programme—the Netherlands’ standardised Groningen Measure Catalogue (GMC)—and assess its relevance to New Zealand’s targeted URM retrofit.

Two details from the GMC catalogue were reviewed against NZ demand (floor-wall connections and out-of-plane wall strengthening with timber strongbacks). Both details appeared to have some applicability, especially in the Medium seismic zone ($0.15 \leq Z < 0.3$).

It is noted that the GMC detailing and the calculations which accompany the details reflect the modular nature of the detailing system. This observation points to the necessity for clear communication within the NZ context of the scope and assumptions of any future suite of centrally-provided standard details.

A further positive lesson is the use of a dedicated coordinator role—akin to the Dutch *bouwkundige*—bridging structure, architecture, and compliance (including heritage and sustainability) to manage on-site integration. Acknowledging these principles, alongside New Zealand’s own lessons from the Hurunui/Kaikōura URM façade-securing programme, would support more consistent, integrated, cost-effective delivery and improved life-safety outcomes.

It should be noted that the authors of this paper are not advocating for a direct lift-and-shift of the Netherlands detailing into New Zealand buildings. There are differences in the types of buildings and the level of seismicity that prevent a direct adoption of the details. However, the integration of architectural concerns, improvement of

insulation and weather-tightness, opportunity for maintenance, and the acknowledgement that the building project is a financial, social and emotional journey for owners are features of the GMC that New Zealand's new system could benefit from observing.

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Capacity/Demand ratios, GMC measure L4-K, for a range of NZ wall conditions

Strongbacks at 600 crs (capacity = 3.3kNm/m) - Capacity/Demand ratio, Height supported = 4.3 m

Wall thickness = 0.11 m					Wall thickness = 0.23 m					Wall thickness = 0.35 m							
Z factor	2.7	3	3.4	3.7	Wall height	Z factor	2.7	3	3.4	3.7	Wall height	Z factor	2.7	3	3.4	3.7	Wall height
0.15	236%	189%	145%	121%		0.15	113%	90%	69%	58%		0.15	74%	59%	45%	38%	
0.22	161%	129%	99%	82%		0.22	77%	62%	47%	39%		0.22	51%	40%	31%	26%	
0.3	118%	94%	72%	60%		0.3	56%	45%	35%	29%		0.3	37%	30%	23%	19%	
0.4	89%	71%	54%	45%		0.4	42%	34%	26%	22%		0.4	28%	22%	17%	14%	

Strongbacks at 600 crs (capacity = 3.3kNm/m) - Capacity/Demand ratio, Height supported = 7.3 m

Wall thickness = 0.11 m					Wall thickness = 0.23 m					Wall thickness = 0.35 m							
Z factor	2.7	3	3.4	3.7	Wall height	Z factor	2.7	3	3.4	3.7	Wall height	Z factor	2.7	3	3.4	3.7	Wall height
0.15	188%	151%	116%	97%		0.15	90%	72%	55%	46%		0.15	59%	47%	36%	30%	
0.22	128%	103%	79%	66%		0.22	61%	49%	38%	32%		0.22	40%	32%	25%	21%	
0.3	94%	75%	58%	48%		0.3	45%	36%	28%	23%		0.3	30%	24%	18%	15%	
0.4	70%	56%	43%	36%		0.4	34%	27%	21%	17%		0.4	22%	18%	14%	11%	

Strongbacks at 400 crs (capacity = 4.7kNm/m) - Capacity/Demand ratio, Height supported = 4.3 m

Wall thickness = 0.11 m					Wall thickness = 0.23 m					Wall thickness = 0.35 m							
Z factor	2.7	3	3.4	3.7	Wall height	Z factor	2.7	3	3.4	3.7	Wall height	Z factor	2.7	3	3.4	3.7	Wall height
0.15	336%	269%	206%	172%		0.15	161%	129%	98%	82%		0.15	106%	85%	65%	54%	
0.22	229%	183%	140%	117%		0.22	110%	88%	67%	56%		0.22	72%	58%	44%	37%	
0.3	168%	134%	103%	86%		0.3	80%	64%	49%	41%		0.3	53%	42%	32%	27%	
0.4	126%	101%	77%	64%		0.4	60%	48%	37%	31%		0.4	40%	32%	24%	20%	

Strongbacks at 400 crs (capacity = 4.7kNm/m) - Capacity/Demand ratio, Height supported = 7.3 m

Wall thickness = 0.11 m					Wall thickness = 0.23 m					Wall thickness = 0.35 m							
Z factor	2.7	3	3.4	3.7	Wall height	Z factor	2.7	3	3.4	3.7	Wall height	Z factor	2.7	3	3.4	3.7	Wall height
0.15	267%	214%	165%	138%		0.15	128%	103%	79%	66%		0.15	84%	67%	52%	43%	
0.22	182%	146%	112%	94%		0.22	87%	70%	54%	45%		0.22	57%	46%	35%	30%	
0.3	134%	107%	82%	69%		0.3	64%	51%	39%	33%		0.3	42%	34%	26%	22%	
0.4	100%	80%	62%	52%		0.4	48%	38%	30%	25%		0.4	32%	25%	19%	16%	

Walls supported at 4.3m are assumed to be the **upper** of two levels with a 450mm parapet above (2-wythe). Walls supported at 7.3m are assumed to be the **upper** of three levels with a 450mm parapet above (2-wythe).

Analysis assumes masonry mass is restrained in flexure by timber strongback. Demand assumptions: IL2, Soil Class C, $N(T,D) = 1$. Acceleration from Parts per NZS 1170.5:2004, calculated at the midheight of the wall section. Capacity taken as 3.3kNm/m for strongbacks at 600mm crs, 4.7kNm/m for strongbacks at 400mm crs per GMC.

APPENDIX: CALCULATED CAPACITY-DEMAND RATIOS FOR GMC MEASURES

Capacity/demand ratios, GMC measure L2-053/L2-054 (3.6kN/m capacity), for a range of NZ wall conditions

Wall supported at 4.3m, with a 3.2m wall above and a 450mm high parapet above, 2-wythe

Wall thickness = 0.23 m						
Z factor	2.7	3	3.4	3.7	Wall height	
0.13	52%	46%	40%	36%		
0.22	30%	27%	26%	27%		
0.3	22%	24%	26%	27%		
0.4	22%	24%	26%	27%		

Wall thickness = 0.35 m						
Z factor	2.7	3	3.4	3.7	Wall height	
0.13	37%	33%	29%	26%		
0.22	22%	20%	17%	16%		
0.3	16%	14%	15%	16%		
0.4	14%	14%	15%	16%		

Wall supported at 7.3m, with a 450mm high parapet above, 2-wythe

Wall thickness = 0.11 m						
Z factor	2.7	3	3.4	3.7	Wall height	
0.13	159%	164%	170%	174%		
0.22	159%	164%	170%	174%		
0.3	159%	164%	170%	174%		
0.4	159%	164%	170%	174%		

Wall thickness = 0.23 m						
Z factor	2.7	3	3.4	3.7	Wall height	
0.13	53%	54%	55%	56%		
0.22	53%	54%	55%	56%		
0.3	53%	54%	55%	56%		
0.4	53%	54%	55%	56%		

Wall thickness = 0.35 m						
Z factor	2.7	3	3.4	3.7	Wall height	
0.13	30%	27%	27%	28%		
0.22	27%	27%	27%	28%		
0.3	27%	27%	27%	28%		
0.4	27%	27%	27%	28%		

Walls supported at 4.3m are assumed to be the **middle** of three levels with a 3.2m wall above + 450mm parapet above (both 2-wythe). No 1-wythe walls checked as this configuration is unlikely.

Walls supported at 7.3m are assumed to be the **upper** of three levels with a 450mm parapet above.

Connection check assumes load from lower portion of wall above + load from upper portion of wall below.

Demand assumptions: IL2, Soil Class C, N(T,D) = 1. Connection demand taken as the lesser of C_m (the acceleration required to induce rocking), $C_p(0.75)$ (the short-period parts acceleration in Ch 8 of NZS1170.5:2004) and an upper limit of 3.6g [Joint Committee, 2025]. In accordance with the notes in C8 counselling caution at the application of C_m due to overconforming mortar tensile strength, an overstrength factor of 1.2 was applied to C_m .

Capacity taken as 3.6kN/m per GMC.